Importance of — Dietary Carotenoid Pigment (Astaxanthin) in Aquaculture

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India is bestowed with rich aquatic resources, both marine and freshwater. These provide an increasing scope for stepping up fish production. So much so, Indian seafood industry achieved a remarkable place in the world seafood trade (Rs.6300 crores, MPEDA, 2001). However, recent reports showed that the growth is stagnant in the capture fishery sector. This is because of several constraints including overexploitation of natural resources. Since, India is having rich freshwater and brackishwater resources, there is much potential for increasing production in the culture sector. The scope for increasing production from culture sectors has generated lot of research in different areas of aquaculture, such as nutrition, genetics, culture methods, disease diagnosis, water quality management etc.

Success in aquaculture depends to a great extent on sound nutritional practices based on precise knowledge of nutrient requirements and the satisfaction of such needs through formulation of optimum diets, keeping in mind the well being and maximization of the growth potentials of the species. Though nutrients play a vital role in aquculture nutrition, and feed contributes 70% of aquaculture expenditure, the importance of non-nutrient dietary components can not be neglected. In this article an attempt is made to give a brief outline of the importance of carotenoids, one of the essential dietary components in aquaculture.

Carotenoid Pigment (Astaxanthin) in Cultured Aquatic Animals

Carotenoids are a group of fat-soluble pigments widely distributed in aquatic animals. It is commonly considered that aquatic animals cannot biosynthesize cartenoids from mevalonic acid, but can alter carotenoids by oxidation and deposit them in their tissues. These are present in the organism either in carotenoprotein complex form or dissolved in lipoprotein. In the case of shrimp, these pigments accumulate mainly in the carapace, epidermis, hepatopancreas, and ovaries. In case of salmonids, these are mainly deposited in the muscle. Because the contribution of trophic chain nutrition of semi-intensively farmed species is the least, carotenoids have to be considered important ingredients during feed formulation. The most commonly used carotenoids in commercial diets are canaxanthin and astaxanthin, but studies have shown that astaxanthin is the most effective pigment. Astaxanthin is the main carotenoid pigment found in aquatic animals. This red-oranged pigment is closely related to other well-known carotenoids such as beta-carotene or Lutein, but has a stronger antioxidant activity (10 times higher than beta-carotene). Studies suggest that astaxanthin can be more than 1000 times more effective as antioxidant than vitamin E.

Role of Astaxanthin in Cultured Organisms

The role of astaxanthin is well understood in the case of terrestrial animals. But, as far as aquatic animals are concerned, the reports are few. However, the available reports bring out useful information regarding astaxanthin in aquaculture. The pigmentation level of an aquatic animal may be an important factor affecting its market value and may also directly indicate the healthiness and quality of an organism. In case of salmonids the flesh is pink in colour due to the presence of astaxanthin (3,3'-dihydroxy- β, β -4,4' – dione). Other functions of astaxanthin are mainly related to the physiology. In a series of experiments, Miki (1991) demonstrated that astaxanthin has a strong quenching effect against singlet oxygen. This quenching is likely to be involved in photo protection of aquatic animals against sunlight. Astaxanthin was also found to be an effective free radical scavenger. The inhibitory activity of astaxanthin against the action of free radicals increased with increasing concentration of astaxanthin, (Miki, 1991). These activities were 100 times stronger than that observed for vitamins stronger than that observed for vitamin E (tocopherol). Some observations showed that the fish eggs developing in poor oxygen conditions significantly contain more astaxanthin than eggs developing under elevated oxygen conditions. This is believed to be an adaptive process for poor oxygen condition, where astaxanthin stores oxygen for development. Astaxanthin has also been identified in the eggs and eyestalks of crayfish, indicating its possible role in larval development and visual process. Pigments have been reported to play an important role in improving the growth and survival of penaeid prawns. Many reports provide evidence that carotenoid pigments have a significant role in both specific and non-specific immune systems (Bendich,1989). These also enhance lymphocyte proliferation as well as cytotoxic T cells and natural killer cell capacities. Similar reports were made in the case of rainbow trout (*Onchorhynchus mykiss*), when fed with diet containing astaxanthin. Yamada *et al.*, (1990) observed a 62% better survival rate between 4 and 8 weeks for *Penaeus japonicus* fed on diets with 100 mg astaxanthin per kg. Similar reports are available for aquatic animals like Atlantic salmon, tilapia etc.

Culture of Algae for Production of Astaxanthin Pigment

Two types of microorganisms have been reported to produce industrial

...staxanthin. These are microalgae, mainly of the genus *Haematococcus* and the yeast *Phaffia rhodozyma*. The yeast *P.rhodozyma* can be grown in large fomenters in a process similar to baker's yeast production. Dried powder of *Spirulina platensis*, a fresh water blue-green alga is being extensively used as a cartenoid source mainly in aquarium fish feeds to improve the pigmentation in fish. Crustacean live feeds like Krill and Squilla caught wild may provide dietary source for astaxanthin. These are cheaper and also provide additional nutrients. Astaxanthin components of feed are generally affected by storage. Storage for 3 months can reduce 20-30% of the original astaxanthin level.

Table 1: Sources of Astaxanthin, their Main Merits, and Demerits

Sources	Astaxanthin (mg/kg dry wt.)	Merits	Demerits
Synthetic	50000-100000	High in astaxanthin	Synthetic
Crustanceans	50-200	Biological sources	Low in astaxanthin
Crustacean oil extract	1000-1500	Biological sources	Moderate in astaxanthin
Microalgae	<10000	Biological, high astaxanthin	Difficult to obtain high biomass
Yeast	<500	Biological, easy	Low in astaxanthin

Source: *Tangeras, A. and Slinde, E. (1994)*

Table 2: Main Forms of Astaxanthin Tissues of Important Aquaculture Animals

Tissues / Species	Skin	Flesh	Digestive gland	Ovaries	Serum	Eggs
Salmonids	Esterified	Free	Free	Free	Free	Esterified
Shrimps	Esterified	Esterified	Free	Free	N.A.	Free
Red Seabream	Esterified	N.A.	N.A.	N.A.	N.A.	N.A.

N.A. : not available

Table 3: Form and Level of Astaxanthin in Selected Important Aquacultured Species of Potential Astaxanthin Sources

Auqaculture species	Content (mg/kg)	Astaxanthin Free/esterified	Main isomer
Sockeye salmon	26-37	Free, esterified**	3S-3'S
Coho salmon	9-21	Free, esterified**	3S-3'S
Chum salmon	3-8	Free, esterified**	3S-3'S
Chinook salmon	8-9	Free, esterified**	3S-3'S
Pink salmon	4-6	Free, esterified**	3S-3'S
Atlantic salmon	3-11	Free, esterified**	3S-3'S
Rainbow trout	1-3	Free, esterified**	3S-3'S
Salmon eggs	0-14	esterified***	N.A.
Red seabream	2-14	esterified***	N.A.
Red seabream eggs	3-8	N.A.	N.A.
Peneaus monodon	10-150	Esterified, free**	3R-3'R
Copepods	39-84	esterified***	N.A.*
Krill	46-130	esterified***	3R-3'R
Krill oil	727	esterified***	3R-3'R
Craylish meal	137	esterified***	N.A.*
Artic shrimp	1,160	esterified***	3S-3'S
Yeast (*Phaffia r.*)	30-800	esterified***	3R-3'R
Synthetic astaxanthin	80,000	free	3R-3'S
Haematococcus Pluvialis	10,000-30,000	esterified***	3S-3'S

**Crustaceans are believed to have mostly the 3S-3'S form, Krill might be the exception.*
***depending on tissues, free or esterified astaxanthin may be found.*
****also contain a small proportion of free astaxanthin.*
N.A.: not available

Dietary Sources of Astaxanthin for Cultured Aquatic Animals

In the case of salmonids the consumers prefer the pink colour of the flesh. This colour can only be achieved if the fish contains at least 4 mg of carotenoids per kg of flesh. A lesser pigment concentration will result in lower muscle colour and hence, lower consumer acceptance. In nursery rearing, salmonids are provided with diet containing shrimp waste as a source of astaxanthin. For optimum results, the salmonids should be fed with crustaceans, containing 50-200 mg of astaxanthin per kg. This limit is more or less the same for cultured shrimp to get optimum results of survival and growth.

Tables 1 to 3 given on this page give particulars of the main forms of astaxanthin, in tissues of important aquacultured animals and the form and level of astaxanthin in selected important aquacultured species of potential astaxanthin sources, their merits, and demerits.

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