*Original Article* https://doi.org/10.47748/tjvr.1393777

TJVR 2024; 8 (1): 43-51

Turkish Journal of Veterinary Research

https://dergipark.org.tr/tr/pub/tjvr

e-ISSN: 2602-3695

# Macroscopic and microscopic characteristics of uropygial gland of budgerigars (*Melopsittacus undulatus*)

Fatma İşbilir [1] Zehra Avci Küpeli [2] İhsan İşbilir [3] İlker Arican [4] Özgür Özyiğit [2]

[1] *Department of Anatomy, Faculty of Veterinary Medicine, Siirt University, Siirt, Türkiye*
[2] *Department of Pathology, Faculty of Veterinary Medicine, Bursa Uludağ University, Bursa, Türkiye*
[3] *Department of Pathology, Faculty of Veterinary Medicine, Siirt University, Siirt, Türkiye*
[4] *Department of Anatomy, Faculty of Veterinary Medicine, Bursa Uludağ University, Bursa, Türkiye*

***Correspondence:*** *Fatma İşbilir (fatmaisbilir42@gmail.com)*

Received: 21.11.2023 Accepted: 16.12.2023

## ABSTRACT

**Objective:** This study was carried out to investigate the anatomical, morphometric, topographic, and histological features of the uropygial gland in adult male and female budgerigars (*Melopsittacus undulatus*).

**Material-Method:** For this study, the uropygial glands of fourteen adult budgerigars (7 male, 7 female) were used in the study. This glandular structure located between the caudal vertebrae and pygostyle was removed by dissection. Morphological and histological characteristics of the dissected uropygial glands were determined. In addition, morphometric measurements and index calculations were performed. Tissue samples were taken to determine the histological structure of the gland, that were stained with Hematoxylin & Eosin (H&E), Masson Trichrome's and Periodic Acid Schiff-Alcian Blue.

**Result:** In the study, it was determined that the gland structure was heart shaped and consisted of two lobes, a papilla and a draining duct system. Uropygial gland weight was determined as 1.57±0.96 g in male birds and 1.52±0.09 g in female birds. As a result of the statistical evaluation, there were significant differences between the sexes in the parameters of lobe width ($p<0.05$), papilla length and papilla width ($p<0.01$). Also, the GULI value had a statistically significant difference ($p<0.05$). Histological examination revealed that the gland had a two-lobed structure surrounded by a capsule composed of connective tissue. It was determined that the gland had a tubuloalveolar-holocrine structure and the epithelial layer consisted of cellular layers as germinative layer, intermediate layer, secretory layer and degenerative layer from the periphery to the centre.

**Conclusion:** As a result of the study, it was determined that the morphological and histological structure of the uropygial gland in budgerigars showed similarities with other bird species as well as showing certain species-specific differences in general.

***Keywords:*** *Anatomy, Budgerigar, Histology, Morphology, Uropygial gland*

## INTRODUCTION

Unlike mammals, bird skin does not contain sweat and sebaceous glands. In birds, there is a specialised structure called uropygial gland that produces oil (Jacob and Ziswiler, 1982; King and McLelland, 1984; Reynolds, 2013).

The uropygial gland is located dorsally on the last caudal vertebrae (Jacob and Ziswiler, 1982). It has also been reported to be located dorsally in the region between the fourth caudal vertebrae and the pygostyl (Lucas and Stettenheim, 1972; Sawad, 2006). It has been reported to develop from a pair of ectodermal invaginations (Jacob and Ziswiler, 1982)

and to be a compound tubulo-alveolar, holocrine gland similar to the sebaceous glands of mammals (Wagner and Boord, 1975).

The size and shape of the glandula uropygialis, which is usually a two-lobed organ, may vary depending on the species (Stettenheim, 2000; Salibian and Montalti, 2009). The gland consists of two lobes and a papilla. The secretion produced in the lobes is transmitted to the nipple-like papilla by a complex duct system (Jacob and Ziswiler, 1982; King and McLelland, 1984; Salibian and Montalti, 2009). The papilla is located just above the tail (King and McLelland, 1984; Stettenheim, 2000). In most bird species, bundles of soft feathers surround the papilla (Lucas and Stettenheim, 1972; Jacob and Ziswiler, 1982; King and McLelland, 1984; Stettenheim, 2000). The beaks of birds are lubricated by these brush-like feather bundles and the secretion is distributed on the feathers in this way (Schumacher, 1919). The gland structure, which is present in the embryonic stages of all bird species, may atrophy in some adult birds (Johnston, 1988; Salibian and Montalti, 2009). It is completely absent in a few species of the pigeon (Columbidae) and parrot (Psittacidae) families and in some ostrich species (Rheidae) (Johnston, 1988).The uropygial gland, which produces an oily secretion, is also called the preen gland (Sandilands et al., 2004; Harem et al., 2005; Chiale et al., 2016) and secretes its secretion through the uropygial duct that extends to the top of the papillae of the glands opening into the porus ductus uropygialis (Bhattacacharyya and Ghosh, 1971; Lucas and Stettenheim, 1972; King and McLelland, 1984; Shawkey et al., 2003).

Johnston (1988) reported that gland size is larger in aquatic species than in terrestrial species, while gland size is dynamic and may increase with age (Møller et al., 2010; Vincze et al., 2013).

The function of the glandula uropygialis is not fully explained. While it has been reported that this gland has functions such as feather maintenance, defence against predators and/or parasites, waterproofing and intraspecific communication (Reynolds, 2013), it has been reported that the secretion of the gland prevents the colonisation and growth of microorganisms on feathers, skin and eggshells due to its antimicrobial properties (Galván et al., 2008). The change in the weight of this structure, which is thought to be involved in intraspecific communication, during the breeding season is evidence that it is associated with social or reproductive behaviour (Kennedy, 1971). In addition, the uropygial gland performs similar functions to sebaceous glands involved in oil production in mammals (King and McLelland, 1984; Salibian and Montalti, 2009). The chemical composition of the secretory content of the gland may also vary depending on sex (Abalain et al., 1984), age and diet (Zık and Erdost, 2002; Sandilands et al., 2004).

The secretory content of the gland consists of cell debris, enzymes that enable fat synthesis, volatile substances consisting of short-chain fatty acids, aldehydes, aliphatic and heterocyclic aromatic amines, ketones and dimethyl sulphides (Bhattacacharyya and Ghosh, 1971; Burger et al., 2004).

Morphometric measurements were performed on bones and soft tissues in mammals and birds. Measurement data can lead to significant differences between species and breeds (Özüdoğru et al., 2023; Dalga, 2021).

The histological descriptions of the gland have been made for several orders of birds and it has been reported that it is generally surrounded by a dense connective tissue capsule (Jacob and Ziswiler, 1982; Chiale et al., 2016; Carril et al., 2019). The gland epithelium consists of different cellular layers: germinative layer, intermediate layer, secretory layer and degenerative layer (Jacob and Zeman, 1972; Carril et al., 2019). In the parenchyma, secretory tubules are arranged radially from the periphery to the center and open into the central cavity. In addition, the tubules are separated from each other by compartments composed of connective tissue (Yılmaz et al., 2018).

The budgerigar (*Melopsittacus undulatus*) is a domestic bird species all over the world and is included in the parrot family. It is one of the most popular cage birds that has been taken from its homeland Australia to all over the world (Petek, 2004).

There is no detailed study on the macroscopic and microscopic structure of the uropygial gland in budgerigars. This study was carried out to determine the macroanatomical, morphometric and histological structure of the uropygial gland in male and female budgerigars and to establish a basic data source by comparing the recorded results between male and female animals and with data obtained from other bird species.

## MATERIALS and METHODS

The uropygial glands of 14 budgerigars (7 females and 7 males) were used as material in the study. The glands were obtained from birds that did not show any clinical signs and died for reasons unrelated to the study. The deceased birds were obtained from a private enterprise where they were sold and the tissues were brought fresh to the laboratory.

### Statistical analysis

IBM SPSS Statistics 23.0 programme was used for statistical analysis. The data obtained as a result of normally distributed measurement parameters and index calculations were analyzed with Independent Sample-t Test to determine the differences between genders.

### Macroscopic examination and morphometric measurements

On macroscopic examination, the topographic location of the uropygial gland was firstly determined. The glands were separated from the surrounding tissues by dissection. The weights of the glands were measured with a precision balance (Weightlab- WL-303L). The glands were photographed (Canon EOS 2000D, Japan) under a stereomicroscope (Olympus SZ61, Japan). Considering the morphological characteristics of the gland, the images taken under stereomicroscope were transferred to ImageJ (1.4) for morphometric measurements. Jacob and Ziswiler, (1982) were used as a guide for morphometric measurement points. Nomina Anatomica Avium (Baumel et al., 1993) was used for nomenclature of anatomical terms. Seven morphometric measurements and four index calculations were made from the glands. Morphometric measurement parameters and index abbreviations and descriptions were given below. Also, these parameters were shown in Figure 1.

**Morphometric parameters:**

LW: Live weight

GW: Gland weight

GUW: Glandulae uropygialis width

GUL: Glandulae uropygialis length

PUL: Papilla uropygialis length

PUH: Papilla uropygialis height

**Index parameters:**

Relative gland weight index (RGWI) = Gland weight (GW) x 100 / Live weight (LW),

Lobus glandulae uropygialis index (LGUI) = Glandulae uropygialis length (GUL) / Glandulae uropygialis width (GUW),

Papilla uropygialis index (PUI) = Papilla uropygialis height (PUH) / Papilla uropygialis length (PUL),

Glandulae uropygialis length index (GULI) = Glandulae uropygialis length (GUL) / Papilla uropygialis length (PUL).

### Histological examination

The uropigial glands were fixed in 10% buffered formalin solution for 48 hours. After fixation step, all tissues were dehydrated in ascending grades of ethanol, cleared in xylene, and then embedded in paraffin. Paraffin blocks were cut at a thickness of 4 μm and stained with Haematoxylin-eosin (H&E) for histological examination, Masson's Trichrome (MT) for collagen and smooth muscle fibres, and Periodic Acid Schiff-Alcian Blue (Ph: 2.5) for the character of secretion produced. Chicken intestinal tissue was used as a positive control for PAS-AB staining.

The procedures applied in the present study were approved by the Siirt University Experimental Animals Application and Research Centre with the ethics committee report numbered 2023/01/04.

## RESULTS

In our study, the presence of uropygial gland was observed in all budgerigars. The gland was located dorsally in the region between caudal vertebrae and pygostyle. After the feathers were removed, the gland was covered with a thin layer of superficial skin (Figure 2-A). Anatomically, the gland structure consisted of two lobes and a papilla system (Figure 2-B, C). Both dorsal and ventral sides of the lobes showed a distinct convexity. The lobes appeared symmetrical when viewed from the outside. They resembled the heart in shape and there was a short papilla at the caudal junction of the ends of the lobes (Figure 2-C). Numerous holes (*porus glandulae uropygialis*) were observed on the papilla, which allowed the internal secretion to flow out. In addition, many bristle structures were observed on these holes (Figure 2-C). The gland was divided into two lobes by an interlobarseptum (Figure 2-D) formed by connective tissue. Inside the lobes, it was determined that there was a light-yellow secretion material with a dense consistency.

The uropygial gland weights of male and female budgerigars were measured as 1.57±0.96 g and 1.52±0.09 g, respectively. As a result of statistical evaluation, GUW ($p<0.05$), PUL and PUH ($p<0.01$) parameters were significantly different between sexes. GUW, PUL and PUW parameters were found

to be higher in male budgerigars than females. At the same time, as a result of the index calculations, there was no difference between the sexes in terms of relative RGWI, LGUI, and PUI, whereas GULI value was higher in female birds and showed a statistical difference between the sexes ($p<0.05$). Descriptive statistics and p values for the measurement parameters are presented in Table 1 and for the index values in Table 2.

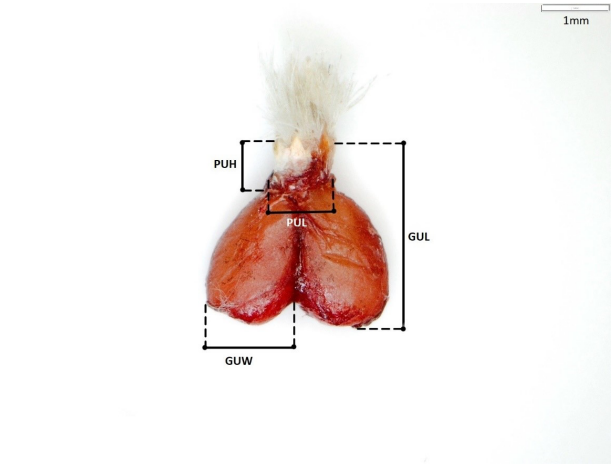


**Figure 1.** Dorsal view of the uropygial gland in the female budgerigar. PUH: *Papilla uropygialis* height, PUL: *Papilla uropygialis* length, GUL: *Glandulae uropygialis* length, GUW: *Glandulae uropygialis* width.

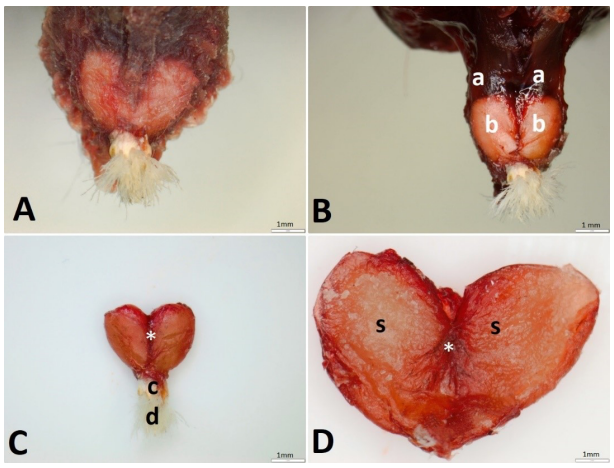


**Figure 2. A:** Pre-dissection view of uropygial gland in the female budgerigar (dorsal), **B:** Post-dissection view (dorsal), **C:** View of the uropygial gland separated from the surrounding tissues and body (dorsal), **D:** View of the internal structure of the uropygial gland in median section. **a:** tail muscles, **b:** *lobus glandulae uropygialis*, **c:** *papillae uropygialis*, **d:** papillae bristle (*pluma*), **s:** secretion, ***:** interlobular septum (external (C) and internal (D) view).

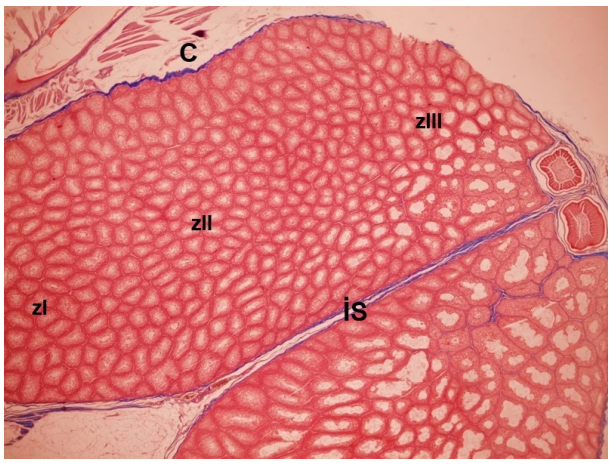


**Figure 3.** Masson's Trichrome staining X4, **zI:** zone I; **zII:** zone II; **zIII:** zone III, **C:** Capsule, **İS:** Interlobar septum.

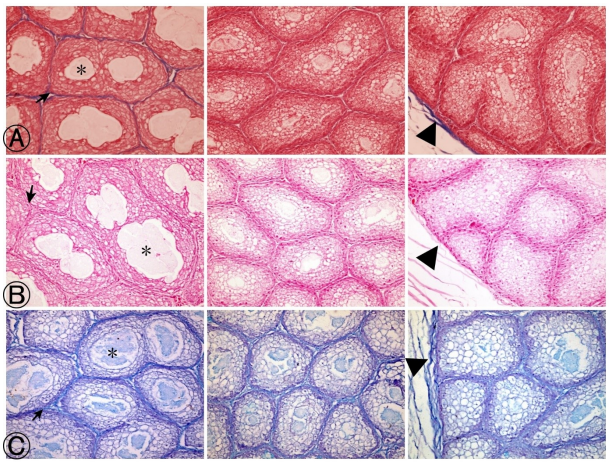


**Figure 4. A:** The capsule of the uropygial gland. MT staining. x40, **B:** The interstitial connective tissue of the uropygial gland. H&E. x40, **C:** Glycogen deposition in the uropygial gland. PAS-AB staining. X40. ***:** Secretion, **Arrowhead:** Capsule, **Arrow:** Interstitial Connective Tissue (Trabecula).

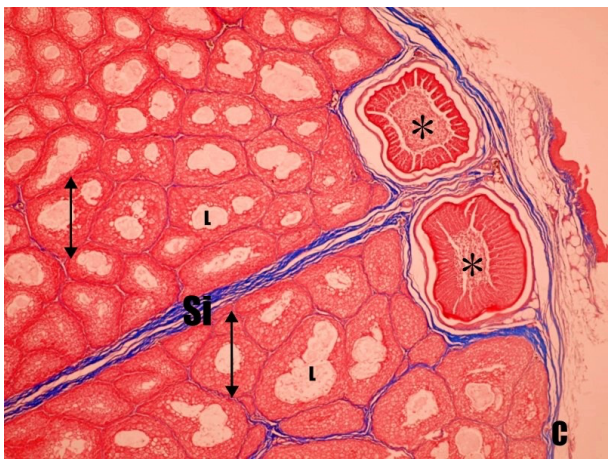


**Figure 5.** General view of adenomers. MT staining. X10 **Double sided srrow:** Adenomer, **L:** Lumen, **C:** Capsule, ***:***Ductus glandulae uropygialis*, **Si:** *Septum interlobare*.

**Table 1.** Descriptive statistics and p values of morphometric measurement parameters of uropygial gland in budgerigars. LW: Live weight; GW: Gland weight; GUW: Glandulae uropygialis width; GUL: Glandulae uropygialis length; PUL: Papilla uropygialis length; PUH: Papilla uropygialis height.

| | Average | | | Male | Female | p |
|---|---|---|---|---|---|---|
| Parameters | Mean±SE | Min. | Max. | Mean±SE | Mean±SE | |
| LW (g) | 40.77±0.68 | 30.40 | 38.40 | 43.38±0.84 | 38.17±1.11 | 0.58 |
| GW (g) | 1.54±0.06 | 1.18 | 1.98 | 1.57±0.96 | 1.52±0.09 | 0.70 |
| GUW (mm) | 1.39±0.01 | 1.30 | 1.47 | 1.41±0.01 | 1.36±0.01 | *<0.05 |
| GUL (mm) | 1.87±0.02 | 1.73 | 2.00 | 1.87±0.39 | 1.88±0.26 | 0.88 |
| PUL (mm) | 0.53±0.02 | 0.39 | 0.65 | 0.60±0.01 | 0.45±0.02 | *<0.01 |
| PUH (mm) | 0.60±0.02 | 0.45 | 0.72 | 0.67±0.01 | 0.53±0.02 | *<0.01 |

*: p<0.05

**Table 2.** Uropygial gland index values in budgerigars. RGWI: Relative gland weight index; LGUI: Lobus glandulae uropygialis index; PUI: Papilla uropygialis index; GULI: Glandulae uropygialis length index.

| | Average | | | Male | Female | p |
|---|---|---|---|---|---|---|
| Index parameters | Mean±SE | Min. | Max. | Mean±SE | Mean±SE | |
| RGWI | 0.04±0.001 | 0.04 | 0.05 | 0.04±0.002 | 0.04±0.001 | 0.53 |
| LGUI | 1.35±0.015 | 1.21 | 1.41 | 1.32±0.027 | 1.38±0.003 | 0.08 |
| PUI | 1.14±0.011 | 1.08 | 1.25 | 1.11±0.009 | 1.16±0.018 | 0.05 |
| GULI | 3.05±1.66 | 1.62 | 4 | 2.77±0.083 | 3.32±0.297 | 0.02* |

*: p<0.05

Histological examination revealed that the gland structure consisted of two lobes and one papilla. MT staining showed that the capsule (Figure 3,4) on the outer part of the glands was stained in a distinctly blue color and branched between the adenomers (Figure 5), limiting them. The interlobular septa (Figure 3) were found to be devoid of fibrocytes. It was determined that the gland had a tubuloalveolar-holocrine structure. The epithelial layer of the gland consisted of four cell layers from the periphery to the center: basal cell, intermediate cell, secretory cell and degenerative cell (Figure 6). H&E staining showed that the nuclei of the cells in the peripheral parts of the adenomeres were centrally located and their cytoplasm contained eosinophilic, secretory material. The cytoplasm of the cells closer to the lumen became light-colored vacuolar and the nuclei shifted to the periphery.

PAS-AB staining showed a weak light blue staining in the cytoplasm of the peripheral cells (glycogen). The cytoplasm of the central cells was not stained and the nuclei were pushed aside (lipid). The secretion in the lumen of the glands was moderate and the thin interstitial connective tissue (*trabeculae* - Figure 4) between the glands was weakly stained light blue (positivity). Histological examination revealed the presence of drainage ducts, which opened and terminated into two large ducts (*ductus glandulae uropygialis*) located caudal to the gland (Figure 5). On the papillae, the presence of numerous holes for the outflow of the secretion was identified (*porus ductus glandula uropygialis*-Figure 7) The presence of Herbst corpuscule was also noted (Figure 8).

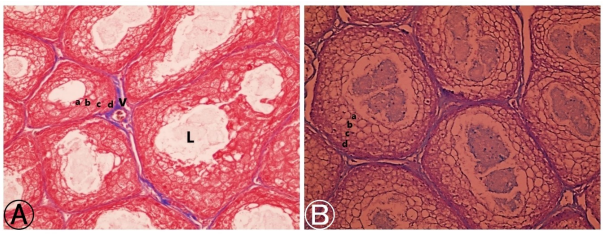


**Figure 6.** The epithelial layers of the uropygial gland. **A:** MT staining. X40, **B:** PAS-AB staining. X40. **V:** Vena, **L:** Lumen, **a:** Degenerative cells, **b:** Secretory cells, **c:** Intermediate cells, **d:** Basal cells.

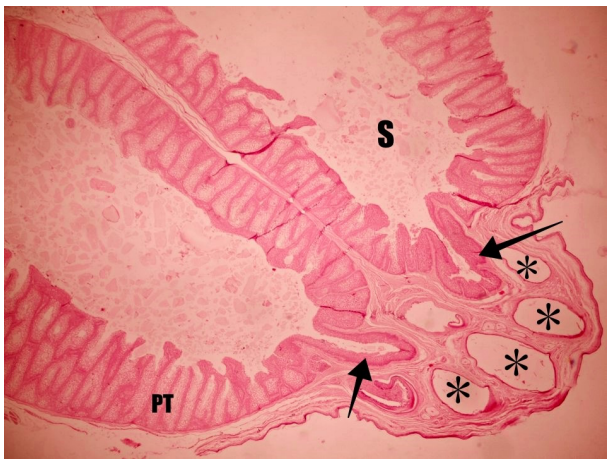


**Figure 7.** The secretion of the uropygial gland. H&E staining X4. **S:** Secretion, **PT:** Peripheral tubule, **Arrow:** *Ductus glandulae uropygialis*, ***:** *Porus ductus glandulae uropygialis*.

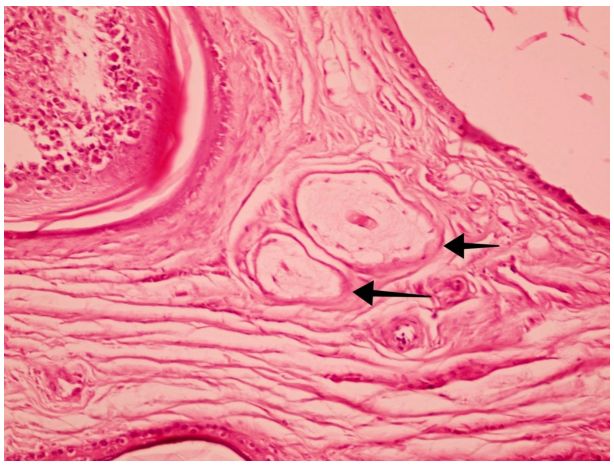

**Figure 8.** The Herbst corpuscule. H&E staining. X40 **Arrows:** Herbst corpuscules.

## DISCUSSION

Although the gland is present in the embryonic stages of almost all bird species, it may atrophy in adults of certain orders, families, genera and species (Johnston, 1988, Salibian and Montalti, 2009). In our study, it was observed that uropygial gland was present in all of the budgerigars examined.

In different birds, the gland is located at the base of the tail, on the pygostyle muscles (Johnston, 1988; Sawad, 2006), between the caudal aspect of the lumbosacral bone and the first coccygeal vertebra (Kozlu et al., 2011). It has been reported to be found on the last caudal vertebra (Jacob and Ziswiler, 1982), in the region between the fourth caudal vertebra and pygostyle (Lucas and Stettenheim, 1972; Yılmaz et al., 2018) and generally on free caudal vertebrae (Moreno-Rueda, 2016; Yılmaz and Yılmaz, 2019). In our study, it was determined that the uropygial gland was located dorsally in the region between the caudal vertebrae and the pygostyle in accordance with the literature.

The size and shape of the uropygial gland have been reported to vary among species (Taşbaş, 1996; Salibian and Montalti, 2009). While the shape of the gland was reported to be heart-shaped in chickens (Yılmaz et al., 2018), it was reported to be similar to the letter "V" in water birds (Gezici, 2002). In the present study, it was detected that the shape of the uropygial gland was heart-shaped and surrounded by a capsule of connective tissue in accordance with what has been reported in gulls (Chiale et al., 2014), monk parrots (Carril et al., 2019) and flamingos (Chiale et al., 2021). The gland was also located directly under the skin.

It has been reported that the gland anatomically consists of two lobes (Jacob and Ziswiler, 1982; Mobini and Ziaii, 2011; Kozlu et al., 2011) and these lobes consist of numerous holocrine secretory alveoli opening into the central cavity (Lucas and Stettenheim, 1972, Menon et al., 1981; Jacob and Ziswiler 1982). It has been stated that the ducts open outwards through a nipple-like papilla located towards the tail, in the midline and dorsally (Gezici, 2002). In the present study, a single papilla structure was observed and the anatomical structure of the gland was similar to the literature. In addition, in accordance with the literature (Chiale et al., 2014; Yılmaz and Yılmaz, 2019), it was identified that there were many bristle structures around the papilla. The papilla structure, which was reported to have a conical shape in Psittaciformes species (Jacob and Ziswiler, 1982), was reported as cylindrical in the Monk parrot (Carril et al., 2019). In our study, the papilla structure was found to have a cylindrical shape. On the caudal end of the papilla structure, the presence of numerous holes (porus glandulae uropygialis), which are involved in the discharge of the incoming secretion through two uropygial gland ducts, was noted.

Chen et al. (2015) reported that the weight of the uropygial gland varied with age, and the gland weights of female and male mule ducks at 49 days of age were 4.76 g and 6.23 g, respectively. In addition, Elder (1954) stated that gland weights can vary greatly seasonally and according to sex. The uropygial gland weights of adult male and female mallard ducks were reported as 4.02±0.26 g and 5.10±0.22 g, respectively (Yılmaz and Yılmaz, 2019). The same value was founded as 0.95±0.15 g and 0.91±0.26 g in Aseel breed roosters and chickens, respectively (Yılmaz et al., 2018). In our study, these values were measured as 1.57±0.96 g and

1.52±0.09 g in male and female budgerigars, respectively.

In previous studies, RGWI was determined as 0.29-0.34 g/100 g in mule ducks (Chen et al., 2015), while it was reported as 0.31 and 0.28 in male and female mallard ducks, respectively (Yılmaz and Yılmaz, 2019). The RGWI was reported as 0.08 in owls (Elder, 1954). In our study, this value was found as 0.04±0.001 on average, close to the value reported in Aseel breed roosters and chickens (Yılmaz et al., 2018) and smaller than the RGWI value determined in Tyto alba (Yılmaz and Yılmaz, 2020).

In a study conducted in endemic bird species in New Zealand, Reynolds (2013) determined the LGUI of glandula uropygialis as 1.4, 1.3, 1.2 respectively. In the same study, the GULI was reported as 4.3, 5, 4.2 respectively. Yılmaz et al. (2018) determined that LGUI values in Aseel breed roosters and hens were 1.64 and 1.87, respectively, and GULI values were 3.35 and 5.4, respectively. The LGUI value determined in our study was smaller than the values reported in male and female mallard ducks (Yılmaz et al., 2018), while the GULI value was higher than these ducks. In our study, the same index values were higher than the values reported in Tyto alba (Yılmaz and Yılmaz, 2020).

In our study, the uropyigial gland had a holocrine gland structure surrounded by a dense connective tissue capsule as reported in many literatures. In addition, thin connective tissue trabeculae branched from the capsule into the organ and bounded around the adenomeres (Yılmaz and Yılmaz, 2020). In histological examinations observed in most bird species such as flamingo (Chiale et al., 2021), parrot (Carril et al., 2019), pigeon (Chiale et al., 2019), cormorant (Stangier et al., 2023), magpie (Balkaya et al., 2016), both lobes forming the gland consist of tubules located around a central lumen (Kozlu et al., 2011; Chiale et al., 2016). In our study, in accordance with the literature, it was founded that the functional part of the gland structure consisted of tubulo-alveolar secretory units (adenomers) covered with stratified epithelium, and the epithelial cells were classified as basal or germinative cell layer, intermediate cell layer, secretory cell layer and degenerative cell layer. It has been reported that the uropygial gland of poultry species such as geese (Hou, 1928), grouse (Sawad, 2006) and starlings (Sadoon, 2011) are completely devoid of smooth muscle cells. However, the presence of smooth muscle cells in the structure of the gland, especially in the interlobar septum and interfollicular septum, has also been reported in studies (Lucas and Stettenheim 1972; Balkaya et al., 2016; Yılmaz and Yılmaz,2019; Madkour et al., 2023). Similarly, smooth muscle cells were found in the magpie, especially in the trabeculae (Balkaya et al., 2016). In our study, smooth muscle cells were found in the interlobular septum and interfollicular septum. In accordance with Balkaya et al. (2016), the presence of fibroblasts, smooth muscle cells and blood vessels were observed in the trabeculae. It was observed that smooth muscle cells were more concentrated especially in the trabeculae around the central lumen. The secretion produced was delivered to the papilla through small and narrow drainage ducts within the gland. Kozlu et al., (2011) and Yılmaz and Yılmaz (2019) determined that the draining duct opening to the glands was located in the centre of the lobe. In our study, similar to Tyto alba (Yılmaz and Yılmaz, 2020), the drainage ducts opened into several collecting ducts caudal to the gland. Yılmaz and Yılmaz (2020) stated that this may be related to the fact that the owl is not an aquatic bird.

In some studies, it can be seen that gland lobules are divided into three regions according to epithelial height and lumen width (Lucas and Stettenheim, 1972; Yılmaz and Yılmaz, 2020). In these zones, which were divided as zone I, zone II and zone III, respectively towards the centre under the capsule, germinative cell layer, intermediate cell layer, secretory cell layer and degenerative cell layers were determined from outside to inside, consisting of different numbers of layers. In agreement with the literature, the intermediate and secretory cell layers were much thinner in zone III compared with the other two zones (Abalain et al., 1984; Chiale et al., 2016; Carril et al., 2019; Chiale et al., 2021;). In addition, the cell layers in all zones consisted of irregularly arranged intermediate cells and secretory cells with a small number of degenerative cell layers at the innermost layer. In accordance with Yilmaz and Yılmaz (2020), intermediate cells have acidophilic cytoplasm and basophilic nucleus. In our study, the lumen of the secretory cells contained numerous large and small, white-coloured fat vacuoles. It was also noted that larger fat vacuoles were present in the cytoplasm of degenerative cells.

Studies on the uropygial gland of Chilean flamingo and Monk parakeet revealed the presence of glycoconjugates containing carboxyl groups and sulphated esters, which reacted positively with PAS- AB (pH:2.5). These compounds are associated

with protective functions in various organs (protecting and maintaining feathers) (Díaz et al., 2008; Yashpal et al., 2014; Chiale et al., 2016). In a study conducted in falcons, the germinative cell layer, germinative membrane and secretion of the adenomere were shown to be PAS-positive (Chiale et al., 2016). The high number of acidophilic cells indicates that there is a large amount of oil synthesis in the gland. (Yılmaz et al., 2018). In our study, staining with Periodic Acid Schiff-Alcian Blue (PAS-AB) showed a weak light blue staining (glycogen) in the cytoplasm of the cells in the peripheral region, while the cytoplasm of the central cells was not stained and the nuclei were pushed aside, indicating a large amount of fat synthesis.

In the light of these results, it was thought that the intracellular secretion in the peripheral region of the glands was mostly glycogen-derived in histochemical staining and changed to lipid character as the secretion pushed the nucleus aside as it descended towards the lumen.

The presence of Herbst's corpuscles, which was revealed for the first time by Harem et al. (2005) in wild ducks, was not determined in mallard ducks by Yılmaz and Yılmaz (2019). In our study, the presence of Herbst's corpuscles was observed similar to laughing dove (Madkour et al., 2023).

## CONCLUSION

As a result of macro-anatomical and histological findings, it was determined that the uropygial gland in budgerigars resembles most terrestrial bird species with its characteristics such as being surrounded by a fibrous capsule, consisting of two lobes and a papilla system, being heart-shaped, having draining ducts opening into several collecting ducts located caudal to the gland, the location of lymphoid follicles and the presence of Herbst corpuscles, but it also shows significant differences with aquatic bird species and some endemic bird species.

## REFERENCES

**Abalain JH, Amet Y, Daniel JY, Floch HH.** Androgen control of the secretion in the sebaceous-like preen gland. J Steroid Biochem. 1984; 20(1):529-531.

**Balkaya H, Özdemir D, Özüdoğru Z, Kara H, Erbas E.** Saksağanda (Pica pica) Glandula Uropygialis'in anatomik ve histolojik yapıları üzerine bir çalışma. Van Vet J. 2016;27 (1):21-24.

**Baumel JJ, King AS, Breasile JE, Evans HE, Berge JCV.** Handbook of avian anatomy (Nomina anatomica avium). 2nd ed. Cambridge, Massachusetts: Publications of the Nuttall Ornithological Club; 1993. p.22-44.

**Bhattacacharyya SP, Ghosh A.** Histochemical studies on the enzymes of the uropygial gland. Acta Histochem. 1971; 39:318-326.

**Burger BV, Reiter B, Borzyk O, Du Plessis MA.** Avian exocrine secretions. I. Chemical characterization of the volatile fraction of the uropygial secretion of the green wood hoopoe, Phoeniculus purpureus. J Chem Ecol. 2004; 30:1603-1611.

**Carril J, Chiale MC, Barbeito CG.** The uropygial gland of the monk parakeet Myiopsitta monachus: Histology, morphogenesis, and evolution within Psittaciformes (Aves). Evol Dev. 2019;22(3):269-282.

**Chen YH, Peh HC, Roan SW.** Establishment of uropygial gland growth curves for white, threeway crossed mule ducklings. Braz J Poultry Sci. 2015; 17:209-218.

**Chiale MC, Carril J, Montalti D, Barbeito CG.** The uropygial gland of the Eared Dove and its evolutionary history within the Columbiformes (Aves). J Ornithol. 2019; 160:1171-1181.

**Chiale MC, Fernández PE, Gimeno EJ, Barbeito CG, Montalti D.** Morphology and histology of the uropygial gland in Antarctic birds: relationship with their contact with the aquatic environment? Aust J Zool.2014; 62:157-165.

**Dalga S**. Applied anatomy to the Gurcu Goat´s mandible in Kafkas and its clinical significance in regional anesthesia. TJVR. 2021; 5(2):51-56.

**Díaz AO, García AM, Goldemberg AL.** Glycoconjugates in the mucosa of the digestive tract of Cynoscion guatucupa: a histochemical study. Acta Histochem. 2008; 110(1):76-85.

**Elder WH.** The oil gland of birds. Wilson Bull. 1954; 66:6-31.

**Galván I, Barba E, Piculo R, *et al*.** Feather mites and birds: an interaction mediated by uropygial gland size? J Evol Biol. 2008; 21:133-144.

**Gezici M.** Deri ve epidermoidal oluşumlar. In: Dursun N, eds. Evcil Kuşların Anatomisi. Ankara: Medisan Yayınevi; 2002. p.207-216.

**Harem MK, Altunay H, Harem İS, Beyaz F.** Yaban ve evcil ördeklerde preen bezi üzerinde histomorfolojik ve histokimyasal çalışmalar. J Health Sci. 2005; 14:20-30.

**Hou HC.** Studies on the glandula uropygialis of birds. Chinese J Physiol. 1928; 2:345-380.

**Jacob J, Ziswiler V.** The uropygial gland. Avian Biol. 1982; 6:199-324.

**Jacob J, Zeman A.** Das burzeldrusensekret der ringeltaube (Columba palumbus). HoppeSeyler's Z Physiol Chem. 1972; 353:492-449.

**Johnston DW.** A morphological atlas of the avian uropygial gland. Bull Br Mus Nat Hist. 1988; 54:199-259.

**Kennedy RJ.** Preen gland weights. Ibis (Lond 1859). 1971; 113:369-372.

**King As, Mclelland J.** Form and function in birds. Great Britain, London: Academic Press; 1985. p.1-52.

**Kozlu T, Bozkurt YA, Ateş S.** A macroanatomical and histological study of the uropygial gland in the white stork (Ciconia cicionia). Int J Morphol. 2011; 29:723-726.

**Lucas AM, Stettenheim PR.** Uropygial gland. In: Avian Anatomy, Part II. Washington: US Dept Agric Handbook; 1972. p.613-626.

**Menon GK, Aggarwal SK, Lucas AM.** Evidence for the holocrine nature of lipoid secretion by avian epidermal cells: a histochemicaland fine structural study of rictus and the gland. J Morphol. 1981; 167:185-199.

**Mobini B, Ziaii A.** Comparative histological study of the preen of broiler and native chicken. Vet Res Bull. 2011; 6:121-128.

**Møller AP, Erritzøe J, Rózsa L.** Ectoparasites, uropygial glands and hatching success in birds. Oecologia. 2010; 163(2):303-311.

**MorenoRueda G.** Uropygial gland and bib colouration in the house sparrow. Peer J. 2016; 4:e2102.

**Özüdoğru Z, Özdemir D, Teke Be, Kırbaş M.** A Study on morphological and morphometrical parameters on the skull of the Konya Merino Sheep. TJVR. 2023; 7(2):59-66.

**Petek M.**Kafes kuşları. J Res Vet Med. 2004; 23(1-2-3):131-136.

**Reynolds S.** The anatomy and histomorphology of the uropygial gland in New Zealand endemic species [Phd Thesis]. New Zealand: Massey University; 2013.

**Sadoon AH.** Histological study of European starling uropygial gland (Sturnus vulgaris). Int J Poult Sci.2011; 10:662-664.

**Salibian A, Montalti D.** Physiological and biochemical aspects of the avian uropygial gland. Braz J Biol. 2009; 69:437-446.

**Sandilands V, Powell K, Keeling L, Savory CJ.** Preen gland function in layer fowls: factors affecting preen oil 9 fatty acid composition. Br Poult Sci. 2004; 45:109-115.

**Sawad AA.** Morphological and histological study of uropygial gland in Moorhen (G. gallinula C. Choropus). Int J Poult Sci. 2006; 5:931-934.

**Schumacher S**. Der Bürzeldocht. Anat Anz. 1919; 52:291-301.

**Shawkey MD, Pillai SR, Hill GE.** Chemical warfare? Effects of uropygial oil on feather-degrading bacteria. J Avian Biol. 2003; 34:345-349.

**Stangier N, Sandhöfer S, Mosig A, Claudia D.** The uropygial gland of the Great Cormorant (Phalacrocorax carbo): I. Morphology. J Ornithol. 2023; 164:591-603.

**Stettenheim PR.** The integumentary morphology of modern birds - an overview. Am Zool. 2000; 40:461-477.

**Taşbaş M.** Veteriner aesthesiologia. Ankara: Tamer Yayınları; 1996.

**Vincze O, Vágási CI, Kovács I, Galván I, Pap PL.** Sources of variation in uropygial gland size in European birds. Biol J Linn Soc. 2013; 110:543-563.

**Wagner RC, Boord RL.** Cytological differentiation in the uropygial gland. J Morphol. 1975; 146:395-413.

**Yashpal M, Kumari U, Mittal S, Mittal AK.** Glycoproteins in the buccal epithelium of a carp, Cirrhinus mrigala (Pisces, Cyprinidae): a histochemical profile. Anat Histol Embryol. 2014; 43(2):116-132.

**Yılmaz B, Harem İŞ, Demircioğlu İ, Özyiğit G, Bozkaya F.** Aseel ırkı horoz ve tavuklarda glandula uropygialis'in anatomik, morfometrik ve histolojik özellikleri. Eurasian J Vet Sci. 2018; 34:65-70.

**Yılmaz B, Yılmaz R.** Macroanatomical and histological features of uropygial gland in mallard ducks (Anas platyrhynchos). Harran Üniv Vet Fak Derg. 2019; 8(2):214-220.

**Yılmaz B, Yılmaz R.** Peçeli baykuşlarda (Tyto alba) Glandula Uropygialis'in morfolojik ve histolojik Analizi. J ResVet Med. 2020; 39(2):143-148.

**Zık B, Erdost H.** Horozlarda acı kırmızıbiberli rasyonla beslemenin üropigi bezi üzerine etkisinin histolojik yönden incelenmesi. Turk J Vet Anim Sci. 2002; 26:1223-1232.

## ACKNOWLEDGMENTS

**Author contributions:** Fİ, ZAK, İİ, İA and ÖÖ designed the study. Fİ and İA material supply, macroscopic examination, morphometric measurements and statistical analyses. ZAK and İİ histological processing of tissues and histological examination. İA and ÖÖ participated in drafting and revising the manuscript.

Fİ: Fatma İşbilir, ZAK: Zehra Avcı Küpeli, İİ: İhsan İşbilir, İA: İlker Arican, ÖÖ: Özgür Özyiğit

**Financial Disclosure:** The authors declared that this study has received no financial support.

**Conflict of Interests:** The authors declared that there is no conflict of interests.

**Additional information:** All authors have read and agreed to the published version of the manuscript Correspondence and requests for materials should be addressed to Fİ.

**Reprints and permissions** information is available at https://dergipark.org.tr/tr/pub/tjvr/policy

**Publisher's note** Dergipark remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.