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Role of Carotenoids in Ornamental Fish Culture: A Review

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A B S T R A C T

One of the most frequent forms of natural pigments, carotenoids, may affect the colour of living creatures. There are around 750 different types of carotenoids. Carotenoids are found in modest amounts in most species. However, it is predicted that there are more than 100 million tonnes of carotenoids in nature. Carotenoids are responsible for the colour of ornamental fish's skin and the pigmentation of their muscles. Fish, like all other animals, are unable to de novo synthesis of carotenoids and must rely on their diet for carotenoids. Successful ornamental fish cultivation in a limited area relies heavily on properly prepared feed. The goal of this review study is to stress the relevance of carotenoids in ornamental fish keeping.

Introduction

Colour is an important component in determining the market value of ornamental fish. The sale of fading ornamental fish fails to pique the curiosity of potential consumers. The value of the ornamental fish trade is predicated on the ability to produce healthy, appealing animals in a short amount of time. In this regard, as has been demonstrated for the cultivation of food fish species, special attention should be paid to feed formulation and nutritional aspects of ornamental fish in order to reduce feed conversion ratios, increase growth performance and survival rates, and also produce attractive colourful fish, all of which will ultimately affect the economic aspects. As a result, several research studies involving nutritional needs have been done, investigating the feasibility of using herbal and microbial additions; herbal additives, in particular, are important in feed formulation.

Carotenoids are the most common major source of coloration in fish skin. This is a category of lipophilic chemicals that includes over 600 colours and is made up of C-40 based isoprenoid pigments. Carotenoids are split into two primary classes based on their chemical structure: carotenes and xanthophyll. Carotenes are hydrocarbon molecules that lack oxygen, whereas xanthophylls are oxygenated carotenoids that include at least one oxygen atom (Olson and Krinsky, 1995). The prominent members of the carotene group are β-Carotene, α-carotene, and lycopene. The essential xanthophylls, including structural components of hydroxy and keto groups, include zeaxanthin, lutein, -and-cryptoxanthin, canthaxanthin, and astaxanthin (Stahl and Sies, 2005). Plants, phytoplankton (microalgae), zooplankton, and crustaceans can manufacture carotenoids; however, other creatures cannot synthesis them and must get them from the food or alter dietary carotenoid precursors through metabolic processes (Maoka, 2011). Carotenoid pigments can be deposited directly in fish chromatophore cells or transformed by cellular metabolism and applied to the skin and other tissues in an array of colours (Chapman and Miles, 2018).

Carotenoid is an important nutrient (Craik, 1985; Grung *et al.,* 1993) that is necessary for animal development, reproduction, and disease resistance (de Carvalho and Caramujo, 2017), and should be provided in all aquatic diets. Dietary carotenoid pigments and other competing physiological traits may be passed on from mother to offspring in carotenoid-adorned animals. Increased yolk carotene accumulation boosts offspring growth and survival, improves offspring immunity, and lowers offspring oxidative stress (Blount *et al.,* 2002; McGraw and Ardia, 2003; BazyarLakeh *et al.,* 2010). A lesser concentration of carotenoids will remain in maternal fish ornaments if a large quantity of carotenoids is contributed by maternal fish to offspring growth and survival (Sefc *et al.,* 2014).

Carotenoid diversity in fish

Fishes have been shown to have species-specific carotenoids (Withers, 1992; Theis, 2012). Tunaxanthin (yellow), lutein (greenish yellow), beta carotene (orange), doradexanthins (yellow), zeaxanthin (yellow orange), canthaxanthin (orange red), astaxanthin (red), eichinenone (red), and taraxanthin (red) are some of the carotenoids found in fish (yellow) (Withers, 1992; Theis, 2012; NRC, 1993). Carotenoids are largely accumulated in the integuments and gonads of fish (Goodwin, 1951; Withers, 1992). With the exception of Salmonidae fish, where astaxanthin accumulates in muscle, astaxanthin is not found in most other fish (Goodwin, 1951; Storebakken *et al.,* 1987; Czeczuga *et al.,* 1991; Chatzifotis *et al.,* 2005). Furthermore, the integuments of catfish contain an esterified version of carotenoids (Goodwin, 1951).

Factors affecting ornamental fish colouration

The type of dietary carotenoid supplemented in the diet, pigment source, concentration, length of carotenoid feeding, other dietary ingredients present in the diet, carotenoid extraction methods, body size and weight, life cycle, genetic, metabolism of carotenoids, environmental factors, and stress all influence the coloration of ornamental fishes (Dong *et al.,* 2014; Safari and Mehraban Sang Atash, 2015; Lee *et al.,* 2017; Jayant *et al.,* 2018; Abd El-Gawad *et al.,* 2019; Heuvel *et al.,* 2019; Kong *et al.,* 2020).

Absorption and transportation of carotenoids

The absorption and distribution of carotenoids in fish is influenced by their age and physiological state, the type of feed they ingest, and their living habitat (Ando, 1986; Foss *et al.,* 1987; Czeczuga *et al.,* 1991; Wozniak, 2000). Because carotenoids are hydrophobic, they are difficult to dissolve in the watery environment of the gastrointestinal system. As a result, carotenoids are linked to lipids in order to transport them. The intestinal absorption of carotenoids involves many processes, including matrix rupture, lipid emulsion dispersion, and solubilization into mixed bile salt micelles before being absorbed in the enterocyte brush boundary. Furthermore, compared to other fish elements, carotenoids absorb significantly more slowly.

Metabolism and deposition of carotenoids

There are no common mechanisms for the metabolism of carotenoids in tissues and their subsequent conversions in fish (Chatzifotis *et al.,* 2005). The metabolism of carotenoids is considered taking place in organs such as the liver and gut, where metabolites of carotenoids occur (White *et al.,* 2002). According to research, fish may be classified depending on their ability to metabolise carotenoids (Dharmaraj *et al.,* 2011). One type of fish requires the addition of specific oxygenated derivatives to its diet because it is unable to perform ionone oxidation, whereas the other type, such as goldfish or fancy red carp, is capable of oxidation of the 4 and 4' positions of the ionone ring and thus has the potential to convert zeaxanthin and lutein to astaxanthin (Gouveia *et al.,* 2003; Dharmaraj *et al.,* 2011).

Sources of carotenoids

From primitive bacteria (Archebacteria) to highly evolved flowering plants (Angiospermae), and from unicellular creatures (protozoa) to humans, carotenoids are found in all living things. More than 750 structurally characterised carotenoids have previously been discovered in nature, including those from land plants, algae, bacteria (including cyanobacteria and photosynthetic bacteria), archaea, fungi, and mammals (Britton *et al.,* 2004). Higher plant carotenoids, algae carotenoids, crustacean carotenoids, and yeast carotenoids are the different types of carotenoids.

Higher plant carotenoids for fish colouration

Carotenoids, flavonoids, and betalains are the three primary classes of pigments that give higher plants their colour (Tanaka *et al.,* 2008). Carotenoids are a combination of α-and β-carotene, lycopene, xanthophyll, lutein, cryptoxanthin, zeaxanthin, violaxanthin, and neoxanthin found in chloroplasts of higher plants (Delgado-Vargas *et al.,* 2000), and they are most broadly distributed in photosynthetic and non-photosynthetic organs. They are biosynthesized and stored in the chloroplast of photosynthetic organs, where they play two important roles: photosynthesis and photoprotection (Young 1991; Maoka, 2020). Carotenoids are photoprotectors, antioxidants, colour attractants, and precursors of plant hormones found in non-photosynthetic organs of plants such as fruits, pericarps, seeds, roots, and flowers (Voutilainen *et al.,* 2006; Maoka, 2020). The production of carotenoids modifies the colour of fruits and seeds in plants throughout the ripening period. Flavonoids, a category of secondary metabolites belonging to the phenylpropanoids family, are divided into two groups: anthocyanins and anthoxantins, and have been found in flowers, seeds, fruits, and vegetables in a variety of colours ranging from pale yellow to red, purple, and blue (Khoo *et al.,* 2017). The nitrogen-containing chemicals betalains are generated from tyrosine and appear in flowers as vivid colours such as red, yellow, and purple (Delgado-Vargas *et al.,* 2000).

Natural carotenoids have been found in higher plants' fruits, flowers, seeds, roots, and leaves (Priyadarshani and Jansz, 2014; Das, 2016), and a number of studies have highlighted the amount of interest in using plant sources of carotenoid pigments. Other factors, such as sensory, immunity, feed conservation ratio, growth performance, social behaviour, and ornamental fish survival rate, have been researched with the combining of carotenoids from higher plants in their diets, in addition to colour improvement (Wang *et al.,* 2006; Baron *et al.,* 2008; Ezhil *et al.,* 2008; Dananjaya *et al.,* 2017).

Carotenoids: natural vs. synthetic

Carotenoids can be produced easily using low-cost chemicals and without the need for extraction in the synthesis of synthetic colours. Furthermore, synthetic pigments are routinely created to meet market demand. The impact of astaxanthin on the pigmentation of goldfish (*Carassius auratus*) was studied, and it was shown that fish fed diets containing astaxanthin at 36–37 mg/kg had a considerable increase in skin pigmentation and survival (Paripatananont *et al.,* 1999). Furthermore, the market share for synthetic carotenoids has grown, and some customers now find that purchasing the necessary pigments is more straightforward and economical. Despite the benefits of directly adding synthetic colours into diets, many customers choose to utilise natural sources over synthetic ones due to increased health awareness, additive toxicity, negative impacts of synthetic goods, restricted synthetic pigments, and market cost.

Fish colouration stability

The most pressing issue for ornamental fish keepers and aquaculturists is the maintenance of the obtained skin colour once the fish are no longer fed. In 2017, Dananjaya *et al.,* discovered that skin coloration of gold fish was unstable after 90 days of upbringing. There is a traditional approach for readily promoting skin coloration (Eslamloo *et al.,* 2015), which involves growing ornamental fish in a tank or pond with carotenoid-rich algae and allowing the fish to develop the desired skin coloration. Although this procedure is straightforward, it does not ensure colour stability and can occasionally result in water quality issues. Fish skin colour may be modified by adjusting environmental factors such as light intensity, temperature, handling stress, and nutritional requirements (Gouveia *et al.,* 2003). To completely understand the stability of fish coloration, more study is required.

There is a scarcity of research on ornamental fish diet and colour enhancement. According to the findings, carotenoids are an essential component of the commercial ornamental fish sector. Natural plant sources can be harnessed and integrated in formulated diets for colour preservation or augmentation in confined environments due to the negative effects of synthetic carotenoids on aquatic environments. It will open up opportunities for the ornamental fish sector, as well as the colour enhancer feed industry and job creation.

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