Journal of Aquaculture & Marine Biology

Mini Review

Open Access

Carotenoids and Pigmentation in Ornamental Fish

Abstract

In recent decades aquariculture has emerged as a globally growing million dollar industry comprising cultivation of various freshwater and marine species of finfish as well as shellfish. Pigmentation is one of the major quality attributes of the aquarium fish for market acceptability. Carotenoids are responsible for pigmentation of muscle in food fish and skin color in ornamental fish. Like all other animals fishes are unable of de novo synthesis of carotenoids and rely on diet for fulfillment of carotenoids. Properly formulated feed is the major backbone of successful culture of ornamental fish in confined environment. In this review paper an attempt has been made to prioritize the importance of carotenoids in aquariculture.

Volume 4 Issue 4 - 2016

Anurag Protim Das, Shyama Prasad Biswas
Department of Life Sciences, Dibrugarh University, India

Correspondence: Anurag Protim Das, Department of Life Sciences, School of Science and Engineering, Dibrugarh University, Assam 786004, India,
Email anuragprotim.99@gmail.com

Received: August 31, 2016 | **Published:** October 20, 2016

Introduction

Aquarium fish keeping has evolved as an indispensible part of interior decoration in the 21st century.[1] Colour is one of the major factors which determine the price of the ornamental fish in the world market.[2,3] The color of fish skin is primarily dependent on chromatophores (melanophores, xanthophores, erythrophores, iridophores, leucophores, and cyanophores) that contain pigments such as melanins, carotenoids (e.g. astaxanthin, canthaxanthin, lutein, zeaxanthin), pteridines, and purines Goodwin[4,5] established that fish do not possess the ability to synthesize carotenoids. The carotenoid pigmentation of fish results from the pigment present in the diet.[6] Many reports have demonstrated that skin color change over time depended on the level of carotenoid in the diet and differed among species.[7-11] Therefore, to increase the skin and flesh colour in captivity, fish must obtain an optimum level of carotenoids in their diet.[12]

Diversity of carotenoids in fish

Species specific carotenoids are known to occur in fishes.[13,4] The diverse carotenoids commonly occurring in fishes with their colours are tunaxanthein (yellow), lutein (greenish yellow), beta carotene (orange), doradexanthins (yellow), zeaxanthin (yellow orange), canthaxanthin (orange red), astaxanthin (red), eichinenone (red) and taraxanthin (yellow).[4,13,14] Accumulation of carotenoids in fishes mostly occurs in their integuments and gonads.[4,5] With few exceptions of Salmonidae fish where astaxanthin accumulates[8] in muscle.[5,9,15] Moreover in catfish, an esterified form of carotenoids exists in the integuments.[5]

Carotenoids absorption and transport

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.[15-19] Being hydrophobic in nature carotenoids are not easily solubilized in the aqueous environment of the gastrointestinal tract. So carotenoids are associated with the lipids to carry out transportation.[2,11,20] 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, before being absorbed in enterocyte brush border.[2,21,22] Moreover the absorption of carotenoids is a much slower process in comparison to other fish nutrients.[2] For example approximately 18 to 30 hours are required for absorption of approximately 35% astaxanthin in Salmonids through the proximal intestine.[2,24-30] In addition the process of passive diffusion is involved in the intestinal absorption from micelles.[30,31]

Carotenoids metabolism and deposition

In fishes there does not exist any universal pathways for metabolism of carotenoids in tissues and its subsequent transformations.[9] It is suggested that organs such as liver or intestine where metabolites of carotenoids exist the metabolism of carotenoids take place.[2,32,27,33,34] Studies indicate fish classification based on capacity of metabolism of carotenoids.[10,23] One type of fish requires inclusion of specific oxygenated derivatives in diet as it is unable to perform the oxidation of ionone and the another type of fish such as gold fish or the fancy red carp are capable of oxidation of 4 and 4´ positions of ionone ring and hence have the potentiality of conversion of zeaxanthin and lutein to astaxanthin.[10,35]

Enhancement of fish pigmentation

Significant work has been done on pigmentation of many commercial fish species using carotenoids. In this respect, Mircoalgae such as *Chlorella vulgaris* is as effective as its synthetic counterpart in pigmentation of two most important ornamental fish species, Cyprinus carpio & Carassius auratus.[36] Enhancement of pigmentation was observed in *Xiphophorus helleri* when fed with formulated feed containing *Calendula officinalis* concluding that this lutein can be used as pigmenting source are some examples.[37]

Natural sources of carotenoids

Animals are incapable of biosynthesizing carotenoids, so diet is their sole source as only plants, bacteria, fungi and algae have the capacity for its synthesis.[38] However certain synthetic carotenoids are being developed for commercial utilization. However synthetic carotenoids have several limitations, firstly, synthetic processes have only specific carotenoids such as beta carotene; moreover they involve petrochemical solvents as well as complex organic solvents causing residual problems. Additionally synthetic carotenoids are costly to be used in many aqua feeds. Contrary to it natural sources contain varieties of carotenoids such as astaxanthin, alpha carotene, beta carotene, zeaxanthin etc. Specific plants such as paprika (*Capsicum* annuum) only contain Red xanthophylls (*capsanthin, capsorubin*) possessing pigmentation efficiency of canthaxanthin nearly half to a third.[39-41] Phaffia rhodozyma a microorganism contain around 85% astaxanthin have much significance as pigmenting source in commercial aquariculture.[2,42] Diet comprising of 1.5-2% carotenoids enriched strain of *Spirulina platensis* with *Haematococcus pluvialis* for a duration of three weeks significantly improves colour intensity in swordtail (Xiphorus helleri), topaz cichlids (Cichlasoma myrnae) and rainbow fish (Pseudomugil furcatus).[43]

Conclusion and recommendations

Detailed study on ornamental fish nutrition and colour enrichment is lacking. The above study depicts that carotenoids are indispensible part of commercial ornamental fish industry. Owing to the adverse effects of synthetic carotenoids on aquatic environment, natural plant sources can be harnessed and incorporated in formulated feeds for colour retention or enhancement in captive environment. It will create avenues for promotion of the ornamental fish industry as well as colour enhancer feed industry and employment generation.

Acknowledgments

None.

Conflicts of interest

None.

References

1. Katia O. Ornamental fish trade. *INFOFISH International*. 2001;3:14–17.
2. Saxena A. Health coloration of fish. International Symposium on Aquatic Animal Health: *Program and Abstracts*. University of California, School of Veterinary Medicine, Davis, CA, USA. 1994;pp.94.
3. Torrissen OJ. Pigmentation of salmonids: *Interaction of astaxanthin and canthaxanthin on pigment deposition in rainbow trout*. Aquaculture. 1989;79(1–4):363–374.
4. Withers PC. Comparative Animal Physiology. *Brook Cole–Tomson Learning*. Saunders College Publishing/harcourt Brace Jovanovich College, USA. 1992;pp.94.
5. Goodwin TW. Carotenoids in fish. In: The biochemistry of fish. Biochemical Society Symposia, USA. 1951.
6. Hata M, Hata M. Studies on astaxanthin formation is some freshwater fishes. Tohoku. *Journal of Agricultural Research*. 1973;24(4):192–196.
7. Duncan PL, Lovell RT. *Natural and synthetic carotenoids enhance pigmentation of ornamental fish*. Highlights of agricultural research, Alabama Agricultural Experiment Station. 1993;40:8.
8. Storebakken T, P Foss, K Schiedt, et al. Carotenoids in the diets for salmonids IV. *Pigmentation of Atlantic salmon with astaxanthin, astaxanthin dipalmitate and canthaxanthin*. Aquaculture. 1987;65(3–5):279–292.
9. Chatzifotis S, Pavlidis M, Jimeno CD, et al. The effect of different carotenoid sources on skin coloration of cultured red porgy (*Pagrus pagrus*). Aquaculture Research. 2005;36:1517–1525.
10. Dharmaraj S, Dhevendaran K. Application of microbial carotenoids as a source of colouration and growth of ornamental fish *Xiphophorus helleri*. *World Journal of Fish and Marine Sciences*. 2011;3(2):137–144.
11. Ho ALFC, Zong S, Lin J. Skin color retention after dietary carotenoid deprivation and dominance mediated skin coloration in clown anemonefish, *Amphiprion ocellaris*. *AACL Bioflux*. 2014;7(2):103–115.
12. Sinha A, OA Asimi. China rose (Hibiscus rosa sinensis) petals: a potent natural carotenoid source for goldfish (*Carassius auratus* L). *Aquaculture Research*. 2007;38(11):1123–1128.
13. Theis A, Salzburger W, Egger B. The function of anal fin egg–spots in the cichlid fish *Astatotilapia burtoni*. *PloS ONE*. 2012;7(1):e29878.
14. National Research Council (NRC). Nutrient requirements of fish. National Academy Press, Washington DC, USA. 1993.
15. Czeczuga B, Dabrowski K, Rosch R, et al. Carotenoids in fish. *Carotenoids in Coregonus lavaretus L*. Individuals of various populations, Acta Ichth. Piscat. 1991;21(2):3–16.
16. Foss P, Storebakken T, Liaaen Jensen S. Carotenoids in diets. V. *Pigmentation of rainbow trout and sea trout with astaxanthin*. Aquaculture. 1987;65(3–4):293–305.
17. Ando S. Studies on the food biochemical aspects of changes in chum Salmon, *Oncorhychus keta* during spawning migration, mechanisms of muscle deterioration and nuptial coloration–Reprinted from memories of Faculty of Fisheries, Kokkaid University. 1986;33(1–2):1–95.
18. Bjerkeng B, Storebakken T, Liaaen–Jensen S. *Pigmentation of rainbow trout from start feeding to sexual maturation*, Aquaculture. 1992;108(3–4):333–436.
19. Wozniak M. Carotenoid contents in the body of rainbow trout *Oncorhynchus mykiss*, from different habitats. *Fol Univ Agric Stetin 214 Piscaria*. 2000;27:215–220.
20. Castenmiller JJM, West CE. Bioavailability and bioconversion of carotenoids. *Annu Rev Nutr*. 1998;18:19–38.
21. Furr HC, Clark RM. Intestinal absorption and tissue distribution of carotenoids. *Nutritional Biochemistry*. 1997;8(7):364–377.
22. Tyssandier V, Lyan B, Borel P. Main factors governing the transfer of carotenoids from emulsion lipid droplets to micelles. *Biochimica Biophysica Acta*. 2001;1533(3):285–292.
23. Tanaka Y. Comparative biochemical studies on carotenoids in aquatic animals. *Mem Fac Fish*. 1978;27(2):355–422.
24. Torrissen OJ. *Pigmentation of salmonids* – a comparison of astaxanthin and canthaxanthin as pigment sources for rainbow trout. Aquaculture. 1986;53(3–4):271–278.
25. Al–Khalifa AS, Simpson KL. Metabolism of astaxanthin in the rainbow trout (*Salmo gairdneri*). *Comparative Biochemistry and Physiology*. 1988;91(3):563–568.
26. Torrissen OJ. *Pigmentation of salmonids*: Interaction of astaxanthin and canthaxanthin on pigment deposition in rainbow trout. Aquaculture. 1989;79(1–4):363–374.
27. White DA, Page GI, Swaile J, et al. Effect of esterification on the absorption of astaxanthin in rainbow trout, *Oncorhynchus mykiss* (Walburn). Aquaculture Research. 2002;33:343–350.
28. March BE, Hajen WE, Deacon G, et al. Intestinal absorption of astaxanthin, plasma astaxanthin concentration, body weight, and metabolic rate as determination of flesh pigmentation in salmonids fish. *Aquaculture*. 1990;90(3–4):313–322.
29. Choubert G, Milicua JC, Gomez R. The transport of astaxanthin in immature rainbow trout *Oncorhynchus mykiss* serum. *Comparative Biochemistry and Physiology*. 1994;108(2–3):245–248.
30. Parker RS. Absorption, metabolism and transport of carotenoids. *FASEB J*. 1996;10(5):542–551.
31. Storebakken T, Hong KN. Pigmentation of rainbow trout. *Aquaculture*. 1992;100(1–3):209–229.
32. Hardy RW, Torrissen OJ, Scott TM. Absorption and distribution of C–labelled canthaxanthin in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*. 1990;87(3–4):331–340.
33. Aas GH, Bjerkeng B, Storebakken T, et al. Blood appearance, metabolic transformation and plasma transport proteins of C–astaxanthin in Atlantic salmon (*Salmo salar* L.). *Fish Physiology and Biochemistry*. 1999;21(4):325–334.

34. Matsuno T, Tsushima M, Maoka T. Salmoxanthin, deepoxy–salmoxanthin and 7,8– didehydrodeepoxy–salmoxanthin from salmon Oncorhynchus keta. *J Nat Prod*. 2001;64(4):507–510.

35. Gouveia L, Rema P, Pereira O, et al. Colouring ornamental fish (Cyprinus carpio and Carassius auratus) with micro algal. *Aquaculture Nutrition*. 2003;9(2):123–129.

36. Ezhil J, Jeyanthi C, Narayanan M. Effect of formulated pigmented feed on colour changes and growth of red swordtail, *Xiphophorus helleri*. *Turkish Journal of Fisheries and Aquatic Sciences*. 2008;8(1):99–101.

37. Schiedt K. Absorption and metabolism of carotenoids in birds, fish and crustaceans. In: Carotenoids Biosynthesis and Metabolism. Britton GS & Pfander H (Eds.), Birkhäuser: Basel, Switzerland. pp.1998.285–358.

38. Huyghebaert G. The utilisation of oxy–carotenoids for egg yolk pigmentation. Thesis of the Univiversity of Gent (Belgium). 1993.

39. Seemann M. Eidotterpigmentierung: Unterschiede bei natürlichen und synthetischen Carotinoiden? *DGS Magazin*. 1997;49(36):24–28.

40. Grashorn MA, Steinberg W, Blanch A. Effects of canthaxanthin and saponified capsanthin/capsorubin in layer diets on yolk pigmentation in fresh and boiled eggs. *XXI World's Poultry Congress*, Canada. 2000;20–24.

41. Andrewes AG, Starr MP. (3R, 3´R)–astaxanthin from the yeast *Phaffia rhodozyma*. *Phytochemistry*. 1976;15(6):1009–1011.

42. Ako H, Tamaru CS, Asano L, et al. *Achieving natural coloration in fish finder culture*. In: Spawning and maturation of aquaculture species, Proceeding of the 28th UNJR aquaculture panel symposium, Kihei, Hawaii. 10–12, U NJR Tech Rep. 2000;28:1–4.