Shell colour variation in farmed *Litopenaeus vannamei*: Comparison of white shell (regular) and brown shell (unusual) *L. vannamei*

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The introduction of Pacific white shrimp, *Litopenaeus vannamei* and its exponential farming has resulted in substantial increase in the quantity of frozen shrimp exported by India[1] (Arathy et al., 2015). Colour is an important factor that determines the consumers' selection of food[2] (Stahl, 2012) and carotenoids are responsible for pigmentation in crustaceans. Colour of the shrimp is largely influenced by a multiplicity of pigment, feed, animal and disease and environmental factors[3,4]. The regular shell colour of farmed *L. vannamei* is off-white to greenish-white but instances of *L. vannamei* with brown-shell colour do occur in farmed shrimp (Figure 1, 2a). Physically, except for colour, the white shell vannamei and brown shell vannamei appear similar.

A study was conducted to determine if there were differences in the white shell and brown shell shrimp vis-à-vis shell colour, meat colour, meat composition and meat texture. White-shell vannamei (n=10) and brown shell vannamei (n=10), harvested from a shrimp culture farm in Andhra Pradesh, India were randomly picked and transported at <4°C to the laboratory and analysed.

Colour analysis of white shell vannamei and brown shell vannamei

The L* (lightness), a* (positive value =red, negative value=green), b* (positive value=yellow, negative value=blue) values were measured using colorimeter (ColorFlex EZ, Hunter Lab). The shell colour of raw and cooked white shell vannamei and brown shell vannamei was determined. Raw white shell vannamei and brown shell vannamei shrimp (each type, n=5) were peeled and the peeled shells were used for colour analysis. Whole white shell vannamei and brown shell vannamei shrimp (each type, n=5) were cooked for 5 min, peeled and the cooked and peeled shells were used for colour analysis.

Cooked shells

A major difference in the redness (a*) value and very minor difference in lightness (L*) and yellowness (b*) values was observed between white shell vannamei and brown shell vannamei. The result of colour analysis indicate that redness (a*) was significantly higher (P<0.05) in brown shell vannamei, both for raw shell (7.9 ±0.3) and cooked shell (17.9 ±0.8) compared to white shell vannamei (4.8 ±0.3 for raw; 14.4 ±1.6 for cooked) indicating distinct colour difference between the two shell types of vannamei shrimps (Table 1).

The main carotenoid pigment responsible for the colour of shrimp is astaxanthin ie 3,3 dihydroxy β-carotene 4,4-dione[5,6]. In live shrimp, astaxanthin is bound to a protein, crustacyanin as astaxanthin-crustacyanin complex and gives a blue-green colour to the shrimp shell. However, the complex is not heat-stable and becomes disassociated up on cooking and releases astaxanthin which makes the cooked shrimp shell appear red in colour. Pigment content in the shrimp

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exoskeleton is always higher than on the abdominal muscle[7]. The result of colour analysis of shrimp meat indicate that a* value (redness) was significantly higher (P<0.05) for brown shell vannamei, both for raw meat (9.1 ±0.5) and cooked meat (26.0 ± 2.3) compared to white shell vannamei (2.7 ±0.2 for raw meat; 16.81 ±0.8 for cooked meat) indicating distinct colour difference in the meat of the two shell types of vannamei (Table 2). Lightness (L*) values of the meat of white shell vannamei and brown shell vannamei did not differ but a significant difference (P<0.05) was observed for yellowness (b*) value. Based on the results, it can be inferred that brown shell vannamei yield a brighter red coloured cooked shrimp product compared to white-shell vannamei shrimp.

Meat composition and texture profile analysis of white shell vannamei and brown shell vannamei

Figure 2. Shell colour variation in raw and cooked farmed Litopenaeus vannamei. A. Raw brown shell vannamei (top), raw white shell vannamei (bottom). B. Cooked brown shell vannamei (left), cooked white shell vannamei (right).

Protein, fat, calcium, potassium, and sodium content of white shell vannamei and brown shell vannamei were determined as per standard methods[8]. Texture profile analysis[9] was performed at room temperature employing a food texture analyser (Lloyd Instruments, UK), equipped with a load cell of 50N. Texture measurement were performed on shrimp meat, compressed twice by a cylindrical probe having a diameter of 50 mm and a test speed of 12 mm/min. Hardness, springiness, adhesion and cohesion are the basic mechanical variables that characterise texture of food.

The results of meat composition analysis (Table 3) indicate that the white shell vannamei had a higher content of sodium (552 mg%) and calcium (264mg%) compared to brown shell vannamei (sodium 331mg%; calcium 188mg%) indicating that mineral imbalance might be a possible reason for the difference in shell colour of vannamei. The meat characteristics as indicated by texture profile analysis (Table 3) showed that white shell vannamei has better texture as indicated by relatively higher values for hardness 1 (13.47N), hardness 2 (7.33 N) and chewiness (11.34 Nmm) compared to brown shell vannamei. The softer texture of brown shell vannamei indicates that these shrimp might have been under certain stress. Several factors were known to influence redness in shrimp. Shrimp become more reddish in colour when infected by a wide range of organisms or when exposed to toxic conditions, which is thought to be due to the release of carotenoid pigments that are normally stored in hepatopancreas[10]. Martinez et al. (2014)[11] demonstrated that redder colour in shrimps may result from exposure to copper. Metals such as cadmium, copper, lead and mercury combine with astaxanthin and form novel complexes that are redder in appearance[12]. Carotenoid supplementation in the diet of *L. vannamei* resulted in redder individuals[13]. Further studies are needed to ascertain the stressors responsible for the variation in shell colour of farmed *L. vannamei*.

Conclusion

Comparison of white shell vannamei (regular) and brown shell vannamei indicate that white shell vannamei was better in meat composition and texture profile but brown shell vannamei yielded bright red coloured cooked product.

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Table 1. Colour values of the raw and cooked shells of white- and brown-shell vannamei

	White shell vannamei		Brown shell vannamei	
	Raw shell	Cooked shell	Raw shell	Cooked shell
L* (Lightness)	37.1 ±1.4a	50.0 ± 2.3b	36.9 ±2.1a	49.2 ±0.8b
a* (Redness)	4.8 ±0.3a	14.4 ±1.6c	7.9 ±0.3b	17.9 ±0.8d
b* (Yellowness)	10.2 ±0.8a	16.5 ±0.7b	9.8 ±0.5a	17.1 ±0.8b

n=5; mean±SD. Values within a row with different superscript letters are significantly different (P<0.05).

Table 2. Colour values of raw and cooked meat of white- and brown-shell vannamei

	White shell vannamei		Brown shell vannamei	
	Raw meat	Cooked meat	Raw meat	Cooked meat
L* (Lightness)	43.8 ±1.7a	64.2 ±0.9b	45.7 ± 0.2a	63.5 ±2.1b
a* (Redness)	2.7 ±0.2a	16.81 ±0.8c	9.1 ±0.5b	26.0 ± 2.3d
b* (Yellowness)	6.5 ±0.2a	21.6 ±0.3c	9.3 ±0.3b	23.6 ±1.7d

n=5; mean±SD. Values within a row with different superscript letters are significantly different (P<0.05).

Table 3: Meat composition and texture profile analysis of the white- and brown-shell vannamei shrimp (raw).

	White shell -vannamei	Brown shell –vannamei
Protein, %	24.09	21.03
Fat, %	3.28	3.82
Sodium, mg/100g	552.18	331.12
Potassium, mg/100g	1131.67	1129.14
Calcium, mg/100g	263.95	188.74
Hardness 1 (N)	13.47	8.477
Hardness 2 (N)	7.33	4.847
Springiness (mm)	3.5	3.0
Cohesiveness	0.239	0.229
Adhesiveness (kgf.mm)	0.011	0.005
Chewiness (Nmm)	11.34	5.68

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Shell Colour variation in raw and cooked farmed Litopenaeus vannamei a)Raw Brown shell-vannamei (top) Raw White shell-vannamei (bottom).