The erosion of high tidal mudflats along GoK was observed to be confined along the northern periphery of the tidal channel linking the gulf with Mahi River. The tidal channels along this region made meanders and the outer banks of the meandering tidal channel have strong current velocities with a potential to erode the coast along its outer periphery. These strong tidal currents along the outer periphery of meanders had possibly initiated the erosion by carving the high tidal mudflats and further causing the tidal channels to migrate landwards.

The massive erosion resulted in extensive changes of the geomorphology along the study region (Figure 4). Figure 5 shows the field photo of the eroded mudflat at northern GoK. The erosion created a vertical scrap of around 10 m showing the severity of the erosion.

Even though the high tidal mudflat is uninhabited, extensive erosion has led to the destruction of a large area of vital habitat. The western parts of the mudflat that were eroded during 2016, nurtured the growth of mangrove. Due to the erosion, coastal settlements near the mudflats are prone to erosion or flooding during high tide condition. Conventional coastal protection measures like seawall or groins are not recommended along the mudflat region due to its soft bottom sediments. To arrest erosion, novel approaches that can reduce the current velocity along the outer channels should be adopted by the coastal management authority.

Another major outcome of erosion is the change in regional hydrodynamics owing to the deposition of the huge volume of eroded materials elsewhere. As the study region is subjected to anthropogenic pressure and is a hotspot for major development activities, a proper study on the further stability of the mudflats, the extent of the impact of erosion, changes in the hydrodynamics of the region are essential requirements for sustainable development.

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Effect of synthetic astaxanthin, Lucantin on colour and physical quality of Indian white prawn, *Fenneropenaeus indicus*

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The effect of a synthetic source of astaxanthin, Lucantin on colour, loose shell/soft shell quality, taste and black spot formation of Indian white shrimp, *Fenneropenaeus indicus*, was studied. Supplementary feed incorporated with Lucantin red and pink at 250 ppm was fed for a period of 45 days prior to harvest. Shrimp fed with the normal feed were considered as control. Shrimp colour and quality were assessed after 15, 30 and 45 days of Lucantin feeding. Significant difference in colour was noticed between control and treatment, whereas no significant difference was observed in loose shell/soft shell and black spot formation. Lucantin is found to be a safe feed additive to improve colour in *F. indicus*.

Keywords: *Fenneropenaeus indicus*, Lucantin, shrimp quality, supplementary feed.

AQUACULTURISTS, shrimp processors and importers consider that visual appearance, especially colour, is one of the most important characteristics of shrimp in determining their selection prior to consumption[1]. Colour can

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Table 1. Shrimp qaulity after Lucantin feeding

	Control			Treatment		
	Days			Days		
Parameters	15	30	45	15	30	45
Colour (fresh shrimp)*	2.2 ± 0.3	2.4 ± 0.4	2.5 ± 0.7	2.4 ± 0.4	3.6 ± 0.6	4.2 ± 0.4
Colour (cooked shrimp)*	2.3 ± 0.1	2.3 ± 0.2	2.2 ± 0.6	2.3 ± 0.4	3.8 ± 0.5	4.4 ± 0.2
Loose shell (%)^{NS}	14.1 ± 1.1	10.3 ± 2.0	14.2 ± 2.1	13.1 ± 2.1	12.0 ± 2.4	13.3 ± 1.8
Soft shell (%)^{NS}	18.0 ± 2.2	20.2 ± 2.1	12.1 ± 2.4	17.3 ± 2.3	19.0 ± 1.5	11.4 ± 1.2
Hard shell (%)^{NS}	68.4 ± 2.8	70.4 ± 3.2	74.6 ± 3.1	70.2 ± 4.1	70.0 ± 3.3	75.4 ± 4.2
Taste^{NS}	2.7 ± 0.4	3.2 ± 0.3	3.4 ± 0.4	2.8 ± 0.3	3.3 ± 0.5	3.3 ± 0.7

*$P < 0.01$; $^{NS}P > 0.01$ ($n = 100$).
Grade score: 1, Bland; 2, Moderate; 3, Good; 4, Very Good and 5, Excellent.

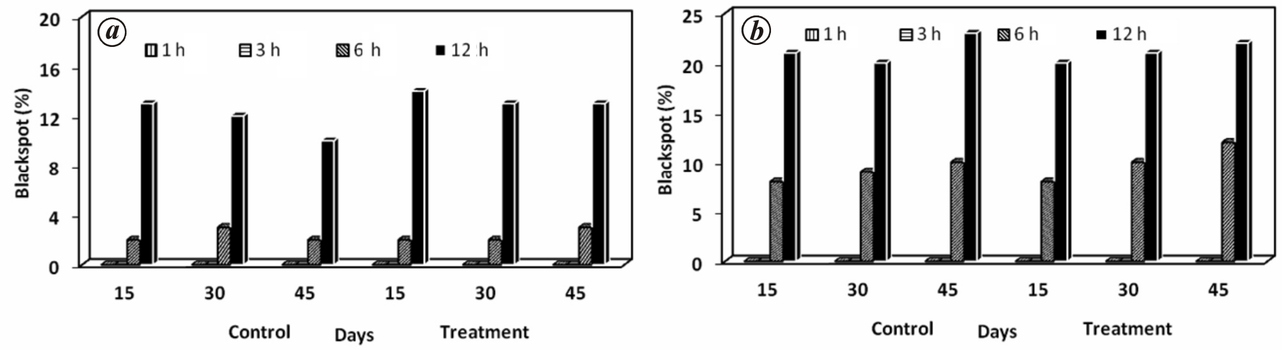

Figure 1. Black spot formation on (***a***) fresh shrimp; (***b***) frozen (one month) shrimp.

significantly impact the price of shrimp, with darker red and bright coloured shrimp preferred in a number of global markets[2,3]. Astaxanthin is a carotenoid pigment found naturally in micro algae and krill plays a significant role in colour development in shrimp[4,5]. Studies have shown that astaxanthin content of penaeids can be increased through supplementary food containing different carotenoids[3,6]. It acts not only as a colouring agent, but also as antioxidant to develop immunity in shrimp[7,8]. Many commercially available synthetic substances are used as exogenic colouring pigments for aquatic animals[6]. Lucantin (BASF, Germany) is a synthetic source of astaxanthin used in aquaculture sector to improve colour of shrimp and fish. Considering the importance of astaxanthin in colour development, a study was conducted to evaluate the efficiency of Lucantin (synthetic Astaxanthin) on colour and physical quality of Indian white prawn, *Fenneropenaeus indicus*, an ideal candidate species for coastal aquaculture.

Semi-extensive culture experiment was conducted in earthen ponds (1 ha) at the National Aquaculture Group (NAQUA), Al Lith, Saudi Arabia for a period of 105 days. The study had control and treatment groups and they were triplicated. After pond preparation and water culture, post larvae of uniform size (PL20) were stocked at the rate of 30 pcs/m^2 in each pond and reared by feeding a supplementary pellet feed having 35% protein in the diet (NAQUA shrimp feed). Lucantin pink and red (BASF, Germany) was incorporated in the feed at 250 ppm each and fed to the shrimp for 45 days from DOC (days of culture) 60 onwards. Ponds provided with standard feed were considered as control, whereas ponds with the feed containing Lucantin were designated as treatment.

Feeding and rearing were done according to the standard operating procedure of the farm. Quality check for colour, loose shell/soft shell, taste and black spot formation of control and treatment shrimp was done from 15, 30 and 45 days of Lucantin feeding. Upon harvest, samples were collected and processed by semi-intensive quick freezing (SIQF) method for shrimp quality evaluation after one month of cold storage. Shrimp quality test (colour of fresh and cooked shrimp, soft/loose shell and taste) was done by a panel of experts (10 members) based on a grade score. For the observation of black spot formation, shrimp samples were processed by treating with sodium metabisulphite (5 ppm) in the NAQUA (Jeddah) processing plant. After processing, samples were kept in cold storage (–20°C) for one month. Black spot observation was carried out at the end of 1, 3, 6 and 12 h of exposure at room temperature (22°C). One-way analysis of variance (ANOVA) was employed to find the statistical difference in colour, shrimp quality and black spot formation between control and treatment shrimp.

Table 1 presents details on shrimp colour and quality. Colour of shrimp (fresh and cooked) was found significantly ($P < 0.01$) increased in treatment ponds when compared to control. High score for colour was observed in shrimp fed with Lucantin for 45 days than for 30 and 15 days. There was no significant difference ($P > 0.01$) in shrimp quality (loose shell, soft shell, hard shell and taste) between control and treatment. Similarly, significant difference in black spot formation was not found on fresh shrimp between control and treatment and also after one month of cold storage (Figure 1 *a* and *b*).

In crustaceans such as shrimp, a bright and appropriate colour is associated with freshness and quality, and the desired coloration shall be preserved through storage, processing and cooking[2,9]. With increasing industrialization in shrimp farming, there is a growing demand for synthetic, nature-identical carotenoids, not only for pigmentation, but also for the maintenance of growth[1,9]. Pigmentation is one of the important quality attributes of aquatic animals for consumer acceptability[10]. In crustaceans, the basic nature of body coloration relies on specific pigments present in the sub-epidermal chromatophores or in the principal layer of the animal's exoskeleton[11]. Reports have shown that synthetic astaxanthin and carotenoids improved colour in *Penaeus semisulcatus* and *Penaeus japonicus* when supplemented for 30 and 40 days[6,12,13]. Dietary astaxanthin enhanced growth and survival in Pacific white shrimp, *Litopenaeus vannamei*, this was due to its antioxidant proterties[4,14]. Results of the present study indicate that dietary incorporation of Lucantin could improve colour on fresh as well as cooked shrimp. It did not affect the quality or black spot formation on shrimp. However, growth and survival of shrimp are not influenced by Lucantin feeding. This may be due to the difference in culture conditions and species specificity.

Since aquaculture feed industry is looking forward to have an ecofriendly colouring substance for improving colour, there is great potential for the use of natural plant-based carotenoids for pigmentation. Therefore, further studies are required to elucidate the antioxidant property of Lucantin in *F. indicus*.

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