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Colour Intensity in Ornamental Fishes: The Prime Factor for Increased Marketability and Profitability

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Ornamental fish industry is an ever-growing industry contributing a hefty share to the global economy with a global trade value of US$ 18-20 billion as a significant economic activity in 125 countries. Around 2500 fish species (60% freshwater and 40% marine) are active in import and export markets. With regard to colouration of the ornamental fishes, it is the most important factor in determining the value, marketability and demand of the fish and therefore, colour manipulations are a top priority among breeders to enhance the colouration and attract buyers in the market and nevertheless, this paves way for many unethical means as well. Here, in this article we elaboratively discuss on the various methods of nutritional manipulation by utilizing several ingredients and sources, and other means which have the potential to effectively work upon this goal ethically and ultimately provide good results.

Introduction

The British, who controlled India until 1947, are credited with introducing the hobby of aquarium keeping in India. Aquarium fish-keeping is the second most popular hobby in the world, after photography. Aquarium keeping is becoming more popular among people than ever, especially in light of the COVID-19 pandemic. People are fascinated by these critters because of their exquisite colouration, which calms the eyes and draws our attention, earning them the moniker "Living Jewels." The commercial value of ornamental fish is largely determined by their appealing colouration. The great market demand and profitability of ornamental fish keeping have led to it being regarded as an industry across the globe. The trade in ornamental fish now generates millions of dollars and over 125 nations are involved in the industry at a commercial level. It was estimated that over 150 million ornamental fish, both marine and freshwater, were sold annually throughout the world, and the trade and its related aquarium accessories were worth over US$7 billion during the 1980s. Each year, more than 4000 species of freshwater ornamental fish and 1471 species of marine ornamental fish are traded internationally. One of the key elements affecting aquarium fish prices on the global market is colour. Under the harsh conditions of intensive culture, colourful fish frequently lose their colour. Like other animals, fish cannot biosynthesize carotenoids and must obtain the same from their diet. According to Kumar et al. (2017), dietary carotenoids content and pigmentation intensity are directly related. New methods to support the ornamental fish business have emerged from research on colour development and enhancement (Sawant et al., 2020). Fish diets have been modified to include several sources of carotenoid pigments, including pure carotenoid pigments, animal sources, and plant sources (Kumar et al., 2017). When light is reflected or emitted from an animal's skin surface, it gives the animal its overall colour. Ornamental fishes' vibrant colours and varied shapes and patterns make their rearing a favourite hobby. This activity has a long history and blossomed following the World War II, thanks to significant developments in civil aviation, after which ornamental fish trade and export started at a global level (Sawant et al., 2020).

Significance of colouration in fish

Fishes display a wide range of exquisite hues and colour patterns, the word "ornamental" is aptly derived from this variety of colour patterns, which also serves as the inspiration for names like "blue damsel", "yellow cichlid", "orange chromide", etc. (Sawant et al., 2020). The colouration of an ornamental fish is among the many physical characteristics that greatly influence its market value and is directly correlated with consumers' acceptance or rejection of the products (Garca-Chavarra and Lara-Flores, 2013).

Mechanism of colouration

Chromatophores are pigment-containing cells that contribute to colouration by controlling how pigments are distributed within them. Chromatophores are pigments that fish have in their dermis whose expression is controlled based on their response to different stimuli. During colour changes, the pigments in these cells are moved to or from the cell's centre. The animal can display different hues and shades, thanks to changes in the pigment's distribution.

Table 1: Chromatophore types in fish (Wucherer et al., 2012)

Chromatophores	Colour	Principle of colouration
Melanophore		Absorption
Xanthophore		Absorption/ reflection
Erythrophore		Absorption/ reflection
Cyanophore		Absorption/ reflection
Blue iridophores		Thin film interference
Silver iridophores		Refraction
White iridophores		Scattering

Biological mechanism of colour development

Step 1. Absorption: Carotenoids are hydrophobic by nature, making it challenging for them to dissolve in the watery environment of the gastrointestinal system. Lipids and carotenoids collaborate to promote transfer. Carotenoids are absorbed in the digestive tract through a number of processes, such as matrix rupture, lipid emulsion dispersion, solubilization in mixed bile salt micelles, and eventually absorption in the enterocyte brush border.

Step 2. Transport: Because carotenoids are hydrophobic, they must be linked to plasma lipoproteins in order to circulate freely in the blood (Aas et al., 1999). High density lipoproteins (HDL) transport fish carotenoids to peripheral organs primarily, while low density lipoproteins (LDL) only to a minor level (5-7%).

Step 3. Metabolism: For the metabolism of tissues' carotenoids and subsequent transformations, there are no shared routes in fish. Zeaxanthin and lutein can oxidise the 4 and 4' locations of the ionone ring, which allows them to transform into astaxanthin in goldfish or fancy red carp (Das and Biswas, 2016). Cyprinidae fish can convert zeaxanthin into (3S, 3'S)-astaxanthin via an oxidative metabolic process (Garca-Chavarra and Lara-Flores, 2013).

Step 4. Deposition: With the exception of a small number of Salmonidae species, where astaxanthin accumulates in muscle, carotenoids in fishes typically accumulate in their integuments and gonads. In Atlantic salmon, the proportion of dietary astaxanthin used for flesh colouration hardly ever goes above 15% (Torrissen et al., 1989).

Carotenoid: Structure, function, source and classification

Kuhn and Karrer first described the structure of carotenoids in 1928-1930, using a basic structure of tetraterpenoids with a carbon backbone of 40 carbon atoms. Since then, more than 750 naturally occurring carotenoids have been identified. They can be generically classified into two groups: carotenes, which consist of carbon and hydrogen, and xanthophylls, which are oxygenated derivatives of carotenes (Sawant et al., 2020). Carotenes are carotenoids made up of eight isoprenoid units in a single molecule. Hydrocarbon carotenes, are oxygen-free, pure hydrocarbons that are either linear or cyclized at one or both ends of the molecule. Oxygenated xanthophylls, on the other hand, include lutein, astaxanthin, zeaxanthin, and other pigments. The most common carotenoids present in fish include tunaxanthin (yellow), lutein (greenish-yellow), beta-carotene (orange), alpha, beta-doradexanthins (yellow), zeaxanthin (yellow-orange), canthaxanthin (orange-red), astaxanthin (red), eichinenone (red), and taraxanthin (yellow) (Manikandan et al., 2020; Swain et al., 2020). Salmonids and other fish with red pigments frequently have astaxanthin, which strangely accumulates in muscle. Although there are many marine species that contain lutein, freshwater fish are more likely to contain it. Yellowtail contains tunaxanthin, which is also frequently found in Scombridae and Carangidae family and also in the Perciformes order of fishes. The presence of tunaxanthin is what gives marine fish their vivid yellow fins and skin (Swain et al., 2020). Though fishes cannot biosynthesize carotenoids, they can change alimentary carotenoids and store them in the integument and other tissues (Sawant et al., 2020). Despite not being able to synthesize carotenoids, some fish can change one type of carotenoids into another.

Table 2: Sources of carotenoids

Plant based	Animal based	Synthetic
Phafia rhodozyma yeast Xanthophyllomyces dendrorhous, Marigold meal (Tagetes erecta), Red pepper extract (*Capsicum* sp.), Yellow corn, corn gluten meal & alfalfa	Shrimp, krill, crab, lobster, crayfish meals, shrimp oil etc.	Astaxanthin (Naturose®) Carophyll, Xanthophylls (Wisdem Golden Y20)

Factors affecting colouration

Accurately replicating fishes' natural colours in captivity is one of the ornamental fish industry's biggest challenges. And in addition to it, many factors which are mentioned below determine the colouration of the fish resulting into bright or dull colouration.

i. Fish: Genetics, sex, species, metabolism
ii. Environment: Water quality, soil quality, temperature, light
iii. Feed: Ingredients, quality, nutrition, intake (FCR)
iv. Pigment: Type, form, stability, biological activity
v. Disease agents: Bacteria, fungus, virus, parasite

Colour development and enhancement strategies

Fishes have skin colour as a result of inheritance, but they cannot synthesize certain pigments (such as, red, orange, yellow, green, and blue pigments); instead, they must attain these colours from the food they consume, as mentioned in several instances previously. There are numerous colour enhancement techniques currently in use, but very few of them have been studied. In addition to common techniques like genetic modification and dietary supplementation of carotenoids, harmful colour enhancement techniques include putting deadly colours into virtually colourless fish like the Indian glassfish (*Chanda ranga*) in order to glitz up the market through unethical means (Sawant et al., 2020). The addition of colourants to the feed, genetic engineering, and the injection of dyes into the fish's subcutaneous layers (commonly known as juicing or painting) are a few effective methods for ornamental fish colour improvement (to gain a competitive edge in the expanding market). Carotenoids-rich colourants are still the most widely utilised method of colour improvement, and they are added to fish diets largely as microalgae, plant/animal sources, and synthetic derivatives (Sawant et al., 2020).

- *Colour enhancement via nutritional manipulation*
- *Colour enhancement via genetic manipulation*
  - ❖ Transgenesis
  - ❖ Masculinization and sex manipulation
  - ❖ Intraspecific and interspecific cross-breeding
  - ❖ Selective breeding
  - *Colour enhancement via subcutaneous injection*
  - *Colour enhancement via dipping methods*

Table 3: Transgenic ornamental fishes developed so far

S. No.	Species	Target genes	References
1.	Zebrafish (*Danio rerio*)	Colour genes	Gong et al., 2003
2.	Zebrafish (*Danio rerio*)	Mylz2	Ju et al., 2003
3.	Japanese rice fish (*Oryzias latipes)*	Vitellogenin	Zeng et al., 2005
4.	Pond loach (*Misgurnus anguillicaudatus*)	GH	Nam et al., 2001
5.	Black tetra (*Gymnocorymbus ternetzi*)	Mylz2	Rasal et al., 2006

Conclusion

As we have understood about the importance and crucial role played by colouration in the industry which determines the marketability, demand and profit, therefore sustainable methods known should be applied efficiently in order to achieve the goal of colour enhancement which ultimately will have a positive impact upon the profitability. With the increasing demand of ornamental fishes and the hot market existing for carotenoids, this area paves way for entrepreneurs to explore the high possibilities of skyrocketing their business. Nevertheless, work is still needed to be carried out at various levels to ensure sustainability, formulation of cost-effective carotenoid supplements, and dissemination of technology among farmers, breeders and entrepreneurs which are crucial keystones that will make the sector stable and keep an exponential pace consistently. Apart from all these requirements, the prime factor is the prevention of genetic pollution or natural habitat alteration that may cause a drastic change in the long run if genetically modified species are introduced in the natural waters.

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