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Role of feed additives in pigmentation of ornamental fishes

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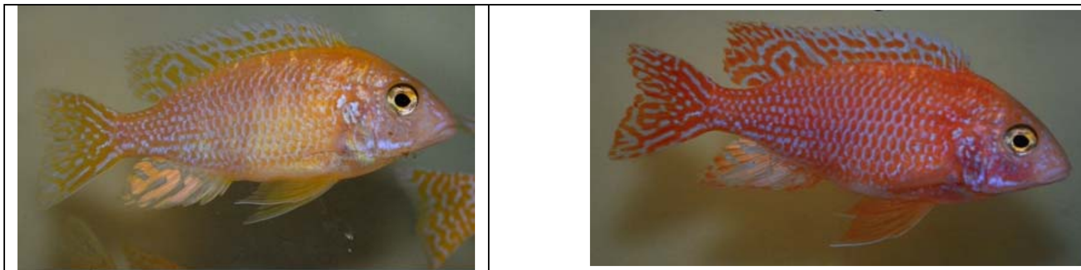
Abstract
Skin coloration is one of the most important factors which decide the aesthetic value, therefore the market value of ornamental fishes. Pigmentation in the skin is responsible for colouration in the fish. In natural environment, the fishes meet their carotenoid requirements by ingesting aquatic plants or through their food chains. But, fishes cannot synthesize carotenoid *de novo*. The enhancement of coloration can be done by administrating pigment enriched feed, it will definitely improve the quality and cost of the fish. Attractive colouration determines the commercial value of ornamental fish. This paper gives information about the pigmentation in fishes, natural sources of carotenoids and its types also. Due to the numerous applications of carotenoids in the pharmaceutical industry, there is an increasing demand for carotenoids in the international market.

Keywords: Color, enhancement, feed additives, ornamental fishes and pigmentation

1. Introduction
"Ornamental Aquaculture, a fast developing 'Aquatic Rainbow Sector' in India demands true innovations and implementation of advanced technologies to promote itself to the next level to compete in the international market [1]. Ornamental fishes are characterized by a wide diversity of colours and colour patterns and success in the ornamental fish trade is very much dependent on the vibrant colour of the fish. Color is one of the major factors, which determines the price of aquarium fish in the world market [2]. Fish are colored in nature often show faded coloration under intensive culture conditions. Fish like other animals do not synthesize carotenoid and depend on dietary carotenoid content for the coloration. Hence, a direct relationship between carotenoids and pigmentation exists in them [3].
If enhancement of coloration can be done by administrating pigment enriched feed, it will definitely improve the quality and cost of the fish because it contains the colour enhancing pigments like carotenoids, xanthophylls etc. [4]. Ornamental fishes are nowadays rapidly gaining importance because of their aesthetic value and also due to their immense commercial value in the export trade world over. Feed additives facilitate feed ingestion and consumer acceptance of the product. Carotenoids are the primary source of the pigmentation on the skin of fishes. In natural environment, the fishes meet their carotenoid requirements by ingesting aquatic plants or through their food chains. But, fishes cannot synthesize carotenoid *de novo*. Carotenoids are responsible for many of the red, orange and yellow hues of plant legumes, fruits and flowers. The colour enhancing diets should contain additional natural pigments to enhance the colours of ornamental fishes [5].

2. Fish pigments
Fish 'skin' has chromatophores, a type of cell that contains color pigments. These pigments utilize carotenoids to bring forth shades of yellow (Xanthophylls), red and orange (Carotenoids), and brown and black (Melanin). Genetics dictate where these colors are, while the diet impacts the actual pigment. Xanthophylls and carotenoids are the most important classes of pigments for fish and crustaceans.
Yellow and Red shades are the two colors most effectively influenced by color enhancing foods, which utilize the chromatophores. However, protein and foods such as seaweed are effective with the chromatophores to produce brilliant blues, purples and greens in fish. Combine that with the possibilities opened by layering and you have a virtual rainbow of fish shades.

The main chromatophores found in fish influence coloration as follows:
Xanthophores: Yellow
Erythrophores: Red
Melanophores: Black / Brown
Leucophores / Iridophores: Reflective crystals [6].



Color of fish before any feed additive | Color of fish after incorporating color enhancing feed additives in fish diet

Fig 1: Color ehancement after incorposration of color enhancing feed additives in fish diet

3. Determination of fish coloration

Fish coloration can be determined by three factors:

- Genetics—whether the fish has inherited the necessary genetic material to show certain colors.
- Nervous system and glandular factors— coloration depends on a fish's mood and general health. All things being equal, a sick fish is probably less colorful than a healthy one. Males also may develop develop strong colors to attract females, and how the color of subordinate males lessens in the presence of dominant males.
- Dietary factors—nutrients and chemical compounds that the fish eats which directly or indirectly influence color [7].

4. Carotenoids and its types

Carotenoids are tetraterpenoid organic pigments that are naturally occurring in the chloroplasts and chromoplasts of plants and some other photosynthetic organisms like algae, some bacteria, and some types of fungus**.** Carotenoids are a diverse family of organic compounds that act as immuno stimulant and antioxidant [8]. Carotenoids also provide. The basis for a wide range of animal pigmentation. Carotenoids are absorbed in animal diets, sometimes transformed into other carotenoids, and incorporated into various tissues. Dietary carotenoids play significant part in the regulation of skin and muscle color in fish. Carotenoids are compounds produced by plants, algae, and certain fungi [9]. Generally, they're produced to help collect light, most often for photosynthesis, the chemical process by which plants generate their own food. Canthaxanthin and Astaxanthin add colour to the flesh and eggs. Carotenoids can be subdivided into:

a. Carotenes (oxygen-free carotenoids) such as lycopenes (in tomatoes) and α, β and γ carotenes (in carrots). Carotenes have a yellowish color but do not color the fish.

b. Xanthophylls or oxy-carotenoids (oxygen-containing carotenoids, xanthophylls means yellow leaves). These compounds have in contrast to carotenes one or more oxygen atoms. These compounds can color the fish, either the fillet or the skin and can also color egg yolks [10].

5. Carotenoids in fishes

Fishes contain various kinds of carotenoids, most dominant of them with their colors are tunaxanthin (yellow), lutein (greenish-yellow), beta-carotene (orange), alpha, beta-doradexanthins (yellow), zeaxanthin (yellow-orange), canthaxanthin (orange-red), asthaxanthin (red), eichinenone (red) and taraxanthin (yellow). Among these, dominant carotenoid is astaxanthin, which is common in red fishes [11]. Carotenoids range from red, to orange to yellow. Most commercial color formulas contain astaxanthin, a red carotenoid that can bring out red color.

5.1 Reds

Food containing astaxanthin really brings out the reds in white cloud mountain minnows, *Fundulopanchax scheeli*, *Gymnogeophagus rhabdotus*, and in the fins of clown loaches. Another source is ground, dried shrimp or krill.

5.2 Orange

Paprika, is made from a ground, dried pepper, *Capsicum annuum*. Paprika is rich in a number of carotenoids, including beta carotene, capsanthin and capsorubin. Ground marigold petals also a good source of orange carotenoids.

5.3 Yellow

Zeaxanthin and lutein are perhaps the most well-known yellow carotenoids. They're present in the yellow vegetables like corn (maize) and probably in the yellow variety of snap beans and the yellow form of bell peppers. They're also found in egg yolk.

5.4 Blue

The non-carotenoid pigment, phycocyanin, brings out the blue color in fish. Phycocyanin is produced by blue green algae, which are contained in spirulina preparations [12].

Normally these are obtained through carotenoid-containing organisms in the aquatic food chain, but commercial feed ingredients such as yellow corn, corn gluten meal, and alfalfa are used as sources of carotenoids such as zeaxanthin and lutein [13]. Other carotenoid-rich ingredients used are marigold meal (lutein), red pepper (Capsicum sp.) extract (capsanthin) and krill or crustacean meals (astaxanthin) [14]. Canthaxanthin has been shown to be an effective pigmenter for the tropical fish *Trichogusfer leeri* [15], and especially to enhance reproductive processes.

6. Classification of ornamental fishes based on the capacity to convert carotenoids

Fishes cannot synthesize carotenoids *de novo*, certain fishes have the capacity to convert one form of carotenoid to another form. On the basis of this capacity, fishes are classified as-

(i) Red carp type- in this group lutein is converted into astaxanthin molecules.

(ii) Sea bream type- in this group lutein and carotene remain in the tissues and cannot be transferred in any other form inside the bodies.
(iii) Prawn type- the beta-carotene molecule can be converted into astaxanthin molecule [11].

7. Carotenoids in aquaculture
Recent review papers on carotenoids and salmonids, with special emphasis on astaxanthin and canthaxanthin, have concerned relevant subjects such as use of Antarctic krill as a feed and carotenoid source [16], carotenoid deposition and metabolism [17], biological activities of carotenoids **[18]**, microbial sources of astaxanthin [19], pigmentation of rainbow trout [20] and factors affecting variations in salmonid pigmentation [21].

7.1 Sources of carotenoids
A variety of carotenoids, both synthetic and naturally occurring products, are available or are
being developed for use in aquaculture. Included are synthetically produced astaxanthin (3,3'-dihydroxy-P, P-carotene-4,4'-dione) and canthaxanthin **(p,** p-carotene-4,4'-dione) and natural materials such as krill, Spirulina, crustacean-meals, marigold, Capsicum, and other xanthophyll-containing vegetable meals. Added to this list are commercially available products of the astaxanthin-rich yeast *P h f i* rhodozyma [19, 22]. Another microbial source being considered is the microalga *Haemafococcus pluvialis* [19].

8. Conclusion
In view of the deteriorating effects on the environment due to use of synthetic pigments, the researchers are emphasizing the need for natural pigment colouring agents which will act as an alternative to synthetic chemicals. As the aqua feed industry seeks a natural, environment friendly source of pigment to improve coloration and to enhance commercial acceptability, there is a great potential for use of natural plant based carotenoids for pigmentation in aquaculture. It paves the way to many aqua feed industries to promote their products as natural with a distinct shift away from synthetic ingredients and colorants.

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