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Effects of carotenoids on pigmentation in fish species: a biochemical approach for economic growth

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ABSTRACT

Pigmentation is one of the most common phenomena found among the fishes. The enormous range of colours and patterns that produced in them are generally related to their habits and habitats which affects the distribution of pigment cells in a large extent. Pigmentation is one of the major quality attributes of the aquarium fish for market acceptability. Among other chomatophores, carotenoids are responsible for pigmentation of muscle in food fish and skin color. In this review, an attempt has been made to highlight the importance of carotenoids in pigmentation and economic growth.

INTRODUCTION

Generally fishes are darker on the dorsal and lighter on lateral sides or ventral side. This mechanism is termed as countershading. However, some fishes have uniform colouration (Saxena 1994) as found in the gold fish (*Carassius auratus*) which has uniform colour all over the body. The general coloration and particularly the characteristic markings are in the form of bars, stripes, spots and blotches (Price et al. 2008). The color of fish skin is primarily dependent on chromatophores; that contain pigments such as melanins, carotenoids, pteridines, and purines (Das and Biswas 2016). A chromatophore is a branched cell with finger like projections, within which the colour pigment can be moved.They are mostly present in the dermis, just beneath the epidermis or scales,also found the brain and spinal cord (Price et al. 2008). As fish has inability to synthesize carotenoids, it has been introduced in the diet; either by applying them to foods directly, or by supplying them indirectly in the animals those are used for food (Gunter et al. 2011; Das and Biswas 2016).

Diversity of carotenoids in fish

Carotenoids are polymers of isopentenyl diphosphate with 40 carbon atoms. They derive chemically from a basic structure formed by the linear sequence of 8 isoprenic units, associated in two groups of four units head to tail. The diverse carotenoids commonly occurring in fishes with their colours (Das and Biswas 2016). Details are listed in Table 1. Among them, dominant carotenoid is astaxanthin,which is common in red fishes (Yimaz et al. 2013). The pink coloration of salmon flesh is mainly due to astaxanthin. Lutein pigment is common to freshwater fishes, but also, widely found in many marine species (Hata and Hata 1975). Tunaxanthin is common in scombrina, carangina and percina fishes, but abundant in yellow-coloured fishes, like yellow tail (*Seriola quinqueradiata*). Some carotenoids are specific to certain groups of fishes. Fish usually contain various carotenoids in smaller amounts, the proportion of which often differs between samples possibly due to their physiological and dietary conditions (Gupta et al. 2006). Accumulation of carotenoids in fishes mostly occurs in their integuments and gonads but in Salmonidae fish, astaxanthin accumulates in muscle. Moreover in catfish, an esterified form of carotenoids exists in the integuments (Kristina et al. 2014; Das and Biswas 2016).

Sorces of carotenoid

Though fishes cannot synthesize carotenoids, certain fishes have the capacity to convert one form of carotenoid into another carotenoid (Backstrom et al. 2014). Lutein is converted into astaxanthin molecules in red carps while in Prawns,the beta-carotene molecule can be converted in to astaxanthin molecule (Gupta et al. 2006). In context of animal based natural carotenoids**,** products of crustacean such as the Antarctic krill (*Euphausia superba*) are used in the meal of crayfish, shrimp, crab etc. These are rich sources of astaxanthin and are used in aqua feed formulation as additive. However, animal based natural carotenoids are limited in supply as there is declining trend in catches of crustaceans. They are also very expensive sources of carotenoids and thus aquaculture feed production becomes costlier (Gupta et al. 2006). Plant based carotenoids are mainly derived from the micro algal pigment. The commercially available products of the astaxanthin rich yeast *Phafia rhodozyma* and fermentation product of *Xanthophyllomyces dendrorhous* is being used widely (Barredo et al. 2017). Feed ingredients such as yellow corn, corn gluten meal and alfa alfa are also used as sources of carotenoids in aqua feed formulation. Other carotenoids rich ingredients used are marigold meal (lutein) and red peppers (*Capsicum* sp.) extract (Gupta et al. 2006).

Carotenoid absorption and Transport

Being hydrophobic in nature carotenoids are not easily solubilized in the aqueous environment of the gastrointestinal tract. So carotenoids are associated with the lipids and lipid digestion products into mixed micelles. Several steps are involved in the intestinal absorption of carotenoids with inclusion of disruption of matrix, followed by dispersion in lipid emulsions and subsequent solubilization into mixed bile salt micelles. Moreover the absorption of carotenoids is a much slower process in comparison to other fish nutrients. There is profound influence of age and physiological state of fish, type of feed and the dwelling environment and not merely species on the absorption and distribution of carotenoids in fishes (Das and Biswas 2016).

Enhancement of fish pigmentation & economic growth

Dietary supply of carotenoids can improve the skin colour as well as market value of ornamental fishes. The pigmentation of Goldfish and Koi is improved by addition of carotenoids and these fishes are found to be capable of metabolizing zeaxanthin to astaxanthin. However, Goldfish lack the ability to metabolize lutein and have limited ability to convert β-carotene to astaxanthin. Skin pigmentation in tiger barb, *Barbus tetrazona*, has been reported to increase,when fed with diet containing carotenoids from Shrimp meal, Marigold petal and Annatto seed extract. The blue green alga has also been used as a source of pigmentation for Koi carp. In Goldfish *Carassius auratus*, the optimum level of astaxanthin for intense coloration was found to be 36-37mg/kg diets and the supplementation significantly improved the survival rate (Johnson and An 1991). In Red velvet sword tail *Xiphophorus helleri*, Rainbow fish *Pseudomugil furcatus* and Topaz cichlids *Cichlasoma myrnae*, the intensity of coloration significantly improved when fed a diet containing 1.5- 2% of a carotenoid rich strain of *Spirulina platensis* and 1% of *Haematococcus pluvialis* for 3 weeks (Gupta et al. 2006). A variety of carotenoids both synthetic and naturally occurring products are available or are being developed for use in aquaculture. Carotenoids derived from synthetic processes provide only specific carotenoids like β-carotene. Synthetic processes involve petro-chemical solvents and other complex organic solvents, leading to residue problems. Further, synthetic carotenoids are expensive and have limitations to be used in aqua-feed formulation depending upon the species. In case of excessive use, synthetic carotenoids can lead to cause deteriorating effects on the environment (Alvarez et al. 2008; Das and Biswas 2016).

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 well as good for economic growth. As the aqua feed industry seeks a natural and 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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Table 1: The commonly occurring carotenes with their resultant colour

Carotene Variant	Resultant Colour	Source
Tunaxanthein	Yellow	Das and Biswas (2016)
Lutein	Greenish yellow	Gupta et al. (2007)
Beta carotene	Orange	Das and Biswas (2016)
Doradexanthins	Yellow	Das and Biswas (2016)
Zeaxanthin	Yellow orange	Gupta et al. (2007)
Canthaxanthin	Orange red	Das and Biswas (2016)
Astaxanthin	Red	Das and Biswas (2016)
Eichinenone	Red	Gupta et al. (2007)
Taraxanthin	Yellow	Gupta et al. (2007)