The Journal of Basic & Applied Zoology (2013) **66**, 121–130

The Egyptian German Society for Zoology

The Journal of Basic & Applied Zoology

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Scanning electron microscopic studies of gill arches and rakers in relation to feeding habits of some fresh water fishes

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Received 4 May 2013; revised 26 June 2013; accepted 23 July 2013
Available online 27 August 2013

KEYWORDS

Pharyngeal cavity;
SEM;
Gill arch;
Gill raker;
Taste bud;
Fishes

Abstract The surface ultrastructure of the gill arches and the gill rakers of the three concerned species *Oreochromis niloticus*, *Chrysichthys auratus* and *Clarias gariepinus* was investigated by scanning electron microscopy. These structures show significant adaptive modifications associated with the food and feeding habits of these fishes. Short and tuberous type gill-rakers in *O. niloticus*, are a well interesting filter of food. In *C. auratus* gill rakers were short with broad base, they serve to strain water which was to bathe the gills and prevent any solid particles from passing over it. Gill rakers in *C. gariepinus* were long, cylindrical in shape and arising at acute angles to the arch, they help to strain food and other materials, thus protect gill filaments from damage.

Prominent epithelial protuberances on the gill rakers and gill arches enable the taste buds, located at their summit, to project well above the surface of the epithelium. This could increase the efficiency of the taste buds in selective sorting of palatable food. Co-occurrence of teeth and taste buds on the epi-and hypopharyngeal bones (Types I–III) denotes that food processing and gestation occur simultaneously in the pharynx. Caniform, villiform and papilliform teeth on the epi- and hypopharyngeal bones of the three studied species respectively in *O. niloticus*, *C. auratus* and*C. gariepinus* were associated with a complex food-processing cycle. Mucous secretions, oozing through mucous cell openings, provide lubrication facilitating smooth passage of food through the pharynx.

Introduction

Oreochromis niloticus, *Chrysichthys auratus* and *Clarias gariepinus* are three of the most important fresh water fishes in the River Nile in Egypt. *O. niloticus* lives almost in inshore water and feeds mainly on periphytes and algae while *C. auratus* lives in middle water, feeds on insects, crustacean, mollusks, nematodes, fish plants and bottom deposits were of minor importance. *C. gariepinus* was completely omnivorous, feeding on fish, insect larvae, mollusks, planktonic organisms, water weeds and bottom deposits.

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Peer review under responsibility of The Egyptian German Society for Zoology.

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http://dx.doi.org/10.1016/j.jobaz.2013.07.005

Gills were the main sites of gas exchange in almost all fishes (Moyle and Cech, 1996). In addition to their respiratory function, the gills play an important role in the excretion of certain waste products and in the maintenance of the fish salt balance (Norman, 1963). The gill dimensions and organization of gill arches and rakers reflect the feeding habits of the fish (Magnuson and Heitz, 1971; Hughes, 1980, 1984; Fernandes and Rantin, 1986; Fernandes et al., 1995; Fernandes, 1996).

Among fishes, diversity of the food resources leads to the evolution of various adaptive characters in the pharynx, which plays an indispensable role in the retention, maneuvering and transport of food for swallowing. The pharynx, in teleost, was characterized by the presence of gill arches. These were located at the boundary between the pharyngeal cavity and the opercular chamber on either side of the head. The gill arches in general were equipped with gill rakers toward their pharyngeal side and were considered to play an important role in feeding. A review of literature revealed that, the surface ultrastructure of gill arches and gill rakers was derived from studies on fish species having different feeding habits that include plankton feeder *Rhinomugil corsula* (Munshi et al., 1984), and *Gadusia chapra* (Ghosh et al., 1988); filter feeder *Brevoortia tyrannus* (Friedland, 1985); ilyophagous (periphyton feeder) *Hypostomus commersonii* (Eiras-Stofella and Charvet-Almeida, 1997), *Prochilodus scorfa* (Eiras-Stofella and Charvet-Almeida, 1998), *Mugil curema*, *Mugil liza* and *Mugil platanus* (Eiras-Stofella et al., 2001); omnivorous *Fundulus heteroclitus* and (Hossler et al., 1985), *Cyprinus carpio* (Sibbing and Uribe, 1985; Sibbing, 1988), and carnivorous fishes *Anabas testudineus* (Munshi et al., 1984), *Notopterous chitala* (Ghosh et al., 1988), *Eugerres brasilianus* (Eiras-Stofella and Charvet-Almeida, 2000), and *Cathorops strigosa* (Fernandes et al., 2003). Kumari et al. (2005) described surface ultrastructure of gill arches and gill rakers in relation to the feeding ecology of a carnivorous catfish *Rita rita*. Vigliano et al. (2006) described the ultrastructural characterization of gills in Juveniles of the argentinian silverside *Odontesthes bonariensis*. Also Pichugin and Sidorov (2006) explained the number and form of gill rakers in Sakhalin trout *Parahucho perryi*. Mir and Channa (2009) used the SEM study to explain the gills of the snow Trout *Schizothorax curvifrons* Heckel. Kumari et al. (2009) described surface ultrastructure of gill arches and gill rakers in relation to feeding in a herbivorous bottom feeder fish of an Indian major carp *Cirrhinus mrigala*. Also Kumari et al. (2011) described the surface ultrastructure of the gill filaments and the secondary lamellae of the carp *C. mrigala*. The present study aimed to give more scanning electron microscopical information about the gill system of three species of fresh water fishes with different feeding habits which inhabit the River Nile; *O. niloticus*, *C. auratus* and *C. gariepinus*.

Material and methods

This study was carried out on fishes of *O. niloticus*, *C. auratus* and *C. gariepinus*. The length of fishes is 2, 7 and 5 cm, respectively. Five fishes from each species were used to demonstrate the gross morphological features. The opercular cavity was opened; the specimens were washed very carefully in physiological saline (Breipohl et al., 1973a,b) to remove the mucus on the surface and then fixed in 10% formalin, examined grossly and photographed. For scanning electron microscopy, three fishes from each species were used. Pieces of the gill arches and gill rakers were taken, fixed in 10% formalin. This procedure was followed by a second fixation in 1% osmium tetroxide (Delton, 1955) for at least 6 h, washing and dehydration in increasing concentrations of ethanol. The dehydration samples were dried with the critical point drier Tousimis Audosamdri-815. The dried material was coated by gold sputter coater (SPI-Module) and samples examined by JEOL-JSM-5500 LV reflection scanning electron microscopy. The material was stored over silica gel, so that it remained in perfect condition for many weeks.

Results

The gill system in the three species, *O. niloticus*, *C. auratus* and *C. gariepinus* had the form of a triangular mass with a caudally directed base. The gill system consisted of four pairs of gills, which were termed from lateral to medial as first (I), second (II), third (III) and fourth (IV) as shown in Figs. 1–3. In addition, *C. gariepinus* had a rudimentary fifth gill.

Each gill was semilunar in shape consisting of a gill arch that carried gill rakers on its concave aspect and gill filaments on its convex aspect. The gill arch had two extremities; rostral and caudal. The rostral extremity of each gill arch joined that of the opposite side in a transverse median bridge. The bridges of the gill arches united together forming an inter-branchial septum between the contra-lateral gills. This septum was flattened dorso-ventrally. The gills of both sides diverged caudo-laterally leaving a triangular shaped area which was bounded rostro-laterally, by the fourth pair of gills and was occupied by the floor of the pharynx. This floor was modified into two distinct structures; hypo-pharyngeal bone (an anterior post-lingual organ) and lower pharyngeal jaw (a posterior edentulous epithelium). The roof of the pharynx, opposite to the lower pharyngeal jaw, was modified into an oval-shaped structure, the epi-pharyngeal bone (the chewing pad) covering the basioccipital region of the skull. The caudal extremities of the four gill arches curved dorsally, rostrally and slightly

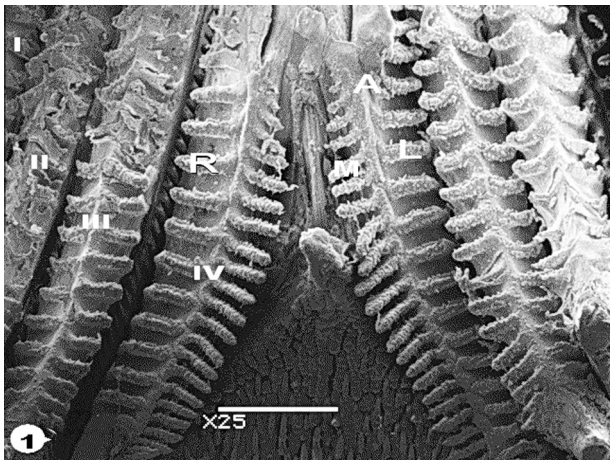

Figure 1 Scanning electron photomicrograph of *Oreochromis niloticus*; showing four gill arches (A), numbered I–IV from lateral to medial and gill rakers (R) which are arranged in two rows lateral (L) and medial (M). The gill rakers appeared short, wide-based and with tuberous end.