



Morphological differences of gill rakers in some sparid fish species (Family: Sparidae), Egypt.

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ABSTRACT

The present study aimed to describe the morphological features of gill rakers in four sparid fish species (*Sparus aurata*, *Diplodus noct*, *Rhaphidosargus haffara* and *Boops boops*); in relation to their feeding habits. Fishes were collected, by irregular visits, from different localities of Egyptian Mediterranean Sea and Suez Gulf, during the period from March, 2014 to November, 2014.

Results showed that, the first gill arch of all studied sparid fish species had bow-like shape and formed of one piece. It carried two rows of gill rakers; the anterior row of rakers at this gill arch was more developed. The gill rakers of this anterior row were longer and more in number compared to those of the posterior one.

The anterior rakers at the first gill arch were short blunt and oval shape in *S. aurata*; finger-like shape and curved to the outside surface in *D. noct*; toes like projections with blunt ends in *R. haffara*. While in *B. boops*, the anterior rakers were elongated thick strips with triangular bases and had slightly pointed ends. The anterior rakers in *S. aurata*, *D. noct* and *R. haffara* carried many spinules on their posterior surfaces. While, these anterior rakers of *B. boops* were provided with minute pointed denticles on their lateral sides.

The posterior rakers of the first gill arch were very short, rounded in shape with small spinules in *S. aurata*; short and rounded in shape with spines giving it shrub-like shape in *D. noct*; short with blunt tips with spinules arranged in two rows in *R. haffara* and short, conical in shape with round tips with needle spinules in shape and irregular distributed on the posterior side of rakers in *B. boops*.

The number of gill rakers on the anterior row of the first gill arch was different in all species. In *S. aurata* it ranged between 14 and 15; in *R. haffara*, it varied from 15 to 16; it fluctuated from 21 to 23 in *D. noct*; and from 23 to 27 in *B. boops*. The average length of anterior rakers was very short in *S. aurata*; gradually increased in *D. noct* and *R. haffara*. While in *B. boops*, these rakers were very long. The mean inter-raker spacing was wider in *R. haffara*, *S. aurata* and *D. noct*, while it was narrow in *B. boops*.

The morphological structures of the gill rakers in the oral row of the first branchial arch differed in the studied sparid fish according to the types of food. This study concluded that these gill rakes are suitable as a distinct taxonomic character.

1. INTRODUCTION

Sparidae is a very large family in the order Perciformes. It is very widely distributed in Atlantic, Indian and Pacific Oceans. They are tropical and temperate littoral or inshore waters, sometimes brackish waters; young and small species gregarious in shallow waters; adults in deeper waters.

Most species are mainly carnivorous (Bauchot & Hurau, 1986; De Bruin *et al.*, 1995 ; Khalaf-Allah, 2009).

Among fish, 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 is characterized by the presence of gill arches. These gill arches are located at the boundary between the pharyngeal cavity and the opercular chamber on either side of the head. The gill arches in general are equipped with gill rakers toward their pharyngeal side and are considered to play an important role in feeding (Zayed & Mohamed, 2004; Kumari *et al.*, 2009 ; Elsheikh, 2013).

The number of gill rakers is often used as a diagnostic character in studies on stock identification (Beacham, 1985; Claytor & MacCrimmon, 1988), species identification (Humphries, 1993) and as a character at lower taxonomic levels such as populations (Yokogawa & Seki 1995).

Little studies are available on the analyzed gill rakers and their adaptations related to feeding in species with the same feeding habit (Langeland & Nost, 1995) or related gill rakers to species identification (Almeida *et al.*, 2013). Although, the gill rakers have been assumed to serve as the filtering structures, the sites and mechanisms of food particle retention are negligible.

Therefore, the present study aimed to describe the differences between some sparid fish species (Family: Sparidae) in the morphological features of gill rakers; in addition to the number and measurements of these gill rakers.

2. MATERIAL AND METHODS

2.1 Specimens collection:

A total of 28 specimens of *Sparus aurata* (7), *Diplodus noct* (4), *Rhaphidosargus haffara* (5) and *Boops boops* (12) were collected from different localities of the Egyptian coasts in Mediterranean Sea and Suez Gulf; during the period from March to

November, 2014. Fishes were freshly examined; standard length was measured and recorded to the nearest millimetres. Gill arch length (L_A) was measured using flexible wire to take gill arch curve and record its length on the ruler in millimetres. Fish were preserved in 10% formalin solution and transported to the laboratory of Marine Biology, Zoology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt, for latter examination.

2.2 Staining of gill arch:

In the laboratory, after carefully dissection, operculum was removed, the first gill arch in the left side of the fish was cut off from the rest of the gill and immersed in 70% ethyl alcohol + 3% Alizarin red for 24 hours, then it was washed in 1% KOH for 2 hours.

2.3 Examination and measurements:

The gill arches were microscopically examined and the number of gill rakers was counted under a dissecting microscope. The digital photographic images were taken using a digital camera mounted on a dissecting microscope. From the digitalised images, the following measurements were made using the Image Pro Plus Program:

1. Gill rakers length (L_R) from tip to base of the longest and the 4 neighboring rakers (μm).
2. The breadth (T_R) at the base of the longest and the 4 neighboring rakers (μm).
3. The inter-raker space (I_R) between these gill rakers, as the distance (μm) between the edge of each gill arch and the edge of the next gill arch.

3. RESULTS

3.1 Gill arch morphology:

The gill system, in the studied fish species of Family Sparidae, was confined within two inter-connected gill chambers. The gill chambers were bounded ventrally by the mandible, dorsally by the roof of the oral and pharyngeal cavities and laterally by the operculum, while medially they appeared continuous with each other. It consisted of four pairs of gills, which were termed from

the lateral to medial as first, second, third and fourth (Fig. 1).

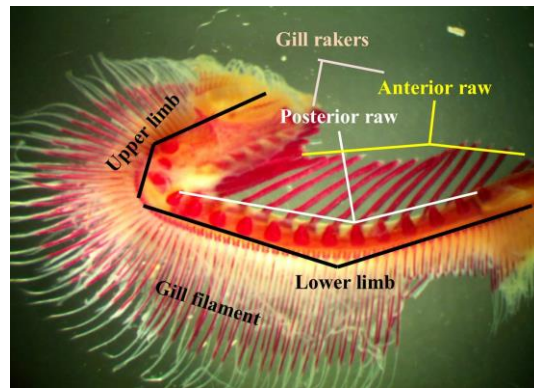


Fig. 1: A photomicrograph of the first sparid fish gill arch

Each gill arch has bow-like shape; formed of one piece. It was displayed semilunar in shape, consisting of two limbs (upper and lower limbs). The gill arch was carried gill rakers on its concave border and gill filaments on its convex border (Fig. 1).

Anterior and posterior rows of gill

rakers were noticed in gill arches of the four studied sparid fish species. The anterior row (oral row) and posterior (aboral row) of gill rakers varied in length and shape in the first gill arch; having long and more developed rakers in the first row and short and less developed in the second one (Fig. 2).

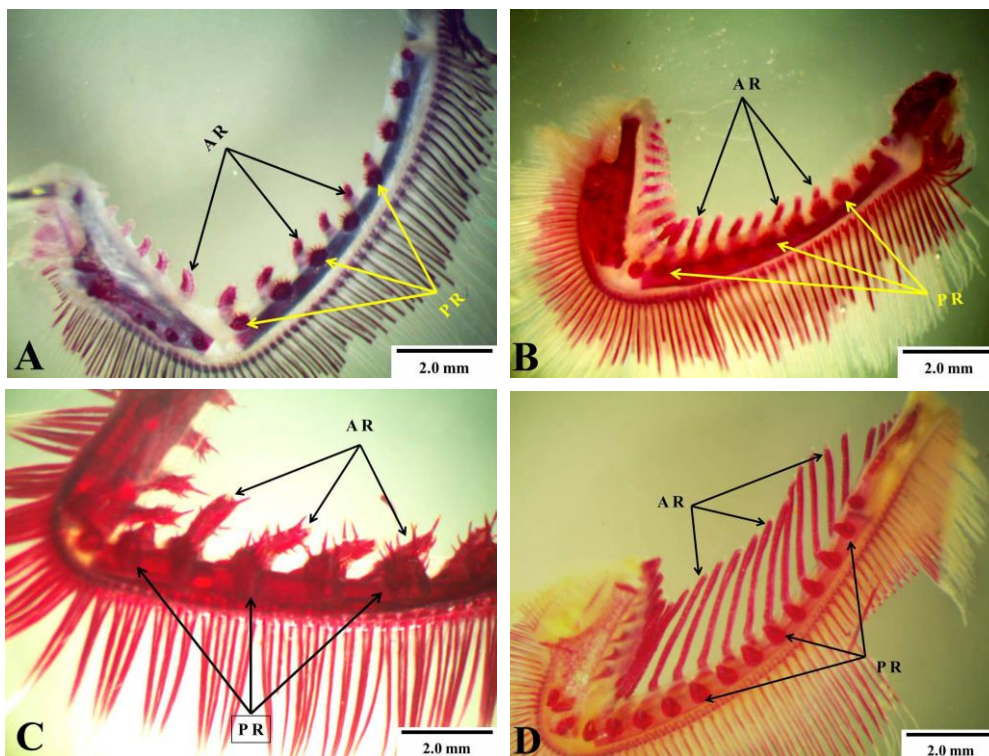


Fig. 2: Photomicrographs of the first gill arch showing the morphological structures of gill rakers in different sparid fish species. (A) *S. aurata*; (B) *D. noct*; (C) *R. haffara* and (D) *B. boops*. AR: anterior row of rakers and PR: posterior row of rakers.

3.2 Gill rakers morphology:

3.2.1 *Sparus aurata*:

In the anterior row of gill rakers- in the first gill arch of *D. noct*- two types of gill rakers are present; long rakers found at the

middle part and short rakers displayed on the upper and lower end parts of first gill arch. The medial group of gill rakers directed dorso-medially, while, the lateral groups

directed latero-medially with round tips (Fig. 2A).

The gill rakers of the anterior row are short blunt and oval in shape, with wide-bases. Many small spinules with pointed

ends were carried on median of their posterior surfaces, which directed in different directions, giving them the saw-like shape; while their lateral surfaces appeared smooth (Fig. 3).

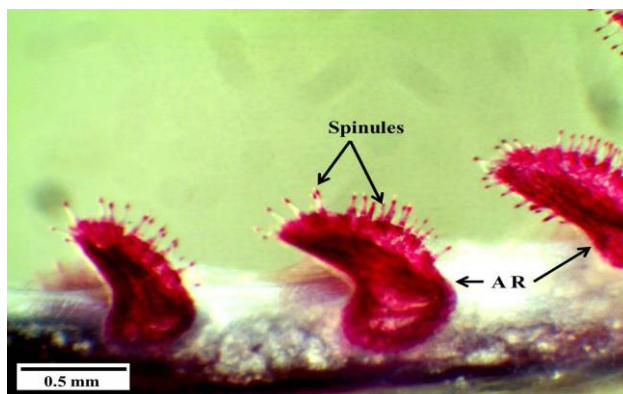


Fig. 3: Photomicrographs of the anterior row of gill rakers (AR) in the first gill arch of *S. aurata* showing morphological structure of gill rakers and spinules.

The rakers of posterior row were short and rounded in shape. Their numbers were slightly less than those on the anterior row. Many large spinules are carried on their

anterior surfaces. These spinules internally curved towards the oral row of gill rakers (Fig. 4).

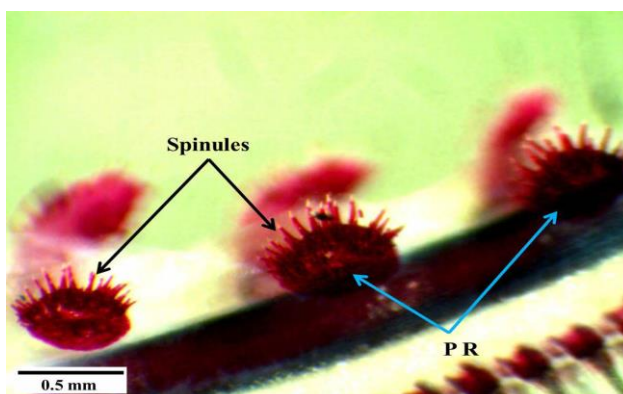


Fig. 4: Photomicrographs of the posterior row of gill rakers (PR) in the first gill arch of *S. aurata* showing morphological structure of gill rakers and spinules.

3.2.2 *Diplodus noct*:

The gill rakers of the anterior row in the first gill arch of *Diplodus noct*, have finger-like shape and curved to the outside surface with wide base. They are similar in shape and equal in size except those rakers displayed on the upper and lower end parts of first gill arch. The medial group of gill rakers is directed dorso-laterally. While, the lateral groups is directed latero-medially with round tips (Fig. 2B).

Each raker of the anterior row carried numerous spinules with tapering tips; it covered

the marginal parts of the posterior surface. These spinules are directed laterally towards the aboral row of gill rakers (Fig. 5).

The gill rakers of the posterior row are short and oval in shape, comparing to those of the anterior row. Their numbers are slightly less numerous than those on the anterior row. Many large spinules (spines) are carried on their anterior surfaces, giving it shrub-like shape. These spinules internally directed towards the oral row of gill rakers (Fig. 6).

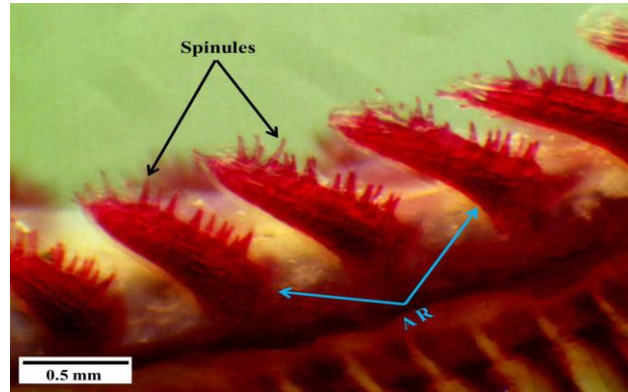


Fig. 5: Photomicrographs of the anterior raw of gill rakers (AR) in the first gill arch of *S. noct* showing morphological structure of gill rakers and spinules.

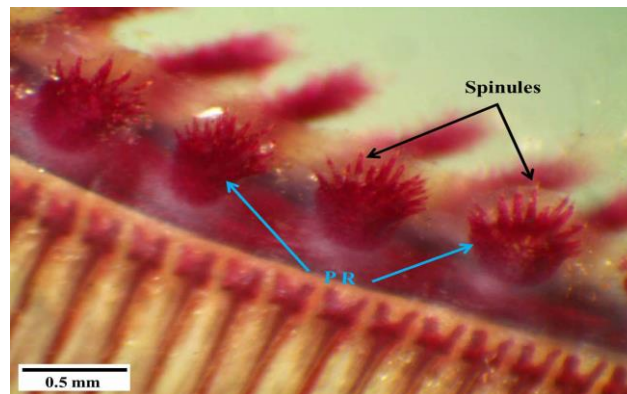


Fig. 6: Photomicrographs of the posterior raw of gill rakers (PR) in the first gill arch of *S. noct* showing morphological structure of gill rakers and spinules

3.2.3 *Rhaphdosargus haffara*:

In the anterior row of gill rakers, there are two types of gill rakers in the first gill arch of *R. haffara*; long lateral rakers with blunt tips are found at the middle part and medial short rakers with blunt or rounded tips displayed on the upper and lower end parts of the first gill arch. While, the rest of gill arch had short rakers are found on the medial and lateral sides. The medial group of gill rakers is directed dorso-laterally, while the lateral group is directed latero-medially with round tips (Fig. 2C).

The gill rakers of the anterior row, on the first gill arch, are toes-like projections, slightly bent outward with wide bases and blunt ends. Many large spinules- with curved pointed ends were carried on the marginal sides of posterior surface of the gill rakers. These spinules were short in the lower part of the raker and gradually increased in length towards the top of raker (Fig. 7).

The gill rakers of the posterior raw are less in number and shorter than those on the anterior one. They are flattened with rounded tips. These posterior rakers have relatively long spinules, which are arranged in two rows and originated from the margin of the posterior side of the rakers and directed towards the oral row of gill rakers (Fig. 8).

3.2.4 *Boops boops*:

The gill rakers of the anterior row, in the first gill arch of *B. boops* are elongated thick strips with triangular bases and slightly pointed ends. These gill rakers are almost similar, equal in size and parallel with deep crypts, except few rakers from upper and lower parts of the gill arch. The longest rakers are found at the middle of gill arch, then it decreases gradually in length towards the upper and lower ends of the gill arch.

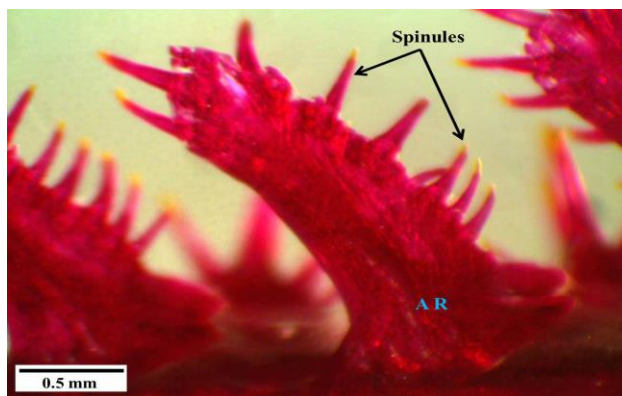


Fig. 7: Photomicrographs of the anterior row of gill rakers (AR) in the first gill arch of *R. haffara* showing morphological structure of gill rakers and spinules.

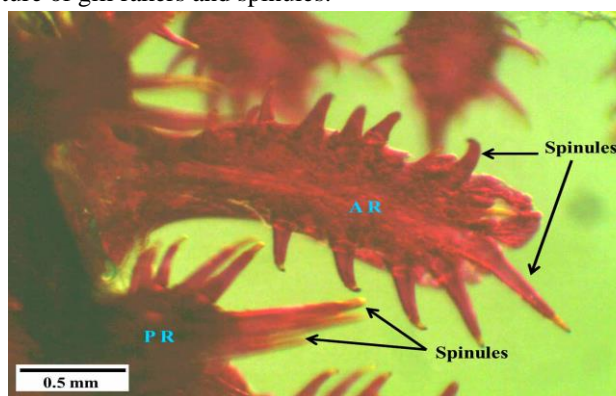


Fig. 8: Photomicrographs of the posterior row of gill rakers (PR) in the first gill arch of *R. haffara* showing morphological structure of gill rakers and spinules.

The widest channels between rakers are found at gill arch ends and the narrowest at the middle. The medial group of gill rakers is directed dorso-medially and the lateral group is directed latero-medially (Fig. 2D).

These gill rakers carried a little number of minute spinules (or denticles) with very sharp tips. These denticles distributed on lateral sides of the posterior surface of the gill rakers (Fig. 9).

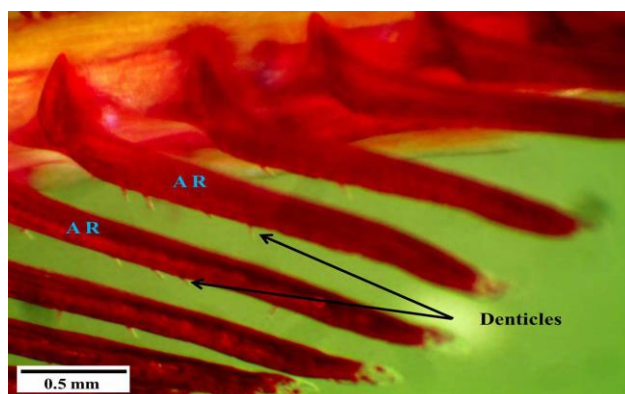


Fig. 9: Photomicrographs of the anterior row of gill rakers (AR) in the first gill arch of *B. boops* showing morphological structure of gill rakers and spinules.

The gill rakers of the posterior row are very short, comparing to those of the anterior one, with cone-like shape. Many small spinules, with curved pointed ends, are

carried on their anterior surfaces. These spinules internally are curved towards the oral row of gill rakers (Fig. 10).

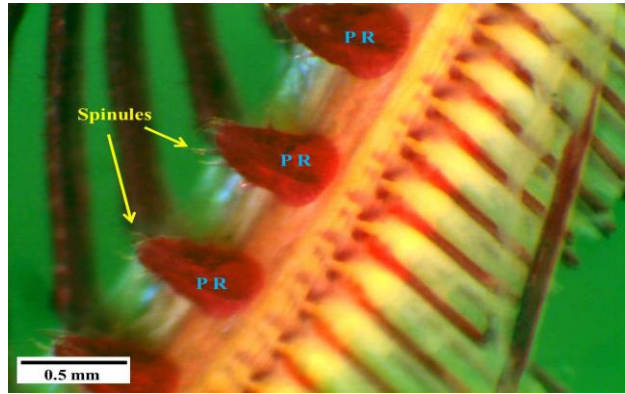


Fig. 10: Photomicrographs of the posterior raw of gill rakers (PR) in the first gill arch of *B. boops* showing morphological structure of gill rakers and spinules.

3.3. Measurements and counts of gill rakers:

3.3.1. *Sparus aurata*:

Data in Table (1) shows that, the average standard length of *S. aurata* was 11.7 ± 0.29 cm. The average length of the first gill arch was 1.8 ± 0.05 cm. The number of gill rakers is ranged from 14 to 15 rakers on the anterior row (oral row). The average length of gill rakers in the anterior row was $851.2 \pm 148.3 \mu\text{m}$. The average inter-raker

spacing was $766.7 \pm 135.2 \mu\text{m}$. The average breadth at the base of gill raker was $469.3 \pm 130.4 \mu\text{m}$. The average length of spinules on the anterior row of rakers was $196.4 \pm 26.2 \mu\text{m}$. The average length of gill rakers in the posterior row was $398.8 \pm 13.6 \mu\text{m}$ and the average gill raker length/arch length ratio was $4.9 \pm 0.48 \%$.

Table 1: Measurements and counts of gill rakers for the first gill arch in studied fish species of family Sparidae

Measurements and counts		<i>Sparus aurata</i>	<i>Diplodus noct</i>	<i>Rhaphdosargus haffara</i>	<i>Boops boops</i>
St. L (cm)	Range	11.5-12.0	9.7 - 9.8	17.0 - 17.5	12.0 - 15.0
	Mean \pm SD	11.7 ± 0.3	9.8 ± 0.05	17.2 ± 0.29	13.5 ± 1.50
L _A (cm)	Range	1.7 - 1.8	1.4 - 1.5	3.2 - 3.5	1.8 - 2.2
	Mean \pm SD	1.8 ± 0.05	1.5 ± 0.60	3.3 ± 0.13	2.0 ± 0.18
RC	Range	14 - 15	21 - 23	15 - 16	23 - 27
	Mean \pm SD	14.7 ± 0.5	21.8 ± 0.8	15.5 ± 0.6	25.0 ± 1.4
L _R (μm)	Range	579.7-1119.8	917.4-1628.1	2003.1-3078.3	3814.7-4768.7
	Mean \pm SD	851.2 ± 148.3	1178.9 ± 174.2	2477.7 ± 404.4	4175.6 ± 340.1
I _S (μm)	Range	477.5-956.8	274.6-418.6	708.1-1597.7	285.1-493.9
	Mean \pm SD	766.7 ± 135.2	348.6 ± 40.3	1143.3 ± 280.4	372.6 ± 63.9
L _B (μm)	Range	732.2-337.1	322.5-562.2	1025.3-1813.3	622.1-880.4
	Mean \pm SD	469.3 ± 130.4	416.8 ± 63.1	1368.6 ± 206.7	756.9 ± 8.3
L _S (μm)	Range	163.6-246.1	120.2-189.8	426.8-787.4	87.7-136.9
	Mean \pm SD	196.4 ± 26.2	160.6 ± 20.8	576.2 ± 123.5	113.4 ± 12.9
LP (μm)	Range	383.4-419.9	433.3-477.5	1022.9-1186.1	576.9-612.7
	Mean \pm SD	398.8 ± 13.6	442.6 ± 20.0	1127.2 ± 2.1	587.8 ± 14.5
L _R /L _A (%)	Range	4.4 - 5.2	7.6 - 8.5	7.0 - 8.2	20.1 - 21.8
	Mean \pm SD	4.9 ± 0.48	8.1 ± 0.46	7.5 ± 0.68	20.9 ± 0.85

St. L: Standard length; L_A: Gill arch length; RC: Gill rakers counts; L_R: Length of gill rakers in anterior row; I_S: Inter raker space of anterior row; L_B: Length of breadth at the base of anterior row rakers; L_S: length of spinules of anterior row rakers and L_P: Length of gill rakers in posterior row.

3.3.2. *Diplodus noct*:

Results in Table (1) reveal that, the standard length average of *Diplodus noct* was 9.8 ± 0.05 cm. The average length of the first gill arch was 1.5 ± 0.60 cm. The number

of gill rakers ranged from 21 to 23 rakers on the anterior row (oral row). The mean length of rakers was $1178.9 \pm 174.2 \mu\text{m}$. The average of inter-raker spacing was $348.6 \pm 40.3 \mu\text{m}$. The mean breadth at the base of gill

raker is $416.8 \pm 631 \mu\text{m}$. The average spinules length of anterior row of raker was $160.6 \pm 20.8 \mu\text{m}$. The average length of gill rakers in the posterior row was $442.6 \pm 20.0 \mu\text{m}$, and the average gill raker length to arch length ratio was $8.1 \pm 0.46 \%$.

3.3.3. *Rhaphdosargus haffara*:

Data in Table (1) shows that, the average standard length of *R. haffara* was 17.2 ± 0.29 . The mean length of the first gill arch was 3.3 ± 0.13 cm. The number of gill rakers on the first gill arch contained from 15 to 16 gill rakers. The average length of rakers was $2477.7 \pm 404.4 \mu\text{m}$. The average of inter-raker spacing was $1143.3 \pm 280.4 \mu\text{m}$. The average breadth at the base of gill raker was $1368.6 \pm 206.7 \mu\text{m}$. The mean spinules length of anterior row of rakers was $576.2 \pm 123.5 \mu\text{m}$. The average length of rakers in the posterior row was $1127.2 \pm 62.1 \mu\text{m}$, and the mean gill raker length to arch length ratio was $7.5 \pm 0.68 \%$.

3.3.4. *Boops boops*:

Results in Table (1) show that, the mean standard length of *B. boops* was 13.5 ± 1.50 cm. The average length of the first gill arch was 2.0 ± 0.18 cm. The counts of gill rakers on the first gill arch ranged from 23 to 27. The average length of rakers was $4175.6 \pm 340.1 \mu\text{m}$. The average of inter raker space was $372.6 \pm 63.9 \mu\text{m}$. The average breadth at the base of gill raker was $756.9 \pm 8.30 \mu\text{m}$. The average spinules length of anterior row of rakers was $113.4 \pm 12.9 \mu\text{m}$. The average length of rakers in the posterior row was $587.8 \pm 14.5 \mu\text{m}$, and the average gill raker length to arch length ratio was $20.9 \pm 0.85 \%$.

4. DISCUSSION

There are one or two rows of gill rakers on each gill arch; one faces towards the mouth (oral row) and the other points to the opposite direction (aboral row). The anterior row at the first gill arch is more developed. The main function of the gill rakers is to prevent prey from escaping through the gills (Khanna, 1962). Gill rakers

allow the solid food to go to gullet and only water is allowed to pass through gills to outside (Kumar and Tembhe, 1996).

In the present study, the gill rakers in *Sparus aurata*, *Diplodus noct*, *Rhaphdosargus haffara* were short and pointed to binding the preys to the oesophagus. These modifications are in conformity with those of the carnivorous fish described by Dasgupta (2000 & 2001); Monsefi *et al.* (2010) and Khalaf-Allah (2013).

But, the gill rakers of *Boops boops* were elongated thick slightly pointed end strips with triangular base modified to sorting of plankton. Similar observations were detected by Bond (1996). He mentioned that, the gill arches may be equipped with projections called gill rakers, which aid in food gathering. In the same manner, the gill-rakers are also specialized in relation to the food and feeding habits. They may be small and few in number in fish that consume large prey. While, the plankton feeders usually have elongated, numerous and variously lamellate or ornamented gill rakers, forming an extensive straining sieve.

The role of the gill raker apparatus is related to the prey retention efficiency, where the gill rakers function as a cross-flow filter (Sanderson *et al.* 2001; Smith and Sanderson 2008). An increasing number of gill rakers enhance cross-flow filtering and the closely spaced gill rakers also limit the escape possibilities of small prey. Accordingly, a high number of long gill rakers are common in planktivorous fish species, whereas benthic species usually display a lower number of shorter gill rakers (Robinson and Parsons, 2002; Kahilainen *et al.*, 2011).

In the present study, the gill rakers in all studied species showed a gradual decline in height toward the dorsal and ventral ends of the gill arches. The surface of gill rakers in *S. aurata*, *D. noct* and *R. haffara* were carried sharp spinules on its top and internal surface of rakers. But, it is provided with fine spinules in *B. boops* which may serve in seizing and preventing escape of smooth prey. Plankton-feeder fish are generally

characterized with numerous and elongated rakers. These rakers carry numerous, fine spinules which are varied in shape. Rakers serve in straining water current entering pharyngeal cavity for seizing food items (Abu-zinadah, 1990 & 1995 ; Salman *et al.*, 2005).

In the present study, the number of gill rakers on the anterior row of the first gill arch was varied from one species to another. The number of gill rakers on the anterior row of the first gill arch of *S. aurata* ranged between 14 - 15, *D. noct* fluctuated between 21 – 23, *R. haffara* varied from 15 – 16 and in *B. boops* ranged between 23 – 27. This character could be used as a taxonomic feature.

In the present study, in all species, the posterior rakers of the first gill arch were shorter and less in numbers compared to those on the anterior row. Similar observations were recorded by Berry & Low (1970) and Lammens *et al.* (1986) in other species, and they were related to respiratory (gaseous exchange) and osmoregulatory (ion exchange) functions (Hughes, 1984), as well as filter feeding mechanism (Gibson, 1988).

However, *S. aurata*, *D. noct* and *R. haffara* are carnivores and they belong to family Sparidae, but the results showed that their gill rakers morphology are greatly different. Thus, the present study concluded that the gill rakers morphology can be used as diagnostic character (finger print) in fish classification.

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