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Role of Broodstock Nutrition and its Impacts on Fish Reproductive Output: An Overview

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ABSTRACT

A major prerequisite for the successful growth of aquaculture is the ability to properly manage sexual maturation and spawning, as well as the production of huge numbers of high-quality seeds. One of the most critical variables impacting a cultured organism's ability to reach its genetic potential for growth and reproduction is proper nutrition. Broodstock diet has long been known to affect fecundity, fertilisation rate, egg quality, embryo development and larval quality, as well as hatchery success. Optimal broodstock management strategies based on a thorough understanding of the nutritional and environmental needs of fishes bred in captivity. Many factors influence fish growth, gonad development and reproduction. Protein, lipids, minerals, vitamins and carotenoids are among these factors. Not only has improved broodstock nutrition and feeding been demonstrated to improve egg and sperm quality, but it has also been shown to improve seed yield. As a result, over the last two decades, increased emphasis has been placed on the levels of various nutrients in broodstock diets. Broodstock nutrition research, on the other hand, is scarce and relatively expensive to do.

Key words: Aquaculture, Broodstock, Nutrition, Fish seed, Nutrients.

To improve aquaculture productivity, adequate nutrition is required, which necessitates supplementary feeding in addition to the natural food present in the pond. Nutritionally balanced supplementary feed is required to meet various nutritional and energy requirements, maximise growth and reproductive efficiency, resulting in a significant increase in fish production. The nutritional composition, digestibility, physical qualities, storage, feeding methods and impact on water quality are all important elements that influence the efficiency of supplementary feed. Nutritional requirements of cultured species, local availability of various items to be utilised, including cost, nutrient composition of materials, ability of fish to utilise and digest nutrients, fish species and size are all required for supplementary feed formulation. Furthermore, because feed components account for more than 60% of total input cost, the quality and quantity of feed ingredients play an important role in the formulation of balanced supplementary feed (Nandi *et al*. 2007). As a result, adequate planning is necessary to reduce feed costs. Unpredictable and variable reproductive performance is a major limiting issue in the successful mass production of juveniles in many farmed fish species, especially those that are new to aquaculture (Izquierdo, 2001). Improved broodstock nutrition and feeding has not only been shown to improve egg and sperm quality, but it has also been shown to increase seed yield (Mazorra *et al*., 2003). Charak *et al.* (2021) studied the physical and biochemical characteristics of semen of *Tor putitora*- an endangered fish species in Himalayan water, the study will be helpful in the selection of high-quality male spawners. Whereas, Meshram *et al*. (2021) studied sexual maturity, spawning periodicity and fecundity of obtuse barracuda *Sphyraena obtusata* along Karnataka coast his study supplements the detailed information on reproductive aspects of *S. obtusata*. Certain critical dietary elements affect gonadal growth and fecundity, notably in continuous spawners with short vitellogenic periods. As a result, over the last two decades, increased emphasis has been placed on the levels of various nutrients in broodstock diets. Nutritional research on broodstocks, on the other hand, is sparse and expensive (Izquierdo, 2001). Aquaculture research is dependent on fish reproduction and breeding. The fundamental component in the breeding process is broodstock management and gonadal maturation is achieved through dietary supplementation. A well-balanced diet improves the fertility, hatching and survival of young-ones. Therefore, relevant studies has been pooled up on the effects of macro and micronutrients in the diet on broodstock reproductive performance.

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Broodstock nutrition

One of the most significant impediments to the development of aquaculture is the scarcity of seed. Many cultivated species' productivity is fully dependent on the collection of broodstock or seeds from wild population (Bromage and

Roberts 1995). As a result, full control on sexual maturity and spawning of fishes as well as their ability to generate high-quality seed, is a must for successful seed production. Egg quality, defined as the properties of the eggs that affect their ability to survive, is a serious issue for many of the currently farmed species. For example, seabream (*Sparus aurata*) having egg quality issues but elevation of dietary a -tocopherol levels and n-3 HUFA have been found to reduce the percentage of abnormal eggs and increase fecundity (Fernandez-Palacios *et al.* 1998). Although several elements have been cited as possible causal agents, including broodstock diet, genetics, ambient circumstances and stress factors like handling and spawning induction, little is still understood about the determinants of egg quality. The quality of eggs supplied determines the production of larval fish, their subsequent growth, development and health, as well as their potential productivity as future broodstock (Bromage *et al*. 1992; Bromage and Roberts 1995). Because egg quality is determined by the amount of macro and micronutrients delivered by the female fish, it is critical that broodstock diet is maximized to guarantee good larval survival and development (Izquierdo *et al*. 2001). Hence, broodstock diets should be designed to me*et al*l of the species' critical nutritional requirements.

Protein

Dietary protein consumption is another nutrient that has been demonstrated to alter the reproductive success of fish. A number of researches on grass carp, *Ctenopharyngodon idella* and common carp, *Cyprinus carpio* (Manissery *et al*. 2001; Khan *et al.* 2004) have demonstrated the importance of protein content optimization on egg and larval performance. Broodstock grass carp were fed formulated diets containing 20 per cent, 25 per cent, 30 per cent, 35 per cent and 40 per cent protein, respectively. The fish on the 30 per cent and 35 per cent protein diets gained the most weight, despite their gonadosomatic index, fertilisation and hatchability rates were similar to those on the 25 per cent protein diet (Khan *et al*. 2004). GnRH release in seabass broodstock has been demonstrated to be affected by two different diets [diet 1 (D1), high protein-low carbohydrate; diet 2 (D2), low protein-high carbohydrate] of the sea bass (Kah *et al.* 1994). Plasma levels of the gonadotropin GtH II, which is known to play a role in oocyte maturation and ovulation, were measured in European sea bass (*Dicentrarchus labrax*) (Navas *et al.* 1996). Protein is required for egg development, spawning, follicle formation, ovarian tissue production and embryo growth and development (Shim *et al.* 1989). The impact of dietary crude protein on fertility differs by fish species (Watanabe *et al.*, 1984). Dahlgren (1980) discovered that guppies fed a high-protein diet (47 per cent) had greater gonado-somatic indices than those fed lower-protein diets (31 and 15 per cent), but no change in fecundity was observed. Shim *et al.* (1989) discovered that fish on a 40% protein diet had the highest gonado-somatic index as well as significantly more oocytes in their ovaries. The impact of dietary protein on numerous tilapia reproduction characteristics has been well documented (Ganasekera *et al*. 1995; 1996; 1997; El-Sayed *et al.* 2003). Surjobala *et al.* (2021) worked on the effect of graded protein levels on the growth, survival and body composition of *Osteobrama belangeri* using semi purified diet and suggests that the optimum dietary protein level of 25% gives the best performance in terms of growth, survival, feed utilization and whole-body carcass composition of *O. belangeri*. Whereas, Prasad *et al.* (2022) studied effect of different dietary protein levels on physio-metabolic response during stunting of milkfish, *Chanos chanos* reared under pond conditions and concluded that that the dietary protein level has a significant role in producing quality milkfish fingerlings during stunting. Squid meal protein, which makes up a large part of the fat-insoluble portion, has been shown to improve egg quality (Fernandez-Palacios *et al.* 1995). Because the amino acid profiles of the meals employed in the study were relatively comparable, the better protein digestibility of gilthead seabream may have contributed to the superior nutritional value of the squid protein-based diets (Fernandez-Palacios *et al.* 1995). In fact, eggs from broodstock fed squid protein-based diets had slightly higher protein levels and generated nearly 40% more eggs/kg/ female than eggs from broodstock fed fish meal-based diets. In diets for gilthead seabream broodstock, replacing protein or lipid derived from squid meal with protein or lipid extracted from soybean meal resulted in lower hatching and 3-day-old larvae survival rates (Zohar *et al.* 2010). This could be owing to the positive effects of squid meal or the negative effects of soybean meal. Although soybean protein has been proven to be a promising protein source for partial substitution of fishmeal in gilthead seabream diets (Robaina *et al.* 1995), it has various antinutritional characteristics that limit its utilisation.

Lipid

In terms of broodstock nutrition, lipids are the most researched macronutrient. Lipids are used by most fish species to supply energy for somatic growth, but they are also a source of essential fatty acids (EFA), which are necessary for the creation of cell membranes and normal larval development (Sargent *et al.* 2002). To allow the generation of robust and healthy larvae, it is critical that the right EFA are delivered. This means that the female broodstock must consume enough energy-giving fatty acids and EFA to drive growth and deliver the critical long-chain polyunsaturated fatty acids (LC-PUFA) needed for successful larval generation. Because most farmed stocks are not dramatically divergent from wild stocks. Lipid and fatty acid content in broodstock diets have been identified as significant dietary factors that affect effective reproduction and progeny survival. Several fish species readily incorporate dietary unsaturated fatty acids into eggs, even during the spawning season. Lipids are the most abundant components in egg yolks and they play a critical role in a variety of reproductive processes including oocyte development, egg production and embryo development (Mazorra *et al*. 2003). Lipids are transferred into oocytes from maternal stores during fish maturation and reproduction, stored and deposited in yolk and then used by developing embryos (Brooks *et al.* 1997). Lipids are a crucial component of membrane structure and function, as well as the most important source of energy in the growing fish embryo (Sargent *et al.* 2002). Muscle lipid content serves as a lipid supply in the ovary, making it a helpful measure of reproductive success. The ability of these fish to build up somatic lipid stores over the rest of the reproductive cycle varies by species and evidence of a reproductive lipid (energy) constraint has been found when body lipid content is low. As a result, it's critical to maintain a steady supply of nutritional energy throughout the cycle. Although around 10% lipid is required in feed to promote protein use, excess fat will restrict intake of other critical nutrients. Many studies have found that the fatty acid profile of lipids in a broodstock diet has a direct impact on the fatty acid composition of eggs and fry (Xu *et al*. 1994; Mourente and Odriozola 1990). Fish oogenesis has been found to be harmed by essential fatty acid deficits (Watanabe *et al.* 1984; Watanabe *et al*. 1985). Warmwater fishes, in general, require polyunsaturated n-6 fatty acids or a combination of n-3 and n-6 fatty acids, whereas coldwater fishes prefer n-3 forms (Webster and Lim 2002). The physiologically active form of the n-6 family is largely arachidonic acid; the active forms of the n-3 family are EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid). In freshwater fishes, EFA requirements are normally supplied by providing the shorter-chain precursors: linolenic acid, linoleic acid, or both, while providing the "bioactive" HUFA forms produced in the diet can sometimes result in superior development performance (Kanazawa *et al.* 1980). Dietary essential fatty acid content is one of the key nutritional variables that have been discovered to have a substantial impact on fish reproductive success (Watanabe *et al.* 1984). Lipids are used by most fish species to supply energy for somatic growth, but they are also a source of essential fatty acids (EFA), which are necessary for the creation of cell membranes, required for normal larval development (Sargent *et al.* 2002). Over the course of two years, a control diet devoid of any LC-PUFA was compared to an experimental diet supplemented with 10% fishmeal and 1% fish oil in a study using the Indian main carp, *Catla catla* (Nandi *et al*. 2007). The spawning response was higher in the supplemented fish (96%) than in the control group (76%) and lipid supplementation improved egg and larvae quality, as demonstrated by increased fertilisation rate and larval survival in the supplemented group (Nandi *et al*. 2007).

To allow the generation of robust and healthy larvae, it is critical that the right EFA are delivered in excess of necessary levels. This means that the female broodstock must consume enough energy-giving fatty acids and EFA to drive growth and deliver the critical long-chain polyunsaturated fatty acids (LC-PUFA) needed for successful larval generation.

Minerals and vitamins

Minerals and vitamins that are required as enzymatic cofactors or antioxidants for seminal plasma as well as a variety of other metabolic processes are considered important micronutrients. Due to the low content of phosphorus in water, it is routinely supplemented. It aids in bone mineralization, growth and lipid and carbohydrate metabolism. As seen in rainbow trout, zinc should be an important component of broodstock diets (Takeuchi *et al.* 1981). The mineral composition of common carp gonads was dramatically changed by removing zinc from the mineral supplement in a fish meal diet, according to Satoh *et al*. (1987). Manganese levels and those of other trace elements in the gonads are affected by the manganese content of the diet (Satoh *et al.* 1987). The mineral content of common carp gonads was considerably altered by the lack of manganese in a fish meal diet. When the iron concentration of rainbow trout eggs was low, the hatching rate was poor (Hirao *et al.* 1955).

Because of their capacity to lessen the stress response in fish, vitamins E and C are termed antioxidants. Vitamins E and A, in particular, are particularly readily transported to developing eggs from dietary fat soluble vitamins (Watanabe, 1990). Vitamin C is required for a variety of metabolic processes, including collagen formation (tissue repair), cell membrane protection, metal absorption and xenobiotic detoxification. Vitamin C is also a reducing agent, both intracellularly and intercellularly. A lot of studies have shown that including appropriate vitamin C in broodstock diets improves the health of fish (Soliman *et al.* 1994; Sandnes *et al*. 1984; Eskelinen 1989). Because L-ascorbic acid's action is time-dependent and oxidation-prone, it's important to eat a varied diet. L-ascorbic- 2-phosphate, which is the most stable form of vitamin C, is used in fish feed (ascorbic acid phosphate). Salmonid reproduction has been demonstrated to be aided by ascorbic acid (Eskelinen, 1989; Blom and Dabrowski, 1995), as well as its function in steroidogenesis and vitellogenesis (Sandnes, 1991). Vitamins C and E have antioxidant properties that can protect sperm cells during spermatogenesis and until conception by lowering the danger of lipid peroxidation, which is damaging to sperm motility. The amount of ascorbic acid in the seminal fluid reflected the amount of this vitamin in the broodstock diet and it had no effect on the quality of the sperm at the start of the spawning season (Ciereszco and Dabrowski, 1995). During the later stages of the spawning phase, however, a lack of ascorbic acid lowered sperm concentration and motility. Vitamin B6 is known to play a role in the manufacture of steroid hormones and folic acid and its absence can lead to slower cell division due to defective DNA and RNA synthesis, as well as affecting egg hatchability (Halver, 1989). Vitamin E insufficiency impacts reproductive performance in higher vertebrates, resulting in underdeveloped gonads, a decreased hatching rate and lower offspring survival.

Carotenoids

As fish, like other animals, do not biosynthesize carotenoids on their own, dietary supplements are required to allow storage in tissue and integuments. Carotenoids are exclusively formed by plants, phytoplankton (microalgae), zooplankton and crustaceans, so the availability of natural or live food to manufacture these molecules has a direct impact on skin pigmentation in ponds. Astaxanthin, zeaxanthin, xanthophylls, lutein and - carotene, taraxanthin and tunaxanthin are the most prevalent carotenoids found in freshwater. It is also been suggested that the carotenoid content of broodstock diets is vital for the correct development of fish embryos and larvae. The relationship between egg carotenoid content and egg quality in salmonids has been a source of debate for more than 50 years (Tacon, 1981; Craik, 1985; Torrissen, 1990; Torrissen and Christiansen, 1995). There have been conflicting reports on the influence of carotenoid egg content on salmonid egg quality. Some researchers have found a link between egg colouring and fertilisation as well as rainbow trout egg survival rates (Harris, 1984; Craik, 1985), whereas others have not (Craik and Harvey, 1986; Torrissen and Christiansen, 1995). Age of broodstock, differences in egg carotenoid content, differences in carotenoids (astaxanthin, canthaxanthin, *etc.*) included in the diet or determined in the egg, sample size *etc.* are used by the different authors. Only a few studies have been carried out to manage the amount of dietary carotenoid in broodstock diets (Harris, 1984; Choubert and Blanc, 1993; Watanabe and Kiron, 1995). Purified astaxanthin supplementation of red seabream broodstock diets was found to significantly improve the percentage of buoyant and hatched eggs, as well as the percentage of normal larvae (Watanabe and Kiron, 1995). Inclusion of β-carotene, on the other hand, had no influence on these parameters. Miki *et al.* (1984) showed that dietary canthaxanthin or astaxanthin can be incorporated into red seabream eggs and that these carotenoids are not converted to β-carotene. Torrissen and Christiansen (1995) found that hydroxy and keto carotenoids were absorbed and deposited differently in fish. Carotenoids are one of the most significant pigment groups in fish, serving a range of activities such as protection from harmful light, as a source of provitamin A, spermatozoa chemotaxis and antioxidant properties such as singlet oxygen quenching.

CONCLUSION

The ability to correctly control sexual maturity and spawning, as well as the production of large quantities of high-quality seeds, is a crucial need for the successful growth of aquaculture.Optimal broodstock management strategies based on a thorough understanding of the nutritional and environmental needs of fish. However, such knowledge is insufficient or unavailable for many existing, emerging and new farmed fish species. As stocks with improved traits in farming conditions are selected, the amount of domestication also plays an important impact. Importantly, dependable indicators of egg quality are still lacking and many farmed fish species still rely on wild harvested broodstock. These critical issues must be addressed immediately in order to ensure the sector’s long-term viability.

Conflicts of Interest

Author doesn’t have any conflict of interest.

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