Hindawi Publishing Corporation
Journal of Histology
Volume 2014, Article ID 987041, 10 pages
http://dx.doi.org/10.1155/2014/987041

Research Article

Comparative Histomorphological and Histochemical Studies on the Oesophagus of Nile Tilapia *Oreochromis niloticus* and African Catfish *Clarias gariepinus*

Ashraf Sayed Awaad,[1] Usama Kamal Moawad,[2] and Mohamed Gomaa Tawfiek[1]

[1] *Department of Anatomy and Embryology, Faculty of Veterinary Medicine, Beni-Suef University, Beni-Suef 62511, Egypt*
[2] *Department of Histology and Cytology, Faculty of Veterinary Medicine, Beni-Suef University, Beni-Suef 62511, Egypt*

Correspondence should be addressed to Mohamed Gomaa Tawfiek; mgtawfiek@yahoo.com

Received 21 June 2014; Accepted 19 October 2014; Published 10 November 2014

Academic Editor: Carlo Pellicciari

The present work aimed to describe and compare both gross and microscopic structure of the oesophagus of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). For this purpose, 60 specimens of oesophagus of Nile tilapia (omnivorous fish) and African catfish (carnivorous fish) were collected and processed. Anatomically, the oesophagus of both species appeared as a short tube with longitudinal mucosal folds. Using scanning electron microscope, the epithelial surface of the esophagus showed primary and secondary mucosal folds in both species while tertiary folds were observed in that of tilapia only. Histologically, the oesophagus consisted of four distinct layers: mucosa, submucosa, muscularis, and serosa. The oesophageal mucosa consisted of stratified epithelium with few mucous secreting cells in catfish and many mucous secreting cells in tilapia. Two types of mucous secreting cells reacted positively with both periodic acid shiff (PAS) and alcian blue (AB); rounded and elongated cells that were recognized in the esophageal epithelium of tilapia and only elongated oval cells were observed in that of catfish. In conclusion, the obtained histomorphological differences in esophagus of both fish species may be attributed to their different feeding habits and type of food.

1. Introduction

The Nile tilapia, *Oreochromis niloticus,* and African catfish, *Clarias gariepinus,* are the most important fresh water fishes in the Nile River in Egypt. According to Gafrd, [1] these two fish species have a great economic importance, where the Nile tilapia constitutes about 32% and African catfish about 17.5% of the total country catch. In this concern, Osman and Caceci [2] reported that tilapia species are the most common fishes in the Egyptian part of the Nile River. These tilapia species are well adapted to live in both fresh and brackish water at the Nile estuary at Rashid, Edku, Damietta (on the Mediterranean Sea), and Ismailia (Ismailia fork at the Suez Canal).

The anatomy and histology of the digestive tract of teleostean fish have been described by many authors [3–9]. On the other hand, there are few studies dealing with the ultrastructure of the digestive tract. The teleost digestive tract is histologically simpler compared to mammals, probably because it is so easy to provide an aqueous vehicle for the digestive products and also because, at least in some species, the rate of digestion can be slow, and less complex digestive glands and a less well-developed muscular apparatus are needed [10]. As a part of the digestive tract, the esophagus is short muscular tube which connects the pharyngeal cavity with the stomach [11]. As in most vertebrates, the main function of esophagus in fishes is transporting food particles from the mouth cavity to the stomach. Also it is provided with the mucous secreting cells for lubrication [12, 13].

The aim of the present study is to describe and compare the anatomical and histological structures of the esophagus of the Nile tilapia (omnivorous fish) and the African catfish (carnivorous fish) using gross, light, and scanning electron microscopy. This may provide comparative bases for the

future studies on the feeding patterns of both species as well as a contribution to the development of fish farming.

2. Materials and Methods

2.1. Sample Collection. A total number of sixty apparently healthy adult fishes of both sexes, 30 of Nile tilapia, *Oreochromis niloticus,* their weights from 145 to 500 g and their lengths from 19 to 28 cm, and 30 of African Catfish, *Clarias gariepinus*, their weights from 175 to 700 g and their lengths from 28 to 42 cm were obtained from the Nile River at different localities in Beni-Suef Governorate. The fishes were transported in plastic aquaria to the laboratory within two hours to allow the aerial respiration for the catfish.

2.2. Gross Examination. Thirty fishes (15 Nile tilapia and 15 African catfish) were used to demonstrate the gross morphological features of the esophagus. At first, the fishes were sacrificed and an incision was made at the ventral aspect of the body from the anal opening to the interbranchial membrane. The esophagus was grossly examined in situ and dissected; the length and diameter were measured using a caliber and photographed using a digital camera (Kodak, 14 megapixels and 4x optical zoom).

2.3. Light Microscopy. For histological studies, twenty fishes (10 Nile tilapia and 10 African catfish) were collected, euthanized, and dissected immediately in the field. Small pieces (0.5 cm × 0.5 cm) from the anterior, middle, and posterior parts of the esophagus were obtained and immediately immersed into Bouin's fluid fixative for 24 hours. The fixed specimens were dehydrated in graded ethanol concentrations (50% to absolute), cleared in two changes of xylene, and embedded in paraplast. Sections of about 4–6 μm thick were obtained and mounted on clean and dry glass slides to be stained with Harris' hematoxylin eosin, periodic acid shiff (PAS), alcian blue, and Crossman's trichrome stain [14].

2.4. Scanning Electron Microscopy. Esophagus samples from ten fishes (5 Nile tilapia and 5 African catfish) were used. The esophageal specimens were fixed in 3% glutaraldehyde solution in phosphate buffer (pH 7.2 to 7.4) and were postfixed with 1% osmium tetroxide in 0.1 M sodium cacodylate buffer at pH 7.2 for 1 h at 4°C. Thereafter, the specimens were dehydrated through graded series of ethanol and critical point-dried. They were attached to aluminum stubs facing upwards, covered with carbon tabs, and then the samples were sputtered with gold. The specimens were examined with a JEOL/EO-JSM-6510 LV scanning electron microscope at Faculty of Science, Beni-Suef University, Egypt.

3. Results

3.1. Gross Morphological Structures. The Nile tilapia had an elongated moderately compressed variable coloration body with large scales. They had distinctive, regular, and vertical stripes extending as far down the body as the bottom edge of the caudal fin. The head was broad and the mouth was small and terminal in position without barbells (Figure 1(a)). The catfish had a slender blackish-colored body without scales and a flat bony head. The mouth was terminal in position with four pairs of barbells (Figure 1(b)). In both fish species, there was no distinct limit for the esophagus, which was, therefore, taken to extend from the posterior structure of the buccopharyngeal cavity to the area where the fundic glands appeared.

The esophagus of Nile tilapia (Figures 2 and 3) was short and dilatable membranous tube connected the pharyngeal cavity to the initial part of the stomach; its shape was cylindrical and straight along its entire length. It was located dorsal to the rostral part of the liver. Its mean was about 2–2.5 cm. It was not divided as its diameter was the same along its whole length; its mean diameter was about 1–1.2 cm.

The esophagus of African catfish (Figures 2 and 3) was short musculomembranous tube about 2-3 cm long beginning at the posterior edge of the pharyngeal tooth pads. It started with a dilated funnel-shaped part about 2–2.2 cm in diameter and its posterior part was tubular in shape. The esophagus extended caudoventrally from the pharynx and passes through the transverse septum, ventral to the anterior kidney, and dorsal to the visceral surface of the liver. The transverse septum was a white glistening fibrous membrane that firmly attached the esophagus to the dorsum of the body cavity. Caudal to the anterior kidney, the esophagus joined the anterior end of the stomach. The transition from the esophagus to the stomach (Figure 3) is only distinguished by the change in size of the mucosal folds in the interior of the stomach. In all examined esophagus specimens of African catfish, these folds were longitudinal and were twelve in number.

3.2. Microscopical Structures. The esophagus of tilapia and catfish was formed of four concentric layers from inside to outside: mucosa, submucosa, double layered muscularis (composed of inner longitudinal and outer circular sublayers), and serosa (Figure 4). The mucosa showed large number of longitudinal folds extending along the whole length of the esophageal tube giving the lumen of the esophagus star-shaped appearance in all examined sections. These longitudinal folds were more prominent in catfish than tilapia.

The mucosal folds of the tilapia (Figure 5(a)) were thicker and shorter and were represented by primary folds only when compared with those of catfish which appeared thinner and taller and were formed of primary carrying secondary folds (Figure 5(b)). These mucosal folds were lined with stratified squamous epithelium which was composed of undifferentiated basal epithelial cells, followed by several layers of mucous secreting cells covered superficially by 1-2 layers of low cuboidal to flattened cells (Figure 6).

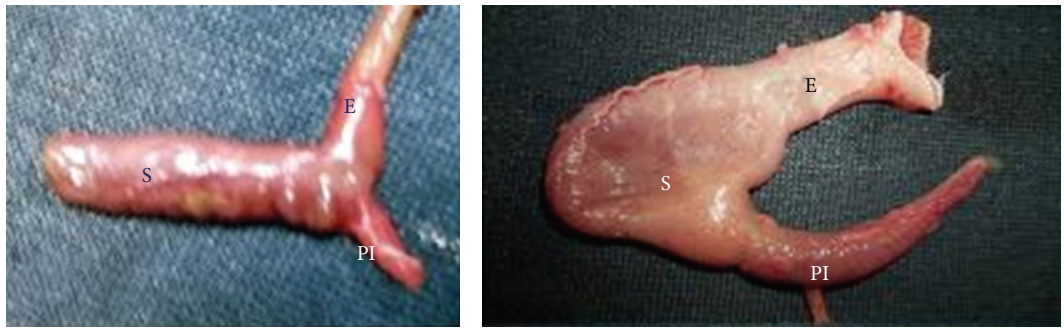
In tilapia, rounded and elongated mucous secreting cells were recognized in the epithelium of the esophagus. The rounded cells were larger in size, concentrated basally, and represented the majority of mucous secreting cells. Elongated cells, on the other hand, have small size and are present in the superficial part of the epithelium. Both cell types were stained purple with periodic acid shiff (Figure 7(a)). In catfish, elongated oval mucous secreting cells were the most prominent mucous cells in the esophageal epithelium and occupied the superficial part of the epithelium (Figure 7(b)).

(a) (b)

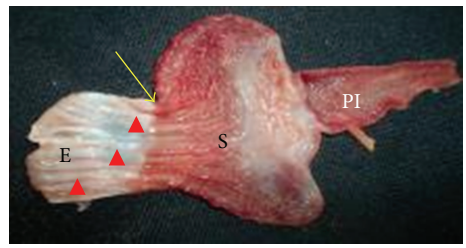
Figure 1: Photographs showing the fishes used in the study; Nile tilapia, *Oreochromis niloticus,* (a) and African catfish, *Clarias gariepinus* (b).

(a) (b)

Figure 2: Photographs of the dissected Nile tilapia (a) and African catfish (b) showing the esophagus (E), stomach (S), liver (L), proximal part of the intestine (PI), transverse septum (TS), and swim bladder (SB).

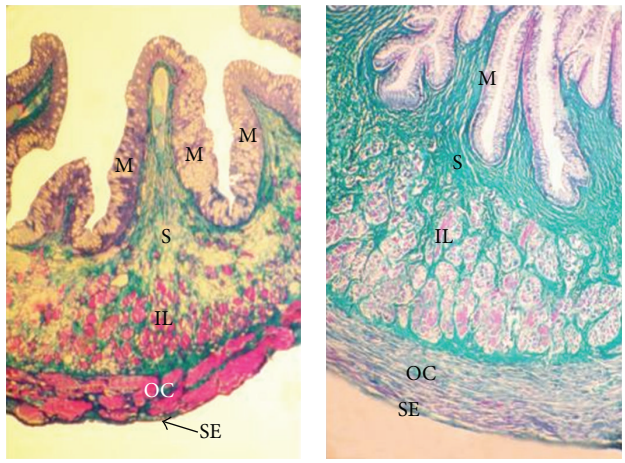


(a) (b)



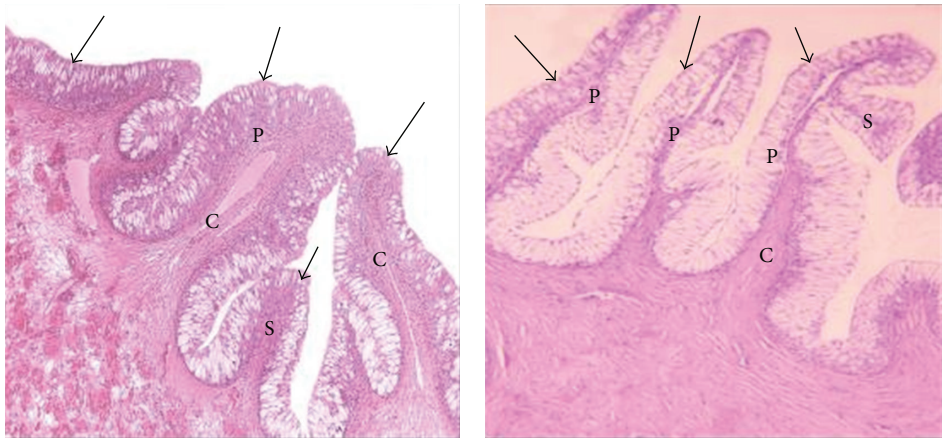
(*b)

Figure 3: Photographs of the esophagus (E) and proximal part of the intestine (PI) connected to the stomach (S) in Nile tilapia (a) and African catfish (b). In African catfish (*b), the esophagus and stomach are opened to show the longitudinal mucosal folds (red arrows heads) in the wall of the esophagus, and yellow arrow indicates the line of demarcation between the esophagus and stomach.



(a) (b)

Figure 4: Photomicrographs of the esophagus in Nile tilapia (a) and African catfish (b) showing four distinct tunics; mucosa (M), submucosa (S), tunica muscularis which consisted of inner longitudinal (IL) and outer circular (OC) and serosa (SE). Crossman's trichrome stain, ×40.



(a) (b)

Figure 5: Photomicrographs of sections in the esophagus of Nile tilapia (a) and African catfish (b) showing the epithelial lining of the esophagus with longitudinal mucosal folds and primary (P) and secondary (S) folds with connective tissue core (C) derived from submucosa. H&E, ×100.

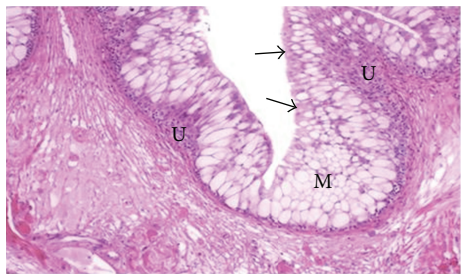
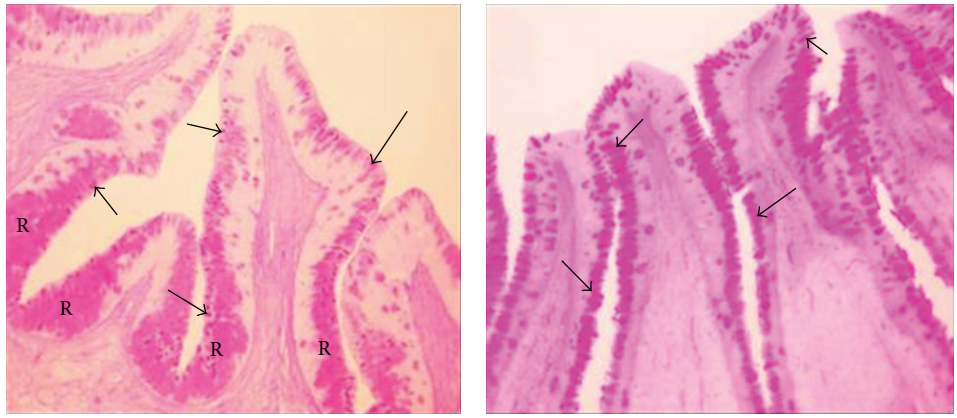


Figure 6: A photomicrograph of a section in the esophagus of Nile tilapia showing the stratified epithelium lining the mucosal folds consisted of a surface layer of cuboidal cells (arrows), midlayers containing polygonal mucous cells (M) and the basal layers of undifferentiated cells (U). H&E, ×200.



(a) (b)

Figure 7: Photomicrographs of sections in the esophagus of Nile tilapia (a) showing two types of mucous secreting cells strongly PAS positive; small elongated cells at the superficial part of the epithelium (Arrows) and numerous large rounded cells (R) distributed all over the epithelial cells over the undifferentiated epithelial cells and moderate PAS reaction in the underlying propria-submucosa and in African catfish (b) showing positive PAS reaction of the mucous secreting cells (arrows) occupied a superficial position. PAS, ×100.

The mucous secreting cells in the esophagus of both fish species showed positive alcianophilic reaction (Figure 8). Moreover, no taste buds could be detected in the esophageal mucosa neither in tilapia nor in catfish.

A thick layer of densely packed collagen fibers and many blood vessels beneath the epithelium was present and extended to fill the cores of the mucosal folds represented the lamina propria-submucosa and appeared thicker in catfish than tilapia. The muscularis mucosa was not found in the esophagus of both species.

The muscularis layer of the esophagus in tilapia was composed of thick inner longitudinal and outer circular layer of striated muscle fibers intermingled with loose connective tissue mainly collagen fibers. These double layered muscular bundles were thicker in the esophagus of catfish (Figures 9(a) and 9(b)). The tunica serosa was composed of two sublayers: lamina subserosa which was composed of loose connective tissue with many blood vessels and lamina epithelialis serosa which was composed of mesothelial cells.

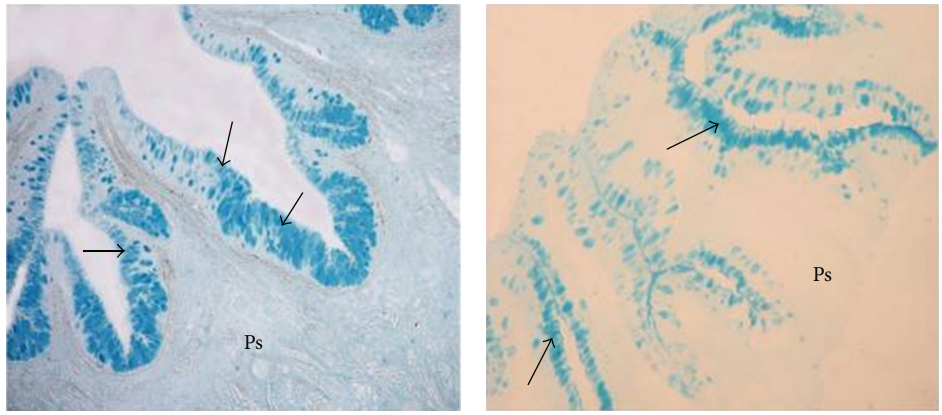
3.3. Scanning Electron Microscopic Observations. The mucosa of the esophagus in both species showed many prominent primary longitudinal folds ran the length of the esophagus and leaving long furrows in between them (Figures 10 and 11) While secondary folding predominated near the pharynx and stomach junctions in both species, only tertiary folds were found in tilapia esophageal mucosa (Figure 10). The characteristic feature of this region was the division of its surface into a series of irregular well-circumscribed areas. These are the so-called stratified epithelial cells which contained many well-defined wavy microridges. Some pock marks representing the luminal surface of mucous secreting cells were found in between the cell junctions. A few circular openings of empty mucous secreting cells were also detected in this region. Mucous droplets secreted by the mucous secreting cells were scattered through the epithelial sheet (Figures 10 and 11). These mucous droplets were of different sizes and more numerous on the sides than on the top of the mucous folds. Similar aggregations of mucus-secreting cells occurred on the tops of these folds, in discrete patches. Taste buds were not detected during the screening of the epithelial surface along the length of the esophagus of either tilapia or catfish.

4. Discussion

The results obtained in this study revealed some differences in the gross and microscopic structures of the esophagus of Nile tilapia (omnivorous fish) compared to that of African catfish (carnivorous fish), which could be attributed to the type of food and feeding habits of both species.

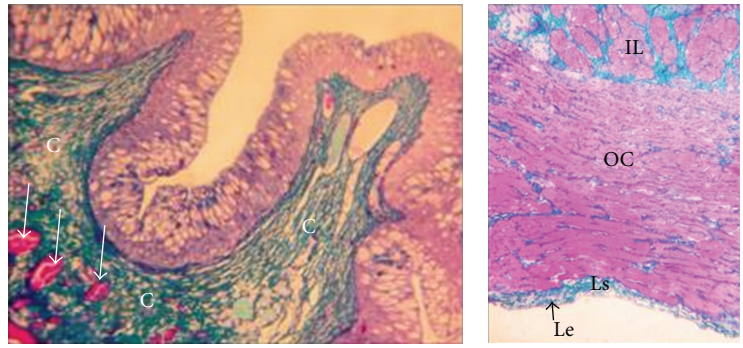
Generally, the principle function of the esophagus in fish is food transferring. However, a greater number of mucous secreting cells appeared in the esophageal epithelium of tilapia and catfish suggested the presence of a pregastric digestion and hence it could be postulated that the esophagus had an additional digestion function as detected in other fishes [15].

The esophageal mucosa in tilapia and catfish was characterized by the presence of longitudinal folds; in the anterior part of the esophagus of catfish, there were numerous mucosal folds that may allow maximal distension for the prey and broken down food, and it was lined by stratified epithelium with mucous secreting cells. The epithelium of the anterior part of the esophagus of carnivorous fish acted as a constitutive adaptation that protected the esophagus against live prey damages [16–18]. Moreover, the gross examination of the entire surface of the esophagus in catfish by the naked eye revealed definite twelve parallel folds arranged longitudinally that could not be observed in the esophagus of tilapia. Microscopically, these folds were deep and involved both the mucosa and submucosa. The transition from the esophagus to the stomach was sharp as observed in some tropical freshwater fishes [19]. The longitudinal folds detected in the



(a) (b)

Figure 8: Photomicrographs of the esophagus in Nile tilapia (a) showing strong positive alcianophilic granules in the mucous secreting cells of the stratified epithelium lining the mucosal folds and moderate reaction in the propria-submucosa. In African catfish (b) showing moderate alcianophilic reaction in the mucous cells and negative reaction in the underlying lamina propria-submucosa. Alcian blue, ×100.



(a) (b)

Figure 9: Photomicrographs of the cross section through the esophagus of Nile tilapia (a) and African catfish (b) showing extensive collagen fibres (C) in the tunica propria-submucosa extending to fill the core of mucosal folds and some bundles of the inner longitudinal layer (arrows) extended to the propria-submucosa in Nile tilapia and double-layered tunica muscularis made up from inner longitudinal (IL) and outer circular (OC) layers with intermuscular connective tissue mainly collagen fibres (arrows) in African catfish. Note the presence of tunica serosa composed of lamina subserosa (Ls) covered by lamina epithelialis serosa (Le). Crossman's trichrome stain, ×200.

esophageal mucosa of tilapia and catfish were numerous and finer in tilapia, while in catfish these esophageal mucosal folds were fewer and large with deep furrows in between. These longitudinal folds may lead to increase the capacity of the organ for distension during the food transportation [20, 21].

Our findings revealed that the esophageal epithelium of both species composed of stratified epithelium with nonkeratinized cuboidal to flattened surface cells along its entire length; this was in contrast with the findings of Abd El Hafez et al. [16] in catfish who stated that the epithelium of the posterior part of the esophagus is composed of simple columnar mucus secreting epithelium. Moreover, in yellow catfish, the epithelial lining of the esophagus is stratified epithelium of columnar type [22] and in Nile tilapia the esophagus was lined by squamous epithelium and numerous goblet cells [23].

The histochemical examination of the esophageal specimens showed positive periodic acid shiff reaction and intense alcianophilic granules of mucosecretory cells of tilapia and catfish giving an explanation to the nature of their contents. The mucous secreted by these cells may be attributed to the lack of the salivary glands in fishes and the mucin secreted by the esophageal epithelium may compensate them [24]. Moreover, the mucin is important for the formation of a continuous sheet along the entire wall of the esophagus, lubrication of food particles, ionic absorption, and protection of the esophageal mucosa against mechanical damage and bacterial invasion [25]. Likewise, the mucous secretion would participate in enzymatic digestion of the ingested food and to facilitate its transformation into chyme [26, 27].

Two types of mucous secreting cells were observed in the esophageal mucosa of tilapia from which two or more types

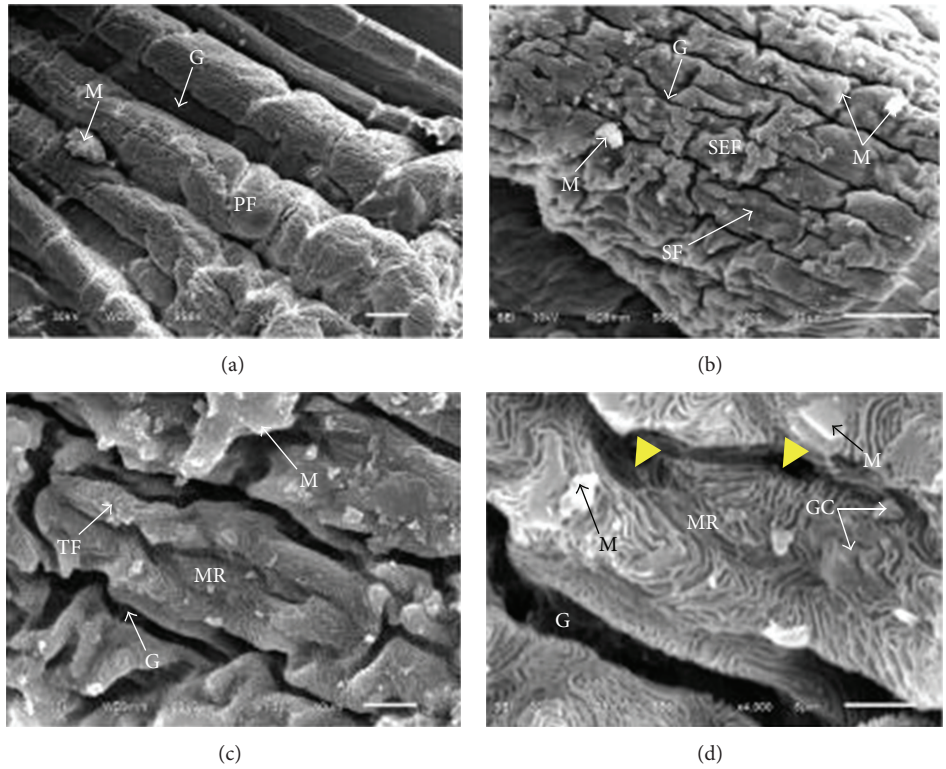


Figure 10: Scanning electron micrographs of esophageal mucosa of Nile tilapia (*Oreochromis niloticus*); (a) prominent longitudinal furrows (G) situated in between the longitudinal primary folds (PF). Note the different size of the longitudinal primary folds and the presence of mucous (M) in the longitudinal furrows (×60). (b) Stratified epithelial cells (SEC) on the primary mucosal folds showing secondary longitudinal folds (SF) interrupted with irregular longitudinal and transverse furrows (G). Note the presence of mucous on the surface epithelium (×500). (c) A third layer of the mucosal folds (TF) appeared on the secondary ones. Note the presence of irregular shaped stratified squamous epithelium provided with wavy prominent microridges (MR) (×1500). (d) Oval elevation in between SEC represented the luminal surface of the mucous cells (GC). Note the presence of opening of empty mucous cells in between SEC (arrow heads) (×4.000). Scale bars: (a) 200 um; (b) 50 um; (c) 10 um; and (d) 5 um.

of carbohydrates were produced. This may be due to different stages of maturation and ages [26]. The undifferentiated cells that occupied the basal parts of the epithelium in both species undergo many cytoplasmic changes and become epithelial cells or goblet cells [28].

The lack of a distinction between the lamina propria and the tunica submucosa in the two species under investigation was common in many teleosts; this was associated with the absence of lamina muscularis mucosa [29]. Thick layer of collagen fibers under the epithelium constituted a layer for support, protection and strengthening in many carnivorous fish [6].

Regarding the thick muscular layer in catfish in comparison to tilapia, this strengthens the esophageal wall and protects it from being engorged during the swallowing of solid particles and the esophagus needs well-developed circular muscles for mechanical transmission and food movement [26].

Combining SEM with light microscopy permits a better visualization of structure-function relationship in this organ [2]. In this connection, the microridges detected in the esophageal region of the studied fishes also have been reported in the esophageal region of many teleosts [30–33]. Similar microridges which have been reported in various epithelial surfaces, such as skin [34, 35] and gills [36], are subject to mechanical stress. This would appear to be an advantage in having a sculpted surface for absorbing impacts. On the other hand, these microridges appeared as striations in rainbow trout [37]. The fingerprint-like microridges observed on the superficial layer of the epithelium of the esophagus of catfish may represent a mechanical adaptation that would withstand the trauma resulting from ingesting bulky materials; similar observations were reported in *Notopterus notopterus* and *Oreochromis mossambicus* [38].

Light and scanning electron microscopical examinations of the esophagus of both species revealed that there were no taste buds in the epithelial lining of the esophagus; this was similar to the findings in walking catfish and piranha [39], silverside *Odontesthes bonariensis* [40] and *Engraulis anchoita* [15]. The lack of the taste buds in the esophageal mucosa of these fishes may suggest that they are not food selective as many other species [28, 33, 41]. On the other hand, presence of the taste buds in the esophageal mucosa was detected in *Mystus aor* [33], silverside *Odontesthes bonariensis* [40], and grass carp [16].

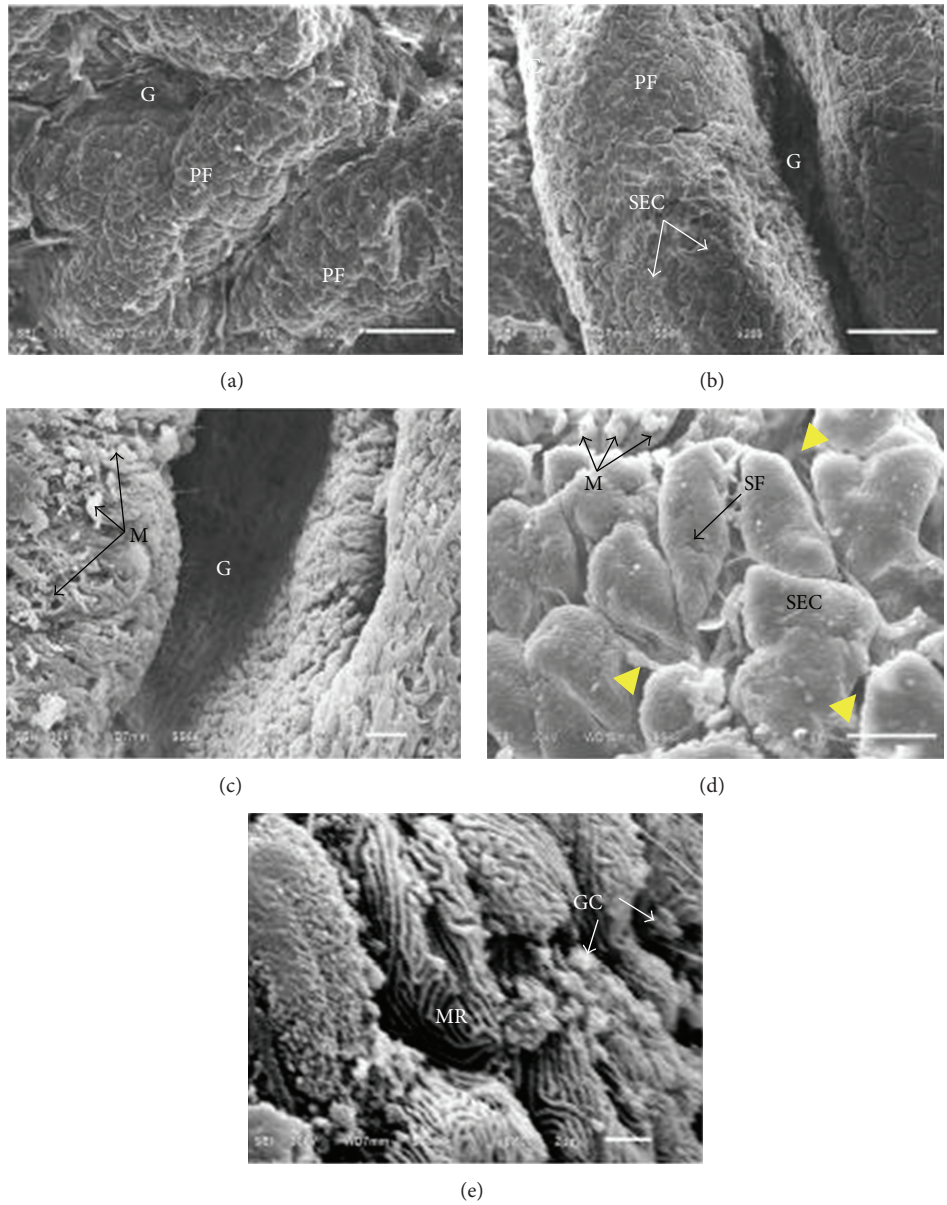


Figure 11: Scanning electron micrographs of esophageal mucosa of African catfish (*Clarias gariepinus*); (a) prominent longitudinal furrows (G) situated in between the longitudinal primary folds (PF). Note the nearly equal size and heights of the longitudinal primary folds (×50). (b) Stratified epithelial cells (SEC) on the primary mucosal folds forming secondary longitudinal folds. Note the deep furrows (G) between the longitudinal mucosal folds (×200). (c) A close look to the longitudinal furrows (G) showing the presence of mucous (M) on the sides on the longitudinal folds. Note the presence of oval shaped stratified squamous epithelium (×600). (d) Squamous shaped SEC forming the secondary folds (SF) with the presence of mucous globules in between (M). Note the presence of openings of empty mucous cells in between SEC (arrow heads) (×1.000). (e) Oval shaped stratified epithelial cells with wavy microridges (MR) on its surface (×6.500). Note the presence of mucous cell (GC) in between. Scale bars: (a) 500 um; (b) 100 um; (c) 20 um; (d) 10 um; and (e) 2 um.

The presence of the striated muscle fibers of the tunica muscularis in the esophagus would indicate that the food might be ejected or kept in this segment of the digestive system, which would induce the gastric secretion [3].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] Gafrd (General authority of fish research development in Egypt), *Annual report for country fish production*, 1996.

[2] A. H. K. Osman and T. Caceci, "Histology of the stomach of *Tilapia nilotica* (Linnaeus, 1758) from the River Nile," *Journal of Fish Biology*, vol. 38, no. 2, pp. 211–223, 1991.

[3] E. J. W. Barrington, "The alimentary canal and digestion," in *The Physiology of Fishes*, M. E. Brown, Ed., vol. 1, pp. 109–161, Academic Press, New York, NY, USA, 1957.

[4] T. Caceci, "Scanning electron microscopy of goldfish *Carassius auratus*, intestinal mucosa," *Journal of Fish Biology*, vol. 25, no. 1, pp. 1–12, 1984.

[5] T. Caceci and T. C. Hrubec, "Histology and ultrastructure of the gut of the black mollie (*Poecilia* spp.), a hybrid teleost," *Journal of Morphology*, vol. 204, no. 3, pp. 265–280, 1990.

[6] B. G. Kapoor, H. Smith, and I. A. Verighina, "The alimentary canal and digestive in teleosts," in *Advances in Marine Biology*, vol. 13, pp. 109–239, Academic Press, London, UK, 1975.

[7] S. S. Khanna and B. K. Mehrotra, "Morphology and histology of the teleostean intestine," *Anatomischer Anzeiger*, vol. 129, no. 1, pp. 1–18, 1971.

[8] S. M. B. Khojasteh, F. Sheikhzadeh, D. Mohammadnejad, and A. Azami, "Histological and ultrastructural study of the intestine of Rainbow trout *Oncorhynchus mykiss*," *World Applied Sciences Journal*, vol. 6, pp. 1525–1531, 2009.

[9] A. B. Mojazi, M. Bakrkazemi, I. Pousti, and A. S. Vilaki, "A histological study on the development of the digestive tract of Caspian salmon *salmon trutta caspius (Kessleri)*, from hatching to parr stage," *Iranian Journal of Fish Sciences*, vol. 5, no. 1, pp. 63–84, 2005.

[10] H. W. Ferguson, *Systemic Pathology of Fish, A Text and Atlas of Comparative Tissue Responses in Diseases of Teleosts*, Iowa State University Press, Ames, Iowa, USA, 1995.

[11] D. R. Hernándezi, M. Pérez Gianeselli, and H. A. Domitrovic, "Morphology, histology and histochemistry of the digestive system of South American catfish *Rhamdia quelen*," *International Journal of Morphology*, vol. 27, no. 1, pp. 105–111, 2009.

[12] M. F. Meister, W. Humbert, R. Kirsch, and B. Vivien-Roels, "Structure and ultrastructure of the oesophagus in sea-water and fresh-water teleosts (Pisces)," *Zoomorphology*, vol. 102, no. 1, pp. 33–51, 1983.

[13] M. S. Mujallid, *Anatomical studies on the freshwater fish Barbus arabius from Saudi Arabia [M.S. thesis]*, Faculty of Science, K.A.U., Jeddah, Saudi Arabia, 1989.

[14] J. D. Bancroft and A. Gamble, *Theory and Practice of Histological Techniques*, Churchill-Livingstone, London, UK, 6th edition, 2008.

[15] A. O. Díaz, A. M. García, C. V. Devincenti, and A. L. Goldemberg, "Morphological and histochemical characterization of the mucosa of the digestive tract in *Engraulis anchoita* (Hubbs and Marini, 1935)," *Anatomia, Histologia, Embryologia*, vol. 32, no. 6, pp. 341–346, 2003.

[16] E. A. Abd El Hafez, D. M. Mokhtar, A. S. Abou-Elhamd, and A. H. S. Hassan, "Comparative histomorphological studies on oesophagus of catfish and grass carp," *Journal of Histology*, vol. 2013, Article ID 858674, 10 pages, 2013.

[17] S. M. El-Gharbawy, T. F. Sallam, and H. El-Habback, "Post hatching age changes of the oesophagus of tilapia fish *Oreochromis niloticus*, light and tem studies," *Veterinary Medical Journal*, vol. 49, no. 3, pp. 451–472, 2001.

[18] C. M. Santos, S. Duarte, T. G. L. Souza, T. P. Ribeiro, A. Sales, and F. G. Araújo, "Histology and histochemical characterization of the digestive tract of Pimelodus maculatus (*Pimelodidae*, *Siluriformes*) in Funil reservoir, Rio de Janeiro, Brazil," *Iheringia—Serie Zoologia*, vol. 97, no. 4, pp. 411–417, 2007.

[19] C. A. Oliveira-Ribeiro and E. Fanta, "Microscopic morphology and histochemistry of the digestive system of a tropical freshwater fish *Trichomycterus brasiliensis (Lutken) (Siluroidei, Trichomycteridae)*," *Revta Brasilian Zoology*, vol. 17, no. 4, pp. 953–971, 2000.

[20] D. A. Vieira-Lopes, N. L. Pinheiro, A. Sales et al., "Immunohistochemical study of the digestive tract of *Oligosarcus hepsetus*," *World Journal of Gastroenterology*, vol. 19, no. 12, pp. 1919–1929, 2013.

[21] G. R. Zug, L. J. Vittand, and J. P. Caldwell, *Introduction Biology of Amphibian and Reptiles*, Academic Press, San Diego, Calif, USA, 2nd edition, 2001.

[22] X. J. Cao and W. M. Wang, "Histology and mucin histochemistry of the digestive tract of yellow catfish, *Pelteobagrus fulvidraco*," *Anatomia, Histologia, Embryologia*, vol. 38, no. 4, pp. 254–261, 2009.

[23] C. M. Morrison and J. R. Wright, "A study of the histology of the digestive tract of the Nile tilapia," *The Journal of Fish Biology*, vol. 54, no. 3, pp. 597–606, 1999.

[24] L. Marchetti, M. Capacchietti, M. G. Sabbieti, D. Accili, G. Materazzi, and G. Menghi, "Histology and carbohydrate histochemistry of the alimentary canal in the rainbow trout *Oncorhynchus mykiss*," *Journal of Fish Biology*, vol. 68, no. 6, pp. 1808–1821, 2006.

[25] M. P. Albrecht, M. F. N. Ferreira, and E. P. Caramaschi, "Anatomical features and histology of the digestive tract of two related neotropical omnivorous fishes (Characiformes; Anostomidae)," *Journal of Fish Biology*, vol. 58, no. 2, pp. 419–430, 2001.

[26] C. Domeneghini, R. Ponnelli Straini, and A. Veggetti, "Gut glycoconjugates in *Sparus aurata* L. (Pisces, teleostei). A comparative histochemical study in larval and adult ages," *Histology and Histopathology*, vol. 13, no. 2, pp. 359–372, 1998.

[27] H. M. Murray, G. M. Wright, and G. P. Goff, "A comparative histological and histochemical study of the post-gastric alimentary canal from three species of pleuronectid, the Atlantic halibut, the yellowtail flounder and the winter flounder," *Journal of Fish Biology*, vol. 48, no. 2, pp. 187–206, 1996.

[28] K. N. Hirji, "Observations on the histology and histochemistry of the oesophagus of the perch *Perca fluviatilis* L," *Journal of Fish Biology*, vol. 22, no. 2, pp. 145–152, 1983.

[29] M. Jaroszewska, K. Dabrowski, B. Wilczyńska, and T. Kakareko, "Structure of the gut of the racer goby *Neogobius gymnotrachelus* (Kessler, 1857)," *Journal of Fish Biology*, vol. 72, no. 7, pp. 1773–1786, 2008.

[30] A. J. Clarke and D. M. Witcomb, "A study of the histology and morphology of the digestive tract of the common eel (*Anguilla anguilla*)," *Journal of Fish Biology*, vol. 16, no. 2, pp. 159–170, 1980.

[31] D. N. Ezeasor and W. M. Stokoe, "A cytochemical, light and electron microscopic study of the eosinophilic granule cells in the gut of the rainbow trout, *Salmo gairdneri* Richardson," *Journal of Fish Biology*, vol. 17, no. 6, pp. 619–634, 1980.

[32] G. M. Sinha and P. Chakrabarti, "Scanning electron microscopic studies on the mucosa of the digestive tract in *Mystus aor* (Hamilton)," *Proceeding Indian natn Science Academy B*, vol. 52, no. 2, pp. 267–273, 1986.

[33] R. F. Sis, P. J. Ives, D. M. Jones, D. H. Lewis, and W. E. Haensly, "The microscopic anatomy of the oesophagus, stomach and intestine of the channel catfish *Ictalurus punctatus*," *Journal of Fish Biology*, vol. 14, no. 2, pp. 179–186, 1979.

[34] J. E. Harris and S. Hunt, "The fine structure of the epidermis of two species of salmonid fish, the Atlantic salmon (*Salmo salar* L.) and the brown trout (*Salmo trutta* L.). I. General organization and filament containing cells," *Cell and Tissue Research*, vol. 157, no. 4, pp. 553–565, 1975.

[35] J. W. Hawkes, "The structure of fish skin. I. General organization," *Cell and Tissue Research*, vol. 149, no. 2, pp. 147–158, 1974.

[36] D. L. Mattey, M. Morgan, and D. E. Wright, "A scanning electron microscope study of the pseudobranchs of two marine teleosts," *Journal of Fish Biology*, vol. 16, no. 3, pp. 331–343, 1980.

[37] E. L. Weinreb and N. Bilstad, "Histology of the digestive tract and adjacent structures of the rain bow trout *Salmo gairdneriirideus*," *Copeia*, vol. 3, pp. 194–204, 1955.

[38] D. K. Mandal and P. Chakrabarti, "Architectural pattern of the mucosal epithelium of the alimentary canal of *Notopterus notopterus* (Pallas) and *Oreochromis mossambicus* (Peters): a comparative study," *Acta Ichthyologica et Piscatoria*, vol. 26, no. 1, pp. 15–22, 1996.

[39] A. R. Raji and E. Norouzi, "Histological and histochemical study on the alimentary canal in Walking catfish *Claris batrachus* and piranha *Serrasalmus nattereri*," *Iranian Journal of Veterinary Research*, vol. 11, no. 3, pp. 255–261, 2010.

[40] A. O. Diaz, A. H. Escalante, A. M. García, and A. L. Goldemberg, "Histology and histochemistry of the pharyngeal cavity and oesophagus of the silverside *Odontesthes bonariensis* (Cuvier and Valenciennes)," *Journal of Veterinary Medicine C: Anatomia Histologia Embryologia*, vol. 35, no. 1, pp. 42–46, 2006.

[41] G. A. El Hag, M. S. Kamarudin, C. R. Saad, and S. K. Daud, "Gut histology of Malaysian river catfish, *Mystus nemurus* (C&V) larvae," *Life Science Journal*, vol. 9, no. 1, pp. 342–347, 2012.