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Specific Nutrients for Improving Gonadal Development and Reproductive Performance of Fishes

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ABSTRACT

In the country, aquaculture development relies heavily on the crucial and primary aspect of fish seed availability. In fish, embryonic development relies entirely on the stored energy of the eggs post-fertilization. The transfer of essential nutrients from the female brood during egg formation is vital for successful development. Hence, good nutrition for broodstock is important because farm-level cultured fish rely almost entirely on given feed for their maturation and seed production. Essential dietary nutrients in the broodstock feed affect fish gonadal development and reproductive performance. Protein, lipids, carbohydrate and vitamins are essential nutrients when formulating broodstock diets, and their quality in broodstock nutrition affects the survival of offspring. Adequate nutrients in the diet could improve fish growth and allow broodstock to attain larger size faster and produce more offspring with better survival.

KEYWORDS

Broodstock feed, Amino acids, Fatty Acids, Vitamins, Carotenoid, Reproductive Performances, Maturation.

Introduction

Aquaculture is ambitious for higher productivity with good larval quality and improved welfare of farmed fish shortly. Improving maturation performance and larval production is vital in enhancing production efficiency. Despite significant technical developments and intense research, some bottlenecks still need to be improved in this sector. One of these is the need for more knowledge of broodstock nutrition. Nutrition plays a critical role in providing the nutrients required for reproduction. It is known to profoundly affect gonadal growth and fecundity, as well as one of the most fundamental constituents for raising healthy broodstock, helping in maturation, enhanced fecundity, and survival of larvae. However, there is no information regarding the nutritional requirement for gonadal maturation in broodstock.

Essential dietary nutrients affect fish gonadal development and reproductive performance (Lupatsch et al., 2010). Protein, lipids, and vitamins are essential nutrients when formulating broodstock diets, and their quality in broodstock nutrition affects the survival of offspring. Adequate nutrients in the diet could improve fish growth and allow broodstock to attain larger size faster and produce more offspring with better survival. Consequently, enriched brooders can produce large-size eggs with more fecundity and hatchability. The quality of eggs is the essential nutrient that contains, dependent on the female's nutrient delivery, which is necessary for the development of yok sac larvae. Therefore, Optimized broodstock nutrition ensures better larval survival and early development. Hence, formulated diet for broodstock, especially at the beginning of the gonadal development period, should provide all essential nutrients for maturation and spawning. As mentioned above, more knowledge about specific nutrients and special ingredients for improving gonadal development and reproductive performance needs to be known.

Specific nutrients

Protein and amino acids

Fish eggs are rich in protein, serving as a crucial energy source for embryonic development among teleost species. The embryo's growth primarily involves protein deposition, with proteins also playing essential roles in fertilization and embryonic development. Notably, yolk-associated proteins, exceptionally high in proline and glutamic acid and low in cystine, contribute significantly to fertilization. Mainly represented by vitellogenin, the amino acid composition of teleost yolk proteins is characterized by high alanine, glutamic acid, leucine, and low serine levels. Pelagic fish eggs show elevated levels of free amino acids, such as leucine, lysine, valine, isoleucine, alanine, and serine. For example, Rønnestad (1992), reported that gilthead sea bream eggs contain more than 43 nmoles per egg.

A balanced diet with adequate protein and amino acid composition is crucial for embryo development through the yolk. The protein level and composition in broodstock diets notably affect spawning quality. For instance, a protein level of around 45% in the diet resulted in optimum egg production in Japanese sea bream. Similarly, Sea bass fed higher protein diets (510 g/kg) showed 1.5 times more fecundity than those on lower protein diets (340 g/kg), reducing deformities (Cerdá et al., 1994). Fecundity in *Labeo rohu* broodstock increased with protein up to 30% but exceeded levels of 35-40% decreased fecundity (Khan et al., 2005). Catfish (*Mystus nemurus*) thrived with 35% protein in diets for maximum fecundity. Turbot required protein above 45%, fat over 10%, and 2% HUFA for the highest fecundity. Therefore, broodstock fish generally require between 30% and 45% dietary protein levels.

The amino acids including tryptophan and taurine are crucial for fish reproduction. Tryptophan influences gonadal maturation via serotonin, benefiting both genders. For example, Ayu (*Plecoglossus altivelis*) broodstock on diets with 0.1% added tryptophan showed increased testosterone, stimulating sperm production in males and prompting female maturation (Akiyama et al., 1996). Taurine, an abundant amino acid in fish tissues, affects antioxidants, osmoregulation, neurotransmitters, calcium, hormones, and bile salts. Yellowtail (*Seriola quinqueradiata*) broodstock diets supplemented with at least 1% taurine improved fecundity, viable eggs, and fertilization rate (Matsunari et al., 2006).

Lipid and fatty acids

Among broodstock nutrition components, lipids have garnered extensive attention. Total dietary lipid and essential fatty acid levels significantly impact fish spawning quality. Fish reproductive performance can be strongly influenced by dietary total lipids, energy, essential fatty acids, and their ratios. However, the intricate relationship among these factors complicates assessing their individual importance due to potential interactions when altering dietary lipid sources.

Total dietary lipids

Raising fat levels in broodstock diets enhances fecundity and 14-day post-hatch larval survival in rabbit fish (*Signatus guttatus*) (Hara et al., 1986). Similarly, elevated fat levels lead to larger larval size even at 28 days post-hatch in gilthead sea bream. As the lipid source in both studies included essential fatty acids, distinguishing the specific impact of increased fat, energy, or essential fatty acid content is challenging.

Essential fatty acids

Essential fatty acid (EFA) significantly impacts egg fatty acid composition, reproductive performance, and larval quality. In general, freshwater fish typically lack the necessary Δ12 and Δ15 desaturase enzymes to convert oleic acid into the n-3 or n-6 series of 18C polyunsaturated fatty acids (PUFA), including linoleic and linolenic acids, resulting in their inability to de novo synthesize of these fatty acids. Therefore, linoleic acid (LA) and linolenic acid (LNA) are the true EFAs in feeds for freshwater fish species, which are essential for maintaining average growth and survival, including maintaining standard cell membrane structure and eicosanoid metabolism. More specially, eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and arachidonic acid (ARA) are essential nutrients in broodstock nutrition. Freshwater fish can synthesize n-3 HUFA (such as DHA and EPA) from PUFA through linked elongation and desaturation reactions. However, their limited ability to convert n-3 HUFA and insufficient requirements during maturation hampered their reproductive performance. Rainbow trout fed a diet deficient in n-3 HUFA for three months before the spawning stage caused a moderate effect on egg DHA content and decreased 50% of egg EPA content (Fremont et al., 1984). Studies on gilthead sea bream indicated n-3 HUFA and other shorter-chain fatty acids level maintenance in the diet could affect the egg fatty acid composition and result in higher spawning quality. Over the past decades, only fewer studies focused on the effect of ARA on the reproduction and egg quality of broodstock when compared to EPA & DHA. ARA is a precursor of highly biologically active eicosanoids, such as prostaglandins, thromboxane, and leukotrienes; these metabolites have a crucial role in the modulation of physiological and biochemical processes, such as reproduction and immunity. Research on European sea bass showed that adequate DHA and a sufficient level of ARA concerning EPA improved egg viability, survival, and hatching.

Carbohydrates

While not essential, carbohydrates hold significant biological roles in fish, serving as a primary energy source in certain tissues. Evaluating the viability of carbohydrate inclusion in broodstock diets has engaged several researchers. For instance, it was observed lowered fecundity in rainbow trout (*Oncorhynchus mykiss*) when fed low-carbohydrate diets (Washburn et al., 1990). Conversely, increasing carbohydrate levels in cod (*Gadus morhua*) broodstock diets led to a slight reduction in spawning quality (Mangor-Jensen & Birkeland, 1993).

Vitamin E

Vitamin E functions as a potent natural antioxidant, preventing lipid peroxidation in animal cells. It enhances spawning quality across various species. However, vitamin E-deficient diets lowered fertilized egg percentage in gilthead sea bream. This decrease might be linked to reduced spermatozoid count and motility, observed in other vertebrates and fish like Ayu, *Plecoglossus altivelis*. Vitamin E needs to rely on dietary polyunsaturated fatty acid levels, which are considered essential for teleosts. Boosting n - 3 HUFA levels while keeping vitamin E constant improved spawning quality in gilthead sea bream, albeit leading to higher rates of yolk sac hypertrophy and larval deformities (Fernandez-Palacios et al., 1998). Yet, elevating both n - 3 HUFA and vitamin E prevented larval deformities. Similar interactions between DHA and vitamin E were observed in cod.

Vitamin C

Ascorbic acid holds significance in fish reproduction as well. In salmonids, vitamin C influences steroidogenesis and vitellogenesis. Broodstock diet's ascorbic acid levels impact seminal fluid concentration, with seminal vitamin C correlating to end-of-spawning-season sperm motility. Rainbow trout egg vitamin C mirrored dietary levels and is linked to enhanced egg quality. Elevating dietary vitamin C up to 1,200 mg/kg in rainbow trout broodstock improved egg-hatching rates (Ridelman, 1981). Similarly, higher dietary vitamin C increased the hatching percentage and normal larvae rate in Nile tilapia.

Vitamin A

Vitamin A, crucial for fish growth, reproduction, and embryonic development, must be diet-derived. Fish harbour vitamin A1 (retinol), vitamin A2 (di dehydroretinol), and retinal (Palace and Werner 2006). Recent findings reveal zebrafish transport ovarian vitamin A as Schiff-base-bound retinal within vitellogenin (Lubzens et al., 2010). This facilitates egg vitamin A concentration regulation, unlike vitamin E and carotenoids, which are largely transported dose-dependently by other lipoproteins.

Carotenoids

Carotenoids, orange to yellow pigments, serve various fish functions: light protection, provitamin A, and antioxidants. Astaxanthin dominates marine carotenoids. In Japanese sea bream, purified astaxanthin in broodstock diets boosted floating and hatching egg rates and normal larvae percentage. Mackerel saw increased fecundity with dietary astaxanthin, but not enhanced egg quality. Paprika-enriched diets improved striped jack's fecundity, fertilization, hatching, and larval survival. For red sea bream, β-carotene supplementation seemed ineffective in improving reproduction due to its poor intestinal absorption compared to canthaxanthin or astaxanthin. While canthaxanthin and astaxanthin integrated into red sea bream eggs, they didn't convert into β-carotene (Torrissen & Christiansen, 1995).

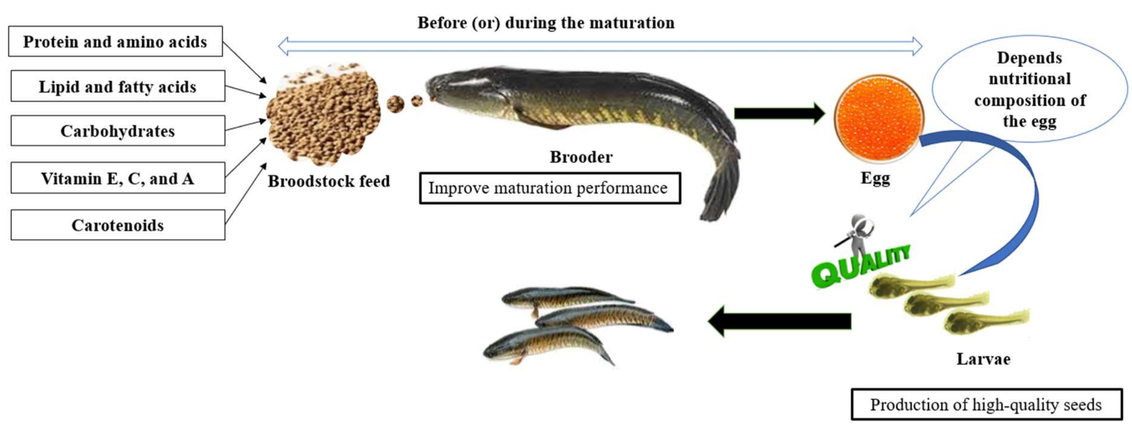

Fig.1: Specific nutrients for improving gonadal development and reproductive performance of fishes

Conclusion

In fish, embryonic development relies entirely on the stored energy of the eggs post-fertilization. The transfer of essential nutrients from the female brood during egg formation is vital for successful development. Hence, good nutrition for broodstock through the specific nutrients is important because farm-level cultured fish rely almost entirely on given feed for their maturation and seed production.

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