Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(7): 1055 –1071 (2020)
www.ejabf.journals.ekb.eg

Comparative study on the histochemical structures of stomach, pyloric caeca and anterior intestine in the grey mullet, *Mugil cephalus* (Linnaeus, 1758)

Diaa, M. G. Farrag; Ahmad M. Azab and Ahmed, N. Alabssawy
Zoology Department, Faculty of Science, Al-Azhar University, Cairo
Corresponding author: amazab2000@azhar.edu.eg

ARTICLE INFO
Article History:
Received: Nov. 22, 2020
Accepted: Dec. 18, 2020
Online: Dec. 28, 2020

Keywords:
Histology;
Histochemistry;
Fish;
Mugil cephalus;
Stomach;
Pyloric caeca;
Anterior intestine

ABSTRACT

The purpose of this study was to compare the histological features of pyloric caeca with that of the stomach and anterior intestine in *Mugil cephalus*. Specimens of *M. cephalus* were dissected and small pieces of each part were cut, fixed for routine histological procedures. The transverse sections were also stained by some stains for histochemical purposes. These sections were examined under a microscope, photographed, and described.

Histologically, the wall of the stomach, pyloric caeca, and anterior intestine in *Mugil cephalus* mainly consists of serosa, muscular, submucosa, and mucosa. While the stomach and pyloric caeca have deeply mucosal folds in a narrow lumen, the anterior intestine has a long mucosal fold protruding towards the wide lumen. The mucosa of the three organs consists of columnar cells and mucus cells; in addition to gastric glands in the proventriculus stomach only. The columnar cells at the gizzard stomach are lined toward the lumen with a continuous koillin layer. The mucus cells are medium in size and numbers at the anterior intestine and less at pyloric caeca, but it absent from the stomach. Lymphocytes and wandering cells are abundant in between columnar cells and in the submucosal layer. Histochemical differences between these three digestive organs were also studied and described.

INTRODUCTION

The grey mullets are found world-wide in temperate to tropical coastal waters readily entering estuaries and even resident in freshwaters. There are about 20 genera and about 75 species **(Nelson *et al.* 2016).** The flathead grey mullet, *Mugil cephalus* (Linnaeus, 1758) is an economically important fish species which inhabits coastal waters of the tropical, subtropical and temperate zones of all seas in marine; fresh and brackish waters **(Saleh, 2006** and **Whitfield *et al.*, 2012).** The histological investigations of the digestive tract through fish species are more valuable as the concern in the fish culture spreads and extra information is required with concern to nutrition and feeding **(Farrag, 2017; Khadse & Gadhikar, 2017** and **Alabssawy *et al.* 2019**).

The alimentary tract in fishes showing a strong similarity to that of higher vertebrates, being composed of an internal mucosal epithelium surrounded by submucosal connective tissue and muscularis, which are enveloped by the circular and longitudinal muscles that form the walls of the tract, and finally the enveloping serosa with a part of the peritoneal tissue **(Nelson *et al.* 2016).**

Among large number of species, though the stomach is defined as actual organ, consists of anterior cardiac region and posterior pyloric region **(Chakrabarti & Ghosh, 2014).** In

Family: Mugilidae, the stomach is a simple U shaped cone which is divided into a thin-walled cardiac crop and a very thick- walled biconical pyloric gizzard **(Thomson, 1997).** The function of the gizzard in fishes is similar to that of birds; to grind or triturate food **(Wilson & Castro, 2010).**

The pyloric caeca are blind-ended sphincter-less ducts associated with the anterior intestine (**Wilson & Castro, 2010** and **Kalhoro *et al*. 2018).** The pyloric caeca is found in various number and diameter in different species in family Mugilidae, which the number of pyloric caeca is an important key for the identification of mugilid species **(Thomson, 1997**). The numbers vary from 2 to 22 in the genus *Mugil*, while in the genus Liza it ranges between 2 and 17 **(Luther, 1977** and **Kurma & Babu, 2013).** The pyloric caeca are 6 – 8 in number in *Lepomis macrochirus*; 2 – 3 in number were recorded in *Perca perca* and 2 in number in *Channa*. Some authors used the term "intestinal caeca" instead of "pyloric caeca" **(Hossain & Dutta, 1996). Khalaf-Allah (2009)** recorded 4 - 8 (usually 4) medium pyloric caeca at the junction between stomach and intestine of *Terapon puta*. It was found that 60% of known fish species possess pyloric caeca, which vary greatly in number (0-1000), length and diameter. In the flounder (*Platichthyes*), the pyloric caeca only appear as a few bumps on the intestinal wall; whereas in the Salmonidae, the caeca are long and numerous. A wide range of looping and coiled arrangements can be seen within the teleosts with long intestines (e.g. Cyprinidae; Loricariidae). However, some fish just have short, straight intestines with no looping or spiral valves (e.g. Cobitidae; Salmonidae) as reported by **Khojasteh (2012)**.

Histological and histochemical features in the digestive tract of teleostean fishes show adaptation to different feeding habits. The adaptation of digestive tract of fish to the normal diet can be clearly seen in the abundance and limitation of the histological elements such as mucus-secreting cells, taste buds, digestive glands and muscular coat. All being subject to much modification which enable digestion, storage, transportation and absorption of the digested food items **(Suíçmez & Ulus, 2005; Chatchavalvanich *et al*. 2006; Khalaf–Allah, 2009; Cao & Wang, 2009; Wilson & Castro, 2010; Banan Khojasteh, 2012; Hopperdietzel *et al.* 2014; Dos Santos *et al.* 2015; Farrag, 2017 and Alabssawy *et al.* 2019)**.

Therefore, the present study aimed to provide a comparative description - on the histological and histochemical adaptations - of pyloric caeca in *M. cephalus* with that of stomach and anterior intestine to understanding the role of pyloric caeca in physiological mechanisms of fish digestion.

MATERIALS AND METHODS

1. Specimens collection:

A total of 20 specimens of *M. cephalus* were collected from Dimru at Sidi Salem City, Kafr El-Shaikh governorate, Egypt **(Fig. 1).** The specimens commonly caught by trammel net or by gill-net reaching the bottom where it usually lives **(Latif, 1974**). Fish were examined either fresh or after preservation in 10% formalin solution. Then they were transported to the Laboratory of Marine Biology in Zoology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt. In the laboratory, fish were confirmed according to **Boulenger (1907)** and **Sandon (1950)** then the following studies were carried out.

2. Histological and histochemical studies:

For histological studies, small pieces (5 mm) of stomach, pyloric caeca and anterior intestine of *M. cephalus* were cut from the dissected specimens, fixed in 10% formalin solution for at least 48 hours, dehydrated in ascending concentrations of ethyl alcohol, cleared in xylene and embedded in wax (M.P.: 58°C). Transverse sections were cut at 4-6 µ in thickness, stained with Harris`s haematoxylin and eosin for routine histological examination **(Humason, 1979)**, Alcian blue and periodic acid Schiff (PAS) for acid and neutral of mucopolysaccharides **(Putt, 1971)**, Masson's trichrome for detection the type of the connective tissue **(Masson, 1928)** and Bromophenol blue for detection of protein (**Mazia *et al.* 1953**). Finally, the stained slides were microscopically examined with light microscope (XSZ-N107T) at different magnifications, and then photographed using digital camera (Toup Cam, Ver. 3.7) mounted on light microscope and described.

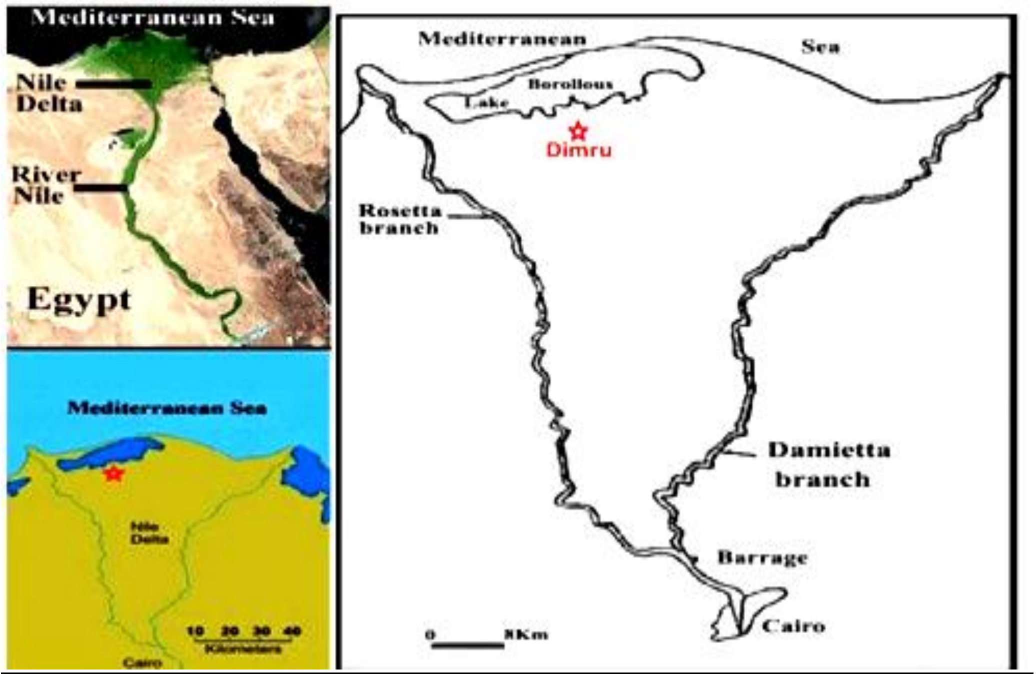

Fig. (1): Map of Nile Delta showing the location of Dimru fishing area (★).

RESULTS

1. Anatomical structures:

Morphologically, the stomach of *M. cephalus* is subdivided into two parts, a glandular proventriculus and a thick-walled muscular gizzard stomach. The proventriculus is cone like shaped while the gizzard is swollen from the median and decreased in size towards upper and lower ends. Two medium pyloric caeca are present in *M. cephalus* at the junction between the gizzard stomach and the anterior intestine in cone - like shape and relatively equal in size. The anterior intestine of *M. cephalus* extends behind the pyloric caeca to the first convoluted part of the intestine. It runs on the right side of the abdominal cavity to attain the form of an inverted U - shaped with the gizzard stomach.

2. Histological and histochemical structures:

2.1. Stomach:

The stomach of the mullet fish, *M .cephalus*, is of a gizzard type. It can be divided into two portions: a glandular stomach (proventriculus) and a thick walled muscular stomach (gizzard). Histologically, the wall of all portions of the stomach is composed of the ordinary four layers; mucosa, submucosa, muscularis and serosa **(Figs. 2A & 3A)**.

2.1.1. Glandular stomach (proventriculus):

The mucosa of the digestive stomach in *M. cephalus* is thrown into large and broad primary folds which give short secondary ones. The primary folds pass simply curved towards the lumen with rounded tips, laying in close contact to each other with relatively wide crypts **(Figs. 2 A&C)**.

The epithelial mucosa is made up of two layers: a thin layer of columnar epithelium and a relatively thick layer of gastric glands. The formers occupy the luminal side while the latters occupy the basal side of the mucosal folds **(Figs. 2 C&D)**. The simple columnar cells are slender with oval nuclei. The gastric glands form a conspicuous layer beyond the columnar cells. The formers open at the top of the columnar epithelium-just at the surface of the places leading to the gastric pits of the mucosal folds. Their cells are polygonal or elliptical in shape with granular cytoplasm **(Fig. 2D)**.

The submucosa is relatively thinner and consists of fibrous connective tissue filled with fibrocytes, lymphocytes and blood vessels**.** Lamina propria is comparatively wider and comprised of fibrous connective tissue richly supplied with lymphocytes and large blood vessels **(Figs. 2 B&C)**.

Muscular coat is comparatively thick and is built up of two layers, an outer longitudinal and an inner circular muscle layers; both of which are unstriated. The inner layer is much thicker than the outer one. The latter was arranged in large bundles held together by fibrous connective tissue **(Fig. 2A)**. The serosa is made up of pavement epithelium, which is either attached directly to the muscularis layer **(Fig. 2A).**

2.1.2. Muscular stomach (gizzard):

This portion of the stomach in *M. cephalus* is highly specialized as a masticator organ for the fish that eat hard vegetable matter. It is characterized by the followings: the tough non-cellular lining, which consists of a thick layer of keratinous substances, called koillin and a thick powerful muscular coat. The epithelial mucosa is thrown into primary folds. The latters are comparatively short, thick and fewer in number. Such structures are elongate towards the intestine, the folds leaving a relatively narrow lumen. These folds are longitudinal in direction and give numerous secondary folds. The latters are thinner, longitudinal in direction, compact with deep crypts and laying in close contact to each other with varied shapes at tips of secondary folds **(Figs. 3A & 2D)**.

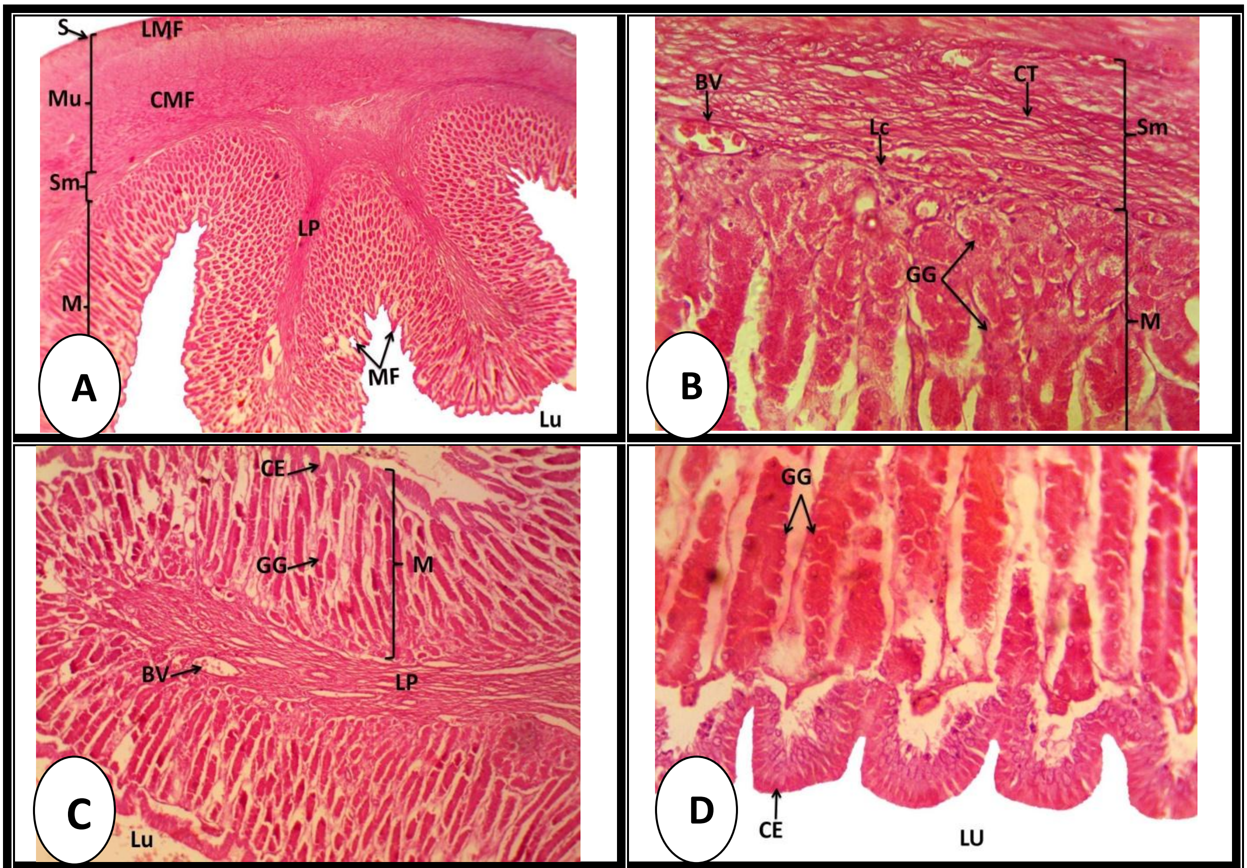

Fig. (2): Photomicrographs of T.S. in the proventriculus stomach of *M. cephalus* showing serosa (S), muscularis (Mu), submucosa (Sm), mucosa (M), mucosal folds (MF), lumen (Lu), longitudinal (LMF) and circular muscle fibers (CMF), lymphocytes (Lc), blood vessel (BV), wandering cell (WC), lamina propria (LP), gastric gland (GG) and columnar epithelial cells (H&E; A: X40, C:X 100 and B&D: X400).

The columnar cells constitute the more common type in the mucosa; the general form of these cells varies slightly according to their location in the mucous membrane. They are cylindrical in shape and wider at their tops than at their bases. Their nuclei are small, oval and sometimes nearly rounded **(Fig. 3B)**. The columnar cells in gizzard stomach are lined toward the lumen with continuous koillin layer that has protein content with the histochemical reaction of Bromophenol blue **(PLATE IA)**. In addition, the reaction with Alcian blue and periodic acid Schiff (PAS) showed layer of neutral mucin surrounding the columnar cells toward the lumen **(PLATE II A&B)**.

The submucosa is built up of a reticular connective tissue resulted by the histochemical reaction of Masson trichrome **(PLATE IB)**. This reticular tissue is richly supplied with fibrocytes, lymphocytes and blood vessels. Lamina propria of primary folds is relatively wide and consists of a highly cellular; lymphoreticular tissue richly supplied with fibrocytes, lymphocytes and relatively large blood vessels **(Figs. 3 B&D)**.

The muscularis, is an extensive thick-layer, consists only of circular muscle fibers which of striated type. Such structures are arranged in thick bundles. The bundles of muscle fibers, however, are rather close with some of interposed fibrous connective tissue that varies from place to another one **(Fig. 3C)**. The serosa is made up of pavement epithelium, which is either attached directly to the muscularis externa or to small amount of sub-serous connective tissue **(Fig. 3 C)**.

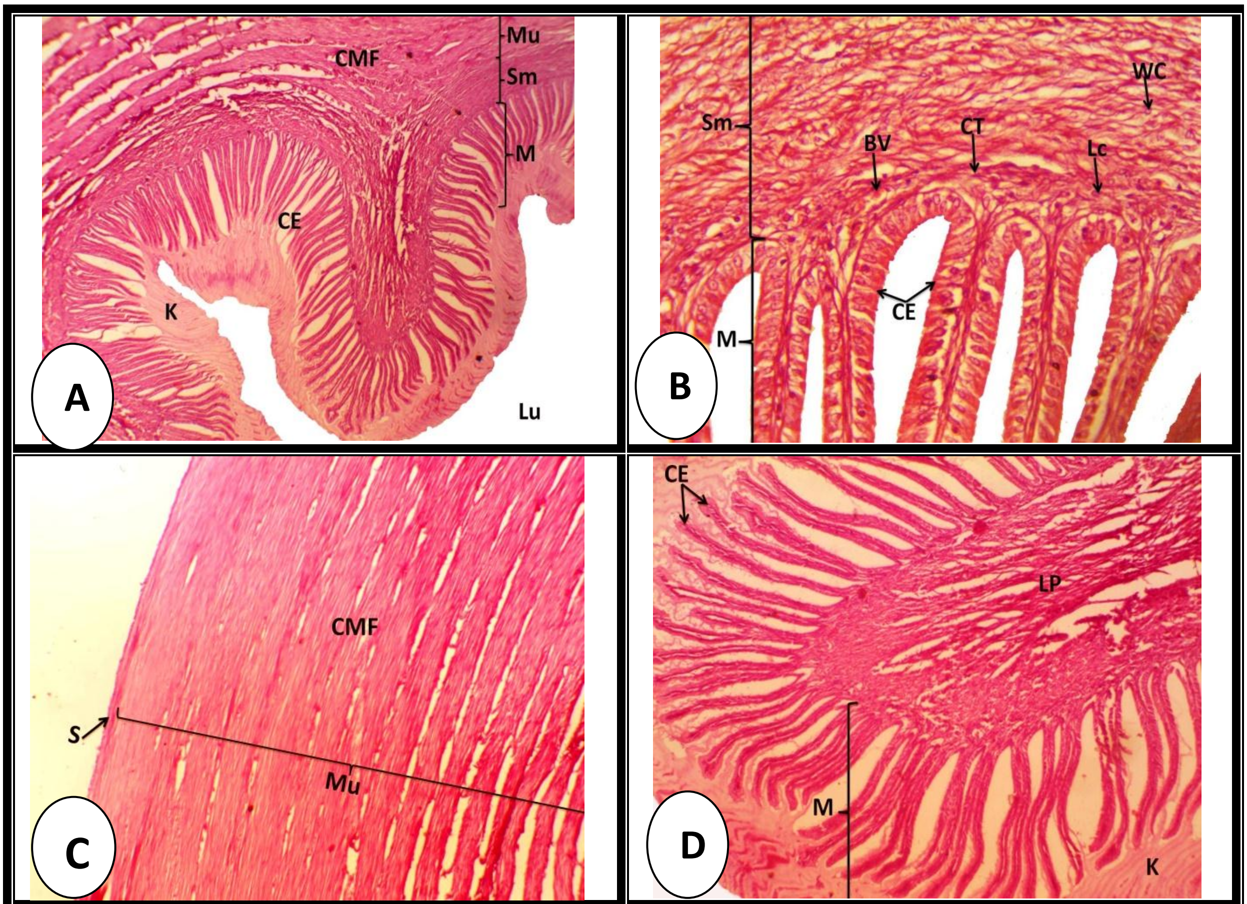

Fig. (3): A Photomicrograph of T.S. in the gizzard stomach of *M. cephalus* showing serosa (S), muscularis (Mu), submucosa (Sm), mucosa (M), mucosal folds (MF), lumen (Lu), circular muscle fibers (CMF), lymphocytes (Lc), blood vessel (BV), wandering cell (WC), lamina propria (LP), gastric cell (GC) and columnar epithelial cells **(H & E; A &C: X40; B: X400 and D: X100).**

2.2. Pyloric caeca:

The wall of pyloric caeca in *M. cephalus* composed of the four distinct principal layers namely mucosa, submucosa, muscularis and serosa.

In proximal region of the pyloric caeca in *M. cephalus*, the mucosa is thrown into a numerous folds or caecal villi which are irregular finger-shaped especially at the base while its wide appear at mid of the folds, these folds hanging inside a narrow lumen **(Fig. 4A)**.

The epithelial mucosa is made up of ciliated columnar epithelium. Goblet cells are numerous and found mostly towards the inner surface of the epithelium but rarely at base of the mucosal folds. These mucus secreting cells almost give a positive reaction of protein content with Bromophenol blue when it found away from the base of mucosal folds **(PLATE IC)**. Moreover, the histochemical reaction of Alcian blue and periodic acid Schiff (PAS) resulted in mixture of acid & neutral mucin at the base of mucosal folds and different concentrations of neutral mucin at each side of mucosal folds of pyloric caeca **(PLATE II C&D)**. Wandering cells and lymphocytes are numerous and scattered between and under columnar epithelium in addition to its diffusion in submucosal layer. The upper surface of mucosal epithelium is bounding the lumen **(Figs. 4, B-D)**.

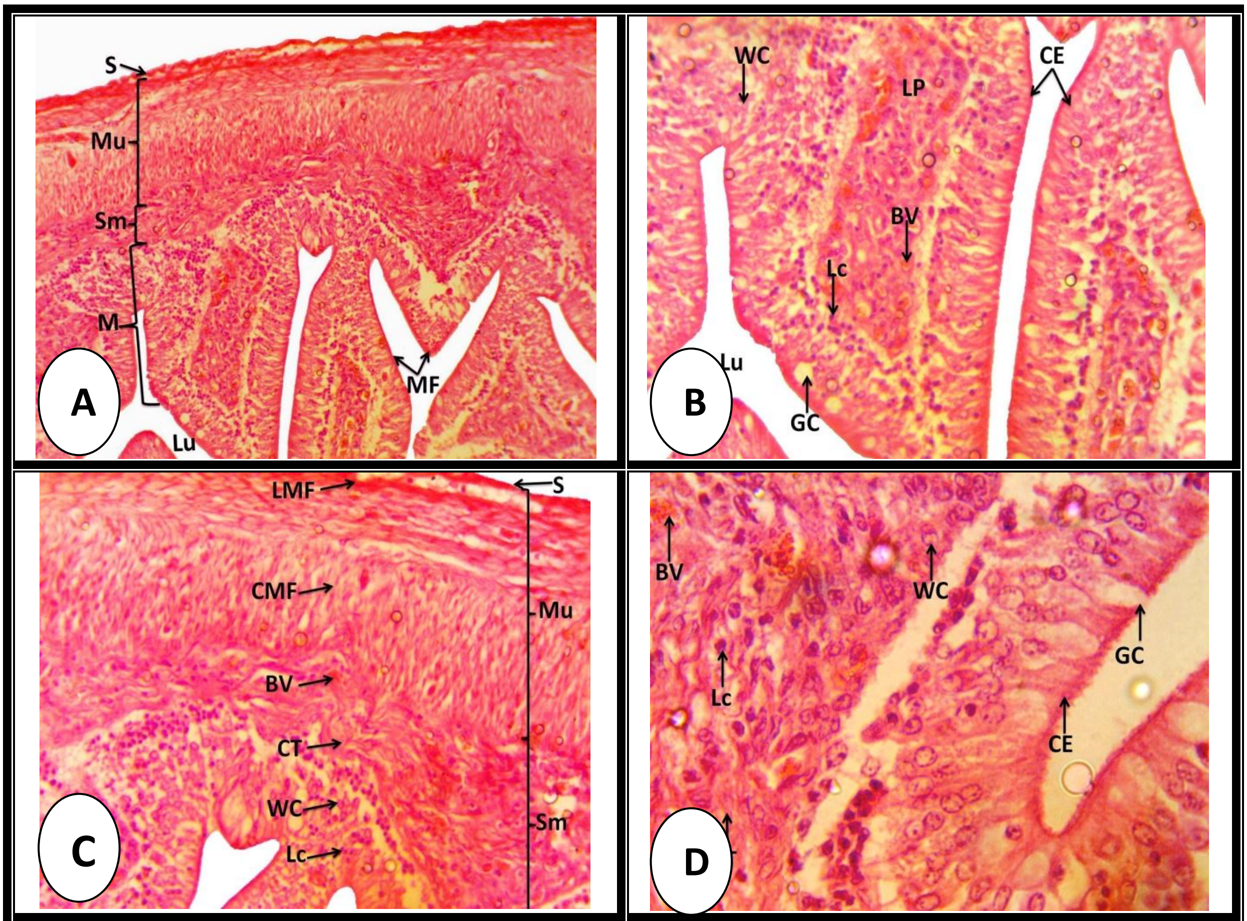

Fig. (4): A Photomicrograph of T.S. in the proximal pyloric caeca of *M. cephalus* showing serosa (S), muscularis (Mu), submucosa (Sm), mucosa (M), mucosal folds (MF), lumen (Lu), longitudinal (LMF) and circular muscle fibers (CMF), lymphocytes (Lc), blood vessel (BV), wandering cell (WC), lamina propria (LP), gastric cell (GC) and columnar epithelial cells **(H & E; A: X200 and B&C: X400 and D: X1000).**

The submucosa of the caecal villi is relatively thin and consists of elastic fibers bundles in connective tissue resulted by the histochemical reaction of Masson Trichrome **(PLATE ID)**. This connective tissue filled with blood vessels, lymphocytes and wandering cells; extends inside mucosal folds by a relatively wide lamina propria. Bundles of longitudinal elastic muscle fibers are mostly present near the muscularis and rarely towards the mucosa **(Fig. 4 B&D)**.

The muscularis consists of an inner thick circular layer and an outer thin longitudinal layer of muscle fibers. Serosa is very thin and it separates from the upper layer of muscle fibers by subserus connective tissue **(Figs. 4 A&C)**.

The distal region of the pyloric caeca in *Mugil cephalus* differs considerably from the proximal one. The caecal villi of the distal region are much folded and the folds interdigitate and unite together to forming a mass seen as a thick mesh-work in transverse sections. The caecal lumen is very restricted and reduced to many lacunae or channels **(Fig. 5A)**.The mucosa is look like that in the proximal region of the pyloric caeca but wandering cells may be less in number as well as the mucus secreting cells **(Figs. 5 B&D)**. Other layers of the caecal wall, submucosa, muscularis and serosa, are relatively lesser than proximal ones **(Figs. 5 A-C)**.

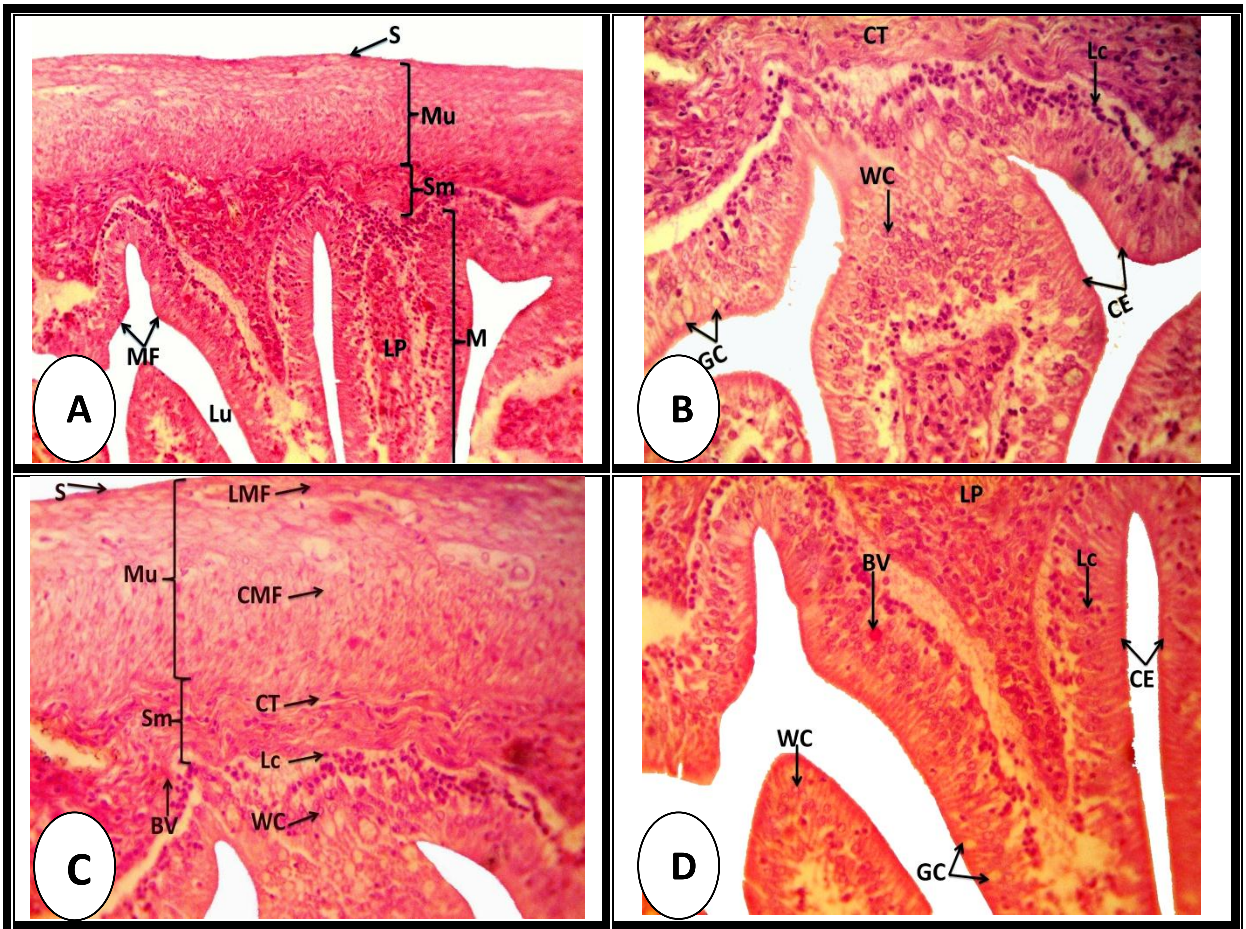

Fig. (5): A Photomicrograph of T.S. in the distal pyloric caeca of *M. cephalus* showing serosa (S), muscularis (Mu), submucosa (Sm), mucosa (M), mucosal folds (MF), lumen (Lu), longitudinal muscle fibers (LMF), circular muscle fibers (CMF), lymphocytes (Lc), blood vessel (BV), wandering cell (WC), lamina propria (LP), gastric cell (GC) and columnar epithelial cells **(H & E; A: X200 and B&C&D: X400).**

2.3. Anterior intestine:

The wall of anterior intestine is made up of the ordinary 4 layers: mucosa, submucosa, muscularis and serosa **(Fig. 6A)**. Its histological structure is similar as far as pyloric caeca, but some differences can be easily detected. The mucosal lining of the anterior intestine of *M. cephalus* is greatly folded. The villi are varied in length**.** Small folds are present at the bases of the crypts in between the comparatively large folds **(Fig. 6A)**. The epithelial mucosa is made up of two kinds of cells: columnar cells and mucus secreting cells. The columnar cells are toward the lumen. Mucus secreting cells are relatively medium in number. The secreting cells have a typical goblet outline; being concentrated at the sides of the folds, rarely on the crests, while in extensive areas along the bases, they are entirely absent **(Fig. 6 B&D)**. These secreting cells almost give a positive reaction of protein content with reaction of Bromophenol blue when it found away from the base of mucosal folds **(PLATE IE)**.

Moreover, the histochemical reaction of Alcian blue and periodic acid Schiff (PAS) resulted in numerous mixture of acidic & neutral mucin at the base of mucosal folds and also different concentrations of neutral mucin at each side of mucosal folds of anterior intestine **(PLATE II E&F)**.

Submucosa is relatively thinner and composed of fibrous connective tissue; resulted by the histochemical reaction of Masson trichrome **(PLATE IF)**. This fibrous connective tissue filled by lymphocytes and blood vessels. Lymphocytes are numerous among the epithelial cells. They tend to be more concentrated near the base of columnar epithelium and appear to be migrating towards the lumen**.** Tunica propria is well defined; it consists of fibrous connective tissue involved with lymphocytes and blood vessels **(Fig. 6, B-D)**.

Muscularis consists of two layers: an inner circular and an outer longitudinal unstriated muscle fibers. They are held together by areolar connective tissue. The outer layer is consisting of groups of longitudinal muscle fibers aggregated together by obvious connective tissue. The inner layer is greatly thicker than the outer one. Serosa consists of simple squamous epithelium **(Fig. 6 A&C)**.

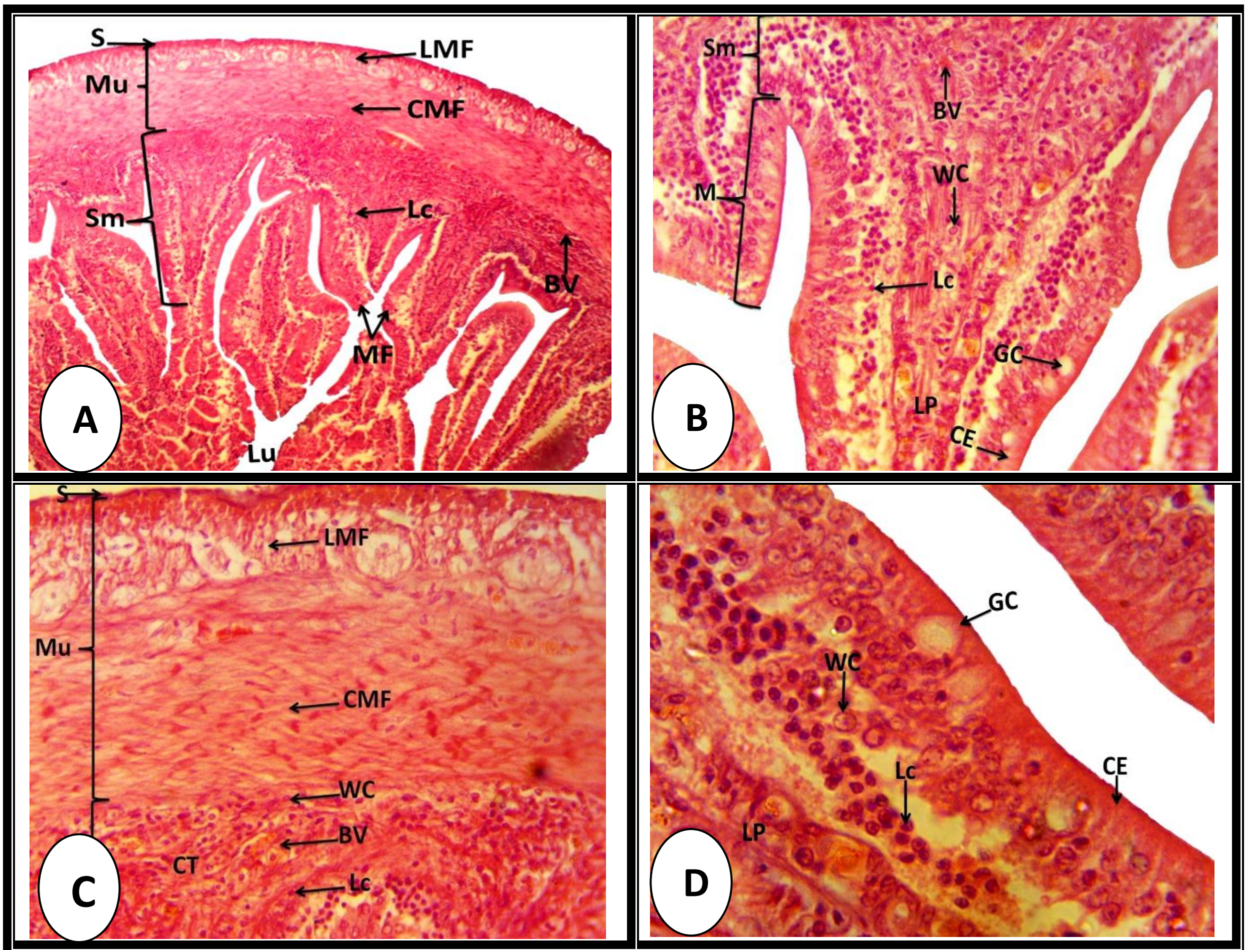

Fig. (6): A Photomicrograph of T.S. in the anterior intestine of *M. cephalus* showing serosa (S), muscularis (Mu), submucosa (Sm), mucosa (M), longitudinal muscle fibers (LMF), circular muscle fibers (CMF), lymphocytes (Lc), blood vessel (BV), mucosal folds (MF), lumen (Lu), wandering cell (WC), lamina propria (LP), gastric cell (GC) and columnar epithelial cells **(H & E; A: X100, B&C: X400 and D: X1000).**

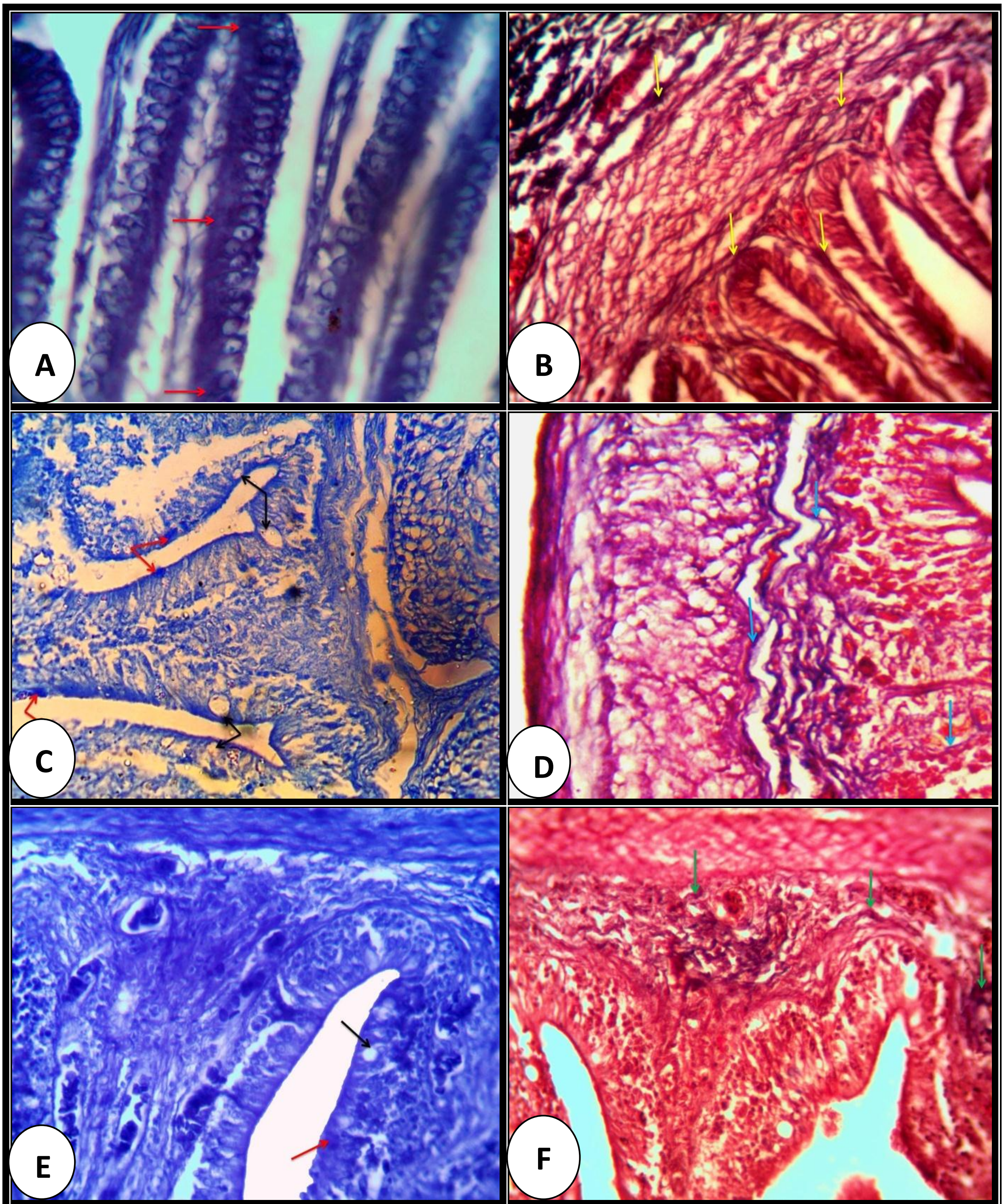

PLATE I

A Photomicrographs of T.S. in the gizzard stomach (A&C), pyloric stomach (C&D) and anterior intestine (E&F) of *M. cephalus* showing protein content (red arrows), watery content (black arrows), reticular tissues (yellow arrows), fibrous tissues (green arrows) and elastic tissues (cyan arrows) **(Bromophenol; A&C&E: X400 and Masson trichrome; B&D&F: X400).**

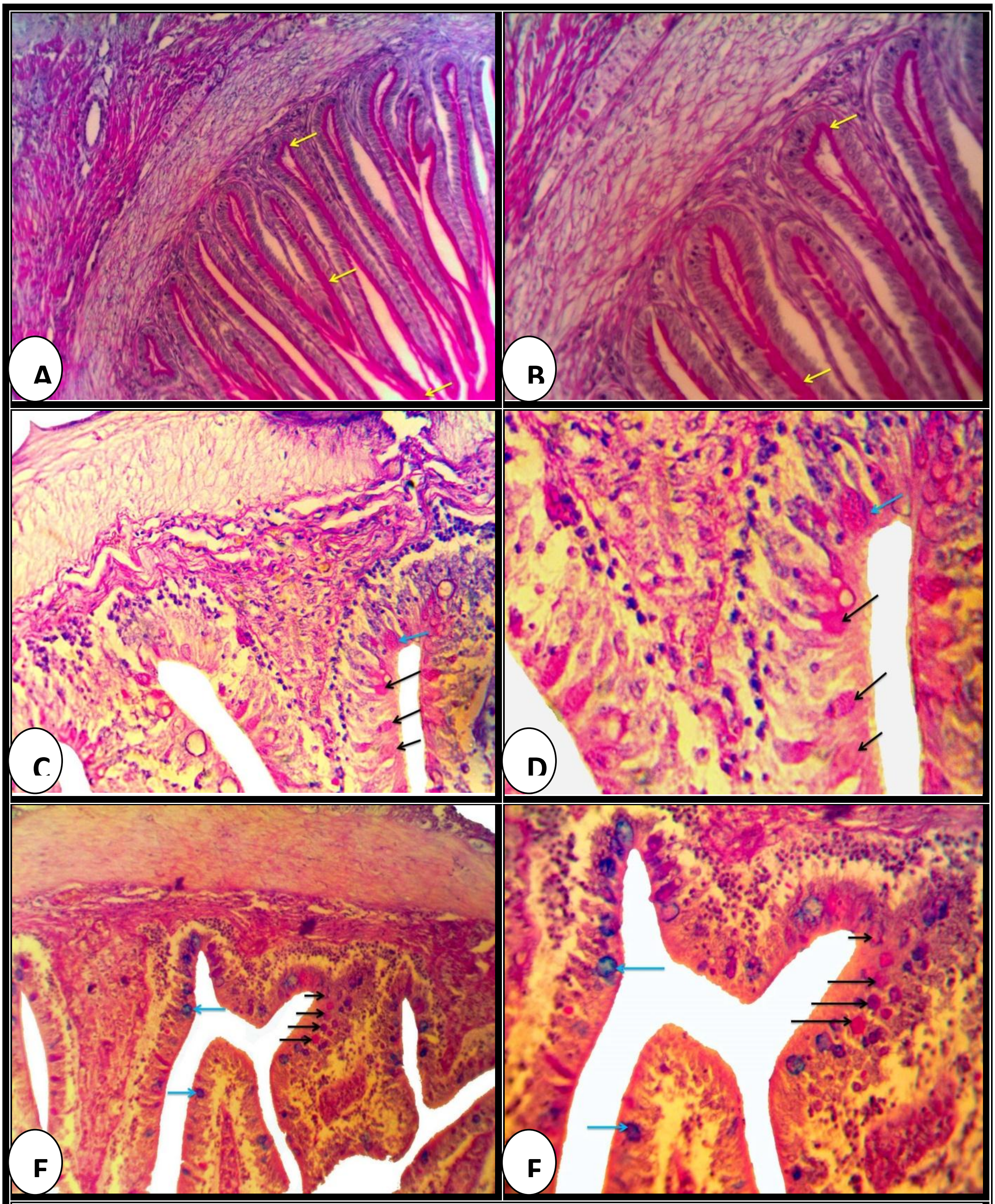

PLATE II

A Photomicrographs of T.S. in the gizzard stomach (A&C), pyloric stomach (C&D) and anterior intestine (E&F) of *M. cephalus* showing layer of neutral mucin (yellow arrows), Mixture of acidic & neutral mucin (cyan arrow) and different concentrations of neutral mucin (black arrows) **(Alcian PAS; A&C&E: X200 and B&D&F: X400).**

DISCUSSION

In the present study, the stomach of mullet fish, *M. cephalus*, is divided mainly into glandular proventriculus and muscular gizzard stomach. The epithelium of the proventriculus stomach in *M. cephalus* has numerous gastric glands for food digestion. The gizzard stomach is characterized by the non-cellular lining and thick powerful muscles, only the circular which contributes to control the passage of the digested food to the intestine. These observations agree with the stomach of herbivorous fish, *Liza aurata* described by **Khalaf Allah (2001)** and agree with the results on different other fish species (**Albattal, 2002; Hussein, 2004; Al-Abdulhadi, 2005; Kozarić *et al.* 2008; Khalaf–Allah, 2009; Farrag, 2017** and **Alabssawy *et al.* 2019).**

Histochemically, columnar cells at the mucosal layer of the gizzard stomach in *M. cephalus* are lined towards the lumen with continuous koillin layer that has protein content when reacted with Bromophenol stain. This layer shows of strong neutral mucopolysaccharides (MPS) lining epithelium of the gizzard stomach when stained by Alcian blue and periodic acid Schiff (PAS). While the submucosa layer shows a reticular fibers with Masson trichrome stain. The abundant amount of neutral MPS detected in gizzard submucosa of *M. cephalus* may be considered as a ground substance and building material. The mucin histochemistry of digestive canal has been studied on different fish species that showed the variety among different species and along its alimentary canals **(Azab *et al.* 1998; Khalaf–Allah, 2001; Diaz *et al.* 2008; Faccioli *et al.* 2014, Shalapy, 2017** and **Alabssawy *et al.* 2019).** Presence of mucus substances in the fishes' digestive tract is related to lubrication, inhibition of microorganisms, protection against photolytic degradation, in addition to osmotic function **(Loretz, 1995; Diaz *et al.* 2008).** ..

In the present study, the pyloric caeca was close to anterior intestine formation in their histological features. A similar indication was declared by **Mumford *et al.* (2007), Canan *et al.* (2012)** and **Mitra *et al.* (2015).** The present research showed that the pyloric caeca and intestine of the grey mullet, *Mugil cephalus* had the four basic layers; serosa, muscularis, submucosa and mucosa. This result is supported by results obtained from diverse species such as *Oncorhynchus mykiss* **(Khojasteh *et al.* 2009)** and *Rastrelliger brachysoma* **(Senarat *et al.* 2015)**, *Ctenopharyngodon idella* **(Mokhtar *et al.* 2015)** and *Belone belone* **(Bocina *et al.* 2017).**

Similar to our investigations of the study, **Murray *et al.* (1996)** reported that the pyloric caeca had a thinner muscularis layer than that of intestine, in Atlantic halibut, the winter flounder and the yellowtail flounder. The function of mixing the food with the digestive enzymes is contributing to the muscularis layer **(Mumford *et al*. 2007).** Therefore, monitoring of the histomorphology of the muscularis layer may be important for the fish nutrition.

The present observations indicated that, the tunica mucosa of the pyloric caeca in the investigated fish is mainly composed of ciliated simple columnar epithelia with mucus-secreting cells and longitudinal folded structure. The chief purpose of the tubular pouches is explained as "absorption" in contrast with mammals that function as fermentation. These are filled up as well as collapsed together by the anterior intestine, expanding the entire absorptive surface.

There are diverse approaches for the histological naming of fish intestine regions. Intestine regions were named as cranial, intermediate and caudal by **Albrecht *et al.* (2001);** anterior and posterior by **Mumford *et al.* (2007);** proximal and distal by **Rodrigues da Silva**

***et al.* (2012);** anterior, intermediate and posterior by **Nazlić *et al.* (2014);** proximal, middle and distal by **Deshmukh *et al.* (2015)** and posterior, middle and anterior by **Bocina *et al.* (2017).**

In the current work, the mucosal folds in the anterior intestine are relatively long and closely set, due to the retention of food for longer period indicate that the function is probably to increase the digestive and absorptive surface; as the mullet fish, *M. cephalus* is a herbivorous and need a long time and surface to digest the plant component.

The present study observed that the intestinal mucosa is covered by columnar epithelia (enterocytes) and mucus secreting cells called the goblet cell, like in other teleosts. Histochemically, columnar cells contain neutral MPS content. The latter may help in its flexibility nature and its peristaltic movement. Goblet cells are relatively quite in size and number. It shows moderate reaction with Bromophenol stain while it shows more intensive positive reaction with PAS stain which indicates presence of mixture of acid & neutral MPS and different concentrations of neutral MPS. Similar observations were detected by **Khalaf–Allah (2001)**.

Carrassón *et al.* (2006) stated that gel-forming mucin secretion produced by goblet cells is involved in epithelial protection as well as in lubrication for nutrient pass way. The increased concentration of mucus-secreting cells indicates that mucus production helps to defend the lining of the intestine and support waste exclusion **(Machado *et al.*, 2013).**

The present observations revealed that the submucosal layer of pyloric caeca in *M. cephalus* is characterized by the presence of elastic fibers when stained by Masson Trichrome. These elastic fibers in connective tissues may play a role in its flexibility nature.

CONCLUSION

This study concluded that the histological and histochemical differences between pyloric caeca and each of stomach and anterior intestine of *M. cephalus* are important for understanding the digestive physiology and related functional mechanisms of fish digestion.

REFERENCES

Al-Abdulhadi, H.A. (2005). Some comparative histological studies on alimentary tract of Tilapia fish, *Tilapia spilurus* and sea bream, *Mylio cuvieri*. Egypt. J. Aqua. Res., **31** (1): 387 - 398.

Alabssawy, A.N.; Khalaf–Allah, H.M.M. and **Gafar, A.A. (2019).** Anatomical and histological adaptations of digestive tract in relation to food and feeding habits of lizardfish, *Synodus variegatus* (Lacepède, 1803). Egyptian Journal of Aquatic Research, **45**: 159 - 165.

Albattal, A.A.E. (2002). Biological studies on the reproduction of *Lates niloticus*. M. Sc. Thesis, Zool. Dep., Fac. Sci., Al–Azhar University Cairo, 294pp.

Albrecht, M.P.; Ferreira, M.F.N. and **Caramaschi, E.P. (2001).** Anatomical features and histology of the digestive tract of two related neotropical omnivorous fishes (Characiformes; Anostomidae). Journal of Fish Biology, **58** (2): 419 – 430.

Azab, A. M.; El-Deeb, R. M. and **Shehata, S. M. A. (1998).** Anatomical and histochemical studies on the alimentary tract of two benthic marine fishes of different feeding habits. Egypt. J. Aqua. Biol. Fish., **2** (4): 425 – 440.

Banan Khojasteh, S.M.B. (2012). The morphology of the post-gastric alimentary canal in teleost fishes: a brief review. International Journal of Aquatic Science, **3** (2): 71 – 88.

Bocina, I.; Santic, Z.; Restovic, I. and Topic, S. (2017). Histology of the digestive system of the garfish, *Belone belone* (Teleostei: Belonidae). The European Zoological Journal, **84** (1): 89 - 95.

Boulenger, G.A. (1907). The Fishes of the Nile. (This forms part of Anderson's Zoology of Egypt, published for the Egyptian Government by Hugh Ress). London, S.W. , 53: 276pp.

Canan, B.; Nascimento, W.S.; Silva, N.B. and Chellappa, S. (2012). Morphohistology of the digestive tract of the damsel fish, *Stegastes fuscus* (Osteichthyes: Pomacentridae). The Scientific World Journal, **2012** : 1- 9.

Cao, X. J. and Wang, W. M. (2009). Histology and mucin histochemistry of the digestive tract of yellow catfish, *Pelteobagrus fulvidraco*," Anatomia, Histologia, Embryologia, **38** (4): 254 - 261.

Carrassón, M.; Grau, A.; Dopazo, L. R. and Crespo, S. (2006). A histological, histochemical and ultrastructural study of the digestive tract of *Dentex dentex* (Pisces, Sparidae). Histol Histopathol., **21**: 579 - 593.

Chakrabarti, P. and Ghosh, S. (2014). A comparative study of the histology and microanatomy of the stomach in *Mystus vittatus* (Bloch), *Liza parsia* (Hamilton) and *Oreochromis mossambicus* (Peters). Journal of Microscopy and Ultrastructure, **2**: 245 - 250.

Chatchavalvanich, K.; Marcos, R.; Poonpirom, J.; Thongpan, A. and Rocha E. (2006). Histology of the digestive tract of the freshwater stingray Himantura signifer Compagno and Roberts, (Elasmobranchii, Dasyatidae). Anatomy and Embryology, **211**: 507-518.

Deshmukh, M.R.; Chirde, S.G. and Gadhikar, Y.A. (2015). Histological and histochemical study on the stomach and intestine of catfish, *Heteropneustes fossilis* (Bloch, 1794). G. J. B. A. H. S., **4** (1):16 - 23.

Diaz, A. O.; Garcia, A. M.; and Goldemberg, A.L. (2008). Glycoconjugates in the mucosa of the digestive tract of *Cynoscion guatucupa*: a histochemical study. Acta. Histochemica., 110: 76 – 85.

Dos Santos, M. L.; Arantes, F. P.; Santiago, K. B. and Dos Santos, J. E. (2015). Morphological characteristics of the digestive tract of *schizodon knerii* (Steindachner, 1875), (characiformes: Anostomidae): An anatomical, histological and histochemical study. Annals of the Brazilian Academy of Sciences, **87** (2): 867 - 878.

Faccioli, C. K.; Chedid, R. A.; Amaral, A. C. Do.; Vicentini, I. B. F. and Vicentini, C. A. (2014). Morphology and histochemistry of the digestive tract in carnivorous freshwater Hemisorubim platyrhynchos (Siluriformes: Pimelodidae). Micron, **64**: 10 – 19.

Farrag, D. M. G. (2017). Comparative studies on the skeletal elements and functional anatomy of the digestive tract and integument of some silurid fish species native to the River Nile, Egypt. M.Sc. Thesis, Zoology Department, Faculty of Science (Boys), AL-Azhar University, Pp: 329.

Hopperdietzel, C.; Hirschberg, R. M.; Hünigen, H.; Wolter, J.; Richardson, K. and Plendl J. (2014). Gross morphology and histology of the alimentary tract of the convict cichlid Amatitlania nigrofasciata. Journal of Fish Biology, **85**: 1707-1725.

Hossain, A.M. and Dutta, H.M. (1996). Phylogeny, ontogeny, structure and function of digestive tract appendages (Caeca) in teleost fish. In: Fish Morphology. Balkema (ed.), Brookfield VT, pp.59-76.

Humason, G.L. (1979). Animal Tissue Techniques. Freeman, W.H. & Co., San Francisco, 641pp.

Hussein, T. D. (2004). Comparative histomorphometric study on the alimentary canal of two bony fish Species: *Clarias gariepinus* and *Bagrus bajad*. Egyptian Journal of Zoology, **42**: 1 - 17.

Kalhoro, H.; Tong, S.; Wang, L.; Hua, Y.; Volatiana, J. A. and Shao, Q. (2018). Gross morphological study of the gastrointestinal tract of *Larimichthys crocea* (Acanthopterygii: Perciformes). Zoologia, **35** (6): 1 - 9.

Khadse, T.A. and Gadhikar, Y.A. (2017). Histological and ultrastructural study of intestine of Asiatic knife fish, *Notopterus notopterus*. International Journal of Fisheries and Aquatic Studies, **5** (1): 18 – 22.

Khalaf–Allah, H.M.M. (2001). Ecological and biological studies on some fishes in Lake Qarun, Egypt. M.Sc. Thesis, Zool. Dep. Fac. Sci., Al–Azhar Univ., Egypt, 331pp.

Khalaf–Allah, H.M. M. (2009). Biological studies on some Mediterranean Sea fish species with special reference to their feeding habits, growth and reproduction. Ph.D. Thesis, Zool. Dep. Fac. Sci., Al-Azhar Univ., Egypt., 432pp.

Khojasteh, B.; Sheikhzadeh, F.; Mohammadnejad, D. and Azami, A. (2009). Histological, histochemical and ultrastructural study of the intestine of rainbow trout (*Oncorhynchus mykiss*). World Applied Sciences Journal, **6** (11): 1525 - 1531.

Khojasteh, S. M. B. (2012). The morphology of the post-gastric alimentary canal in teleost fishes: a brief review. International Journal of Aquatic Science, **3** (2): 71 – 88.

Kozarić, Z.; Kužir, S.; Petrinec, Z.; Gjurčević, E. and Božić, M. (2008). The development of the digestive tract in larval european catfish (*Silurus glanis* L.). Anatomia, Histologia, Embryologia: Journal of Veterinary Medicine, Series C, **37** (2): 141 – 146.

Kurma, R.R. and Babu, K.R. (2013). Studies on grey mullets collected from Interu swamp, at Krishna Estuarian region, Andhra Pradesh, India. Research Journal of Marine Sciences, **1** (2):12-16.

Latif, A.F.A. (1974). Fisher of Lake Nasser. Aswan regional planning. Lake Nasser Development Center, Aswan, Vol. **1974**: 95 - 105.

Loretz, C. A. (1995). Electrophysiology of ion transport in teleost intestinal cells. In: cellular and Molecular approaches to fish ionic regulation (C.H. Wood and T.J. Shuttleworth eds). London Academic Press, pp. 25 – 56.

Luther, G. (1977). New characteristics for consideration in the taxonomic appraisal of grey mullets. The Marine Biological Association of India, **19** (1-2):1 - 9.

Machado, M.R.F.; Souza, H.O.; de Souza, V.L.; de Azevedo, A.; Goitein, R. and Nobre, A.D. (2013). Morphological and anatomical characterization of the digestive tract of *Centropomus parallelus* and *C. undecimalis*. Acta Scientiarum, Biological Sciences, **35**: 467 - 474.

Masson, P. (1928). Carcinoids (argentaffin cell tumors) and nerve hyperplasia of the appendicular mucosa. Amer. J. Pathol., **4 :**181 - 211.

Mazia, D.; Brewer, P.A. and Alfert, M. (1953). The cytochemical staining and measurement of protein with mercuric bromophenol blue. Biol. Bull., 104 - 57.

Mitra, A.; Mukhopadhyay, P.K. and Homechaudhuri, S. (2015). Histomorphological study of the gut developmental pattern in early life history stages of featherback, *Chitala chitala* (Hamilton). Arch. Pol. Fish, **23**: 25 - 35.

Mokhtar, D.M.; Abd-Elhafez, E. A.; Abou-Elhamd, A. S. and Hassan, A.H.S. (2015). Light and scanning electron microscopic studies on the intestine of grass carp (*Ctenopharyngodon idella*): I-Anterior Intestine. J. Aquac. Res. Development, **6** (11).

Mumford, S.; Heidel, J.; Smith, C.; Morrison, J.; MacConnell, B. and Blazer, V. (2007). Fish Histology and Histopathology. 4th Edition, US Fish & Wildlife Service (USFWS), National Conservation Training Center (NCTC) West Virginia, 357pp.

Murray, H.M.; Wright, G.M. and Goff, G.P. (1996). 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, **48** (2): 187 - 206.

Nazlić, M.; Paladin, A. and Bočina, I. (2014). Histology of the digestive system of the black scorpion fish *Scorpaena porcus* L. ACTA ADRIAT., **55** (1): 65 – 74.

Nelson, J. S.; Grandle, T. C. and Wilson, M.V.H. (2016). Fishes of the world. 5th edition, Hoboken, John Wiley & Sons, 707pp.

Putt, F. A. (1971). Alcian dyes in calcium chloride: a routine selective method to demonstrate mucins. Yale J. Biol. Medic., **43**: 279 - 282.

Rodrigues da Silva, M.; Natali, M.R.M. and Hahn, N.S. (2012). Histology of the digestive tract of *Satanoperca pappaterra* (Osteichthyes, Cichlidae). Acta Scientiarum. Biological Sciences Maringa, 34 (3): 319 - 326.

Saleh, M.A. (2006). Cultured aquatic species information programme, *Mugil cephalus.* Food and Agriculture Organization (FAO), Fisheries and Aquaculture Department. http://www.fao.org/fishery/culturedspecies/Mugil_cephalus/en.

Sandon, H. (1950). An illustrated guide to the fresh water fishes of Sudan, Sudan Notes and Records, Khartoum.

Senarat, S.; Kettratad, J.; Jiraungoorskul, W. and Kangwanrangsan, N. (2015). Structural classifications in the digestive tract of short mackerel, *Rastrelliger brachysoma* (Bleeker, 1865) from Upper Gulf of Thailand. Songklanakarin J. Sci. Technol., **37** (5): 561 - 567.

Shalapy, W. T. S. H. (2017). Comparative study on the structural adaptation due to feeding strategy in some coral reef fishes. Ph.D. Thesis, Zool. Dep. Fac. Sci. Girl, Al-Azhar Univ., Egypt, 241pp.

Suiçmez, M. and Ulus, E. (2005). A Study of the anatomy, histology and ultrastructure of the digestive tract of Orthrias angorae Steindachner, 1897. Folia Biologica, **53** (1-2): 95 – 100.

Thomson, J.M. (1997). The Mugilidae of the world. Mem. Queensland Mil: Memorial Museum. **41**: 457 - 562.

Whitfield, A.K.; Panfili, J. and Durand, J.D. (2012). A global review of the cosmopolitan flathead mullet, *Mugil cephalus* Linnaeus 1758 (Teleostei: Mugilidae), with emphasis on the biology, genetics, ecology and fisheries aspects of this apparent species complex. Rev. Fish Biol. Fish, Worthington, **22**: 641- 681.

Wilson, J.M. and Castro, L.F.C. (2010). Morphological diversity of the gastrointestinal tract in fishes. In: The Multifunctional Gut of Fish. Grosell, M.; Farrell, A.P. and Brauner, C.J., (eds.), Academic Press is an Imprint of Elsevier, **30**: 1 - 55.

ARABIC SUMMARY

دراسة مقارنة للتراكيب الهستولوجية والهستوكيميائية للمعدة والأعاور البوابية والأمعاء الأمامية في سمكة البوري

ضياء مجدي جوده فراج، أحمد مسعد عزب، أحمد نصر محمد العبساوى
قسم علم الحيوان - كلية العلوم - جامعة الأزهر - القاهرة

تهدف الدراسة الحالية إلى دراسة التراكيب الهستولوجية والهستوكيميائية لكلا من المعدة والأعاور البوابية والأمعاء الأمامية ومقارنتهم مع بعضهم البعض فى سمكة البورى. ولذلك تم تجميع عشرون عينة من أسماك البوري. وقد تم عمل قطاعات نسيجية من هذه الأجزاء وصباغتها بالطريقة العادية للدراسة النسيجية وكذلك استخدام بعض الصبغات الخاصة بتوضيح النشاط الكيميائي في الأنسجة، وتم فحص القطاعات ووصفها وتصويرها.

أوضحت نتائج الدراسة أنه لا يوجد أي إختلاف ملحوظ في جدار المعدة والأعاور البوابية والأمعاء الأمامية في سمكة البوري حيث أنه يتكون من الطبقات الأساسية الأربعة (المصلية والعضلية وتحت المخاطية والمخاطية). إلا أن معدة البورى القانصة تحتوي على طبقة عضلية سميكة من ألياف العضلات المخططة الدائرية فقط والتى تستخدم فى الهضم الميكانيكى لطحن الطعام ليسهل هضمه وإمتصاصه فيما بعد. وبينما تظهر ثنيات مخاطية عميقة في تجويف ضيق فى كلا من المعدة والأعاور البوابية ، فإن الثنيات المخاطية للأمعاء الأمامية تكون طويلة والتى هى متوائمة مع إبقاء الغذاء بالمعدة لكى يتم هضمه ثم زيادة مساحة سطح الأمعاء للإمتصاص حيث أن سمكة البورى نباتية التغذية.

أوضحت النتائج أن الطبقة المخاطية للأعضاء الثلاثة فى سمكة البورى تتكون من خلايا طلائية عمودية وخلايا مخاطية بالإضافة إلى غدد هاضمة في المعدة الهاضمة فقط. كما تُبطن الخلايا العمودية في المعدة القانصة بطبقة من الكويلين ذات المحتوى البروتينى والذى له دور فى حماية الطبقة المخاطية.

بينت نتائج الدراسة أيضا أن الخلايا المخاطية تكون متوسطة الحجم والعدد في الأمعاء الأمامية ولكنها أقل في الأعاور البوابية بينما تكون غائبة فى المعدة. الخلايا الليمفاوية والخلايا المتجولة شائعة الإنتشار بين الخلايا العمودية للأمعاء الأمامية والأعاور البوابية كما توجد أيضاً في الطبقة تحت المخاطية لهما، بينما تظهر الخلايا الليمفاوية بالأعداد الأقل في المعدة. هذا وقد تمت دراسة ووصف الاختلافات الهستوكيميائية بين الأعضاء الهضمية الثلاثة.