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REVIEW

Role of Carotenoids in Ornamental Fish Nutrition: A Review

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ABSTRACT

A bright colourful fish is the primary attraction of an aquarium. This colouration is due to skin pigments, underlying tissues and body fluids. Carotenoids are the major group of colouring pigments among other similar compounds. These pigments have a significant role in the reproduction, respiration, membrane permeability, light absorption, reflection and the efficiency of the immune system *etc.* Unfortunately, fish, cannot produce the carotenoids themselves and are reliant upon a dietary source. Coloured fish often show faded or degraded coloration especially when the fishes are kept under captivity and also in intensive culture condition. This faded colouration can be improved with feed containing either pure natural /synthetic carotenoids directly or indirectly through natural sources of microbial, plant and animal origin. This review article deals with carotenoids, their types, function, sources and physiological effect on fish in a comprehensive manner.

Keywords: Aquarium, Astaxanthin, Colouration, Carotenoid, Ornamental fish feed

INTRODUCTION

Aquarium keeping is amongst the most popular of hobbies worldwide. In the past 60-70 years ornamental fish keeping were mainly restricted to members of well to do family but now a days it has become ubiquitous and is very popular activities in town and in cities across the world. Many of the fishes which were used for ornamental purpose are small in size and also, they have got attractive colours. Ornamental fish culture has made a great progress from last few centuries. A considerable growth has been seen from last 4-5 decades, not only in culture but also in diversification in the international trade in ornamental fishes.

Indigenous ornamental fishes have a vast potential in the domestics as well as in the international market, but since this sector is mainly done through wild collection so there is always a shortage in the number of fishes and cannot fulfil the demand from wild collection alone until and unless breeding methods of indigenous fishes are evolved. In spite of the fact that this sector has a vast potential for development, there is a problem in developing this multibillion-dollar business. This can be attributed to the lack of knowledge and other information regarding breeding under captivity, the lack of knowledge about the food and feeding habits and behaviours of fishes and also the absence of low cost and good quality feed.

Coloration is one of the most important factors in which the value of fish in the market depend i.e. the better is the colour the best is the price. The colour of the skin of ornamental fish and the colour of the food is the major concern for farmers and traders because it is the colour of the skin which will determine its price in the market. Coloured fish often show faded or degraded coloration especially when the fishes are kept under captivity and also in intensive culture condition.

Many shows and exhibition reveal that the competition in ornamental fish is mainly dependent on achieving vibrant colour. The value of the fish in the market reflects these requirements and hence farmers, researchers and many entrepreneurs and many others are mainly involving themselves in discovering methods of enhancing skin colouration. Colour enhancement by using colour additives is now being studied although very few research papers have been published.

It is also known throughout the animal kingdom that male having the flashiest looks have got the best chance of finding mate. But researchers have found the reasons for this only recently. Males which are flashy

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and brightly coloured are able to use carotenoids as ornaments and they are also stronger and healthier. Carotenoids have been shown to increase not only growth of young fish but also their survivals.

A fish cannot synthesize these pigments, they rely on dietary supply of carotenoids to achieve their natural skin pigmentation. Carotenoids are found in nature the largest group being the fat soluble carotenoids and xanthophylls; the carotenoids mostly found in the green plant material and have α and β form. β-Carotene a precursor of vita- A. Carotenoids having role in the reproduction, respiration, membrane permeability, light absorption reflection and the efficiency of the immune system. Many animals also use colours to communication warning, mating call, feeding signal and camouflage. The predominant carotenoids present in the aquatic environment are lutein (green yellow), zeaxanthin (yellow orange) and (alpha) carotene (light yellow) astaxanthin (red) animal the algae have higher amount of alpha carotene alpha and grass meal have a preponderance of β carotene, this would (spirulina) the algae from the pond would more efficient utilized by fish. Natural Carotenoids are found all section of the living world.

1. Mechanism of coloration in fish

Colouration is due to skin pigments, underlying tissues and body fluids. There are specialized pigments containing cells called 'chromatophores' located beneath the scales which can cause coloration. The most common types of chromatophores are melanophores; these contain black and brown coloured melanin crystals. Carotenoids are not only among the most widespread of naturally occurring group of pigments, but also have the important function.

2. Carotenoids

2.1 Definition

A Carotenoid may be defined as a nitrogen free pigment, consisting wholly or chiefly of carbon atoms united in an uninterrupted sequence of conjugated double bonds. These pigments vary in colour from a bright yellow to a deep red or even a violet or dark blue, the depth of a shade increasing with the number of conjugations in consecutive union and decreasing as the double bonds are saturated. Although carotenoids occur in low concentration the total carotenoids production in nature has been estimated to be over 100 million tons per year with the majority being synthesized via the photosynthetic pathway and subsequently being stored in leaves, algae and zooplankton.

2.2 History

Carotenoid was first discovered in the roots of carrot (*Daucus carota*). The name 'carotene' was derived from the carrot from which it was first isolated. Its wide distribution in nature probably accounts for the subsequent use of the class name, "carotenoids" to include all the pigments of related chemical composition. Carotenoids are responsible for many of the red orange and yellow hues of plant leaves, fruits and flower as well as the colours of some birds, insects, fish and crustaceans. Some familiar examples of carotenoid colouration are the oranges of carrot and citrus fruits, the reds of peppers and tomatoes, the pinks of flamingos, salmon and rainbow colours in ornamental fishes. Some 600 different carotenoids are known to occur naturally and new carotenoids continue to be identified.

3. Carotenoids in fish

Coloration plays a role in social structure as well as defence of fish in the wild. Fish depend a great deal on visionary cues. All but a few species (mainly cave

1.1 Types of chromatophores and properties

Chromatophores	Pigment	Type	Colours
Melanophores	Melanins	Colour	Black, Brown
Xanthophores	Pteridins & Carotenoids	Colour	Red, Orange
Erythrophores	Pteridins & Carotenoids	Colour	Orange, Yellow
Iridophores	Guanine & Other Purines	Reflective	White, Silver, Blue, Other

dwellers) have well-developed eyes. As is the case in many other groups of animals, the body colours of fish are predominantly dependent on the presence of special cells in the skin, called chromatophores. These contain pigments or light scattering or light-reflecting organelles. In biology, any substance that can impart colour to the tissues or cells of animals or plants can be called a pigment. There are four main groups of pigments that can be used to provide colour in these cells: melanins, carotenoids, pteridines, and purines. Melanins are responsible for the dark coloration seen in fishes. Carotenoids are lipid soluble, gives yellow to red colours dominate the other pigments. Pteridines are water-soluble compounds and result in bright coloration. Pteridines play a small role in coloration when compared to carotenoids. In the purine compounds, mostly guanine predominates. A large amount of guanine can be found in the silvery belly skin of most fish species. These molecules can combine with other biomolecules, like proteins, to produce the blue, violet, and green colour ranges seen in fishes. In the flesh (muscle), the carotenoids are the dominant pigment. In lobsters and shrimps, astaxanthin is attached to a protein to produce the carotenoprotein, crustacyanin. This carotenoprotein imparts a blue colour in living crustacea; in the presence of heat the carotenoprotein molecule is cleaved, which subsequently results in the characteristic astaxanthin red colour of cooked lobsters and shrimps. To date, over 600 carotenoids have been identified in nature, varying in colour from yellow to red. Most carotenoids are polyunsaturated hydrocarbons, containing 40 carbon atoms, and comprising of two terminal ring systems. Carotenoids that are composed entirely of carbon and hydrogen are known as carotenes, while those that contain oxygen are termed xanthophylls. Carotenoids are the major pigmenting compounds and cannot typically be synthesized by fish. Whereas, most other pigmenting compounds can be made by the fish. Carotenoids are used in aquaculture feeds to provide the colour associated with consumer products, such as the bright vibrant colours of ornamental fish. The same carotenoid, astaxanthin, found in wild salmon is used in aquafeeds to impart this natural, pink-red colour to farmed salmon fillets. Colour matters, particularly with regards to consumer preference for aquaculture products. As is the case with other carotenoids, salmonids cannot endogenously synthesize astaxanthin; therefore, it must be supplemented in the fish's ration. Research also indicates additional benefits from dietary carotenoids besides coloration. Astaxanthin, for example, has biological functions related to growth, reproduction and tissue health in salmonids and shrimp, possibly due to the compound's strong antioxidant properties.

Only a small number of plants and micro-organisms can synthesize carotenoids. Higher animals, including fish, depend upon the dietary carotenoids. They absorb the carotenoids from the feed and deposit them in their tissues. Astaxanthin accounts for more than 90% of the total carotenoid content found in the flesh of wild salmonids (salmon and trout) and gives salmon flesh its characteristic rich pink-red colour. In the wild, salmonids absorb astaxanthin from the crustaceans they eat. The absorbed carotenoid is transported via blood to the muscles and skin to be deposited. In other fishes and to a limited extent in salmonids, additional carotenoid compounds are the source of other bright colours. Research results indicate that tunaxanthin is a rather common pigment in marine fish and is especially abundant in yellow-coloured fishes. Astaxanthin, by contrast, seems to be dominant in red marine fish. Lutein is also widely found in many marine species. Carotenoids commonly occurring in freshwater fish include beta-carotene, lutein, taraxanthin, astaxanthin, tunaxanthin, alpha-, beta-doradexanthins, and zeaxanthin *etc.*

In nature, plants and micro algae can produce carotenoids. Animals cannot synthesize carotenoids by their own, so they are dependent on plants and algae to obtain these pigments (Britton *et al.,* 1995). The pigments found in fishes are gained from these sources or from their prey that have accumulated in. These absorbed carotenoids are then transported in the blood to the muscle skin where it is deposited. Carotenoids in fishes have been studied and observed that some species contain a variety of carotenoids, where others contain specific ones (Fox, 1957), e.g. the Carotenoid 'tunaxanthin' is especially abundant in yellowtail (*Seriola quinqueradiata*).

3.1 Common carotenoids in fishes

i. Lutein :- greenish-yellow
ii. Tunaxanthin :- yellow
iii. Beta-carotene :- orange
iv. Doradexanthin :- yellow
v. Zeaxanthin :- yellow- orange
vi. Canthaxanthin :- orange- red
vii. Astaxanthin :- red

4. Use of carotenoids in aquaculture

In natural condition fishes obtain carotenoids from variety of sources like micro algae, crustaceans, and insects but in culture conditions this pigmentation is obtained by supplementing or complimenting diets with carotenoid pigments. Various synthetic carotenoids (β-carotenoids, canthaxanthin, zeaxanthin and astaxanthin) and natural sources yeast, bacteria algae plant and crustacean meal have been used as dietary supplement to enhance the pigmentation of the fish and crustacean (Shahidi *et al.,* 1998). Natural carotenoids are usually composed of several carotenoids in various form and various degree of digestibility making their pigmentation efficiency complicated. Supplementation of feed with various natural pigment sources of plant origin for good growth and attractive colorations, carotenoids from carrot gives satisfactory result. Significant deposition of total carotenoids and astaxanthin as well as visual enhancement of the flesh colorations was observed in trout. Swimming performance, courtship behaviour of guppy due to carotenoids differ in different upstream and downstream water.

Salmonidae, cannot synthesize carotenoids and therefore rely on dietary intake under intensive culture condition. Carotenoids are among the most important micro ingredients used in many intensive aquaculture systems. This group of compounds has been linked to many important biological functions associated with their strong antioxidant properties.

4.1 Pigmentation using pure carotenoid pigments

Many researchers have used pure carotenoid pigments in the fish diet to enhance pigmentation. Astaxanthin is added to feed in order to make up for the lack of natural dietary sources of the pigment. Torrissen *et al.* (1989), Fey and Mayers (1980) showed that canthaxanthin at the rate of 0.005% enhances colour in the pearl gourami (*Trichogaster leeri*) and they also exhibited greater iridescence in the chromatophores along the entire integument. Kim *et al.* (1999) found that the number of total carotenoids in the group of bitterlings (Rhodeus*uyrkii)* fed with supplemented carotenoids (astaxanthin, lutein, and β-carotene) were relatively higher than the control group of fish fed with no carotenoid supplementation. To enhance colouration in ornamental fish a combination of synthetic and natural carotenoid pigments can be added at the rate of 0.04 to 2.00% of the diet (Chapmann, 2000).

Astaxanthin is very commonly used supplement as it not only provides pigmentation in farmed animals but also has been found to be essential for their proper growth and survival (Torrissen and Christiansen, 1995). Synthetic astaxanthin is the major form currently being used in fish feeds (McCoy, 1999).

4.2 Pigmentation using natural sources

4.2.1 Animal sources

Many studies have shown that fish can be pigmented by inclusion of crustaceans and crustacean wastes in their diets (Torrissen *et al.,* 1981). Allapichay *et al.* (1984) shown that the rate of Carotenoid deposition in red sea bream *Chrysophrys major* fed with raw Atlantic krill (*Ephausia superba)* and raw mysid (*Neomysis sp.*) was significantly higher and resulted in distinct pigmentation. Atlantic krill (*Ephausia superba*) oil containing astaxanthin diester was shown its significance in pigmenting the flesh of coho salmon (Oncorhynchus *kisutch*) (Arai *et al.,* 1987). But the use of crustacean or crustacean waste brings several problems (Spinelli & Mahnken, 1978). The drying of crustacean or crustacean waste brings significant loss of carotenoid pigments from it (Brinchmann, 1967). Incorporation of large quantities of shrimp meal or waste modifies the mineral composition of diet (Meyers and Rutledge, 1971).

4.2.2 Plant sources

Several workers have utilized carotenoid pigments from the plant sources. Bitzer (1963) used paprika, Savolainen and Gyllenberg (1970) used yeast (*Rhodotorula sanneii)*, Neamtu *et al.* (1976) used chestnut flowers, Johnson *et al.* (1977) used yeast (Phaffia *rhodozyma*) in salmonids to improve the colour of the flesh. Tsushima *et al.* (1998) demonstrated that paprika was effective for pigmentation in gold fish and its effect was significantly increased by sunlight. The goldfish accumulated capsanthin and oxidized it into 4-keto capsanthin. Nhan *et al.* (2019) evaluated the effect of dietary natural carotenoid sources like sweat potato and gut weed on skin colour enhancement of false clownfish *Amphiprion ocellaris.*

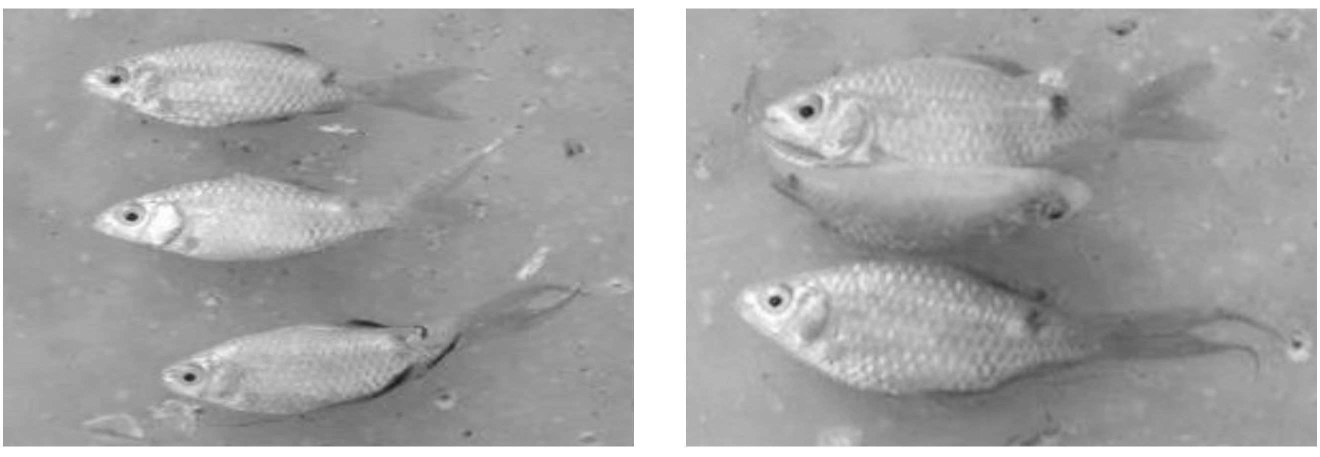
Rose petals

Rose flowers (*Rosa canina*) are available in different colours. Commonly petals of the flowers collectively called as corolla which are rich in carotenoids and polyphenols that provides colour to the flowers which attracts the insects useful for pollination. The main pigments present in the rose flowers are water soluble flavonoids and non-water-soluble carotenoids. Anthocyanin which is abundant in rose flower is part of diverse family of aromatic molecules called flavonoid which is derived from phenyl alanine and malonyl coA (Shirley, 2001). Anthocyanin is a sub class of plant flavonoid responsible for orange to blue colour of flower and other plant organs; these are accumulated in the vacuole. There are three major types of anthocyanin that contribute the colour of flower (Zuker *et al.,* 2005). The flavonoids that are present is rose flower are – cyaniding, pelarogonidin and the flavonols. The flavonols like quercetin and kaempferol cyanidin are responsible for deep red colour pelarogonidin responsible for orange red, quercefin and kaempferol are for white creamy colour. But the appearance of dark red and purple colour in rose flower is due to presence of cyaniding. The blue or purple colour in rose is produced by delphinidin, red or magenta colour by cyanidin & orange, red or pink colour is due to presence of pelarogonidin. Rose flower is primarily composed of structurally simple 3,5 diglucosides (anthocyanin). Pailan *et al.* (2012a, 2012b) used the rose petals meal as a carotenoid source on pigmentation and growth of dwarf gourami (*Colisa lalia*).

Marigold

Marigold is a herb very commonly found all over the world. Marigold is normally used for decorating the gardens. The petals of marigold flower are commercially valuable as a natural source of lutein pigments (yellow orange pigments). It is used in poultry industry as a feed additive to improve the colour of egg yolk to orange and skin yellow. The main pigments present in the marigold flower are xanthophylls and lutein which are present in the form of ester of palmitic and myristic acids. Marigold flower can be used as feed additive either in dried form or as solvent extracts.

Marigold petal meal was used by Boonyaratpalin and Lovell (1977) for the tiger barb (*Puntius tetrazona*) and found the tiger barbs more brightly coloured than the fishes fed with control diet. Ezhil *et al.* (2008) used the marigold as a carotenoid source on pigmentation and growth of red sword tail (*Xiphophorus helleri*). Gocer *et al.* (2006) used marigold flower along with red



Carotenoids gain in fish fed with different experimental diets

pepper and synthetic astaxanthin on pigmentation growth and proximate composition of *Penaeus semisulcatus* and they found marigold as a carotenoid source was as useful as the synthetic astaxanthin for the shrimp. Pailan *et al.* (2015) observed that marigold petal meal at 4% level can be supplemented in the diet of swordtail for improvement of skin coloration through increase in carotenoids concentration in skin without any adverse effect on body composition, growth and feed conversion efficiency.

Other plant-based sources

The plants like paprika (*capsicum annum L.*), red pepper, carrots are also the good source of natural carotenoids for fishes. Paprika was used in salmonids diets by Ellis, (1979). Some dried flower can be used as well (Torissen *et al.,* 1989). Sheriff and Mathew (1996) demonstrated that carrot meal produced gold yellow colour in gold fish. China rose (*Hibiscus rosasinensis*) petals was used as a source of natural carotenoid for gold fish (*Carassius auratus*). Agus *et al* (2019) observed that supplementation of 10% RDFM (Red dragon fruit by product meal) could be added into the diet to enhance skin coloration of koi carp.

4.2.3 Microbial sources of carotenoids

There are several microbes like algae, fungus, yeast and some bacteria are reported to produce carotenoids. Though the synthetic carotenoid is available, there is a renewed interest in microbial sources of carotenoids (Nelis and De Leenheer, 1991).

Algae

Algae can be called as the base of the food chain which is rich in carotenoids. Production of β-carotene by algae *Dunaliella* sp. is well developed tech. (Ben-Amotz 1998, 1999). Red algae *Haematococcus pluvialis* can be used for the commercial product of astaxanthin. Other blue green algae Spirulina can be used as a carotenoid source due to its occurrence in almost all environment. Spirulina has been used as source of carotenoid in rainbow trout and fancy carp (Choubert 1979). It is also used as carotenoid sources for the pigments of the blue gourami (*T. trichopterus)* (Alagappan *et al.,* 2004). It also accelerated the growth, sexual maturity and increase of fertility in fishes like African cichlids and gold fish, which ate a lot of algae (Matsuno *et al.,* 1980). Spirulina is also rich in nutrients like protein (55-70%), carbohydrates (15-25%) (Hudson and Karis, 1974) and pigments like carotenes, chlorophyll and phycocyanin (Choubert, 1979). The cell wall of spirulina sp has been used in fish diets in *C. macrocephalus* and *P. goninotous,* colour was increase with the quantity of spirulina. The undesirable yellow coloration of edible trout flesh can be observed in pond with heavy algal growth. The trout consume varying quantity of algae with their food and their yellow pigment is assimilated in the musculature. Algae destruction with gramoxone is recommended as a counter measure.

5. Absorption of carotenoid in fish

Hata and Hata (1972) have suggested that the occurrence of hydroxyl group within molecular configuration of carotenoid enhances its absorption by the digestive epithelium. Thus astaxanthin, dihydroxy cathaxanthin may be more easily absorbed than canthaxanthin. Pigmentation depends upon verity of factors like dietary pigment source and concentration, period of feeding and continuity of feeding the pigmented diet, size of the fish, temp. of water, developmental stage (sexual maturity), hormonal status of the fish, chemical form of the carotenoid fed, photoperidod regime, dietary lipid/ emulsifier concentration and the availability of natural food organisms. In salmon astaxanthin and canthaxanthin were deposited unchanged but astaxanthin was better retained (Bjerkeng *et al.,* 1990) due to higher digestive retention rate. Efficiency of gastrointestinal absorption of the carotenoid mainly depends on the carotenoid and on the composition of the diet (Van Het Hof *et al.,* 2000). Digestibility coefficient for astaxanthin & canthaxanthin increases with increase in the dietary level, thus, the higher carotenoid in the flesh of rainbow trout. Canthaxanthin pigmented farmed salmon is more yellowish than astaxanthin pigmented wild salmon (Skrede and Storebakken, 1986). Idoxanthin (3,3´, 4´-trihydroxy- β, β -carotene-4-one), an astaxanthin metabolite, may accumulate in considerable amounts in the muscle up to 30% of total carotenoids in large Atlantic salmon (Schiedt *et al.,* 1981). It has a shorter chromophore than astaxanthin, and appears as more yellow. Accumulation of idoxanthin in the muscle may therefore contribute to a more yellowish hue of the flesh as indicated by Hatlen *et al.* (1995).

6. Functions of carotenoids

The carotenoids have several major biological functions. Astaxanthin plays an important role in salmonid growth and health (Christiansen *et al.,* 1995). Astaxanthin has also been shown to increase the survival of crustaceans (Chien and Jeng, 1992). It has been suggested that *Penaeus semisulcatus*, requires astaxanthin and not retinol, per se (Dall, 1995). Yet, it is important to stress that carotenoids do not replace the requirement for vitamin A in fish diets. The mobilization of carotenoids and their transport from the flesh to the skin and ovaries during maturation has led to the hypotheses that carotenoids have a function in reproduction. Possibly carotenoid functions included: a fertilization hormone, a source of pigments for chromatophores, a function in cellular respiration, protection from light, resistance to elevated temperature and ammonia, and as provitamin A. Carotenoids also have excellent antioxidative characteristics. Cold-water fishes, like salmon, have a high level of polyunsaturated fat in their membranes, and protection of lipid tissue from peroxidation seems to be a metabolic function for astaxanthin (Bell *et al.,* 2000). Astaxanthin has been shown to be one hundred times more effective than vitamin E as an antioxidant (Miki, 1991).

7. Application of carotenoids

7.1 Medicines

Age-related macular degeneration (AMD) is the most common cause of blindness at old age. Carotenoids like lutein and zeaxanthin were found to be associated with reduced risk of AMD. These two carotenoids are obtained primarily from dark green leafy vegetables such as spinach and coloured greens. The lens and cornea of human eye filter out ultraviolet light, but still visible blue light reaches the retina. This near-UV radiation can cause photo damage. Lutein and zeaxanthin enter the eye from the plasma and selectively accumulate in the retina, where, they filter out visible blue light. These carotenoids may also protect against per oxidation of fatty acids in the photoreceptor membrane, and thus protects the blood vessels that supply the macular region.

7.2 Feed additives

Carotenoids play important role in animal health by inactivating harmful free radicals produced in normal cellular activity and in stress. Carotenoids like astaxanthin and β-carotene were also reported for prevention of gastric ulceration of stressed rats (Yoshiyuki *et al.,* 1999). Pure carotenoids or carotenoid-containing preparations are also playing important role as feed additive for pigmentation in aquaculture. Astaxanthin is the major carotenoid used for pigmentation of fishes and salmons. Yeast *Phaffia rhodozyma* is widely used as astaxanthin source in aquaculture industries (Johnson *et al.,* 1977). Biotechnology companies active in the pigment business have devoted considerable research and development efforts to this organism (Nelis and De Leenheer, 1991).

7.3 Fish diets for skin and flesh colour

The characteristic red/pink colour of salmon flesh is perceived by the consumer as one of the most important quality criteria (Baker and Gunther, 2004). Salmonids seem not to deposit other red carotenoids than astaxanthin and canthaxanthin in the flesh to significant amount. Corn gluten, containing lutein, reduces the deposition of astaxanthin or canthaxanthin. It is well documented that astaxanthin is more efficiently deposited in the flesh of rainbow trout compared to canthaxanthin (Storebakken and Choubert, 1991). A similar difference seems not to be evident in Atlantic salmon. Astaxanthin and/or canthaxanthin are added to aqua feeds for salmonids (*Salmo, or Salvelinus spp.*) to obtain astaxanthin level and flesh colour comparable to those of their wild counterparts. The astaxanthin is normally supplemented to diets throughout the whole grow-out phase (100 g to harvest) and at levels between 30 to 100 mg/kg complete feed in order to obtain the desired pigment level, depending on species, fish size dietary lipid level, farming environment and initial astaxanthin level.

7.4 Antioxidant

Carotenoids are free radicals scavenger both in vitro and in vivo (Deshpande *et al.,* 1996). The antioxidative behaviour of carotenes is closely related to their own oxidation. The polyene chain of the molecule is highly reactive, electron-rich system that is susceptible to attack by peroxyl radicals and other electrophilic reagents. It is responsible for the instability of carotenoids toward oxidation and at the same time an important property of the molecule concerning free-radical (Britton *et al.,* 1995). Carotenoid are therefore sensitive to oxygen, light, heat, acid and alkali, particularly combinations of these factors (Britton, 1995). Although majority of the work on antioxidative activity of carotenoids has been done on β-carotene (Yanishlieva *et al.,* 1998), theoretically, all carotenoids with similar conjugated double bond system should have antioxidant properties (Britton *et al.,* 1995). Carotenoids are able to quench free radical species such as singlet oxygen. In addition to quenching reactive species formed by photochemical reaction, carotenoids may also act as chain-breaking antioxidants, although they do not have the characteristic structural features associated with this class of antioxidants (Deshpande *et al.,* 1996). The antioxidant potency of carotenes depends on several factors such as oxygen pressure, intrinsic chemical reactivity of the molecule toward radicals, site of generation and reactivity of the radicals, concentration and mobility in the microenvironment, stability and fate of carotene-derived radicals, and interaction with other antioxidants (Yanishlieva *et al.,* 1998).

In some food and model systems, carotenoids work as pro-oxidants under certain conditions and as antioxidants under other condition depending on their concentration. The balance between pro-oxidant and antioxidant behaviour is very delicate, and the antioxidant behaviour is most pronounced at low oxygen partial pressure (Jorgensen and Skibsted, 1993).

CONCLUSION

The colours resulting from the deposition of carotenoids are considered to be of significant behavioural importance to the animal. However, in addition to their coloration properties, the carotenoids have major biological functions. There are several ways in which the colouration of ornamental fishes can be improved by dietary means and make them more valuable. There is a vast natural resource in earth, which need to be explored and novel carotenoids to be found.

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