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Review Article

The Color of Marine Shrimps and Its Role in the Aquaculture

Abstract

In the present review, we have described aspects of the color of marine shrimp of importance in aquaculture (mainly *Penaeus japonicus, Litopenaeus vannamei and Penaeus monodon)* and in the world. It is generally described some ecological aspects and some factors that affect the color of the shrimp. It describes in a general way, ecological aspects and some factors that affect the color of the shrimp, as well as, specific aspects like the color change, the importance of the pigments in the color and the effect of the cooking and storage processes on the color of the shrimp. As well as some strategies that have been used to improve the color during the last decades are discussed. As well as the ability to select genetic lines of color shrimp.

Abbreviations

CRCN: Crustacyanin; H: Homogeneous Individuals; ST: Striped Translucent Shrimp

Introduction

The color in aquatic organisms has been studied mainly in an ecological and evolutionary context [1]. It has been found that color is perceived by aquatic organisms differently than humans, so this has motivated effort to quantify both color traits and their visual environments [2]. Color traits are studied for understanding morphological adaptation, visual orientation, communication, and deception as well as for exploring processes such as speciation and mimicry or camouflage [3].

The yellow, orange and red pigmentation, present in aquatic organisms is mostly caused by carotenoids [4]. They occur in free form, esters, glycosides, sulfates and carotenoproteins and the oxidized derivatives are called xanthophylls [5]. Among the 750 reported carotenoids found in nature, more than 250 are of marine origin. Marine animals contain carotenoids that show structural diversity [6]. In general, marine animals (as Crustaceans) do not synthesize carotenoids *de novo*, and so those found in shrimp are either directly accumulated from food or partly modified through metabolic reactions [5]. Carotenoids are confined to certain microorganisms, fungi, algae, and higher plant exclusively [7]. Shrimp can synthesize astaxanthin from precursors as β-carotene into astaxanthin or astaxanthin into astaxanthin esters ingested from dietary sources. Free astaxanthin in shrimp is bound within a multimeric protein called CRCN [8]. CRCN is widespread amongst crustaceans, producing the dark blue/slate colorations of the carapace which is common in this phylum [9]. The interaction of CRCN and astaxanthin produce the naturally red carotenoid to blue or any other color, producing the diverse array of colors in the shrimp [10]. Crustaceans present a wide range of species-specific colors and patterns, which are used for protection through cryptic coloration, reproduction, and communication [11]. The color plays a role in consumer acceptability, perceived quality and price paid for commercial crustacean species [12] mainly *L. vannamei* currently (Figure 1). This color may be in the exoskeleton or structures in pigments within the underlying hypodermic layer known as chromatophores [13]. The amount and distribution of pigment are dependent of dietary, environmental and genetic factors [14]. The main purpose of this study was to review the importance of color in the marine shrimps that are cultivated in ponds in the world. It examined the ecological, evolutionary and practical bases and aspects of importance in the marketing of shrimp.

Discussion

Ecological aspects in shrimp color

The habitats of shrimp are very heterogeneous and exhibit

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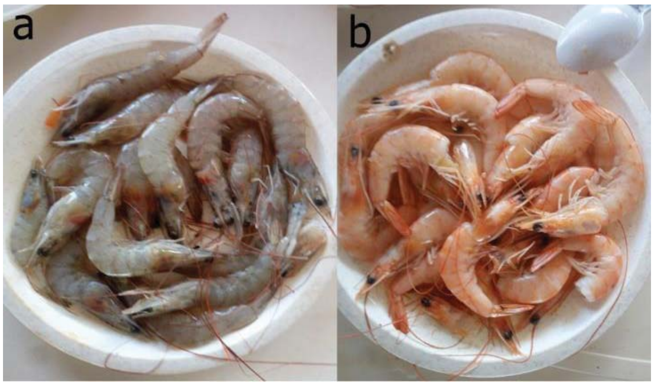

Figure 1: Common presentation of white shrimp *L. vannamei* (a) Fresh shrimp; (b) Cooked shrimp.

wide diversity in color, brightness, and pattern. It has been found that decapod crustaceans among other invertebrates have the ability to change color in short and long time, in the first case in seconds, minutes and hours, and in the second associated with phenotypic plasticity and development [15,16]. The main function is to reduce the risk of detection and recognition to be depredated through camouflage [17].

It has been found that marine shrimps present two strategies mainly of morpho-specific camouflage (based on color and polymorphism) and habitat selection, which can be classified as H with different coloration, more trends greenish-brown or pink, and ST [18]. The shrimp of the genus *Penaeus* and *Litopenaeus* belong to category H, where camouflage utilizes a strategy specialized to a limited number of backgrounds at any time. They are capable of changing color in just a few days towards to the type of background in which they are and the affinity of habitats higher for H shrimp, whereas swimming activity is higher for the ST morph, which indicates that strategy H shrimp tend to have a more benign life-style [18]. It is known that shrimps are able to change body color in relation to environmental conditions [19].

Color change

The color changes are under control of eyestalk hormones, they are rapid, reversible and rhythmic [13,14]. Others are slower and more permanent, with modifications of exoskeletal pigment composition or concentration. Several questions have been raised about the nature, mechanisms, evolution, and adaptive value of color changes and plasticity for concealment [17]. Color changes in shrimp are due to several reasons including camouflage, thermoregulation, signals, stress and ultraviolet light protection. In most shrimp the color change can involve physiological processes involving the contraction and dispersion of pigments within the chromatophore cells [20]. Most of the studies have focused on the physiological processes, functional and ecological aspects, and scarcely on pigmentation patterns and the importance of color in the commercialization of the main species of culture in the world [17,21], due to increased consumer acceptance, improved product quality and price paid for commercial shrimp species [22,23], with dark red colored shrimp attracting premium prices.

Color and pigments

The colors of aquatic animals are derived from natural compounds such as chlorophyll, porphyrins, and carotenoids. Shrimp color is largely dependent on the amount of pigment (mainly astaxanthin) present in the exoskeleton and the epidermal layer [24]. Shrimp pigmentation is influenced by the interaction of several factors, among which is the amount of dietary carotenoid, the distribution of hypodermal pigments, background substrate color, photoperiod, light intensity, stress, temperature, heavy metals (mainly copper) and genetics [15,25,26]. Body color is one of the factors that determine the quality, preference and price of shrimp [27] and the concentration of astaxanthin controls the color of the shrimp [28] and avoid damage caused by excess light [29]. Niamnuy et al. [30], determined that the degradation of astaxanthin and color was found to follow a first-order Kinetic reaction, and temperature dependence was explained by the Arrhenius relationship. In addition, adequate correlations between astaxanthin degradation and color changes were also observed.

The effect of some factors on color

Background: It has been found that diet and background color in combination affect shrimp color [15]. The shrimp growing on white substrates show poor color [31]. However when placed in dark substrate they show an intermediate color, which improves when supplying astaxanthin in the diet and short term exposure to black substrates can have positive effects on shrimp color and dietary inclusion of astaxanthin improves shrimp pigmentation [15]. The body color of *P. monodon* weakens when grown indoors [32]. A disparity in shrimp color response in different ponds to black or white substratum exposure has been found in aquaculture farms, and this may influence the shrimp response to the color of the substrate [25]. An animal that is dark may not present a strong response to dark substrates as compared to a shrimp that is less pigmented prior to exposure.

Physical and chemical stressors

The reddish color of the shrimp usually occurs by thermal effect or hypoxic stress, but the effect can be reversed when the stress is eliminated [33]. There is also the condition that redder color may result from exposure to copper and challenge the concept that highly pigmented shrimp is healthier than pale shrimp [26].

Color in cooked shrimp

When the shrimp are cooked the interaction between CRCN and astaxanthin is disrupted, which causes the different red colorings of cooked shrimp [25]. It is recommends that shrimp when harvested are kept alive prior to cooking, and the posterior salt brine application is very good at maintaining color and flavor. Wade et al. [25], found that post-cooking storage in ice was having minimal, if not a slightly beneficial, effect on prawn color.

Color of dried shrimp during storage

The production of dried shrimp consists of three steps:

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boiling shrimp in salt solution, drying and storage [30]. It has been found that shrimp dried by vacuum drying had greater astaxanthin content than that dried by hot air drying [34]. Drying at 70 °C was recommended because the color and sensory quality of the dried shrimp were most acceptable [35]. The first-order kinetic model was the best fit for the astaxanthin degradation and all color changes data. The increase in lightness and decrease in redness and yellowness of dried shrimp correlated well with the loss of astaxanthin during storage [30]. So there is a relationship between astaxanthin degradation and color changes.

Strategy to improve color

A common practice to improve shrimp color is through supplement of synthetic astaxanthin in the diets [5]. Several other rearing and harvesting factors (particularly pre- and post-slaughter conditions) such as transportation, color of holding containers, handling, conditioning, fasting, killing method, chilling and storage may have influence on shrimp color [6]. In contrast to the abundant evidence that shrimp color can be improved through manipulation of environmental factors and husbandry practices, there has been a paucity of scientific research in quantitative genetic aspects of shrimp color.

The color in shrimp can be improved by supplying astaxanthin in the diet, by the abundance of epithelial and astaxanthin esters [36]. Shrimp have the metabolic ability to convert canthaxanthin and ß-carotene, into astaxanthin [37]. In general, astaxanthin supplementation between 25 and 100 mg/kg in the feed for about one month has been found to produce adequate pigmentation for commercialization of several species of shrimp such as *P. japonicus*, *L. vannamei* and *P. monodon* [15, 38-40]. The krill oil / meal, crawfish oil, *Pleuroncodes* red cab, *Phaffia* yeast, *Haematococcus pluvialis* microalgae, *Capsicum* paprika, *Tagetes* marigold, and Carophyll Pink synthetic astaxanthin are used alone or combined as carotenoids in shrimp feeds. Consumer demand for natural products makes synthetic pigments much less desirable. The accumulation of carotenoids and the formation of specific axon fatty acid esters are related to the metabolism, storage, mobilization or deposition of astaxanthin within various tissues [40].

Color and genetic selection

The body color of the shrimp can respond positively to genetic selection [41]. Selection for dark color is also expected to increase redness of cooked shrimp. The association of body color of raw and cooked shrimp with morphometric traits was positive, suggesting that both body color and morphometric traits can be improved in breeding programs [41].

Conclusion

Color changes in shrimp are due to several reasons including camouflage, thermoregulation, signals, stress and ultraviolet light protection. Carotenoids are used for pigmentation in aquaculture shrimp. Synthetic and natural astaxanthin from *Phaffia* yeast, *Haematococcus* algae and Lutein from marigold is widely used for the pigmentation of marine shrimp, among other natural colorants. The color in shrimp can be improved by supplying astaxanthin in the diet, by the abundance of epithelial and astaxanthin esters. It is recommends that shrimp when harvested are kept alive prior to cooking, and the posterior salt brine application is very good at maintaining color and flavor. New carotenoids can still be found to pigment marine shrimp and body color and morphometric traits can be improved in breeding programs.

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