



AVIAN STOMACH ANATOMY – A MINI REVIEW

H. HRISTOV

Department of Veterinary Anatomy, Histology and Embryology,
Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

Summary

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The stomach of birds comprises three parts – glandular (*proventriculus gastris*), muscular (*ventriculus gastris*) and pyloric (*pars pylorica gastris*). Depending on the diet, these three parts are well differentiated in omnivorous, herbivorous, insectivorous and granivorous birds and slightly differentiated in fish- and meateaters. In fruit-eating, nectar-eating and testacivorous birds, the stomach has an intermediate structure between the two types. In some birds from the genus *Tangara*, the stomach is reduced to a diverticulum.

Key words: avian, morphology, stomach

The digestive apparatus in birds has went through a multitude of changes during the evolution to become a unique anatomical and physiological structure compared to mammals on one hand, and presenting a number of specific features between the different avian species and breeds on the other. According to its general structure, *apparatus digestorius* is a short, tube with a complex structure that begins from the beak and ends with the cloaca. Morphology of the stomach has been widely studied in different species of birds – carnivorous, piscivorous, herbivorous etc. (Baumel *et al.*, 1993; Rossi, 2005; Ogunkoya & Cook, 2009; Hassan & Mousa, 2012; Hsu *et al.*, 2014).

Dyce *et al.* (2010) defines the stomach of birds as the part of the avian digestive

system with the most species-related peculiarities. Langlois (2003) defines the morphology of birds' stomach as unique amongst vertebrates, adapted to a wide variety of nutrients in the course of evolution. The author describes the birds' stomach as a set of several parts – proventriculus, an intermediate zone, a ventriculus and a pylorus. The proventriculus varies in shape and size in different birds. It is relatively small in granivorous species and relatively voluminous in carnivorous birds. Svihus (2014) considers the proventriculus and the ventriculus as a single compartment with relation to the digestive function since food migrates repeatedly during contractions between the two parts.

The stomach in birds consists of three parts – glandular (*proventriculus gastris*),

muscular (*ventriculus gastris*) and pyloric (*pars pylorica gastris*). The anatomical topography and microstructure of the particular parts are influenced by the specific way of breeding and by the diet of the species (McLelland, 1990; Baumel *et al.*, 1993; Gadzev, 1997). Depending on the diet, two main types of stomach are acknowledged in birds. The first type is with relatively undifferentiated parts and is found in piscivores and carnivores. In these species, the stomach is a place not only for chemical digestion of food but also for its storage. The second stomach type with clearly differentiated proventriculus and ventriculus is typical for omnivorous, herbivorous, insectivorous and granivorous birds. In some species, e.g. fruit-eating, nectar-eating and testacivorous birds, the organ takes an intermediate position between the two types (Baumel *et al.*, 1993; Gelis, 2006; König *et al.*, 2016). According to König *et al.* (2016) the stomach in some fruit-eating birds (genus *Tangara*), is reduced to a rudimental diverticulum in the digestive apparatus.

Kots (2009) describes the shape, the size, the macro-relief of the *tunica mucosa*, the presence of glands in their ducts and openings, the presence of the cuticle and the thickness of the wall as the main characteristics of the avian stomach. The author defines the stomach of the studied carnivorous birds as a simple thin-walled glandular type, different from the complex stomach of the granivorous, omnivorous and herbivorous birds. Kharchenko (2012; 2014) pays attention to the number of chambers, the shape of the stomach, the structure and the macro-relief of the mucosa in the birds examined. The author divides the birds into two groups: such with a single-chambered glandular type stomach and with a two-chambered one. The single-chambered glandular type

stomach may have a distinct pyloric bladder (Ciconiiformes) and no pyloric bladder (Falconiformes, Strigiformes). The two-chambered stomach in birds is divided into glandular and muscular part. The shape of the glandular part varies from spindle-shaped, cylindrical to conical. The mucous membrane of the glandular part of the stomach has furrowed relief and forms papillae (*papillae proventriculi*) with concentric folds around them. According to the author, the digestive system in birds, regardless of their eating habits, has a relative universality in terms of anatomical, histological and biochemical structures. He takes the shape of the stomach of the golden eagle as elongated spindle-shaped and indicates two folded areas of the mucous membrane. The first zone corresponds to the proventriculus and has pronounced longitudinal folds with a big amount of gastric pits, in which the glands, secreting pepsin, are opening. The second zone corresponds to the muscular stomach. The screech-owl has a big single-chambered stomach with a round shape and thin walls. The relief of the mucosa is smooth. Cranially, the light colour of the mucous membrane with the macroscopically visible openings of the glands functionally corresponds to the proventriculus in two-chambered stomachs. König *et al.* (2016) add information about the stomach of storks and seagulls and describe it as a highly expanding single-chambered sac with poorly developed musculature. Kharchenko & Lykova (2013) define the stomach of some swamp birds as two-chambered with glandular and muscular part.

In granivorous, the two parts of the stomach (*proventriculus gastris* and *ventriculus gastris*) are separated externally by a narrowing (*isthmus gastris*) and differ in terms of appearance and structure of

the wall. The glandular part is cranial to the muscular one (Gadev *et al.*, 1992; Harcourt-Brown, 2005; Mihaylov, 2006; Hena, 2012; Georgaki, 2014).

Domestic birds (hen, turkey, duck, goose, Japanese quail, guinea-fowl, pigeons) are adapted to mechanical digestion of food. Their stomach has a glandular and a better developed muscular part, separated with an isthmus. The proventriculus in poultry is spindle-shaped, located to the left on the median plane and dorsally to the left lobe of the liver. The wall of the proventriculus is thicker than that of the esophagus' with insignificant difference in the diameter of the lumen (Ahmed *et al.*, 2011; Dahekar, 2014; Al-Saffar & Al-Samawy, 2015b; Madkour & Mohamed; Saran *et al.*, 2019). In Nigerian indigenous chickens, Mahmud *et al.* (2015) describe the proventriculus as a relatively small tube shaped organ. Dimitrov (2014) defines the glandular stomach as an ellipsoid enlargement (similar to a lemon fruit) of the digestive canal that comes after the esophagus. Vrakin & Sidorova (1984) and Zhilin (2010) distinguish an apex, body and intermediate zone of the glandular part of the stomach. The apex is localised between the chest air sacs; the body is located between the lobes of the liver to which it is attached with connective tissue. Al-Saffar & Al-Samawy (2016) report that the stomach of the domestic pigeon (*Columba livia domestica*) is formed by a tubular proventriculus and a spindle-shaped ventriculus.

According to McLelland (1975), the proventriculus is oriented craniocaudally, somewhat ventrally and to the left, occupying the left ventral part of the body cavity. The authors affirmed that in male individuals, it is located between 5th thoracic to 3rd lumbosacral vertebra and in female individuals – between 4th and 7th

thoracic vertebra. The left lobe of the liver covers the left and the ventral surface of the proventriculus. The spleen is located to the right and caudodorsally. On the dorsal surface of the caudal part of the proventriculus lies the left testicle in male, respectively the ovary and the cranial part of the oviduct in female birds. The mucosa is whitish, covered with simple columnar epithelium and forming numerous macroscopic elevations of the mucous membrane – *papillae proventriculi*. In the hen, on top of each papilla opens the excretory duct, corresponding to a multilobular gland, located in the propria of the proventriculus (McLelland, 1975). In turkeys the mucosa of the proventriculus bears longitudinally oriented rows of papillae, each showing 3–5 openings of the deep glands (Berenfeld, 2011). In some hen breeds proventricular papillae are arranged in close contact in the cranial and the caudal part of *regio glandularis* unlike the middle part where they do not contact with each other (Das *et al.*, 2013; Sinha *et al.*, 2016; Mal *et al.*, 2017). The transition from the glandular to muscular part of the stomach has thinner wall without papillae, folds and glands (McLelland, 1975; Ghetie, 1976; Ivanov & Kowalski, 1976; Dyce *et al.*, 2010).

In companion birds, including parrots, the stomach is formed by glandular and muscular parts, separated by a narrowing (*isthmus gastris*) and is located left to the median plane (Klasing, 1999; Matsumoto *et al.*, 2009; Siqueira, 2014; Wanmi *et al.*, 2014; 2015). The proventriculus of the Blue-and-yellow macaw (*Ara ararauna*) is spindle-shaped, has a softer wall than that of the ventriculus and bright spots on the *tunica serosa*, representing the deep proventricular glands. The proventricular mucosa forms papillae enveloped by concentric folds (Aizawa *et al.*, 2012). Often

the coilin layer from the ventriculus goes towards the proventriculus and covers *zona intermedia* (Dyce *et al.*, 2010).

Hristov *et al.* (2017a; 2017b) describe the stomach of the domestic canary (*Serinus canaria*), formed by a cranial (*proventriculus gastris*) and a caudal part (*ventriculus gastris*), separated by a narrowing (*isthmus gastris*). The authors report that *proventriculus gastris* in the median plane at the base of the heart and at a distance of 4–6 mm behind the tracheal bifurcation. Anatomically and topographically, the proventriculus lies between the III–VII ribs, is cone-shaped and has a longitudinal axis with left caudal orientation, touching the rib wall at the last three ribs. The so marked *proventriculus gastris* is situated entirely in the chest part of the common body cavity. Ventrally, the left lobe of the liver covers the *proventriculus gastris*. Craniolaterally the proventriculus touches the lungs and caudolaterally the caudal thoracic air sac is inserted between the proventriculus and the medial surface of the rib wall, in the area of the last two (three) ribs. The right lobe of the liver is medial to the *proventriculus gastris*. This finding is well observed during the dissection with a left ventrolateral inspection of the body cavity. The proventriculus in the domestic sparrow (*Passer domesticus*) is cone-shaped identically to that of the domestic canary (Daniel *et al.*, 1982).

The ostrich has a big, thin-walled proventriculus that passes dorsally with a wide opening in the ventriculus (Langlois, 2003). Illanes *et al.* (2006) describe macroscopically the proventriculus as being with a crescent shape, pale pink colour and a wide lumen, and covered with a small amount of fat. Wagner *et al.* (2001) add that the proventriculus in the ostrich expands caudally and passes behind the ventriculus. Oliveira *et al.* (2008) report

the proventriculus of the ostrich as an elongated, spiral-shaped organ. Other avian species (emu and cassowary) have a large proventriculus of approximate size of the ventriculus. In birds from genus *Rhea*, the proventriculus is smaller than the ventriculus but the coilin layer passes into the proventriculus. The distribution of the proventricular glands is not similar in all birds. They are usually distributed evenly throughout the wall of the proventriculus. The openings of the deep proventricular glands are macroscopically observed at the apex of the papillae. In some bird species (owls) the glands are restricted to longitudinal sections and in snakes they are placed in a separate diverticulum. According to Lumeij *et al.* (1994) and Langlois (2003) in ostrich birds and nandu, the deep proventricular glands are confined to a circular section in the area of the great curvature.

In the cattle egret (*Bubulcus ibis*), the stomach is made up of three parts (chambers) – glandular, muscular and pyloric. The proventriculus and the ventriculus form a common and large pear-shaped cavity. The shape of the proventriculus varies as trapezoid, rectangle or cone (El Nahla *et al.*, 2011; Hussein & Rezk, 2016). A low fold is observed internally between the esophagus and the proventriculus. The proventricular mucosa forms papillae and folds. The authors take the cuticle-covered line as the region, separating the proventriculus from the ventriculus. In the common moorhen (*Gallinula chloropus*), the proventriculus is cone-shaped with light brown outer and smooth papillae-free inner surface (Jassem *et al.*, 2016). Unlike other species of birds, the proventriculus in petrel, ostrich and penguin-like birds is larger than the ventriculus and has a highly reservoir function (Degen *et al.*, 1994). When examining the

stomach of bustards, Bailey *et al.* (1997) describe the proventriculus as cone-shaped. Slightly outlined hexagonal sections are observed on the serous surface and the entire inner surface is covered with papillae.

The stomach of the birds from genus *Falco* (*Falco berigora*, *Falco subbuteo*) is located in the middle part of the thoraco-abdominal cavity. The well-developed glandular part is spindle-shaped and buff to green in colour. The mucosa of the proventriculus is folded extensively and lacking papillae. The muscle of the stomach is relatively smaller and the isthmus is absent (Abumandour, 2013; 2014; Al-tae, 2017). The stomach of the owl (*Otus Scors Brucei*) consists of two externally distinguishable chambers: a short proventriculus with a thick wall and a thin-walled round ventricle (Al-Saffar & Al-Samawy, 2015a).

CONCLUSION

The review of the literature shows that the stomach of birds is located in the left half of the common body cavity. It is formed by three anatomical parts: glandular, muscular and pyloric, which are differentiated depending on the diet.

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Correspondence:

H. Hristov
Department of Veterinary Anatomy,
Histology and Embryology,
Faculty of Veterinary Medicine,
Trakia University,
Stara Zagora, Bulgaria
e-mail: klokkende@abv.bg