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TASTE BUD DISTRIBUTION PATTERN ON ORAL CAVITY IN BLACK SEA ANCHOVY (*Engraulis encrasicholus* L., 1758)

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Abstract
Taste buds are one of the most determinant structures of the general behavior of the fish, particularly the feeding behavior. By examining the distribution pattern of this sense organ in the fish body, the behavioral responses of the fish to different physical conditions might be predicted. In this aspect, the taste bud distribution pattern of the Black Sea anchovy, *Engraulis encrasicholus,* was investigated. The gills and the upper and lower jaws were observed and photographed in a scanning electron microscope. Taste buds of Black Sea anchovy are distributed only in the epithelium of the oral cavity and pharynx. Taste buds are between the gill teeth on the gill rakers' edge. Taste buds were also seen close to the teeth on the pharynx. No taste buds were found on the lips, the oral valve, and the whole-body surface. In conclusion, the Black Sea anchovy has taste buds only in the mouth and between gill teeth in the gill rakers, and no external taste buds even on the lips, as a typical characteristic of pelagic plankton feeders.

Keywords: Black Sea anchovy, *Engraulis encrasicholus,* taste bud, oral cavity

Introduction
The peripheral organ belonging to the gustatory system is the taste buds which appear to be associated with feeding. Taste buds are distributed not only within the oral cavity, pharynx, and esophagus but, depending upon the species, also on an external portion of the body, including lips, barbels, flanks, and caudal fins. (Sorensen & Caprio, 1998; Hansen et al., 2002; Kasumyan & Doving, 2003). The taste bud distribution and density vary according to fish species and dwelling location (Kasumyan & Doving, 2003). Most planktivorous fish, such as anchovies, can be classified into two functional groups: visible particulate and non–visual filter feeders

(Leong & O'Connell, 1969). Non–visual filter feeders encounter prey and consume them without bias; they tend to consume smaller and less evasive prey than visual particulate feeders in the same water mass. Visual filter feeders identify and consume prey particles of choice. Studies performed in the laboratory on the feeding behavior of *E. mordax* (Leong & O'Connell, 1969), *E. capensis* (James & Findlay, 1989), and *E. encrasicolus* (Plounevez & Champalbert, 2000) have shown two patterns of behavior which were a filter-feeding mechanism on small prey and a particulate feeding mechanism on larger prey. During the filter feeding, the anchovy gave five to six tail beats, and their mouths remained open until the last tail beat; then, the anchovy glided with their mouths closed. In the particulate feeding mechanism, the anchovy mouth remained closed during tail beats and was opened only during the glide to swallow whole prey. (Leong & O'Connell, 1969; James & Findlay, 1989). Many studies concerning the feeding behavior of anchovies have been reported (Holanov & Tash; 1978; Uotani, 1978; Leong & O'Connell; 1969; Bulgakova,1996; Plounevez & Champalbert, 1999). However, no information indicates the prominent role and significance of the taste organs in feeding behavior. The anchovy industry plays a vital role in Turkey's fisheries sector. The Black Sea region is known for its anchovy production. According to recent statistics, Turkey ranks among the top global producers of anchovies, with a significant share in the global market. For instance, in 2020, Turkey's anchovy catch reached around 171,000 tons. This shows the significant contribution of anchovy fishing to Turkey's overall fishery output (TUIK, 2022).

Thus, this study was conducted to obtain basic knowledge on the distribution of taste buds in the oral cavity and pharynx, and on the gill of Black Sea anchovy (*Engraulis encrasicholus* Linnaeus, 1758) and to describe possible roles and functions of taste buds in their behavior.

Materials and Methods

Specimens of Black Sea anchovy (*Engraulis encrasicholus* Linnaeus, 1758), 9–12 cm in total length, were obtained from a local fisherman in Sinop, Türkiye, and preserved in formalin solution. For scanning electron microscopy (SEM) observation, the fish were measured (Lt), and the gills and the upper and lower jaws from specimens were removed for study. Removed parts of specimens were fixed in 3% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) for 24 h. These SEM samples were rinsed in 0.1 M phosphate buffer (pH 7.4), postfixed in 2% osmium tetroxide for one h, dehydrated through a gradient series of ethanol, freeze-dried using t-butanol and coated with platinum. The gills and the upper and lower jaws were observed and photographed in a Hitachi S4100 scanning electron microscope. All SEM observations were executed in the Fishing Technology Laboratory, Faculty of Fisheries, Kagoshima University, Japan.

Results

Taste buds of Black Sea anchovy are distributed only in the epithelium of the oral cavity and pharynx (Figure 1), between the teeth of both the upper and the lower jaws, and on the gill rakers. No taste buds were found on the lips, the oral valve, and the whole-body surface.

The taste buds are sparsely and randomly distributed within the epithelium of the oral cavity and situated on little epidermal hillocks or papilla. The Black Sea anchovy has conical teeth on the upper and lower jaws. Scanning electron microscopy showed that taste buds occur between jaw teeth (Figure 2). The upper lip and the upper and lower wall of the oral cavity have mucous cells (Figure 3).

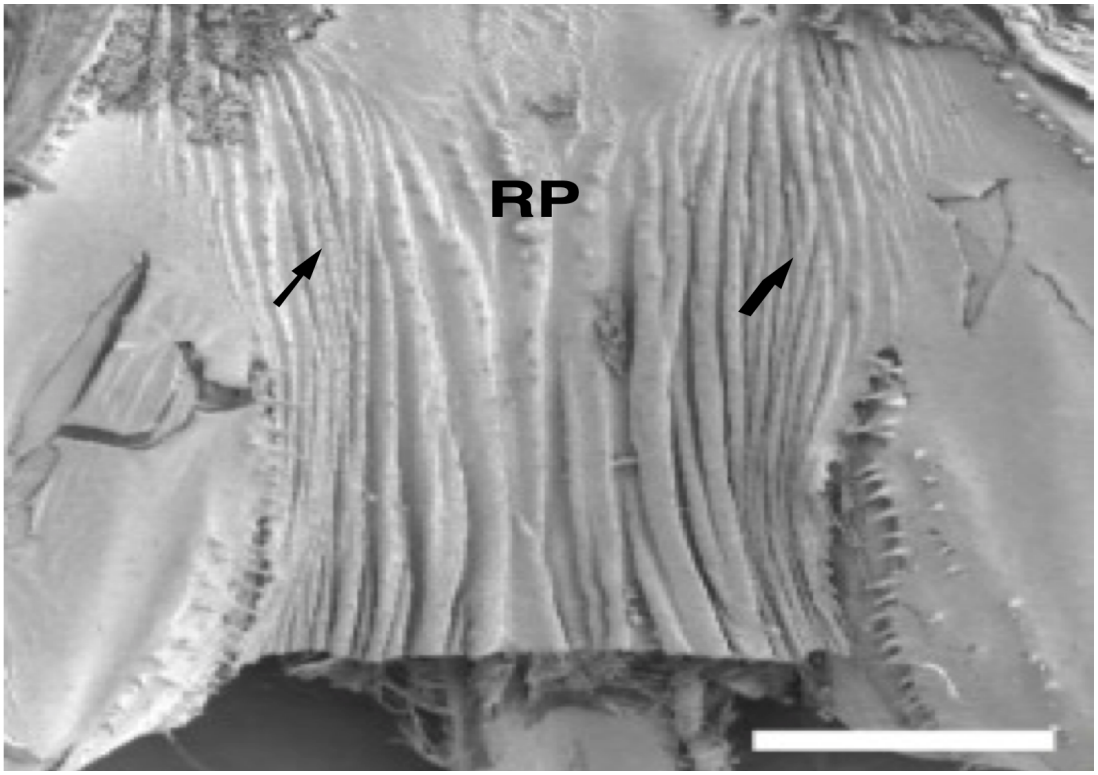

Figure 1. Scanning electron micrographs of the upper part of the oral cavity of Black Sea anchovy *Engraulis encrasicholus*. Scale bar = 750 µm. RP, palatine ridges with TB papillae; arrow, ridges with papillae on palatinum.

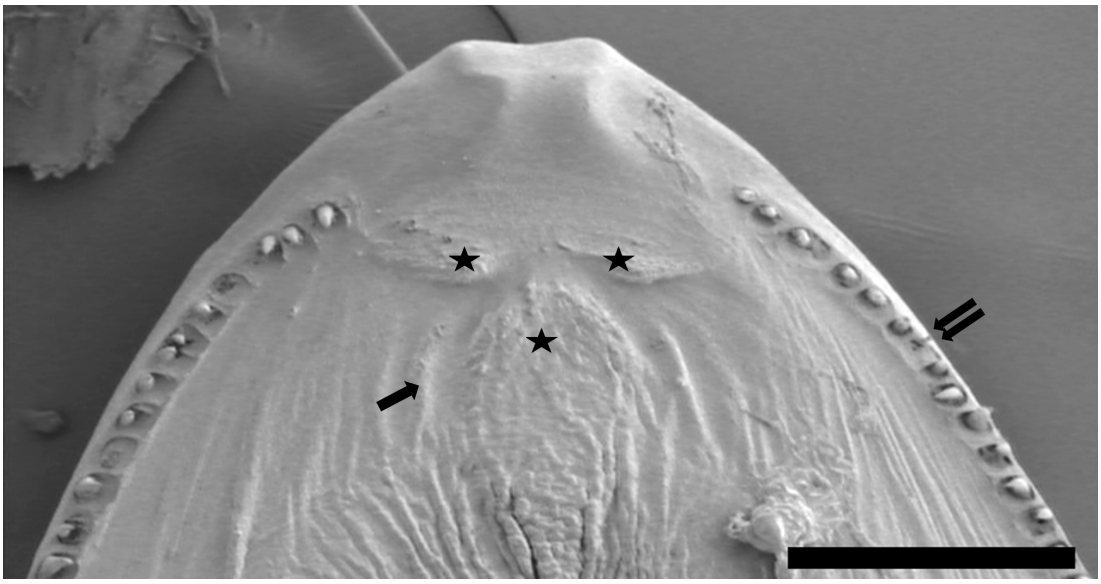

Figure 2. The lower jaw of *E. encrasicholus*. Scale bar = 375 µm. LL, Lower lip; arrow, ridged with taste buds; doubled arrow, conical teeth; asterisk, location of the taste buds of the oral cavity.

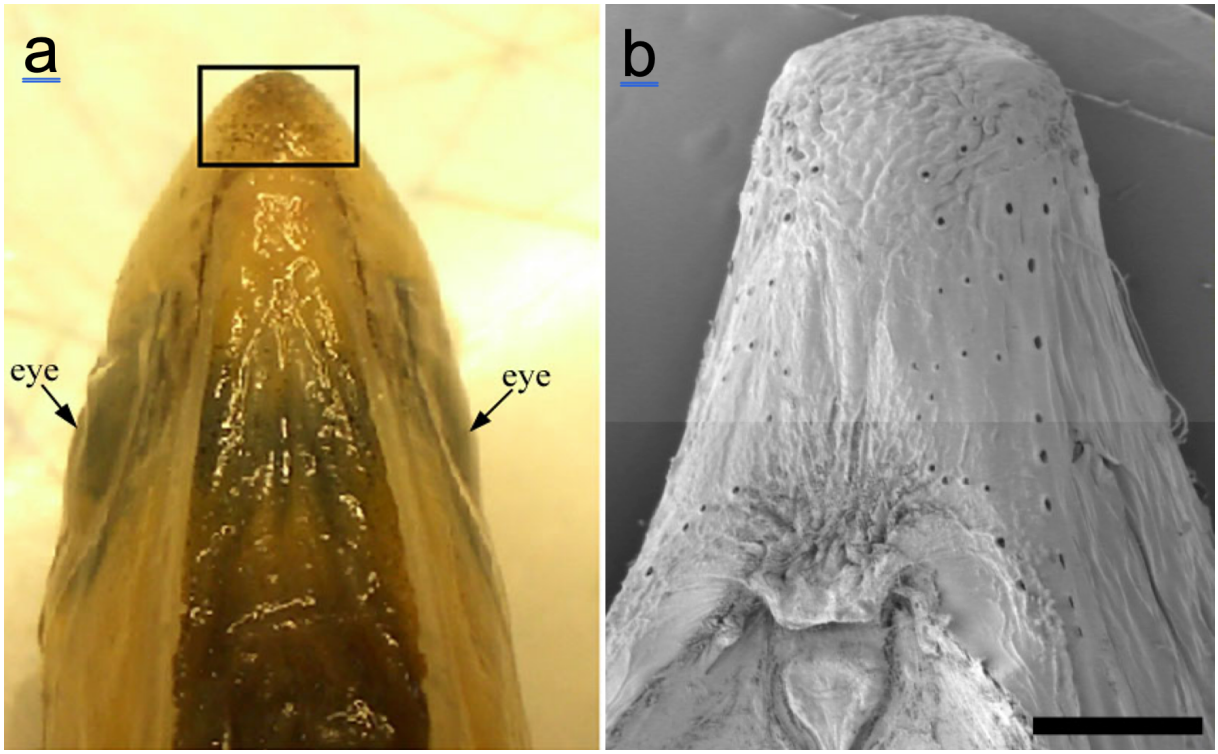

Figure 3. (a) Upper jaw picture of *E. encrasicholus.* (b) Scanning electron micrograph of mucous cell in the upper lip (rectangle area shown in (a), Scale bar = 750 µm).

The gills are bilaterally situated on either side of the pharynx and consist of gill arches with long gill rakers and two rows of gill filaments. The epithelium of the gill arches and rakers has numerous conical teeth called gill teeth. The gill rakers bear teeth on the edge, upper face, and lower face. Taste buds are between the gill teeth on the gill rakers' edge (Figure 4). Taste buds were also seen close to the teeth on the pharynx.

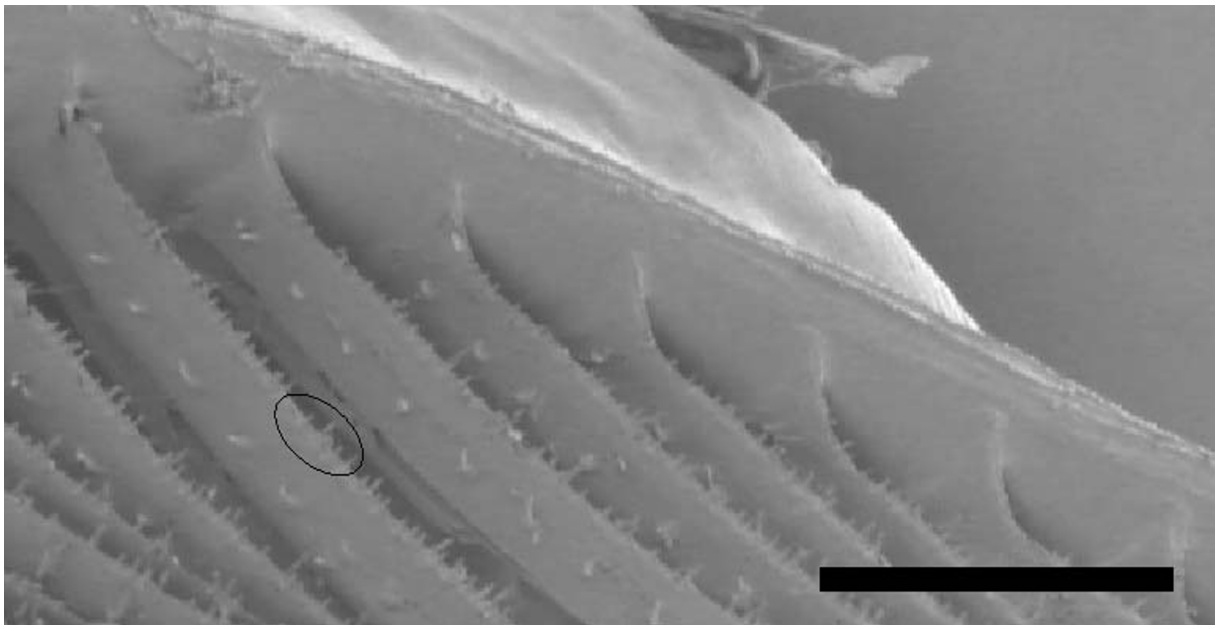

Figure 4. Scanning electron micrograph of the gill rakers. Taste buds are located in the encircled area between the gill teeth of *E. encrasicholus*. Scale bar = 500 µm.

Discussion

Taste buds in fishes are common gustatory organs described in many research articles. They are highly developed and essential for feeding, orientation, and social behavior (Boudriot & Reutter, 2001). Fish use their taste buds to sample potential food, selecting or rejecting substances according to their edibility. The distribution and density pattern of taste buds in fish change according to species (Reutter & Witt, 1993).

The distribution of the taste buds is also significantly correlated with the feeding patterns of fish species (Khanna, 1968; Kasumyan & Prokopova, 2001). External taste buds are rare or completely absent in fish that live in surface waters under good illumination and find food chiefly by vision, and their density is lower in plankton feeders than in bottom feeders (Kasumyan & Doving, 2003). Visual - planktivorous fish feed by attacking and swallowing individual prey (particulate feeding), and filter feeders strain numerous small food particles from the water with their gill rakers (Brooks, 1968). Most fish species, fresh or seawater, have well-developed taste buds in the gills, but some others do not have taste buds on the gill rakers. There is a close relationship between the morphologic specialization of the gill rakers and the feeding mechanism in fish (Iwai, 1964).

The Black Sea anchovy has taste buds only in the mouth and between gill teeth in the gill rakers and no external taste buds even on the lips, as a typical characteristic of pelagic plankton feeders. The Black Sea anchovy *Engraulis encrasicholus* swims with its mouth wide open, filtering plankton from the water and passing through the gill raker. We presumed that this species sensed the prey brought into its mouth by respiratory currents with the taste buds located there. We made no special studies to determine the senses initiating filter feeding in Black Sea anchovy, but our findings of taste buds in the gill rakers indicated that filter feeding in this species is probably induced by gustation and not by vision during the mechanical filtration of food by the gill teeth. This combination of mechanical filtration and gustation in the Black Sea anchovy seems to be much more advanced than a simple mechanical filtration as it is reported for Japanese anchovy (Uyan et al., 2006) without chemical food selection reported in the mullets *Mugil curema, Mugil liza,* and *Mugil platanus* which have a few taste buds on the anterior portion of the gill rakers (Eiras-Stofella et al., 2001).

The distribution of the taste buds in the mouth shows that they can choose to selectively feed on larger zooplankton prey by using vision for particulate feeding. Bulgakova (1993) concluded that inert items such as phytoplankton, copepod eggs, and veligers were ingested by filtration, and larger swimming prey such as adult copepods and fish larvae were caught by particulate feeding. Studies on the feeding behavior of anchovies showed that they filter-feed on small prey and grab larger prey quite often, like in other species capable of both filter and particulate feeding (Leong & O'Connell, 1969; Loukashkin, 1970; Hunter & Dorr, 1982; Uotani et al., 1978; James & Findlay, 1989; James & Probyn, 1989).

The presence of mucous cells on the upper lip may lubricate the surface and protect the epithelium from abrasions at these regions that are likely to be subjected to wear and tear during frequent friction and adhesion of the food to the mucosa (Pinky et al., 2002). Although the Black Sea anchovy is economically the most important pelagic fish species in Turkey, behavioral studies are particularly scarce. Sense organ morphology in fish is a reliable primary identifier of fish behavioral patterns. For this reason, it can be said that there is a need to increase the number of sense organ morphology studies, which have the potential to affect the behavior of anchovy directly and to investigate the effects of physicochemical environmental alterations,

which are the most crucial risk source for the Black Sea, on sense organs and therefore the behavior of anchovy.

Conclusion

The distribution of the taste buds in the mouth shows that the Black Sea anchovy, *Engraulis encrasicholus,* can selectively feed on larger zooplankton prey by using vision for particulate feeding.

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Ethical approval

The experiment was performed under the approval of the Committee on Animal Ethics, Kagoshima University, Japan.

Informed consent

Not available.

Data availability statement

The authors declare that data are available from authors upon reasonable request.

Conflicts of interest

There is no conflict of interest in publishing this study.

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Contribution of authors

The author contributed to conceptualization, data curation, formal analysis, writing the original draft, investigation, methodology, resources, validation, visualization, and finalizing the paper.

References

Boudriot, F., & Reutter, K. (2001). Ultrastructure of the taste buds in the blind cave fish *Astyanax jordani* ("*Anoptichthys*") and the sighted river fish *Astyanax mexicanus* (Teleostei, *Characidae*). *Journal of Comparative Neurology, 434*, 428–444. https://doi.org/10.1002/cne.1185

Brooks, J. L. (1968). The effects of prey size selection by lake planktivores. *System, 17*, 272-291.

Bulgakova, Y. V. (1993). Daily feeding dynamics of the Black Sea anchovy, *Engraulis encrasicholus*. *Journal of Ichthyology, 33*(7), 78-88.

Eiras-Stofella, D. R., Charvet-Almeida, P., Fanta, E., & Vianna, A. C. C. (2001). Surface ultrastructure of the gills of the mullets *Mugil curema*, *M. liza* and *M. platanus* (*Mugilidae, Pisces*). *Journal of Morphology, 247*, 22-133. https://doi.org/10.1002/1097-4687(200102)247:2<122::AID-JMOR1007>3.0.CO;2-5

Hansen, A., Reutter, K., & Zeiske, E. (2002). Taste bud development in the zebrafish, *Danio rerio*. *Developmental Dynamics, 223*(4), 483-496. https://doi.org/10.1002/dvdy.10074

Holnov, S. H., & Tash, J. C. (1978). Particulate and filter feeding in threadfin shad, *Dorosoma petenense*, at different light intensities. *Journal of Fish Biology, 13*(5), 619-625 https://doi.org/10.1111/j.1095-8649.1978.tb03475.x

Hunter, J. R., & Dorr, H. (1982). Thresholds for filter feeding in northern anchovy, *Engraulis mordax*. *California Cooperative Oceanic Fisheries, Investigations Reports, 23*, 198-204.

Iwai, T. A (1964). comparative study of the taste buds in gill rakers and gill arches of teleostean fishes. *Bulletin of the* Misaki *Marine Biological Institute, Kyoto University, 7*, 19-34.

James, A. G., & Findlay, K. P. (1989). Effect of particle size and concentration on feeding behaviour, selectivity and rates of food ingestion by the Cape anchovy *Engraulis capensis*. *Marine Ecology Progress Series, 50*, 275-294. https://www.jstor.org/stable/24827769

James, A. G. & Probyn, T. (1989). The relationship between respiration rate, swimming speed and feeding behaviour in the cape anchovy *Engraulis capensis* Gilchris. *Journal of Experimental Marine Biology and Ecology, 131*(2), 81-100. https://doi.org/10.1016/0022-0981(89)90001-4

Kasumyan A. O., & Prokopova O. M. (2001). Taste Preferences and the Dynamics of Behavioral Taste Response in the Tench *Tinca tinca* (Cyprinidae). Journal of Ichthyology, 41(8), 640–653.

Kasumyan, A. O., & Døving, K.B. (2003). Taste preferences in fishes. *Fish and Fisheries, 4*, 289-347. https://doi.org/10.1046/j.1467-2979.2003.00121.x

Khanna, S. S. (1968). The structure and distribution of the taste buds and the mucus secreting cells in the buccopharynx of some Indian teleosts (Pisces). *Studies DSB Government College, Nainital India, 5*, 143–148.

Leong, R. J. H., & O'Connell, C. P. (1969). A laboratory study of particulate and filter feeding of the northern anchovy (*Engraulis mordax*). *Journal of the Fisheries Research Board of Canada, 26*(3), 557-582.

Loukashkin, A. S. (1970). On the diet and feeding behavior of the northern anchovy, *Engraulis mordax* (Girard). *Proceedings California Academy of Science, 37*, 419–458.

Pinky, T., Mittal, S., Ojha, J., & Mittal, A. K. (2002). Scanning electron microscopic study of the structures associated with lips of an Indian hill stream fish *Garra lamta* (*Cyrinidae, Cyriniformes*). *Journal of Morphology, 40*, 161-169. https://doi.org/10.1076/ejom.40.3.161.16685

Plounevez, S., & Champalbert, G. (2000). Diet, feeding behaviour and trophic activity of the anchovy (*Engraulis encrasicolus* L.) in the Gulf of Lions (Mediterranean Sea). *Oceanologica Acta, 23*(2), 175-192. https://doi.org/10.1016/S0399-1784(00)00120-1

Reutter, K., & Witt, M. (1993). Morphology of vertebrate taste organs and their nerve supply. In S. A. Simon, & S. D. Roper (Eds.), *Mechanisms of taste transduction*. (pp. 29-82). CRC Press, Boca Raton, Florida.

Sorensen, P. W., & Caprio, J. (1998). Chemoreception. In D. H. Evans (Ed.). *The Physiology of Fishes*. (pp. 375–405). CRC Press, Boca Raton, Florida.

TUIK. (2022). *Fishery Statistic of Türkiye* (No: 37252). Turkish Statistical Institute. https://data.tuik.gov.tr/Bulten/Index?p=37252&dil=2

Uotani, I., Izuha, A., & Asai, K. (1978). Food habits and selective feeding of anchovy larvae (*Engraulis japonica*). *Bulletin of the Japanese Society of Scientific Fisheries, 44*(5), 427-434.

Uyan, S., Kawamura G., & Vazquez Archdale, M. (2006). Morphology of the sense organs of anchovy *Engraulis japonicus*. *Fisheries Science, 72*, 540–545.