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Comparative analysis of the digestive system's anatomical parts in two zoophagous bird species: White Stork (*Ciconia ciconia*) and Common Buzzard (*Buteo buteo*)

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Abstract. Aristotle in his anatomical observations is marking the beginning of functional anatomy followed by Georges Cuvier that formulate the low of the correlation of parts. According with this we can expect that the digestive system structures tend to be similar between species that consume approximately the same type of food. In this study we chose to evaluate macroscopic the digestive system of two different zoophytophagous species, with similar body size but different life behavior and feeding strategies: White Stork (*Ciconia ciconia*) and Common Buzzard (*Buteo buteo*). Data were collected after the dissection of 10 carcass (5 White Stork and 5 Common Buzzard). The digestive tract and its structures were measured and weighed. In common buzzard the beak is strong and short adapted for the laceration of the prey. In white stork the beak is long, strong, straight adapted to capture prey like a harpoon. In both species, the esophagus is located on the right side of the neck, the length is different, proportional to the neck. In common buzzard the crop is present and absent in white storks. The cuticle or koilin layer is highlighted in white stork compared to common buzzard. In common buzzard, the small intestine is reduced in size, without marked transition between the duodenum and the ileum. The white storks have a long small intestine with many loops, with no transition between the segments. In both species, the cecum is reduced in size and has a vestigial appearance; the colon is reduced in size, and extends from the level of the ileo-colic junction to the cloaca. The digestive system is adapted to a strictly carnivorous diet and the differences identified between the anatomical structures of the digestive tract of the two species are correlated with the differences of their feeding behavior.

Keywords: functional anatomy, esophagus, crop, intestine, feeding behavior

Introduction

Speaking about anatomy, Aristotle mentioned: "As among themselves, [birds] differ in their parts in respect of the more and less […] some of them have long legs, some short ones […] and similarly with the other parts. […] Another peculiarity of birds is the beak, an extraordinary appendage to the head. It is made of bone, and serves them instead of teeth and lips. […]. Birds' beaks also differ according to their different [ways] of life. Some beaks are straight, some curved; straight if they are used simply for feeding, curved if the bird eats raw meat, because a curved beak is useful for overpowering their prey. Those who spend their lives in swamps and are herbivorous have broad beaks, which are useful for digging and pulling up their food and for cropping plants" (Peck, 1983). In this way Aristotle in his anatomical observations and analysis brings the form in relation to function and opens, we believe for the first time, a path to the functional anatomy (Blits, 1999).

Starting from the idea of the relationship between form and function, Georges Cuvier, analysing the dissections performed on numerous individuals of different vertebrate, formulate the low of the correlation of parts. Cuvier said that based on an animal's skull, all the other anatomical structures of the systems that compose it can be deduced, all being are correlated with each other and with its life behaviour (Larson, 2006; Kardong, 2011).

These ideas about the relationship between form and function and the low of the correlation of parts were essential for the foundation of anatomy, comparative anatomy and evolutionary biology. However, nowadays observations can nuance these principles that underlying anatomy. Based on this, we can expect that the digestive system structures and its attached glands, tend to be similar between species that consume approximately the same type of food.

In this context we chose to evaluate macroscopic the digestive system with the related grands and structures of two different zoophytophagous species, with similar body size but different life behavior and feeding strategies: White Stork (*Ciconia ciconia*) and Common Buzzard (*Buteo buteo*).

Both species consume exclusively animal food. White Stork eats a wide variety of species, depending on availability and locality; in dry years, it may consume mostly insects and mice, in wet years mostly aquatic organism. They consume insects and larvae (especially Coleoptera and Orthoptera), amphibians (particularly adult frogs as *Rana esculenta, Rana temporaria*), tadpoles, reptiles (lizards, snakes), small mammals (*Microtus* and *Arvicola*, mole (*Talpa europaea*), young rats), less often young and eggs of ground-nesting birds, molluscs and crustaceous, fish and scorpions. Odd items include young goats, cats, weasels, domestic ducks and chickens (Cramps and Perrins, 1986).

Common Buzzard consumes small mammals (predominantly rodents *Microtus arvalis*, *M. agrestis*, *Arvicola terrestris, Clethrionomys glareolus,* hamsters (*Cricetus cricetus*), wood mouse (*Apodemus sylvaticus*), rats), rabbits (*Oryctolagus cuniculus*), young hare, moles (*Talpa europaea*), squirrels, birds, reptiles, amphibians, larger insects and earthworms. In summer, they eat mainly nestlings and just-fledged young, occasionally adults (Starlings (*Sturnus vulgaris*), thrushes (Turdidae), crows (Corvidae), finches (Fringilidae), larks (Alandidae), woodpeckers (Picidae)), reptiles (most frequently lizards (*Lacerta*) and slow-worm *Anguis fragilis*, snakes *Natrix natrix*, *Elaphe scalaris*, *Vipera),* amphibians (*Rana*, *Bufo, Pelobates, Bombina*). Cases of cannibalism were recorded (Cramp and Perrins, 1987).

The aims of our study were (i) to describe the components and topography of the digestive system of dissected individuals from the two species; (ii) to highlight the macroscopic anatomical peculiarities of the digestive system and (iii) to compare the data obtained after dissections and analyse them according to the particularities of the feeding behaviour.

Materials and methods

Data and observations were collected after the dissection of 10 carcass (5 of White Stork and 5 of Common Buzzard), obtained from the Zoological Museum of the Cultural University Heritage of UBB (attestation 40/19.01.2021). The cause of death of dissected individuals was result of accidents (electrocution, road accidents) or were euthanized due to injuries that no longer allowed them to be rehabilitated into the wild.

The dissection protocol was following Cătoi (2003). From the level of the head, the skin was incised on the lateral commissure of the beak and continues to the ventral side of the neck, lateral to trachea, up to the level of the cloacal orifice. With scissors, we cut transversely the abdominal muscles from the posterior part of the sternum, posterior to the xiphoid appendix. On each side of the sternum, the initial abdominal incision continues, up to the level of the chondrocostal junctions. The abdominal wall is sectioned longitudinally, up to the cloaca and broken laterally. We cut the chondrocostal junctions with scissors, bilaterally, up to the level of the scapulohumeral joints; the coracoid bones and the clavicle are cut, the sternum is removed, after the pericardial sac is disintegrated. The organs located in the cavity are detached, both commissures of the beak were cut, with the lower jaw detached, together with the oesophagus and a portion of the trachea. The skin and the musculature adjacent to the cloacal orifice were cut in order to detach it, together with the digestive tract and the attached organs.

The digestive tract was examined only macroscopically, *in situ*, and separately from the carcass. We cut and opened the oesophagus, the glandular stomach, the shredding stomach, the small intestine, the large intestine, the cloacal orifice.

The first measurements were made before the body was opened, using the electronic scale and a measuring tape. The bodies were measured from the top of the head to the top of the tail. After opening the bodies, the entire digestive tract was isolated and weighed. The liver was isolated from the digestive tract, weighed and measured. The pancreas was identified in few bodies, so it was excluded from the measurements. The entire digestive tract was weighed, without liver, following the measurement of the digestive tract in segments: oesophagus, glandular stomach and gizzard together, then small intestine and large intestine, also together.

A digital camera, Nikon COOLPIX P900, was used to collect the images.

Results and discussion

Data regarding measurements of the digestive system of the two species can be found in Table 1.

Table 1. Digestive tube measurements (BW - Body weight, BL - Body lenght, DtWL - Digestive tube weight with liver, L- Liver, we – weight, le – lenght, wi – width, DtW - Digestive tube weight without liver, AD - Anterior digestive tract, PD - Posterior digestive tract (*anterior digestive tract – esophagus, proventriculus (glandular stomach) and the gizzard (muscular stomach); **posterior digestive tract – small intestine and large intestine)

		Ciconia ciconia				*Buteo buteo*			
		Mean	Min.	Max.	SD	Mean	Min.	Max.	SD
BW(g)		2421	1885	2900	371.8	829.2	600.2	1012.8	153.8
BL(cm)		77.2	73	83	3.76	48.6	47	51	1.62
DtWL(g)		350.8	313	400	39.63	39.86	43.8	56	4.86
L	we (g)	50.4	40	59	6.28	14	8	18	3.63
	le(cm)	3.4	5	6	0.37	5.6	5	6	0.37
	wi (cm)	6.6	6	7	0.48	5.4	4	7	1.01
DtW(g)		300.4	273	352	40.35	34.16	32.5	40	4.69
AD* (cm)		49	45	61	6.09	15.6	15	25	3.46
PD** (cm)		147.8	115	171	24.86	129	120	135	4.93

Beak, tongue and oral cavity

The beak of Common Buzzard is strong and curved; it includes parts of the upper maxilla and lower maxilla. It was observed that the upper maxilla is better developed compared to the lower maxilla. This anatomical feature was described by Lacasse (2015), Denbow (2000), Murray (2014) and Ford (2010). On the surface, the beak is covered by several layers of hard keratin, scientifically called rhamphotheca, a peculiarity of the Aves class. Part of the rhamphotheca which covers the maxilla is called the rhinotheca, and the segment which covers the mandible is the gnatotheca (Denbow, 2015). At the base of the jaw of rhamphotheca, we identified a fleshy formation called the ceroma. This is the boundary between the beak and the front part of the head and includes the two nostrils. The dorsal median limit of the maxillary rhamphotheca is called the culmen, and the ventral median limit of the mandibular rhamphotheca is called gonys. The sharp edge of the rhamphotheca is called tomia. The anatomical name of these regions in the beak structure were mentioned by Speer and Powers (2016), Denbow (2015) and McLelland (1990). Also, we noticed that the soft palate and oropharyngeal isthmus is absent in common buzzard. Due to this anatomical peculiarity, a common cavity is created, the oropharynx (common characteristic of the Aves class) (Fig. 1). At the level of the hard palate, we identified two longitudinal cracks that connects the nasal cavity to oropharyngeal cavity - the choana. At short distance, aboral from the choana, in the bottom part of the pharyngeal ceiling, we identified the infundibular cleft, which is medially located and is the common opening to the auditory tubes (Fig. 2). All these features are mentioned by Denbow (2015), Speer and Powers (2016), McLelland (1990), Klassing (1999).

White storks have a long and straight beak with the tip of the beak slightly sharp. The upper maxilla and the lower maxilla have the same length, the rhamphotheca is well formed. The beak of the white storks has no sharp edge, as can be seen in the common buzzard, nor the tomial tooth. At the base of the upper rhamphotheca ceroma was not identified, the nostrils are elongated and included in the structure of the upper maxillary, bounded by the rhamphotheca (Fig. 3). The soft palate and oropharyngeal isthmus is absent. The choana was identified at the level of the hard palate, presenting on its surface the openings of the salivary glands; posterior from choana we identified the infundibular cleft. These features were described by McLelland (1990), Fidget and Dierenfeld (2008).

Figure 1. The beak of *Buteo buteo* (a. Rhinotheca: 1.The tip of the curved beak 2.Culmen, 3.Ceroma and nostrils; b. Gnatotheca: 4.Gonys, 5.Tomia)

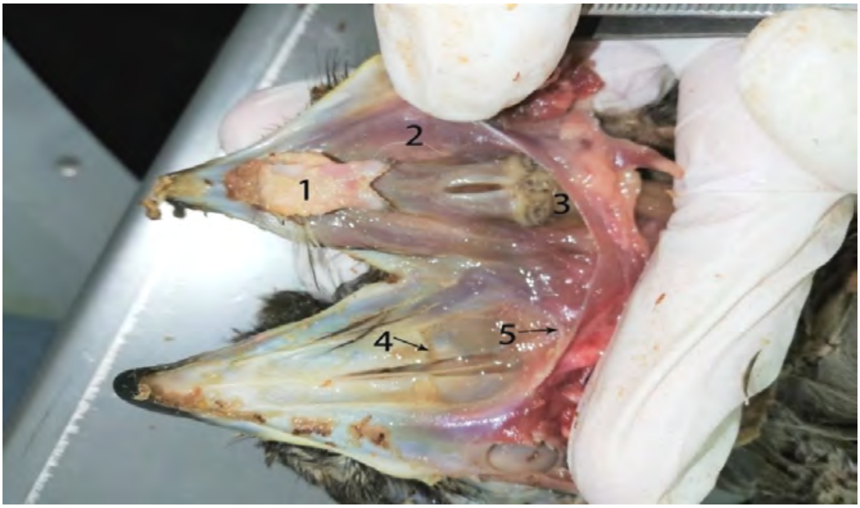

Figure 2. Oropharynx (Jaw: 1. Tongue; 2. Laryngeal protuberance with glottal orifice; 3. The esophageal orifice; Maxilla: 4. Choana; 5. Infundibular fissure, The presence of cornified papillae is indicated with the help of arrows)

Figure 3. The appearance of the beak of White stork (*Ciconia ciconia*) (a: Rhinotheca. 1- The tip of the beak slightly sharp, no tomial tooth 2- Elongated nostrils, bounded by rhamphotheca, b: Gnatotheca, free of gonys)

Oropharyngeal cavity

Common buzzard has in the oropharyngeal cavity, on the surface of the palatine ridges, tongue and glottal process, cornified epithelial projections; on tongue, these cornified papillae are arranged in the form of the letter V, with an aboral opening (Fig. 4). These characteristics were also reported by Ford (2010),

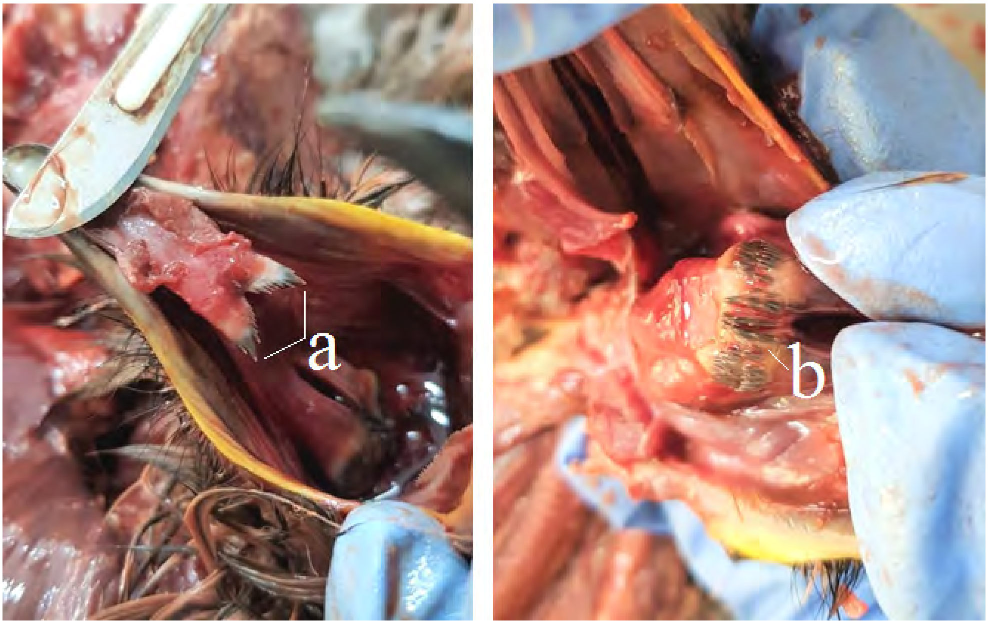

Figure 4. The cornified papillae in common buzzard (*Buteo buteo*)
(Present on the surface of the tongue, oriented in V (a) and cornified papillae located on the surface of laryngeal protuberance (b))

claiming that raptors have a greater limb mobility compared to parrots, whose tongue is thicker and poorly mobile. White storks have a short, immobile tongue, resembling with a rounded spear tip, without cornified formations on the surface, which continues with a well-developed laryngeal protuberance (Fig. 5). At the level of the lower maxilla, close to the half of the oropharyngeal cavity and the tip of the tongue, longitudinal folds are present and can increase the volume of the cavity. These peculiarities were also described by Fidget and Dierenfeld (2008) (Fig. 5).

Larynx

In the inspected birds, the larynx has a laryngeal protrusion with an oro-aboral opening slit, representing the tracheal entrance (Fig. 6). In the common buzzard, the esophagus is short and has two part: cervical part, which is reduced, and the thoracic part, more developed (Fig. 7). This particularity is also mentioned in the literature by Ford (2010) and Denbow (2000). In the last segment of the oesophagus, we identified a crop, an expansion of the oesophagus, identified in all common buzzards we have studied (Fig. 8). The crop is continued

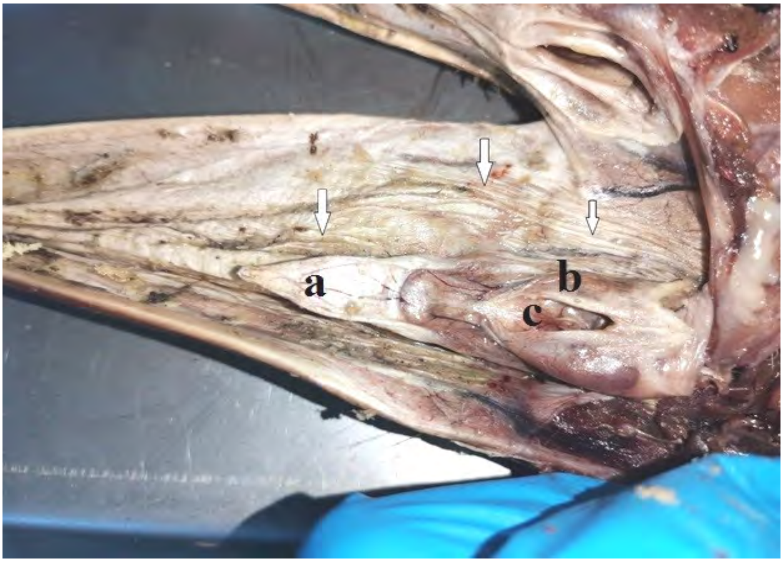

Figure 5. The appearance of lower maxilla in white stork *(Ciconia ciconia*): the presence of longitudinal folds at the level of the lower maxilla indicated with arrows and the short and immobile tongue (a), continued by the laryngeal protuberance (b) and the entrance in the trachea (c)

Figure 6. Appearance of the oropharynx cavity with laryngeal protrusion (a) and entrance in the trachea (b) in common buzzard (first image) and white stork (second image)

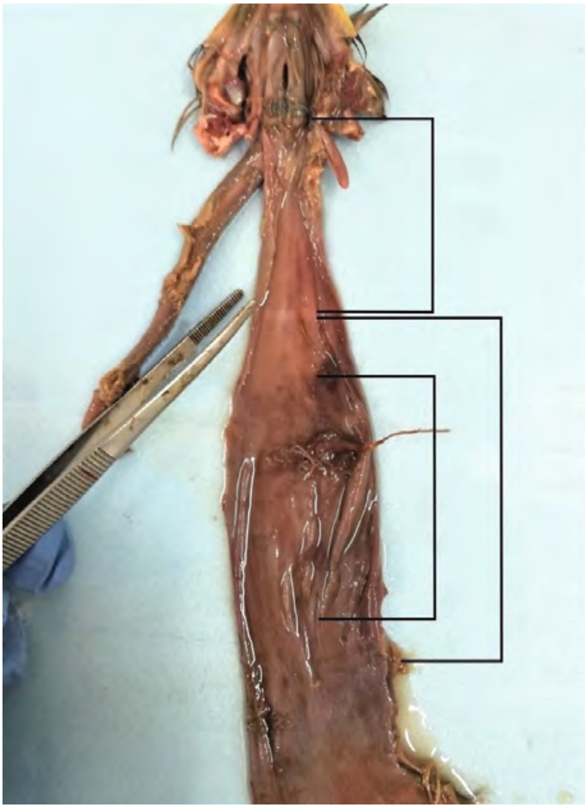


Figure 7. (left) Delimitation of the esophagus in common buzzard, highlighting the crop, which is located in the last esophageal segment
Figure 8. (right) Highlighting the length of the esophagus in white stork

with the glandular stomach through a demarcation represented by a poorly developed sphincter. In the literature, Houston and Duke (2005) recall the presence of a poorly developed crop in raptors and the absence of this anatomical segment in owls. In white storks, the oesophagus has logitudinal folds among its entire length - it is long and distensible, without a crop (Fig. 9 and Fig. 10). Near the glandular stomach the folds fade and become a girdle (Fig. 10). These features were also highlighted by McLelland (1990) and Fidget & Dierenfeld (2008).

Figure 9. The absence of the crop and the appearance of longitudinal folds of the esophagus in white stork.

Stomach

Common buzzards have a small glandular stomach, interconnected with the thin wall of the ventricle. Both structures -glandular and muscular stomach- form a pear-like shape structure. This aspect is also mentioned by Ford (2010), which makes a comparison between the degree of development of the proventriculum and ventriculum in raptors, compared to Psittaciformes or other granivores. The proventriculus and gizzard are separated by a girdle, which is poorly represented in raptors (Fig. 10). Ford (2010) claims that this isthmus is absent, the passage between the ventricles is represented by a cavity. Denbow (2000) reports the presence of a girdle between the glandular and muscular stomach, both cavities are developed differently, depending on the species. The pyloric region connects the gizzard with the duodenum and it

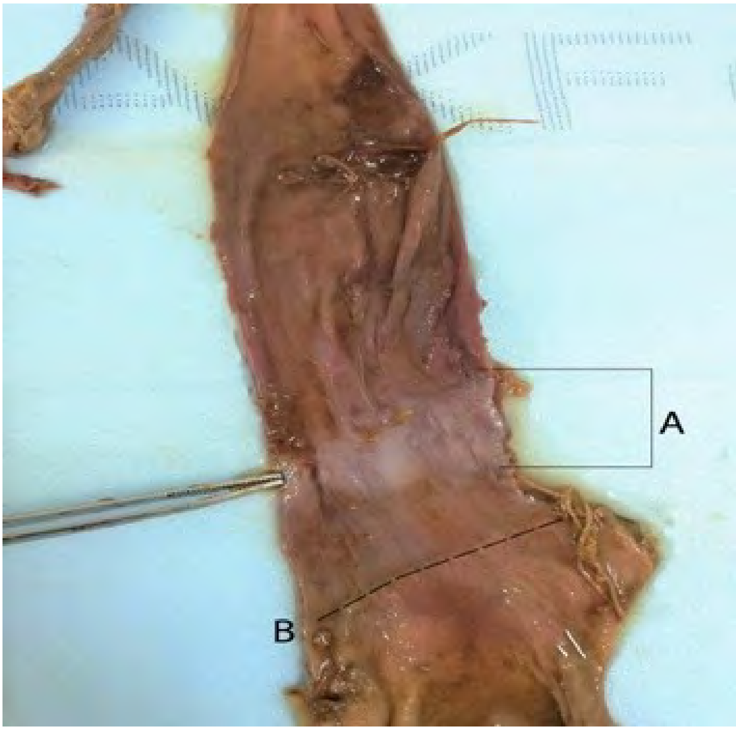

Figure 10. The passage between the glandular stomach (A) and the muscular stomach (B) is dominated by an isthmus or girdle (indicated with continuous line)

is located on the right side of the organ, 90° from the longitudinal axis of the muscular stomach. White storks have a poorly developed glandular stomach and on the surface of the mucosa we observe numerous channels of the secretory glands (Fig. 11). The passage between the glandular and muscular stomach is represented by a girdle or isthmus (Fig. 11). From this level, the mucosa of the muscular stomach is folded and covered by koilin. In the inspected bodies, koilin has a brownish-green color (Fig. 11). The pyloric region is located close to the isthmus between the two gastric parts, at about 45° from the axis of the oesophagus-glandular stomach-gizzard. Unfortunately, we did not find information in the literature to make a comparison.

Figure 11. The appearance of the two compartments of the stomach in white storks: the fading area of the esophageal folds near the proventriculus (a), the glandular stomach or proventriculus (b), the isthmus marking the area of passage from the origin to the ventricle (c) and the folded appearance of the mucous membrane of the muscular stomach, covered with koilin

Intestines

In common buzzard, the intestinal mass is compact, positioned in the caudal portion of the thoraco-abdominal cavity, surrounded by adipose tissue (Figs. 12 and 13). The small intestine is short and it extends from the level of the pyloric region of the ventricle to the level of the cecum and colon (Fig. 14). This is also mentioned by Ford (2010), Murray (2014), Houston and Duke (2005). Ford (2010) states that the duodenum - the first segment of the small intestine - is long, aspects also identified in the studied birds, and some species (birds of the genus Haliaeetus, family Accipitridae) have secondary loops. The duodenal portion is long, without an obvious delineation between duodenum and ileum. Murray (2014) also supports the presence of additional loops and performs the following classification:

• duodenal loop, contains the pancreas (Ford, 2010); it is elongated in hawk and eagles (King, McLelland, 1984, quoted by Murray, 2014)

• the axial loop presents Meckel's diverticulum; at this level, the transition between jejunum and ileum occurs (King, McLelland, 1984, quoted by Murray, 2014)

• the supraduodenal loop - the most distal loop of the ileum, is located dorsally from the duodenum (King, McLelland, 1984, cited by Murray, 2014)

• the supracecal loop, presented only in a few species of birds, is located near the ileo-rectal junction (King, McLelland, 1984, quoted by Murray, 2014).

Figure 12. (left) Adipose tissue that incorporates the digestive tract of common buzzard

Figure 13. (right) Topography of organs in the thoraco-abdominal cavity in common buzzard after removing the adipose tissue: 1. Heart and pericardial sac 2. Hepatic lobes 3. Small intestine, compact mass 4. Ventricle or muscular stomach 5. Colon

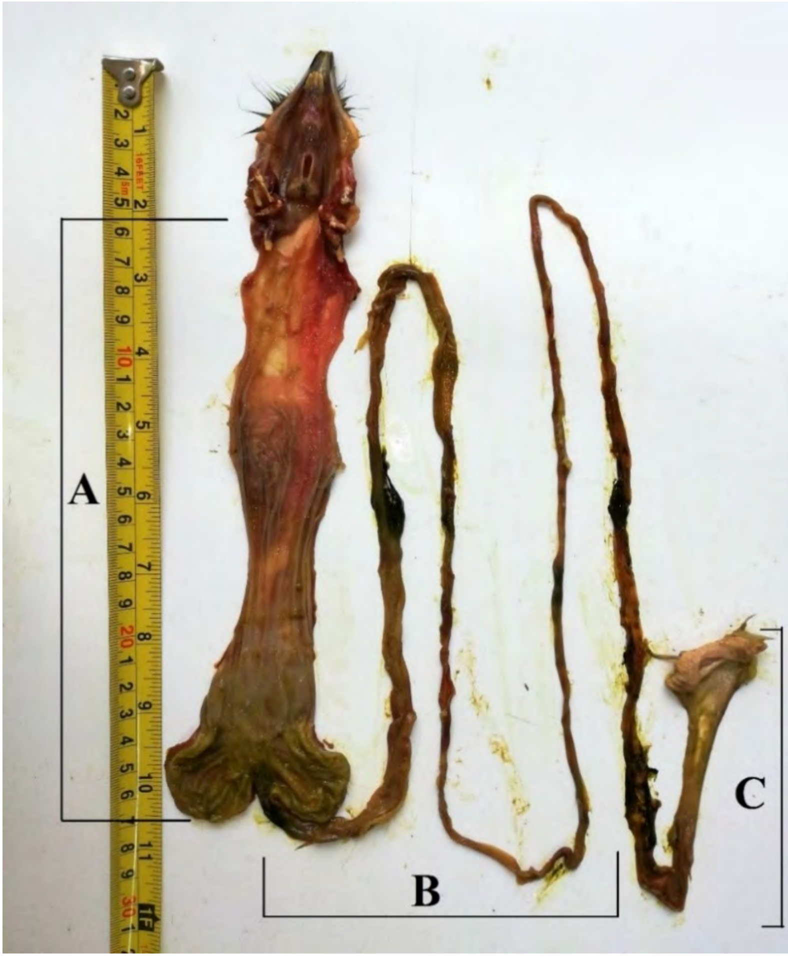

Figure 14. Approximative delimitation of the digestive tract in common buzzard (A. Esophagus with the crop, glandular stomach and muscular stomach; B. Small intestine, without a clear demarcation of the duodenum, jejunum and ileum. C. Large intestine, with colon, cecum and cloaca)

In white storks, the intestinal mass is compact, positioned in the caudal portion of the thoraco-abdominal cavity (Fig. 15). The small intestine is long, extending from the level of the pyloric region of the ventricle to the level of the ileo-ceco-colic junction (Fig. 16). The small intestine is folded into numerous loops, with the help of mesentery – there is no clear delimitation between segments of the small intestine (Fig. 17).

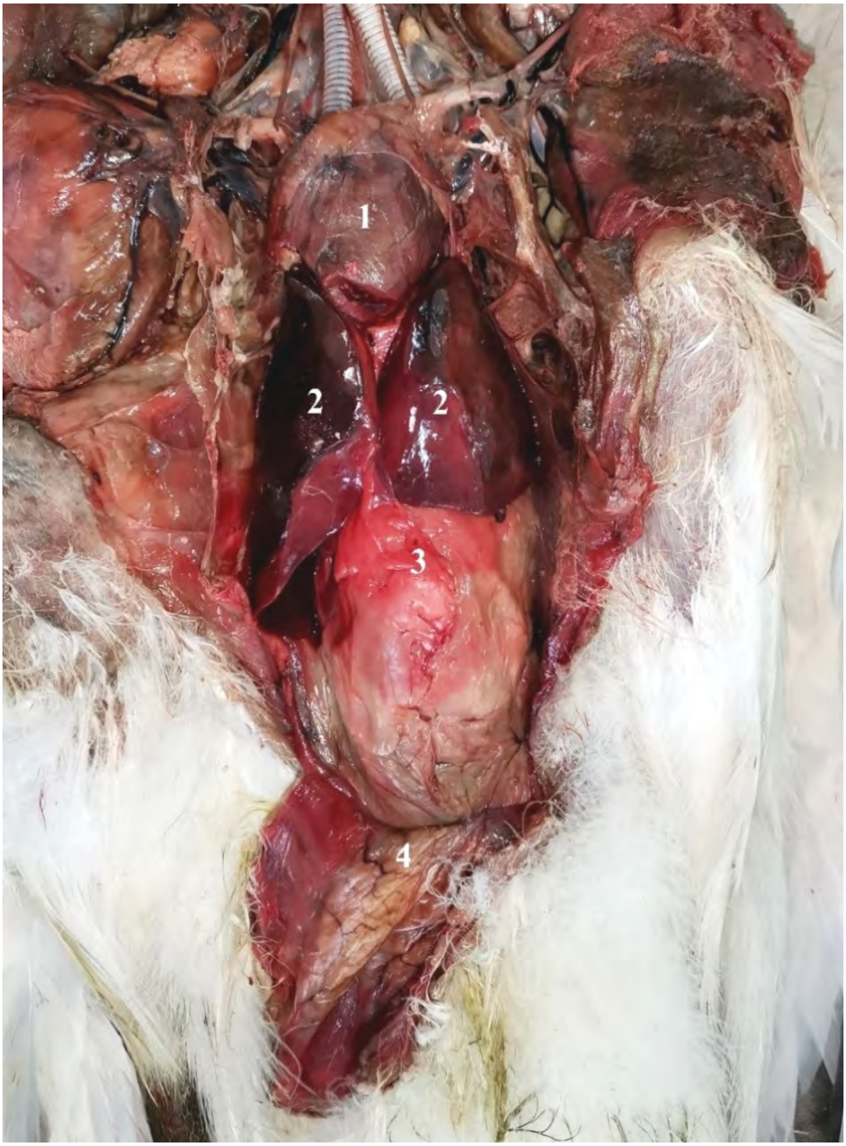

Figure 15. Topography of organs in the thoraco-abdominal cavity after removal of adipose tissue in white stork: 1. Heart and pericardial sac 2. Hepatic lobes 3. Muscular stomach 4. Colon

Figure 16. Intestine of *Ciconia ciconia*: delimitation of the small intestine from the level of the pyloric region of the ventricle (a) to the ileo-ceco-colic junction (marked by arrows), highlighting the location of the pancreas in the first part of the duodenum, near the pyloric orifice (b), the delimitation of the colon (c) continued by the cloaca (d) that opens outside through the anal orifice.

Cecum and cloaca

In the common buzzard, the ceca is represented by two rudimentary vestigial formations, observed in all the studied birds, aspects mentioned by Murray (2014), Clench (1999) and McLelland (1989), identified as a lymphoid-type ceca (Fig. 18). The colon is short, extending from the level of ileo-cecale junction to cloaca, as reported in the literature by Murray (2014) and Ford (2010). The cloaca extends from the distal portion of the colon to the anal orifice (Fig. 19). In white storks, the ceca is small in size, vestigiale, lymphoid, characteristic for the birds of the order Ciconiiformes. This was pointed out by Clench (1999) and McLelland (1989). The colon is short and opens outwardly through the anal orifice (Fig. 19).

Figure17. Part of small intestine folded with the help of mesentery in a white stork; blood vessels can be seen in the structure of adipose tissue and ligament

Figure18. Cecum in a common buzzard: represented by the two rudimentary formations, characteristic for the birds of the order Accipitriformes

Figure 19. Delimitation of the large intestine in common buzzard: at the junction between the ileum and the colon (A)we identified the ceca (arrow).The colon continues with the cloaca and the cloacal orifice (B).

Pancreas

We didn't identify the pancreas in common buzzard bodies due to the quality of the preserved corpses. In white stork corpses, we identified the elongated-looking pancreas, located in the first part of the duodenum, near the pyloric orifice (Fig. 20).

Figure 20. The presence of the pancreas in a white stork, indicated with an arrow and its localization in the first part of the duodenum.

Liver

In common buzzard, the liver have two lobes joined cranially in the midline, located in the thoracic-adominal cavity; the lobes surround the apex of the heart (Fig. 21). Similar data describing the location of this organ was reported in the literature by Samour and Naldo (2007). The right lobe is larger compared to the left lobe (fig .22), aspects also found in the descriptions of Samour and Naldo (2007), while Murray (2014) does not consider this to be a peculiarity for the raptors. All the studied bodies have a gallbladder, located on the ventral side of the right lobe, well developed (Fig. 22). The presence of the gallbladder and the topography of the liver is confirmed by Murray (2014), Samour and Naldo (2007), Klaphake and Clancy (2005).

In white stork, the liver has also two lobes that join cranially on the midline, located in the ventro-cranial part of the thoraco-abdominal cavity and surrounds the apex of the heart (Fig. 22).

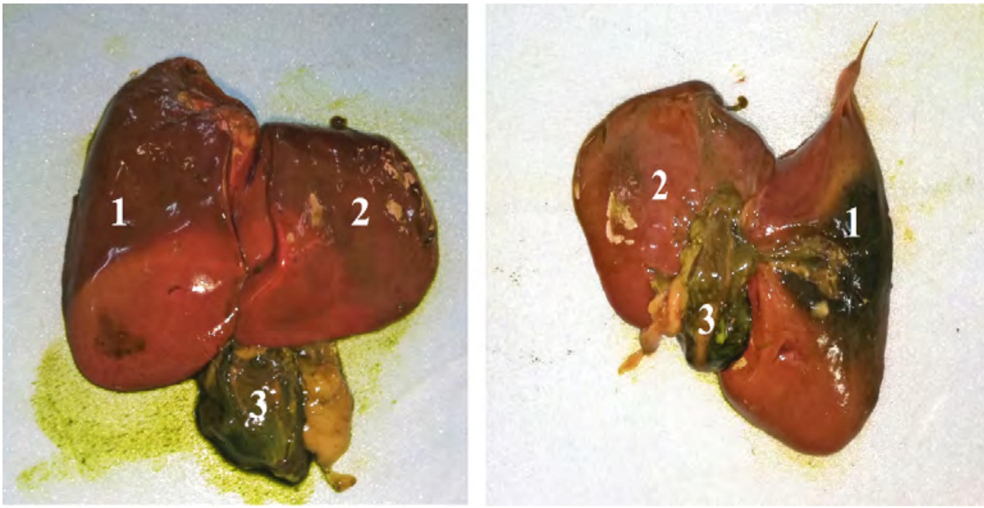

Figure 21. The liver in common buzzard (*Buteo buteo*): the two hepatic lobes, the right lobe (1) visibly larger than the left one (2) and the gallbladder (3), the view from the parietal part (the first picture) and the visceral face of the liver (second picture)

Like the common buzzard, the liver of storks has two lobes of different sizes, the right lobe being more developed compared to the left lobe (Fig. 23). All corpses of white stork have a poorly developed gallbladder, located on the visceral side of the right lobe, covered with fat tissue (Fig. 22).

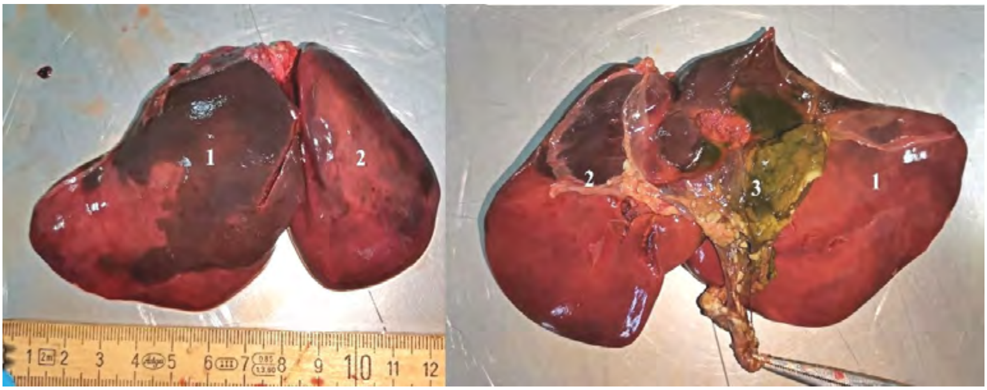

Figure 22. The two hepatic lobes in white stork (*Ciconia Ciconia*): the right lobe (1) visibly larger than the left one (2) and the gallbladder (3), the view from the parietal part (the first picture) and the visceral face of the liver (second picture)

Conclusions

We concluded that the digestive system is adapted to a strictly carnivorous diet. The differences identified between the anatomical structures of the digestive tract of the two species are correlated with the differences that appear in their feeding behavior.

The beak is showing visible differences, in common buzzard the beak is strong, curved, adapted for the laceration of prey. In white stork the beak is long, strong, straight, the upper maxilla is about the same length as the lower maxilla, adapted to capture prey by hitting it like a harpoon.

In common buzzard the tongue is slightly mobile, and on its surface we identified the cornified papillae. The absence of the soft palate created a common cavity with the pharynx (oropharyngeal cavity). In white stork the tongue is immobile, located on the floor of the oro-pharyngeal cavity, without cornified papillae on its surface, looking like a spearhead.

In both species the esophagus is located on the right side of the neck, it can widen its diameter due to longitudinal folds. Obviously, the length is different, directly proportional with the neck, longer in white storks, shorter in common buzzards. In common buzzard, the terminal part of the oesophagus shows a dilation, the crop, located cranially in the chest cavity, which has the role of storing the ingested food. The crop is absent in white storks.

In both species, the proventriculus and ventriculus are poorly developed in comparison with non-carnivorous birds. The koilin layer is better highlighted in white stork compared to common buzzard.

In common buzzard, the small intestine is reduced in size, without obvious macroscopic transition between the duodenum and the ileum. The white storks have a long small intestine with many loops, without a transition between the segments (duodenum, jejunum and ileum).

In both species, the ceca is reduced in size and has a vestigial appearance; the colon is reduced in size and it extends from the level of the ileo-colic junction to cloaca.

The liver has two lobes, the right lobe is well developed in comparison with the left lobe. In common buzzard, the gallbladder is well developed, located on the ventral side of the right lobe; in white storks, the gallblader is poorly developed, located on the ventral side of liver, the visceral face of the right hepatic lobe.

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