

Haematococcus algae meal as a source of natural astaxanthin for aquaculture feeds

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The pink to red hue of the flesh of salmon and trout is a distinguishing characteristic of these fishes, and consumers demand such coloration from farmed and wild fish alike. Similarly, consumers expect lobsters, shrimp and crayfish to possess reddish tones in their shells and meat. The pigment responsible for the color of all of these popular food animals is the carotenoid astaxanthin (Fig. 1). Because these animals are unable to biochemically synthesize astaxanthin *de novo*, they rely on the supply of the pigment or closely related precursor molecules in their diet. In the wild, plants, fungi, bacteria and especially algae produce astaxanthin; the pigment is passed up the food chain as microalgae are consumed by zooplankton and other crustaceans, and these in turn are consumed by fish. Farmed salmonids and crustaceans must have carotenoid pigments, principally astaxanthin, added to their feed in order to reproduce the coloration found in wild stocks. In addition, numerous studies have found dietary astaxanthin supplementation to impart health and reproductive benefits to aquacultured species; these effects may in part be related to the potent antioxidant properties of this fat-soluble pigment¹. Most of the astaxanthin used in aquaculture feeds is synthetically derived, however, growing consumer demand for natural products has provided the opportunity for commercial production of astaxanthin from natural sources.

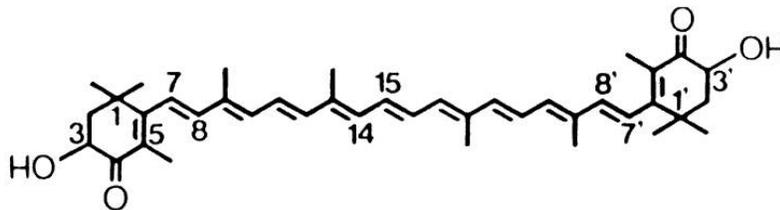


Figure 1. Chemical structure of astaxanthin.

Natural astaxanthin sources that have been exploited for aquaculture feeds include the extracted oils of crayfish and krill, the red yeast *Xanthophyllomyces dendrorhous* (formerly known as *Phaffia rhodozyma*) and the freshwater green alga *Haematococcus pluvialis*. Because the crustacean oils and the yeast have relatively low astaxanthin concentrations (0.15-0.40% of dry weight), they have been commercially less attractive than the algae, which can contain up to 3% astaxanthin by dry weight². *Haematococcus* algae meal has been approved in the United States, Japan and Canada as a color additive for salmon feeds, and is presently used in the diets of farmed salmon, trout, sea bream, prawns and ornamental fish.

Haematococcus pluvialis is a common single-cell Chlorophyte species, with worldwide distribution mainly in temperate regions. Under optimal conditions for growth, *Haematococcus* is a green, free-swimming organism (Fig. 2a). When the algae are stressed due to low nutrients, high light or other unfavorable environmental conditions, they form spores and rapidly accumulate astaxanthin (Fig. 2b). This blood-red color is often seen in rock pools and bird baths as their water is dried up by the sun. It is thought that *Haematococcus* produces astaxanthin as a protective barrier against harsh ultraviolet rays during times of environmental stress. Indeed, *Haematococcus* spores can “hatch” back into green swimming cells after years of dormancy when conditions are again conducive for growth.

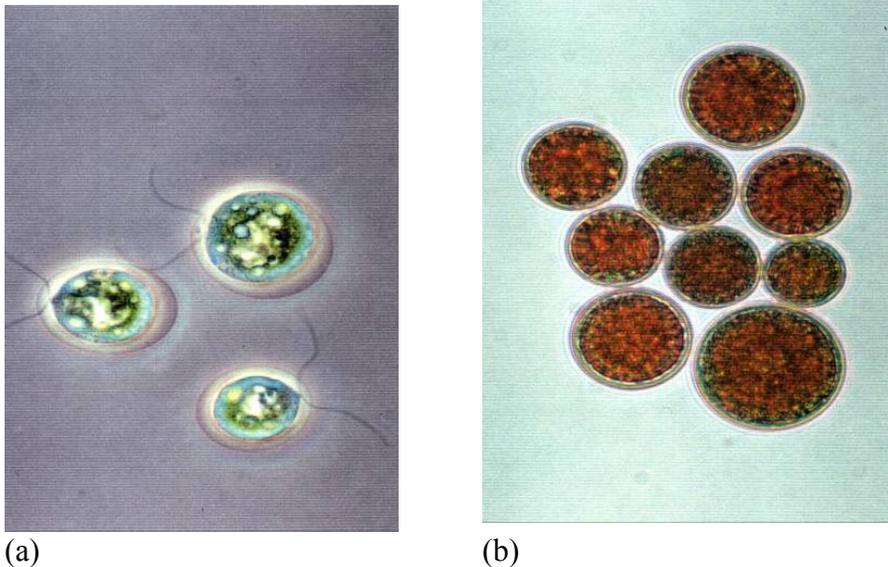


Figure 2. *Haematococcus pluvialis*. Vegetative cells (a) and astaxanthin-rich resting spores (b).

In principle, the production of *Haematococcus* algae meal as a source of natural astaxanthin is relatively straightforward because the algal cultures grow readily in very simple nutrient media. However, because *Haematococcus* grows in a neutral culture medium, contamination by other strains of microalgae and protozoa can present problems. These challenges are magnified as processes are scaled up, and therefore require advanced technology to control. Another technical challenge to developing *Haematococcus* algae astaxanthin has been the tough cell wall of the spores, which must be ruptured to allow the cell contents to be

effectively digested by animals³. Cyanotech Corporation in Hawaii uses a combination of closed photobioreactors and open culture ponds to successfully mass produce astaxanthin-rich *Haematococcus* biomass, and proprietary milling technology to crack the cell walls. The product is then spray-dried and preserved with ethoxyquin or other antioxidants to ensure adequate shelf life. The Cyanotech facility (Fig. 3) has an annual production capacity of more than 70 metric tons of NatuRose[®] *Haematococcus* algae meal (minimum 1.5% astaxanthin).



Figure 3. Cyanotech Corporation natural *Haematococcus* algae astaxanthin production facility in Kailua-Kona, Hawaii. The large ponds hold approximately 500 cubic meters of algal culture.

The general composition of *Haematococcus* algae meal consists of common carotenoids, fatty acids, proteins, carbohydrates, and minerals (Table 1). The astaxanthin in *Haematococcus* is approximately 70% monoesters (linked to 16:0, 18:1 and 18:2 fatty acids), 25% diesters and 5% free pigment. This esterified composition is similar to that of crustaceans, the natural dietary source of salmonids, and is readily metabolized. At 1.5% astaxanthin, only 5.33 kg of *Haematococcus* algae meal needs to be added per ton of feed to achieve an astaxanthin concentration of 80 ppm.

Table 1. General properties of *Haematococcus* algae meal

Astaxanthin	>1.5%
Total carotenoids	>1.75%
Protein	20-30%
Carbohydrates	30-40%
Fat	7-25%
Ash	5-15%
Moisture	4-9%
Color	red to dark red
Particle size	5-25 microns
Bulk density (tapped)	0.370-0.435 g/ml

In a recent feeding trial sponsored by Cyanotech, NatuRose[®] natural astaxanthin was found to be equally effective with synthetic astaxanthin at pigmenting rainbow trout⁴ (Fig. 4). Two other recently published studies comparing *Haematococcus* algae astaxanthin with synthetic astaxanthin have reached the same conclusion^{5,6}. In another recent trial, the algal product was found to be more effective than the synthetic product at raising serum astaxanthin levels in trout when the fish were fed a low-fat diet⁷. Successful pigmentation trials using *Haematococcus* algae meal have also been recently reported for red seabream⁸ and various ornamental fish⁹.

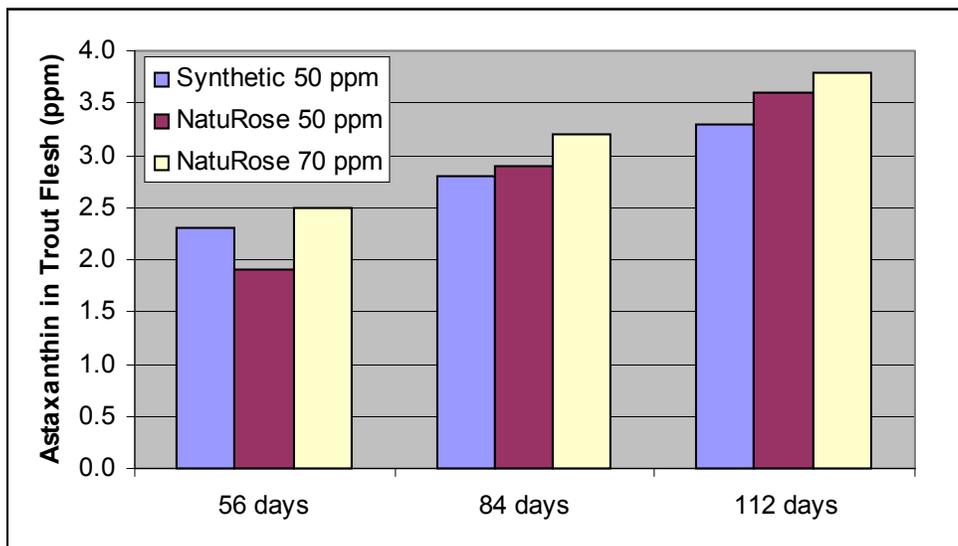


Figure 4. Pigmentation of trout flesh as measured by HPLC after dietary supplementation with synthetic astaxanthin and two levels of NatuRose[®] natural astaxanthin from *Haematococcus pluvialis* algae.

In summary, *Haematococcus pluvialis* is an alga found worldwide that produces high concentrations of astaxanthin for use in aquaculture feeds. *Haematococcus* algae meal provides a minimum of 1.5% astaxanthin in an esterified form similar to that from krill and crawfish. A manufacturing process must crack cells to ensure maximum bioavailability. Studies have proven that *Haematococcus* algae meal is an efficacious source of astaxanthin, is safe, and has never been associated with toxicity in the reported literature or field studies.

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