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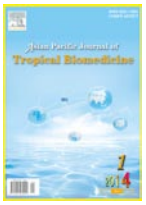

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Morphological study of the asymmetrical buccal cavity of the flatfish common solea (*Solea solea*) and its relation to the type of feeding

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PEER REVIEW

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Comments

Both science and fairness of this papaer are correct.

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Comments

This is a valuable work and was the first description of the architecture of the buccal cavity of flattened fish with asymmetrical buccal cavity. The results are interesting with high quality light and SEM photographs. This work is important to those who study fish biology, fish aquaculture, vertebrates comparative anatomy, histology and scanning electron microscopy.
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ABSTRACT

Objective: To investigate the surface architecture of the asymmetrical buccal cavity of *Solea solea* which are considered one of the most important predators in benthic communities.
Methods: Adult *Solea solea* were obtained from Mediterranean Sea near Damietta. The heads were removed and processed for scanning electron microscopy. Its buccal cavity is asymmetrical and divided into roof and floor and the tongue for histological studies.
Results: The buccal cavity roof is formed from upper jaw, velum and the palate. The upper jaw has several wing like processes with teeth arranged in several rows which may help in cutting and pushing the food to the entrance of the digestive canal while the floor is formed from the lower jaw and the tongue. The tongue is divided into apex, body and root. There is a gradual decrease of goblet cells in the tongue from anterior to posterior. These goblet cells function in protection of the epithelium.
Conclusions: Teeth in the floor of the buccal cavity and taste buds can be considered adaptive changes of the oral cavity related to the feeding habits and was a source to identify new and better methods of nutrition in aquaculture of *Solea solea*.

KEYWORDS
Buccal cavity, Scanning electron microscope, Histology, Flatfish, *Solea solea*

1. Introduction

The buccal cavity of fish plays an important role in the seizure and selection of food and rejection of undesirable items ingested by fish. The lips of fish and its associated structures may be participated with selection, capture, deglutition and predigestive preparation of food[1-3].

The ultrastructure of the buccal cavities of fish results from studies on carnivorous fish species, *Gadus morhua*, *Mystus*, *Sparus aurata*, zebra fish (*Danio rerio*), the cat fish (*Rita rita*), sea bass (*Dicentrachus labrax*), while studies on buccal cavities of a herbivorous fish include the carp, *Cirrhinus mirgala* and *Oreochromis niloticus*[4-8].

Taste buds of teleost varied in structure depending on the species examined and even on their location in the body[9]. Taste buds in fish participate in food identification by

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detecting distinct chemical substances at short distance[10].

Taste buds in fish are found on tongue, the surface of the pharynx, lips and on the barbles around the mouth, gills, pectoral fins or the trunk[11]. Taste buds distribution is a species specific adaptation to the habitat, food preference and feeding behaviour[12,13].

The common solea is a nocturnal feeder belongs to order Pleuronectiformes (flatfishes), which are considered one of the most important predators in benthic communities. During the daynight hours it remains buried in the sand, moving little. The solea only succeeds in finding food that lie on the sea bed and will not notice material suspended above it. The mouth of the sole is positioned so as to facilitate picking up objects from the bed of the sea. Soleids have been considered apt for commercial aquaculture since the end of 19th century and the beginning of the 20th century.

Among the Euteleostean order Pleuronectiformes (flatfishes), the family Soleidae is characterized by asymmetrical features, especially by their oral jaw apparatus[14,15]. The oral jaw apparatus includes a much reduced premaxilla on the ocular side and a shortened mandible with a high coronoid process on the blind side[16]. The present work was under taken to investigate the surface architecture of the asymmetrical buccal cavity of *Solea solea* (*S. solea*) in relation to its food and feeding habits which helps in aquaculture of it.

2. Materials and methods

Live specimens of *S. sole* were collected from Mediterranean Sea near Damietta and were maintained in the laboratory conditions at controlled room temperature. The fish were anaesthetized. The heads were excised and rinsed in physiological saline. They were fixed in 10% formalin, post fixed with 1% osmium tetroxide in 0.1 mol/L 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 aluminium stubs facing upwards, covered with carbon tabs, sputtered with gold and then examined with a scanning electron microscope (JSM. 5300) at an accelerating voltage of 15 kV in Electron Microscopy Unit of Aexandria Faculty of Science.

After fixation, the samples of tongues were dehydrated in ethanol series, cleared in xylene and embedded in paraffin wax and sectioned at 5 μm. After dewaxing with xylene and hydration in ethanol series of descending concentration, sections were stained for general histological purposes with haematoxylin and eosin stain.

3. Results

The buccal cavity of *S. solea* is asymmetrical, wide and slightly with anteriorly protrusible subterminal mouth bordered by the upper and the lower lips. The buccal cavity is divided into two regions, the dorsal roof and the ventral floor. The upper and the lower jaw are edentulous.

3.1. The roof of the buccal cavity

The buccal cavity roof is formed from upper jaw, velum and the palate. The roof of the buccal cavity is asymmetrical with apointed anterior portion. At the left side of the upper jaw several semicircular layers are seen (Figure 1a). The upper lip has several wing like processes arranged in several rows (Figure 1b).

Each wing like structure has a central portion with branched folds (Figure 1c) and a peripheral portion with about eleven folds (Figure 1d). From the latter emerge a number of elongated teeth. Some of these processes have teeth. There are some openings between these processes (Figure 1e). The velum is characterized by a great number of compressed folds (Figure 1f). The epithelial layer covering it has numerous taste buds (Figure 1g). Palatinum has longitudinal folds with numerous epithelial projection (Figure 1h) the unculi. The unculi was found parallel to each other and has a concave surface with different diameter and a raised margin.

3.2. The floor of the buccal cavity

The floor is formed from the lower jaw and the tongue. The lower jaw has flattened tip with semicircular folds (Figure 2a). There is a depression in the lower jaw for the attachment of the tongue (Figure 2a). The tip of the lower lip has several microridges (Figure 3b) The central part has several leaf like projection (Figure 2c). The central part of the floor has deep folds (Figure 2d).

The lateral left part of the floor has epithelial projection (Figure 2e) with microridges (Figure 2f). The epithelia between the folds has several microridges and numerous openings between them (Figure 2g).

Anterior lateral part of the lip has several taste buds (Figure 2h-i) with huge epithelial projection. The floor of the buccal cavity has numerous fungiform teeth with parallel longitudinal lines (Figure 2j-l).

The tongue occupies most of the oral cavity. It is not mobile and can not be extended. It is rounded apically and divided into three regions, apex, body and root. The apex bears several epithelial protrusions, flagella and taste

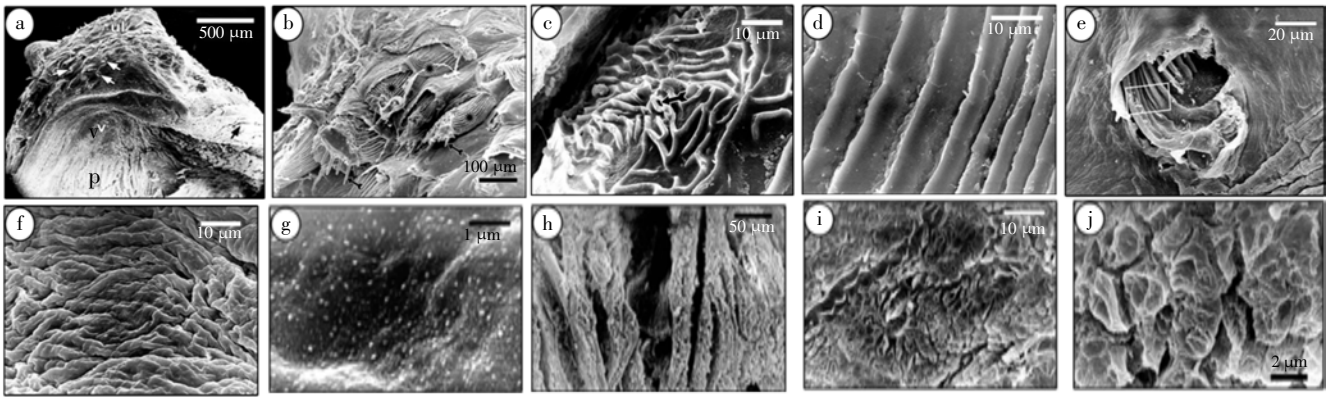

Figure 1. Roof of the buccal cavity of *S. solea*.

a: Asymmetrical upper jaw showing upper lip (ul), vomer (V) and palatinum (p); Several processes (white arrows) and semicircular ridges in the left of the jaw (black arrow). b: Part of upper jaw and lip showing wing like process (star) with teeth (black arrow). c: Center of the wing like process with branched ridges (black arrow). d: Per iphery of the wing like process with parallel ridges. e: Opening at the upper lip with several folds internally (rectangle). f: Epithelia at the velum. g: Several taste buds in the velum. h: Palatinum with longitudinal folds. i: Several processes (unculi) with a compressed internal cavities. j: Enlarged part of palatinum showing uncli with a compressed internal cavities.

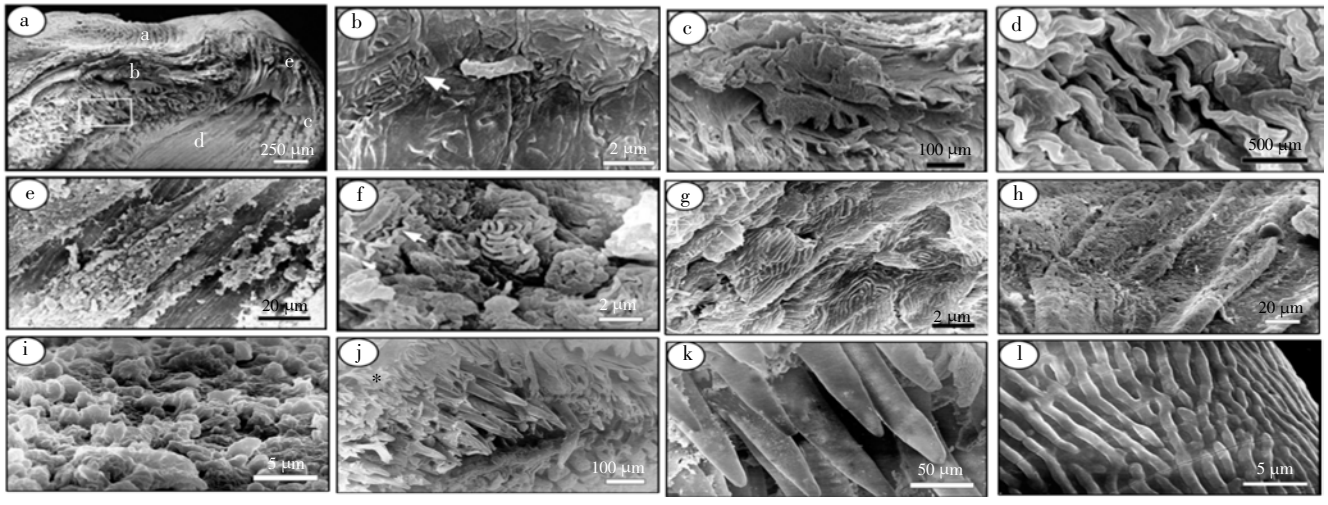

Figure 2. Floor of the buccal cavity of *S. solea*.

a: Buccal cavity differentiated into four regions (a-tip, b-central, c-lateral, d-tongue position). b: Tips characterized by several microridges (white arrow). c: Central part characterized by leaf like projections. d: Central part characterized by deep folds. e: Lateral part characterized by superficial folds. f: Enlarged lateral part of the floor showing microridges (white arrow). g: Surface epithelia between folds in the lateral part of the lip. h & i: Epithelia of the anterior lateral lip. j: Numerous fungiform teeth. k: Enlarged fungiform teeth. l: Net of calcareous plates.

buds. The body has microridges. The root was characterized by epithelial projection with presence of taste buds and absence of cilia. The transition from the apex to the body was marked by the gradual decrease of cilia and increasing of epithelial projections (Figure 3).

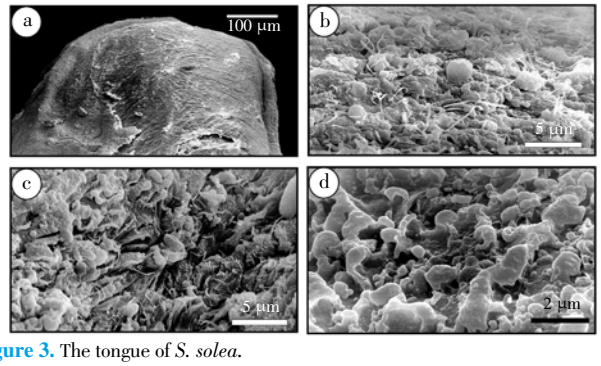

Figure 3. The tongue of *S. solea*.

a: Tongue of *S. solea*. b: Apex of the tongue. c: Body of the tongue. d: Root of the tongue.

Histological investigation of the tongue revealed that the thickness of the epithelium and the number of goblet cells increased from anterior to posterior parts (Figure 4).

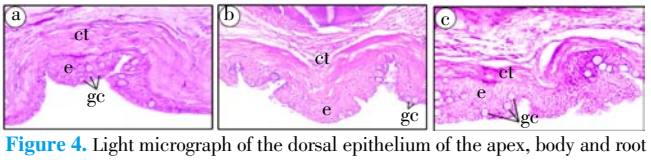

Figure 4. Light micrograph of the dorsal epithelium of the apex, body and root of the tongue of *S. solea* showing the epithelium (e) with central connective tissue (ct) and numerous goblet cells (gc).

4. Discussion

This study was the first description of the architecture of the buccal cavity of flattened fish with asymmetrical buccal cavity. *S. solea* is a sedentary species living on

muddy bottoms in the rivers and near the river mouth and also digging into sea bottoms. Mouth of *S. solea* is subterminal which facilitate finding food that lie in the sea bed. In the floor of the buccal cavity, the lower jaw has a flattened tip which adapt according to its mode of feeding and help to catch the food beneath it. Observations of the present work indicate that buccal cavity of *S. solea* are modified according to their peculiar mode of feeding.

The upper and lower jaws are edentulous but the upper and the lower roof of the bucccal cavity have teeth which of great significance in hold, grasp and tear the food. The edentulous jaws are reported in herbivorous fish[17-19].

The most important findings of our work was the presence of wing like processes in the roof of the buccal cavity of *S. solea*. Each one has central part with branched folds and a parietal portion with eleven parallel line and a number of teeth. Its central part may help in lubrication of food. The teeth at the parietal part helping in cutting and pushing the food to the entrance of the digestive tract.

The unculi appears on the lips and associated structure in the fish lacking jaw teeth. The observed unculi in the palatinum of the roof of the buccal cavity of *S. solea* is modified into unculi which may function in epithelial surface to protect against abrasion, food scrapers or anchors[20], assist firm anchorage on the substratum and prevent the fish from being swept away in fast flowing turbulent streams[21,22].

Epithelial surface of the lip of the floor in the buccal cavity has several openings of glands between microridges which play a mechanical role in protection and lubrication of the epithelial surface. The epithelial cells secretions is an adaptation to lubricate and protect the epithelia from abrasion and to inhibit the invasion and proliferation of pathogenic microorganisms[21].

The taste buds are used to guide the animal to food and act as long range distant receptors. The taste buds on lips participate in food localization and triggering a reflex with the barbles of some fish. The taste buds distribution is reflection of the feeding behaviour and the habitat in which the fish live[23].

Anatomical investigation of the tongue indicate that it consists of three parts: apex, body and root. The abundance of taste buds in the epithelial protrusion of the tongue showed that the tongue played an important role in the gustatory system. The tongue of fish is devoid of teeth completely. The presence of flagella and taste buds in the oral cavity of *S. solea* is considered as an adaptation of the oral cavity to the type of feeding. These data may help in the aquaculture of this species.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgements

This work was funded by Damietta University-Faculty of Science- Zoology Department with grant No. 541113.

Comments

Background

The buccal cavity of fish plays an important role in the seizure and selection of food and rejection of undesirable items ingested by fish. The lips of fish and their associated structures may participated in selection, capture, deglutition and predigestive preparation of food.

Research frontiers

The present work was under taken to investigate the surface architecture of the asymmetrical buccal cavity of *S. solea* in relation to its food and feeding habits which helps in aquaculture of it.

Related reports

Using SEM the buccal cavity of *S. solea* is asymmetrical and divided into roof and floor. The buccal cavity roof is formed from upper jaw, velum and the palate. The upper jaw has several wing like processes with teeth while the floor is formed from the lower jaw and the tongue. The tongue is divided into apex, body and root.

Innovations and breakthroughs

The most important findings of this work was the presence of wing like processes in the roof of the buccal cavity of *S. solea*. Each one has central part with branched folds and a parietal portion with eleven parallel line and a number of teeth. Its central part may help in lubrication of food. The teeth at the parietal part helping in cutting and pushing the food to the entrance of the digestive tract.

Applications

This study was a source to identify new and better methods of nutrition in aquaculture of *S. solea* which is

a nocturnal feeder belongs to order Pleuronectiformes (flatfishes), which are considered one of the most important predators in benthic communities.

Peer review

This is a valuable work and was the first description of the architecture of the buccal cavity of flattened fish with asymmetrical buccal cavity. The results are interesting with high quality light and SEM photographs. This work is important to those who study fish biology, fish aquaculture, vertebrates comparative anatomy, histology and scanning electron microscopy.

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