

Macroscopic comparative aspects among two species of birds of prey: *Falco tinnunculus* (Common kestrel) and *Tyto alba* (Barn owl)

Alexandra-Iulia Preja¹, Mircea Florin Cipou^{1*}, Alexandru N. Stermin² and Aurel Damian¹

¹ University of Agricultural Sciences and Veterinary Medicine, Department of Comparative Anatomy of domestic animals, Cluj-Napoca, Romania; e-mail: alexandraiuliap@gmail.com; mircea.cipou@usamvcluj.ro; damian56aurel@yahoo.com;

² Babeş-Bolyai University, Department of Taxonomy and Ecology, Romania; e-mail: alexandru.stermin@ubbcluj.ro;

* Correspondence: M.F.C. mircea.cipou@usamvcluj.ro;

Abstract: Birds of prey are at the top of the food chain and play an essential role in controlling populations of birds and rodents that are harmful to habitat. This study was conducted on 11 bird carcasses, 5 *Falco tinnunculus* carcasses and 6 *Tyto alba* carcasses, donated by the UBB Zoological Museum of Academic Cultural Heritage, in order to examine the gross anatomical structures of the digestive system and to highlight the anatomical differences in both carnivorous species. Dissections were conducted at the Department of Comparative Anatomy at the Faculty of Veterinary Medicine in Cluj-Napoca, according to an established protocol. The beak is short and slightly curved in both species studied, the tomial tooth being highlighted in *Falco tinnunculus*. Conical papillae and salivary duct openings are more numerous in both species. The oropharyngeal cavity has lateral longitudinal folds of the tongue and glottis, with a distensible esophagus along its whole length in *Tyto alba*. *Falco tinnunculus*, however, has ingluvium and a less distensible oesophagus. The stomach is undeveloped in both species, with the appearance of an elongated pear, and the small intestine varies in length, shorter in *Falco tinnunculus* than in *Tyto alba*, but in both species it is arranged in several loops with the help of the mesenterium. The cecum is different, poorly developed, vestigial type in *Falco tinnunculus*, and well developed, with two elongated caecal protrusions in *Tyto alba*. The digestive system is characteristic of carnivorous species and is a reflection of how it has adapted to feeding behavior.

Keywords: oesophagus, ingluvium, cecum, nocturnal raptor, diurnal raptor

1. Introduction

Birds of prey play a significant part in the ecosystem because they are at the top of the food pyramid, and their digestive system is adapted to a strictly carnivorous diet (Ford, 2010). The term "raptor" refers to a wide variety of bird species with different natural history, anatomical and dietary characteristics. In general, when we talk about raptors, we most often talk about eagles, falcons and owls. Although these birds share similar characteristics, they are framed into separate taxonomic groups [11].

The morphology of the gastrointestinal tract, metabolic performance and the physiology of digestion have evolved over time according to the principle of integrality, to satisfy nutritional requirements based on the food available in the natural habitat [9]. During evolution, the avian digestive system underwent changes to make the flight easier: the teeth disappeared, the digestive tract is shortened, and the avian organs (liver, muscle stomach) crowded around the centre of gravity [4]. The digestive system may be represented as a continuous tube, with an opening to two ends: the beak, at the oral end, and the anocecal orifice, at the posterior end [9]. Compared to mammals, birds do not have teeth and jawbone muscles are much less developed [4].

The purpose of this study is to examine the anatomical structures of the digestive tract for two species selected from the Falconiform and Strigiform orders, *Falco tinnunculus* (Common kestrel), of the order Falconiformes, family Falconidae, and *Tyto alba* (Barn owl), of the order Strigiformes, family Tytonidae, and to bring to light the ana-

Received: 11.06.2023

Accepted: 15.06.2023

Published: 17.06.2023

DOI:10.52331/cvj.v28i1.45



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tomical differences of the digestive system in both carnivorous species.

Falco tinnunculus or the Common kestrel is a common bird and one of the most common diurnal raptors in Romania, adapted to various habitats: it is found in mountain regions, in the plains, in the urban environment [7]; typically consumes small mammals, particularly mice, birds; in warmer areas, the diet is composed of insects and lizards [3].

Tyto alba or the Barn owl is a nocturnal bird, found in the western and northern parts of the country, nesting in agricultural areas with sparsely planted groves, gardens [7]. It feeds on small mammals, birds (including other Strigiformes, but smaller in size), frogs, moles, bats [3].

2. Materials and Methods

The birds we had examined came from the Zoological Museum of the University Cultural Heritage of BBU (Babeş-Bolyai University). Birds died from accidents (electrocution, road accident) or were euthanized due to injuries that no longer allowed them to be rehabilitated in nature. Each bird is accompanied by a note on which is written the year of death, the provenance and the name in Romanian/Hungarian or Latin.

The opening of the body was carried out in several stages. The dissection was performed after the protocol and instructions used in the Faculty of Veterinary Medicine of Cluj-Napoca [2].

The plucking of the corpses was carried out strictly in the area of the incisions. At the level of the head, the skin from the lateral commissure of the beak is incised. The skin incision continues on the ventral side of the neck, lateral to the trachea and up to the level of the cloacal orifice. With a pair of scissors, we made transversely section of the abdominal muscles from the posterior part of the sternum to the posterior of xiphoid appendix. On each side of the sternum, the initial abdominal incision is continued up to the level of the chondrocostal junctions. The abdominal wall is sectioned longitudinally up to the cloaca and is turned laterally. The sectioning of the chondrocostal joints is continued with scissors, bilaterally, up to the level of the scapulohumeral joints, the coracoid bones and the clavicle are sectioned, the sternum is removed after disengaging the pericardial sac. The organs located in the cavity are detached, both commissures of the beak are sectioned, the lower mandible is detached, along with the oesophagus and a portion of the trachea. The skin and muscles from the cloacal orifice were sectioned and we detach it together with the digestive tube and the accessory digestive organs. The digestive system was examined only macroscopically, *in situ*, and separated from the carcass. The oesophagus, proventriculus, ventriculus (gizzard), small intestine, large intestine, cloacal orifice were opened with scissors. A digital camera, Nikon COOLPIX P900, was used to make the images.

3. Results and discussions

In *Falco tinnunculus*, the beak is strong and curved; the upper jaw is more developed than the lower jaw. The tomial tooth, located in the upper jaw, is well developed. At the base of the beak, the ceroma is identified, which surrounds the nostrils (Fig 1). These peculiarities have been pointed out by Murray [11], Ford [6], Lacasse [10]. During examination of the oropharyngeal cavity, the partially hard, conical papillae may be identified, which surround the edge of the hard palate. Caudal to choana, the openings of the salivary glands can be highlighted in large numbers, particularly on the sides of the infundibular cleft. The tongue is short, with the rostral portion firm and rough. The conical, partially hard papillae can be identified at the base of the tongue, arranged in the form of the letter V, with an aboral opening. In addition, caudal to the glottis, the same hard, conical papillae can be seen. The oropharyngeal cavity has numerous openings of the salivary glands close to the base of the tongue and in the aboral part of the hard palate (Fig.2). These features have not been documented in the literature on this species.



Figure 1. Head *Falco tinnunculus*. Arrows-ceroma that encompasses the narinas and the tomial tooth



Figure 2. Oro-pharyngeal cavity of *Falco tinnunculus*. The first arrow points at the tip of the beak. All the other arrows indicate the presence of hard papillae on the floor, tongue and glottis, respectively the openings of the salivary gland

Table 1. Measurements taken during dissections on the bodies of *Falco tinnunculus*

Nr. ord.	Body weight	Length of body	TD weight without skull	Liver weight	Liver length	Liver width	TD weight without liver	Long. Esophagus+proventricule	Length of small+large intestine
1	102 g	20 cm	4 g (without skull)	1 g	2 cm	4 cm	4 g	11,5 cm	40 cm
2	130 cm	29 cm	16 g (without skull)	4 g	3,5 cm	5 cm	10 g	10, 5 cm	54 cm
3	120 g	32 cm	11 g (without skull) 27 g (with skull)	1 g	2 cm	3 cm	8 g (without skull) 33 g (with skull)	11 cm	43 cm
4	107 g	30 cm	10 g (without skull) 30 g (with skull)	1 g	3 cm	3 cm	8 g (without skull) 28 g (with skull)	11 cm	45 cm
5	108 g	30 cm	8 g (without skull) 27 g (with skull)	2 g	2,5 cm	3,5 cm	8 g (without skull) 26 g (with skull)	12 cm	15 cm

Compared to the previously described species, *Tyto alba* has a short beak with a pointed ventral tip. The cerome was identified at the base of the upper jaw, but not around the nostrils. The oropharyngeal cavity doesn't have a soft palate and a pharyngeal isthmus. Conical and hard papillae are present on the surface of the hard palate, most highlighted caudal in the choana and lateral in the infundibular cleft (Fig.3), on the lingual surface, in the caudal part, at the lingual base, on the surface of the glottis (Fig.4). Salivary gland channel openings are evident on the floor of the oropharyngeal cavity and its lateral surfaces (Fig.4). The oropharyngeal cavity has longitudinal folds, most visible near the lingual base and on the glottis side, at the entrance of the esophagus. These characteristics are not reported in the literature for this species.



Figure 3. The top of the Oro-pharyngeal cavity at *Tyto alba*. Arrow-presence of conical papillae

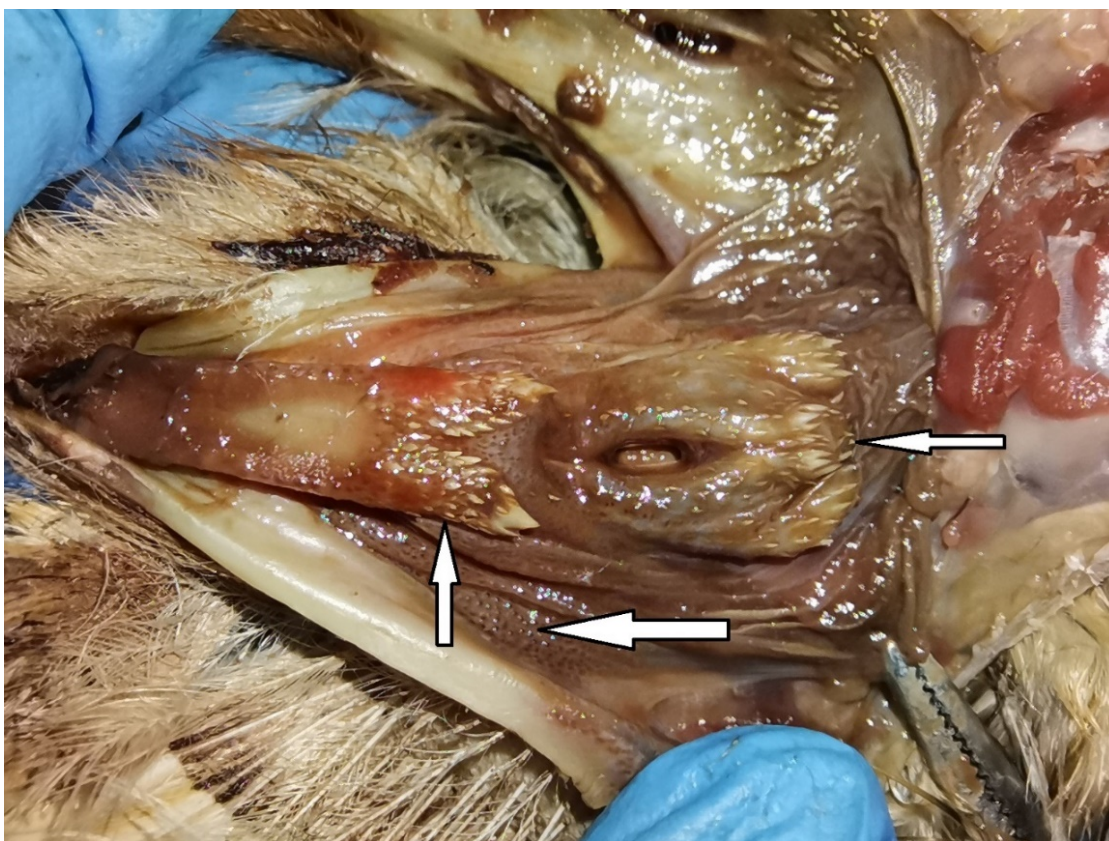


Figure 4. The top of the Oro-pharyngeal cavity at *Tyto Alba*. Arrows-presence of hard papillae and salivary glands openings

Table 2. Measurements taken during dissections on bodies of *Tyto alba*

Nr. ord.	Body weight	Length of body	TD weight without skull	Liver weight	Liver length	Liver width	TD weight without liver	Long. Oesophagus+proventric+ventricle	Length of small+large intestine
1	287 g	30 cm	x	X	x	x	x	x	x
2	291 g	33 cm	x	X	x	x	x	x	x
3	295 g	31 cm	x	X	x	x	x	x	x
4	309 g	30 cm	26 g (without skull)	6 g	5 cm	4 cm	20 g	13 cm	41 cm
5	203 g	32 cm	14 g (without skull) 50 g (with skull)	3 g	3,5 cm	4,5 cm	13 g (without skull) 58 g (with skull)	14 cm	35 cm
6	274 g	31 cm	26 g (without skull)	X	x	x	20 g	15 cm	44,5 cm

In the case of the Common kestrel, the esophagus is short and it presents a crop or ingluvies. The crop is represented by an enlargement of the cervical part of the esophagus, with the function of food storage, with a fusiform aspect. This aspect was highlighted by Duke et al. [5], who note that the crop, the glandular and the muscular stomach are similar in appearance and have the same dimensions as other birds from the family Falconidae. The stomach, the next part of the digestive tract, is considered a dilated continuation of the oesophagus, has a pear-shaped form and is situated to the left of the median and dorsal line to the liver; it is divided into proventriculus and gizzard (the proventriculus is placed before the gizzard). Cranially, the proventriculus is separated from the esophagus by a constrictive region. Caudal, the proventriculus is separated from the gizzard by a reduced constriction zone, and no obvious boundaries can be observed inside. The longitudinal folds observed on the inner surface of the oesophagus do not occur at the proventricular level. Proventriculus is underdeveloped, and many openings in the secretory gland can be seen on its surface. The gizzard is similar to a biconvex lens with thick sides (Fig. 5). Due to the advanced state of decomposition of the cadavers, the internal particularities of this intestinal segment cannot be highlighted.



Figure 5. Cranial portion of the digestive tract in *Falco tinnunculus*. The arrows (in order) the ingluvies or the crop, the proventriculus, the passage area between the glandular and muscular stomach, the gizzard and the pyloric orifice, near the passage area between the proventriculus and the gizzard

Tyto alba has a long, narrow, straight esophagus which stretches from the level of the oropharyngeal cavity to the level of the glandular stomach. This aspect was highlighted by Umar and Atabo, [12]. The longitudinal folds are visible throughout the surface of the esophagus; they suddenly disappear with the transition between the esophagus and the glandular stomach. The crop is not observed. The transition between the glandular stomach and the muscular stomach is abrupt, without a isthmus or zona intermedia gastrica. The glandular stomach is small in size, with many openings of the secretory gland on its surface. The ventricle is well developed, with thick walls (Fig. 6), but because of the advanced state of decomposition of the corpses, no other morphological peculiarities can be distinguished.



Figure 6. Gastrointestinal tract in *Tyto alba*. The arrows indicate, in order, the oesophagus, the proventriculus, the opening of the pyloric hole, near the passage between the glandular and muscular stomach, the gizzard.

For both species studied, the pyloric orifice opens on the right side of the gizzard, close to the transition zone between the proventriculus and gizzard (Figs 5, 6). *Falco tinnunculus* has a short small intestine arranged in multiple loops, it occupies mainly the caudal part of the coelomic cavity, situated on the right side of the proventriculus and the gizzard. This aspect was underlined by Al-Aaraji and Al-Kafagy, [1]. Because of the advanced state of decomposition of the bodies, a clear dividing line between duodenum, jejunum and ileum cannot be established. *Tyto alba* has a short small intestine; the duodenum comes from the proximal part of the gizzard, is long and folded in several loops using the mesentery fold. This aspect was highlighted by Umar and Atabo, [12]. Because of the advanced state of decomposition of the corpses, a clear line between duodenum, jejunum and ileum cannot be drawn.

The ceca is located at the ileo-cecal junction. *Falco tinnunculus* presents a poorly developed, vestigial cecum (Fig. 7). Hongxing et al., [8], argues that the ceca of this species is underdeveloped compared to herbivorous species. The ceca in *Tyto alba* is a well-developed organ, with two long tubular projections, which attach to the small intestine with the help of the mesentery (Fig. 8), a feature brought up by Umar and Atabo, [12]. For both species, the large intestine is short and straight, it opens outward through the cloaca opening.



Figure 7. Falco tinnunculus digestive tract. The arrows indicate the ceca.



Figure 8. Digestive system in Tyto alba. The arrow indicates the ceca.

The pancreas has not been identified in any examined bodies of the *Falco tinnunculus* species. In *Tyto alba*, the pancreas may be identified at the first duodenal loop, with an elongated appearance (Fig. 9). It has not been reported in the literature.

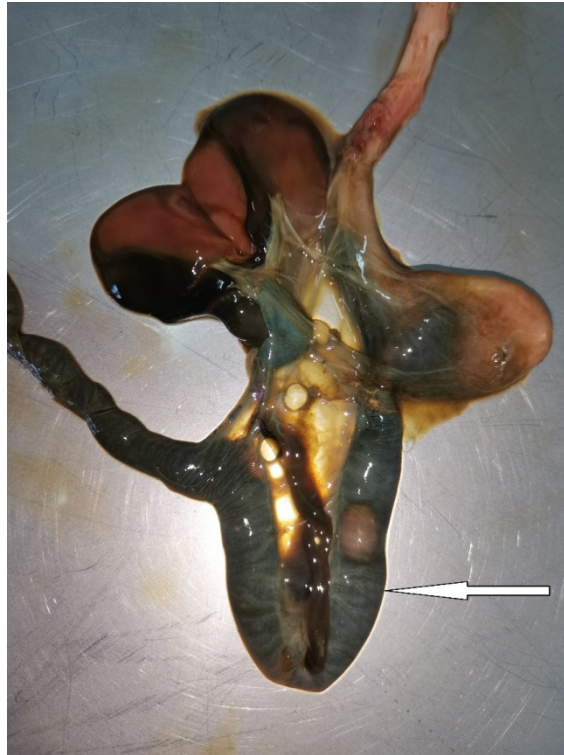


Figure 9 First duodenal loop in *Tyto alba*. In the duodenum loop, the pancreas is indicated by an arrow.

In both species examined, the liver consists of two lobes, the right liver lobe is more developed than the left liver lobe, which cranially surrounds the apex of the heart and joins on the midline. The *Falco tinnunculus* gallbladder is well developed, located on the visceral surface of the right lobe of the liver, as reported in the literature by Murray [11]. (Fig 10, 11). In the bodies examined by *Tyto alba*, the gall bladder is not well developed (Fig 12, 13), located on the visceral side of the right lobe of the liver. This aspect was not reported in the literature.



Figure 10. The appearance of the parietal surface of the liver in *Falco tinnunculus*. The arrow indicates the gall bladder.



Figure 11. The visceral surface of the liver in *Falco tinnunculus*. The arrow indicates the gallbladder



Figure 12. Parietal liver surface in *Tyto alba*

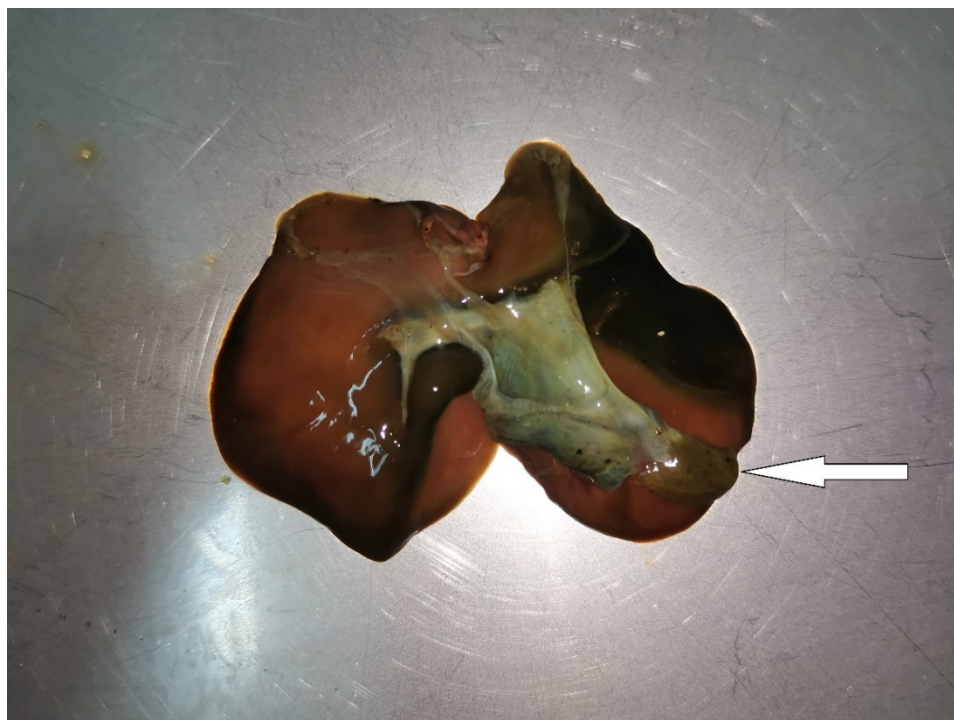


Figure 13. The visceral liver surface in *Tyto alba*. The arrow indicates the gallbladder.

4. Conclusions

The digestive system of the two species studied is adapted to a strict carnivore diet. The beak varies depending on the reference species, but both species have short, light beaks. *Falco tinnunculus* has a tomial tooth, a characteristic formation of the upper jaw and found in many bird species, in particular those of the family *Accipitridae*, *Falconidae* and *Laniidae*.

Both species have hard, conical papillae in the oropharyngeal cavity, with multiple openings of the secretory gland. In *Tyto alba*, the oro-pharyngeal cavity can increase its volume with the help of longitudinal folds, an appearance observed near the lingual and lateral base of the glottis at the entrance to the oesophagus. In the case of *Falco tinnunculus* species, the esophagus shows a crop in its cranial segment, with fusiform-like aspect. The crop is absent in *Tyto alba*. *Tyto alba* has a distensible esophagus throughout its surface, with well-highlighted longitudinal folds, which suddenly disappear at the boundary between the esophagus and the glandular stomach. Both species have weak, pear-like stomachs, divided into two chambers, the proventriculus or glandular stomach and the gizzard or muscular stomach, separated, on the internal surface, by a weak isthmus. The small intestine is short in both species in relation to the length of the body, but is arranged in multiple loops with the help of the mesentery fold. The cecum, located at the ileocecal junction, is little developed at *Falco tinnunculus*, with a vestigial aspect, and well developed at *Tyto alba*, with elongated cecal extensions. The liver has two liver lobes, the right liver lobe is more developed than the left liver lobe. *Falco tinnunculus* has a well-developed gallbladder in comparison with *Tyto alba*, located on the visceral side of the right liver lobe.

Supplementary Materials: Figure S1: title, Table S1: title, Video S1: title.

Author Contributions: All authors had equal contributions and all authors read and agreed with the final form of the manuscript.

Funding: This paper received financial support through the project "Development of advanced and applied research skills in STEAM Logica + Health"/POCU/993/6/13/153310, project co-financed by the European Social Fund through the Human Capital Operational Program 2014-2020".

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Acknowledgments: This paper received financial support through the project "Development of advanced and applied research skills in STEAM Logica + Health"/POCU/993/6/13/153310, project co-financed by the European Social Fund through the Human Capital Operational Program 2014-2020".

Conflicts of Interest: "The authors declare no conflict of interest." "The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results".

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