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Effect of biotic and abiotic factors in feeding activity in teleost fish: A review

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Abstract
Aquaculture is the fastest growing food sector in the world, which provide food, nutrition, income and livelihoods to millions of people worldwide. Production of aquatic animals from aquaculture in 2014 amounted to 73.8 MMT, with an estimated worth of US$160.2 billion. With increasing population, the demand of the food will increase and aquaculture has the potential to meet the increasing demand. Fish feed is one of the most expensive elements needed for fish culture. Feed intake can have effects on the overall culture cost and it could result in the deterioration of water quality. This review gives insights on the biotic and abiotic factor’s effect on the feed intake of teleost fishes.

Keywords: Aquaculture, Aquafeed, feeding activity, teleost fish, biotic and abiotic factors

Introduction
Fish feed is one of the most expensive element needed for a fish culture. For the best and the most efficient use of feed, it is critical when raising fish to determine what affects the fishes' ability to feed in a specific rearing scenario. Many factors can affect the fishes' feeding activity. The importance of understanding the feeding behavior in fish and their effect is demonstrated in numerous publications (Cowey *et al*., 1985; Thorpe and Huntingford, 1992; Houlihan *et al*., 2001) [10, 24, 32, 35, 13, 21] This chapter will examine the biotic and abiotic factors that initiate or cause fish to feed and may also cause them to stay on feed. The biotic factors, including chemo-attraction, visual, electric sensory and social interactions and the abiotic factors such as light intensities, day length, water temperature and the physical properties of the feed will all be discussed.

Biotic Factors
The following sections describe biotic factors that affect feeding in fish, including chemo-attraction, vision, electrosensory and mechanoreception systems, social interactions and prey avoidance behavior.

Chemo-attraction
Chemo-attraction can be very important in initiating the feeding response and influencing the acceptability of the feed. Olfactory stimulants, as referenced by Rust (2002) [30], are highly soluble, low molecular weight compounds such as amino acids, steroids, nucleotides, and sugars. Gustatory stimulants have been identified as intact proteins, amino acids, vitamins, minerals and fish oils (Stradmeyer, 1992) [32]. The long-range chemical attraction (smell) brings the fish within range to feed. Whether the fish is a sight or a chemosensory feeder, the chemoattractant is still important for the feed to be swallowed (Adron and Mackie, 1978) [1]. In a review of feeding stimulants, Mackie and Mitchell (1985) [24] identified several compounds that positively influenced feeding in a wide range of fish species. These compounds consisted of a mixture of L-amino acids (D-amino acids were ineffective), inosine 5'-monophosphate (found in mollusks, fish, squid, and crustaceans), and betaine (trimethylglycine). In some behavioral tests done by Mearns (1986) [25], certain L-amino acids did trigger a feeding response in Atlantic salmon and brown trout first feeding fry. Hughes (1989a) [14] tested the effect of aspartic acid, phenyalalanine, and glycine on actual food intake in juvenile Atlantic salmon. The amino acids were added to the tank water as a 1% solution and not added to the feed. Hughes found that only glycine in the solution significantly affected the feed intake of

the fish. Research on striped bass by Papatryphon and Soares (2000) [27] using L-alanine (Ala), L-serine (Ser), inosine-5'-monophosphate (IMP) and betaine (Bet) as feeding stimulants showed positive results. All combinations of the stimulants exhibited increased feed intake of the control diet.

Vision

Vision can be a very important means for the fish to locate prey items. Often other faculties—electric sensing, mechanoreception, and olfaction—are used to find the prey. However, close range vision is used in several species at the final approach (Hyatt, 1979) [16]. Fish with scotopic vision, or dark-adapted eyes (twilight vision), use rod vision and fish with photopic vision use more cones. Cones can have between one and four pigments with different peak absorbance, depending on the fish species (UV 340-380 nm; violet, 380-420 nm; blue, 420-480 nm; green, 480-540 nm; yellow, 540-600 nm; and red, 600-650 nm) (Losey *et al*., 1999; Rust, 2002) [23, 30].

Electrosensory

Electrosensory systems can enable the fish to locate objects, communicate with each other and navigate. For prey location, they can give information concerning the location, size, shape, and quality of the objects in the predator's vicinity. Fish that have well-developed eyes and an electrosensory system can use the electrosensory system in situations of poor visibility (Hyatt, 1979) [16]. Ampullae of Lorenzini sac-like structures with a gelatinous filling found in the head region primarily of sharks and rays—are the electroreceptors on the elasmobranchs that help them to locate their prey (Lagler *et al*., 1977) [22]. Other fish have smaller ampullary organs such as 'small pit organs' or 'microampullae'. These smaller electroreceptors are found in freshwater fishes, rays, gymnotoids, mormyroids, catfishes, lungfishes and polypterids (Bond, 1979) [5].

Social interactions and prey avoidance behavior

Social interactions, including competition within species and predator/ prey interactions, can have a large impact on the ability of fish to feed. Brown and Laland (2002) [9] found that shoaling or schooling may be important for the fish to learn foraging techniques. Brown and Laland (2002) [9] demonstrated that fish that were pretrained with prey items could influence the naive fish to accept the novel Prey. if a hierarchy is established, the social interaction of the dominant fish will allow them to get most of the food. The stress of this situation will negatively affect— possibly permanently—the ability of the subordinate fish to obtain food, as has been observed in Coho smolts and green sunfish (Olla *et al*., 1998) [26].

Abiotic Factors

The next several sections cover abiotic factors that affect feeding in fish. The factors discussed in this section include light and day length, temperature, water quality and physical properties of the food.

Light and Day Length

Light and light level is critical for many fish to be able to feed. In both the physical feed properties and vision sections of this chapter, the importance of light for feeding has been emphasized (Ginetz and Larkin, 1973; Hyatt, 1979; Losey *et al*., 1999; Rust, 2002) [12, 16, 23, 30]. Several researchers, while determining the habitat use and peak feeding times, have examined how day length (season) and light level or intensity either increases or decreases fish feeding activity (Bachman, 1984; Sagar and Glova, 1988; Paspatis and Boujard, 1996; Erkinaro and Erkinaro, 1998; Amundsen *et al*., 2001) [3, 31, 28, 11, 2]. The results of some of these studies have been contradictory. Basically, even though the light is important in determining exactly when the fish feed, there are a number of variables—some species-specific—that also impact that behavior.

Temperature

For optimum growth and survival, fish are restricted to specific environmental conditions, in this case, temperature. Water temperature can be one of the major driving factors determining feed intake because fish are poikilotherms and their metabolic rate is determined by the environmental temperature. Sockeye salmon, for example, have a growth optimum temperature range of 15-16^0 C and feed intake is maximum at 19^0 C (Brett, 1971) [7]; rainbow trout exhibit a growth optimum at 16.5^0 C and feed intake is maximum at 19.5^0 C (Wurtsbaugh and Davis, 1977) [36]; and the goldfish's growth optimum temperature is at 28^0 C and feed intake is maximum at >28^0 C (Kestemont, 1995) [20]. Generally, the growth, feeding, upper critical and lower critical temperature ranges have been determined for adult fish or fish in an aquaculture grow-out situation. It will be important to have temperature information concerning the effects on different temperature ranges for the various life stages of the fish, i.e., embryo, fry as well as adult fish (Barton, 1996) [4].

Water Quality

Low oxygen is a serious stressor for fish and causes them to stop feeding (Kestemont and Baras, 2001) [21]. Catfish reduce their feed intake when the oxygen drops below 1 or 2 mg L-1, whereas trout may die at oxygen concentrations of 2.5 to 3.5 mg L- 1 (Boyd, 1990) [6]. Other water quality factors that could affect feed intake would be turbidity, pH, carbon dioxide, ammonia, nitrite, and hydrogen sulfide. Turbidity can be caused by plankton, humic substances or suspended clay particles. In pond fish culture, turbidity, to a point, is not necessarily a negative factor. Although visibility is restricted and feeding may be reduced, plankton blooms can limit the growth of underwater weeds, provide food organisms and provide cover for the fish. The other water quality factors, pH, carbon dioxide, ammonia, nitrite, and hydrogen sulfide, will negatively impact the fish and, as a side effect, the fish will reduce their feed intake (Barton, 1996) [4]. Needless to say, good water quality is essential for optimal feed consumption and growth.

Physical Properties of the Food

The physical properties of the food are very important to get the fish to approach, take, and ingest the food item. Various factors initially attract the fish. Some of those characteristics are color, shape, and size of the pellet. Ginetz and Larkin (1973) [12] tested several colors on a food item using rainbow trout. They used rainbow trout eggs as the food item and dyed them red, blue, black, brown, green, yellow and orange. Their feeding trials indicated that the trout had color preferences and that background color also had an effect. Jentoft *et al*. (2006) [19] found tank color could be an important factor for Eurasian perch when locating feed. Earlier, Wolf and Wales (1953) [37] had determined that rainbow trout ate red pellets more readily than the brown, uncolored ones. Jakobsen *et al*. (1987) [18] suggest that feeding Atlantic salmon a mixture of two colors of pellets increases the ability of the smaller parr to be able to discern and capture the food.

Size and shape of the feed pellets are also important to attract fish and have them ingest the feed (Stradmeyer *et al*., 1988; Stradmeyer, 1992) [33, 32]. The feed shapes tested included long and thin, long and fat and round shapes. (Stradmeyer *et al*., 1988) [33]. The long, thin pellet was preferred over the other two shapes. Irvine and Northcote (1983) [17] indicated that the prey size preference for rainbow trout fry was determined by the size of the fry. However, prey body movement was considered very important for predator selectivity. In a river setting, through most of the year, prey selection has been found to be fish size dependent and caused some diet segregation between the one- and three-year-old Atlantic salmon parr (Amundsen *et al*., 2001) [2].

Textures of feed have also been tested on fish. Stradmeyer *et al*. (1988) [33] found that soft-textured pellets were eaten twice as often as the hard ones. Poston (1974), in a comparison feeding trial, fed brown trout a low- (9.6%) or high-moisture diet (55%) and found that the fish on the moist diet consumed almost twice as much as the fish on the dry diet. Hughes (1989b) [15] determined that Atlantic salmon fed a low-moisture feed had a significantly higher weight gain and better feed efficiency than the fish fed the diets with moisture added (highest moisture was 30%).

In short, the other physical factors of feed may be such to cause the fish to approach and take the feed but if the ingredients and quality of the feed have been altered or are not fresh, fish will reject the feed, not ingest it.

Conclusion

This review has given an idea about the effect of biotic and abiotic factor’s effect on the feed intake. Biotic factors like chemo-attraction, vision, electrosensory and mechanoreception systems, social interactions and prey avoidance behavior and abiotic factors like light and day length, temperature, water quality and physical properties of the food have shown the effect on the feed intake. But there is still lack of research in this area.

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