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Food Modulation Controls Astaxanthin Accumulation in Eggs of the Sea Urchin *Arbacia lixula*

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Abstract: The carotenoid astaxanthin has strong antioxidant properties with beneficial effects for various degenerative diseases. This carotenoid is produced by some microalgae species when cultivated in particular conditions, and, interestingly, it is a predominant carotenoid in aquatic animals throughout a broad range of taxa. Recently, astaxanthin was detected in the eggs of the sea urchin *Arbacia lixula* in relevant concentrations when this organism was maintained in culture. These results have paved the way for deeper research into astaxanthin production by this species, particularly in regards to how astaxanthin production can be modulated by diet. Results showed that the highest content of astaxanthin in eggs was observed in sea urchins fed on a diet enriched with *Spirulina platensis*. This result was confirmed by the high antioxidant activity recorded in the egg extracts of these animals. Our results suggest that (i) the sea urchin *A. lixula* is able to synthesize astaxanthin from precursors obtained from food, and (ii) it is possible to modulate the astaxanthin accumulation in sea urchin eggs by modifying the proportions of different food ingredients provided in their diet. This study demonstrates the large potential of sea urchin cultivation for the eco-sustainable production of healthy supplements for nutraceutical applications.

Keywords: food enrichment; aquaculture; nutraceutical; astaxanthin; *Arbacia lixula*

1. Introduction

Marine photosynthetic organisms produce secondary metabolites that can be considered high-value bioproducts with beneficial effects for human health. Algae-derived products possess antioxidant properties, as well as anticancer and antimicrobial activities [1]. In particular, the red ketocarotenoid astaxanthin (3,3′-dihydroxy-carotene-4,4′-dione) is known as a highly biologically active molecule, and for this reason, it is significantly dominating the health care and aquaculture market. The high astaxanthin market request is due to its multiple known health benefits, from its pronounced antioxidant activity, to the most recent discovery of astaxanthin's roles as an antidepressant, and in the prevention of UVA-induced skin photoaging [2,3]. Currently, commercial astaxanthin is mainly chemically synthesized, but it is also extracted from natural producers, such as the green algae *Haematococcus pluvialis*, the genetically mutated yeast *Xanthophyllomyces dendrorhous* (*Phaffia rhodozyma*), the bacteria *Paracoccus carotinifaciens* and *Lactobacillus* sp., and crustacean exoskeletons collected from shrimp processing waste [4,5]. However, among the aforementioned natural sources, only astaxanthin produced from *H. pluvialis* is accepted and guaranteed for human consumption. On the other hand,