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Health & Welfare

Genetics, environment define crustacean color

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By Nicholas M. Wade, Ph.D.

Color helps avoid predation

In crustaceans such as the tropical rock lobster, the diverse shell colors and intricate patterns are produced by an interaction between the protein crustacyanin and carotenoid astaxanthin. Once cooked, as shown at the bottom, this interaction is destroyed, and the red carotenoid is released.

The familiar red coloration that consumers highly desire in cooked seafood is produced by the carotenoid astaxanthin. Astaxanthin can be modified for storage and also converted to other closely related carotenoids.

Like many animals, crustaceans cannot synthesize carotenoids and must obtain them from their diets. Consequently, in aquaculture, synthetic astaxanthin supplements form a substantial cost component of commercial shrimp feeds.

As well as performing a coloration function, carotenoids are strong antioxidants that have a role in maintaining general health. Dietary carotenoid levels have been determined for improved health and coloration in many species, although the process of absorption and transport of carotenoids in animals, particularly crustaceans, is generally poorly understood.

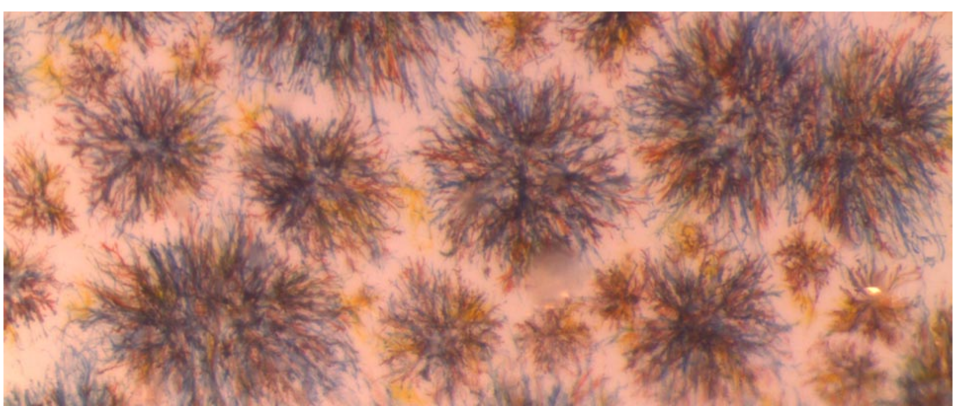
The mechanisms for carotenoid uptake, movement and storage in shrimp represent a key area that requires further research, but also provides a clear area for improvement to consistently produce optimally colored, higher-value animals.

Color and environment

Decapod crustaceans are able to adapt the intensity of their coloration to the color of their environments. Through an extensively studied system of hormones secreted from the eyestalk, within hours they can expand or contract specialized pigment structures called chromatophores. Some species of shrimp are particularly adept at this process, with the color of their expanded or contracted chromatophores clearly visible through their thin outer shells.

Species with hard, calcified shells, such as crabs and lobsters, have chromatophores and are able to respond to their background environments in a similar way, but in a slower and more limited capacity. For all crustaceans, color provides a means of protective coloration to avoid predation, but for consumers, marked coloration of the cooked product attracts a premium market price.

Although not yet tested, variability in the color of earthen ponds may explain some of the variability in harvested shrimp across ponds or farms. However, incorporating a dark background color treatment just prior to or during harvesting of cultured shrimp may provide a means to maximize the consistency and intensity of coloration and therefore enhance the value of farmed animals.



In this magnified view, shrimp pigment structures called chromatophores have expanded in response to a black background. However, the number, color and patterning of chromatophores do not change and are genetically determined in each species.

Unique mechanism

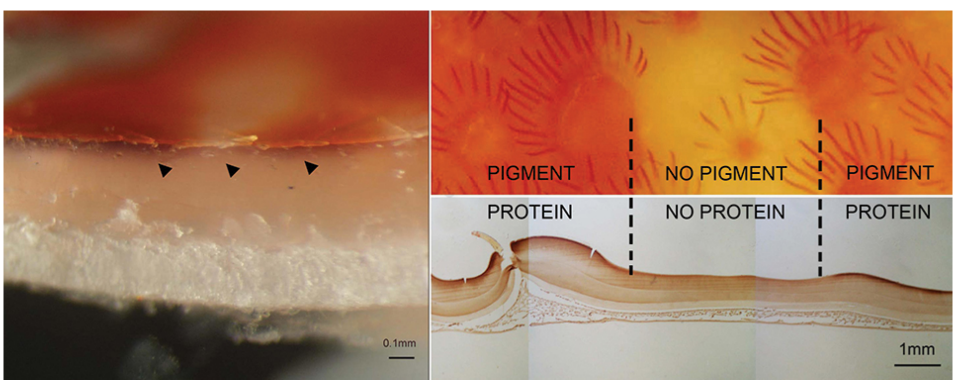
A protein called crustacyanin forms a specific interaction with the carotenoid astaxanthin. This interaction changes the color of astaxanthin from red to any other color in the visible spectrum. In combination, this protein and carotenoid form a simple “one molecule, many colors” system that is responsible for most of the external colors seen on crustacean shells. However, this interaction is easily disrupted, as seen upon heating during cooking, when the original red coloration of the carotenoid is released.

In a recent survey of a range of organisms, crustacyanin was exclusively found in crustaceans like shrimp, crabs and lobsters. Furthermore, the presence of crustacyanin was shown to specify the color and precise patterning of the animals’ shells. This means these crustaceans have a unique mechanism of producing their color and intricate shell patterns that is not found in any other group of animals. Their colors and patterns are genetically determined, consistently recreated across each molt as they grow, and play a major role in protective camouflage, communication, mate selection and potentially speciation.

Color and genetics

Understanding the genetic regulation of crustacean coloration provides a unique avenue to maximize the efficiency of this process in aquaculture. Stimulating or selecting for animals with consistently high expression of the crustacyanin gene may provide a more powerful means to manipulate external color and also ensure that color is consistent across a large number of animals irrespective of or in combination with environmental influences.

Other genetic improvements can be made by selecting animals that absorb carotenoids more efficiently. Maximizing the uptake and utilization of carotenoids would potentially decrease the carotenoid requirement in crustacean diets.



In a close-up view through a lobster shell (A), color patterns form on the very outer edge of the hard, calcified shell. These regions of color, which create patterns such as the stripe in B, contain the protein crustacyanin in red areas but not in white areas (as shown with a specific stain in C) and are not simply due to the presence or absence of the carotenoid.

Perspectives

Crustacean color is produced by the combination of diet, environment and genetics. Dietary carotenoid intake and background substrate both affect the intensity of the animals' color, but underlying genetics determine the exact color and patterning the animals display. Without the presence of the crustacyanin protein, neither diet nor background affect crustacean color.

Editor's note: This article was based on "Evolution of a Novel Carotenoid-Binding Protein Responsible for Crustacean Shell Colour," an article by the author recently published in Molecular Biology and Evolution.

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Author

NICHOLAS M. WADE, PH.D.

CSIRO Food Futures National Research Program
CSIRO Marine and Atmospheric Research
P. O. Box 120
Cleveland, Queensland 4163 Australia

nick.wade@csiro.au (mailto:nick.wade@csiro.au)