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Quality Characteristics of Blue Swimming Crab (*Portunus pelagicus*, Linnaeus 1758) Meat Fed *Gracilaria edulis* (Gmelin) Silva

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ABSTRACT

This research aimed to study the growth and meat quality of blue swimming crab fed with different diets. The possibility of using red seaweed as a food-stuff or as supplementary food for cultures of blue swimming crabs was studied. Crabs, with an initial weight of 25 g on average, after 8 weeks of being fed with chopped fish had the highest weight gain (128.64%), crabs fed with moist pellets had the highest survival rate (90.00%) and crabs fed with red seaweed had a composition determined by proximate analysis that was lower than the other diets, but the contents of cholesterol (358.99 mg/100 g dry weight) as well as arginine and methionine were higher than the others (1.59 and 0.33 g/100g, respectively) ($P \leq 0.05$). The fatty acid profile was significantly different for stearic acid, linoleic acid and lignoceric acid ($P \leq 0.05$). The color of the meat from various parts of the crab was significantly different. Meat from crabs fed with red seaweed showed the lowest lightness but the highest redness. Crabs fed with moist pellets had the toughest meat (9.35 N). Nevertheless, no significant differences in taste, odor or texture of crab meat were found.

Key words: blue swimming crab, *Portunus pelagicus*, *Gracilaria edulis*, quality characteristics, red seaweed

INTRODUCTION

Blue swimming crab (*Portunus pelagicus*, Linnaeus 1758) is found throughout the Andaman Sea and the Gulf of Thailand. Up until the last few years, blue swimming crab for consumption and for use as a raw material in the processing industry were caught from the sea. In 2004, the production of blue swimming crabs was 29,500 tons a decrease of 8.67%, compared with production in 2003 and the downward trend has been continuing (Department of Fisheries, 2005). Therefore, the aetificial culture of blue swimming crab was considered as the way to increase the production of blue swimming crab that would solve the problems associated with catching blue swimming crab from the sea (Tiensongrasamee, 2004).

To succeed in feeding crabs, it is necessary to have satisfactory culture conditions, access to a suitable foodstock of ingredients that assist good growth, as well as a knowledge of how feeding affects the quality of the crab. Different food ingredients for the mud crab (*Scylla serrata*)

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have been tested by Prinpanapong and Youngwanichsaed (1992) and How-Cheong *et al*. (1992). There was also some information on feeding Chinese hairy crab (*Eriocheir sinensis*) with different protein levels and different sources of lipid that affected their growth performance and reproduction response (Mu *et al*., 1998 and Wen *et al*., 2002).

The culture and growth of blue swimming crab (*P. pelagicus*) has been extensively investigated (Jiampreecha and Chantarasri, 1980; Yoodee, 1981; Tuntikul, 1983; Singhagraiwan, 1989 and Ngansakul and Pimoljinda, 1994), but information on the crab's meat quality in chemical, physical and sensory terms lacking. The aims of this experiment were to: study the growth of the blue swimming crab (*P. pelagicus*); study the qualitative characteristics of crab fed with red seaweed (*Gracilaria edulis*) and the possibility of using red seaweed as a foodstock or supplementary food for the cultured blue swimming crab to decrease the cost of feeding; and improve the meat quality of the crab.

MATERIALS AND METHODS

Diets

Four diets consisting of chopped fish, moist pellets, moist pellets with *G. edulis* and only *G. edulis* were used. The determined by proximate analysis composition of the experimental diets is shown in Table 1.

Growth trials

The blue swimming crabs, *P. pelagicus*, from the Klongwan Fisheries Research Station, Prachuapkhirikhan province, Thailand (initial weight 25 g on average) were reared in experimental concrete tanks (2×4×1) filled to a depth of 60 cm with aerated seawater. One hundred and twenty were reared in each treatment.

Water temperature, salinity, dissolved oxygen, pH and alkalinity were measured daily. Water temperature ranged from 22.5 to 30.5 °C, salinity ranged from 25 to 30 %, dissolved oxygen ranged from 6.4 to 8.4 mg/l, pH ranged from 7.7 to 8.4 and alkalinity ranged from 76.5 to 153 mg/l. Other materials (PVC tube, plastic net etc.) were put in the tanks to provide shelter for the crabs. All groups were hand-fed with their respective diets twice daily at 8.00 a.m. and 4.00 p.m.

All tanks were cleaned daily in the morning by replacing waste water and scum containing waste material and exuviae. Any dead crabs that were visible were immediately removed and recorded.

Every seven days, the crabs in each tank were counted and weighed as a group to follow their growth and food intake. When the crabs were removed, the tanks were thoroughly cleaned, waste water was drained and refilled with clean water. The duration of the experiment was 8 weeks. At the end of the trial, weight gain, the specific growth rate (SGR), protein efficiency ratio (PER) and feed conversion ratio (FCR) were calculated.

Table 1 Composition of the experimental diets. (determined by proximate analysis)

Diets	Composition (% dry weight)					Moisture	Energy (kcal/100g DM)
	Protein	Lipid	Fiber	Ash	NFE		
1 (Chopped fish)	68.95	2.92	-	11.66	15.94	75.72	345.30
2 (Moist pellets)	45.95	9.69	-	14.52	29.84	31.67	344.87
3 (Moist pellets with seaweed)	42.30	8.76	0.69	15.66	32.60	37.06	330.54
4 (*G. edulis*)	9.40	0.37	6.87	25.88	57.48	85.60	201.50

Chemical composition analysis

At the termination of the experiment, crabs were analysed for tissue composition involving: moisture, crude protein, ash and lipids according to AOAC. (2000). Fatty acid composition was analyzed by gas chromatography, Variance Model 3800. Total cholesterol was analyzed by gas chromatography and amino acid composition was analyzed by an amino acid analyzer.

Physical measurement

Crabs from each dietary treatment were investigated for the colorimetric measurement by using a Chroma Meter, Minolta Model CM-3500d Four parts of the crab (claws, legs, chunks and flakes) were steamed for 10 minutes prior to measurement. The data were presented in the *L* a* b** system, representing lightness, redness and yellowness as indicated by CIE (1986).

Samples of meat from crabs' claws in each dietary treatment were investigated for toughness using a Texture analyzer Stable Micro System Model TA-HD to measure toughness (Newton) and a Warner-Bratzler blade (speed: 5 mm/s) for cutting the claw into two pieces.

Sensory evaluation

Cooked crab meat from each dietary treatment was assessed for sensory evaluation by seven trained panelists, who evaluated the meats using a multi-sample test and descriptive tests. The multi-sample test aimed to discriminate among diets and then the descriptive test was used to evaluate the following sensory attributes: appearance (color, meat appearance), texture (firmness, juiciness), odor, flavor (salty, sweet) and overall acceptance.

Statistical analysis

Data were analyzed by a one way ANOVA test and Duncan's multiple range tests to determine the differences among the treatment means. Results were considered statistically significant at the 0.05 level. SPSS software version 14.0 was used.

RESULTS AND DISCUSSIONS

Growth

Changes in crab weights in all treatments over the entire period are shown in Figure 1. The average, final weight-gain, specific growth rate,

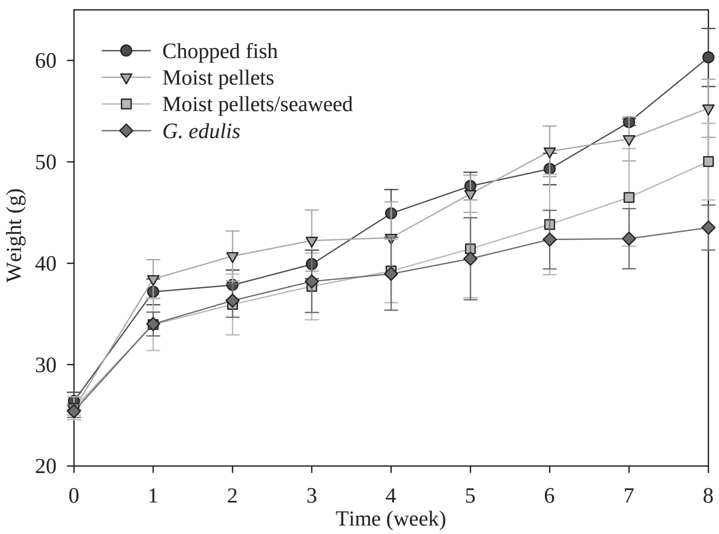

Figure 1 Weight changes in blue swimming crab fed with various experimental diets.

survival rate and utilization, are shown in Table 2. Crabs fed with a chopped fish diet had the highest weight gain and specific growth rate, but these were not significantly different from crabs fed with the moist pellets diet. However this was significantly higher than crabs fed with the moist pellets and seaweed diet as well as the seaweed *G. edulis* diet. Growth of crabs fed seaweed was the lowest, due to the low protein and fat content but high fiber of seaweed. Seaweed was less digestible than chopped fish and moist pellet because of the high fiber content.

There was a gradual decrease in survival of the crabs fed with different experimental diets during the eight week feeding period. At the end of experiment, crabs fed with the moist pellets had the highest survival (90.00%), although this was not significantly different from crabs fed with the moist pellets and seaweed (86.66%). Crabs fed with *G. edulis* had the lowest survival (74.72%), but this was not significantly different from crabs fed with chopped fish (75.83%).

The protein efficiency ratio was the best for crabs fed with chopped fish (1.98) while crabs fed with *G. edulis* had the worst protein efficiency ratio (1.21). However this ratio for crabs fed with moist pellets and for crabs fed with moist pellets and seaweed were not significantly different (P>0.05). The protein efficiency ratio in this study was similar to that in Goytortúa-Bores *et al.* (2006) for *Litopenaeus vannamei*.

Feed conversion was the best for crabs fed with the chopped fish diet (4.04) but was not significantly better than for those fed with moist pellets and moist pellets and seaweed (4.43 and 4.76 respectively). Crabs fed with the *G. edulis* diet had the worst feed conversion value (6.75), which was significantly higher than for crabs fed with the other diets. Feed conversion values in this experiment were high compared with Tiensongrasamee (2004) who reported a feed conversion of crab fed with chopped fish 3 to 3.5, but lower than for *L. vannamei* where feed conversion was in the range of 1.18 to 2.55 (Lim *et al.*, 1997 and Goytortúa-Bores *et al.*, 2006).

Chemical composition

The chemical composition of the crab meats analyzed at the end of this experiment from each of the experimental diets is shown in Table 3. The crabs fed with a *G. edulis* diet had significantly lower contents of protein and lipid (8.49 and 0.38%, respectively), but had higher contents of moisture and cholesterol than crabs fed with the other diets (84.76% and 358.99 mg/100 g dry weight, respectively) (P≤0.05). The ash content of crabs fed with moist pellets, moist pellets with seaweed and only seaweed were not

Table 2 Weight gain, specific growth rate, survival rate and utilization of blue swimming crab fed with various experimental diets[1].

Diet	Weight gain (%)	SGR[2] (% day^{-1})	Survival[3] (%)	PER[4]	FCR[5]
1 Chopped fish	128.64±8.60a	1.48±0.07a	75.83±4.17b	1.98±0.21a	4.04±0.45b
2 Moist pellets	116.13±8.39a,b	1.38±0.07a,b	90.00±5.00a	1.52±0.09b	4.43±0.27b
3 Moist pellets with seaweed	94.50±10.06b,c	1.19±0.09b	86.66±3.82a	1.50±0.16b,c	4.76±0.53b
4 *G. edulis*	71.95±18.18c	0.96±0.19c	74.72±5.42b	1.21±0.13c	6.75±1.47a

[1] Means ± SD in the same column with different superscript letters are significantly different (P≤0.05)
[2] SGR = 100 × [(final body weight – initial body weight)/duration]
[3] Survival = (Number of crabs left × 100)/number of initial crabs
[4] PER = wet weight gain/crude protein intake
[5] FCR = Dry feed intake/wet weight gain

significantly different (P>0.05), due to the fact that moist pellets and seaweed had a higher ash content than chopped fish.

The amino acid composition of crab meats in g/100 g samples is shown in Table 4. The amounts of alanine, arginine, aspartic acid and methionine in crabs fed with *G. edulis* were higher than in other crabs, but the cystine level was lower. Crabs fed with chopped fish and moist pellets had higher glycine level than in other diets.

Table 3 Chemical composition (on a wet weight basis) of meat in blue swimming crabs fed with various experimental diets[1].

Chemical composition	Treatments				
	Crabs from the sea	Chopped fish	Moist pellets	Moist pellets with seaweed	*G. edulis*
Moisture (%)	82.31±0.31b	77.16±0.55e	78.33±0.67d	80.25±1.13c	84.76±1.13a
Protein (%)	14.15±0.88a	12.24±0.66b	12.10±0.26b	10.86±0.41c	8.49±1.24d
Lipid (%)	1.03±0.08a	0.94±0.25a	0.27±0.14b	0.49±0.04b	0.38±0.18b
Ash (%)	1.79±0.17b	1.79±0.24b	2.33±0.37a	2.69±0.13a	2.51±0.20a
Carbohydrate (%)	0.72±0.64d	7.87±0.54a	6.97±1.34a,b	5.71±0.91b	3.86±1.90c
Cholesterol (mg/100g dry weight)	309.58±0.44b	263.12±0.09e	269.52±0.23d	281.42±0.14c	358.99±0.28a

[1] Means ± SD in the same row with different superscript letters are significantly different (P≤0.05)

Table 4 Amino acid compositions of meat in blue swimming crab meats fed with various experimental diets[1].

Amino acid (g/100 g sample)	Treatments				
	Crabs from the sea	Crabs fed chopped fish	Crabs fed moist pellets	Crabs fed moist pellets with seaweed	Crabs fed *G. edulis*
Alanine	0.47 ± 0.01b	0.48 ± 0.02b	0.48 ± 0.03b	0.53 ± 0.01a	0.53 ± 0.00a
Arginine	1.39 ± 0.02b	1.42 ± 0.03b	1.45 ± 0.04b	1.40 ± 0.02b	1.59 ± 0.00a
Aspartic acid	2.00 ± 0.02b	2.00 ± 0.02b	2.04 ± 0.06b	2.07 ± 0.02a	2.15 ± 0.00a
Cystine	0.70 ± 0.02a	0.71 ± 0.02a	0.70 ± 0.01a	0.74 ± 0.03a	0.46 ± 0.01b
Glutamic acidns	1.53 ± 0.01	1.60 ± 0.03	1.52 ± 0.02	1.57 ± 0.06	1.54 ± 0.01
Glycine	1.12 ± 0.02b	1.23 ± 0.04a	1.26 ± 0.05a	1.11 ± 0.01b	1.14 ± 0.00b
Histidinens	0.49 ± 0.01	0.57 ± 0.09	0.49 ± 0.01	0.45 ± 0.00	0.57 ± 0.04
Isoleucinens	0.24 ± 0.01	0.27 ± 0.01	0.25 ± 0.03	0.26 ± 0.01	0.27 ± 0.00
Leucinens	0.78 ± 0.01	0.79 ± 0.01	0.77 ± 0.02	0.73 ± 0.08	0.77 ± 0.00
Lysinens	0.95 ± 0.06	1.00 ± 0.01	1.00 ± 0.01	0.93 ± 0.04	0.95 ± 0.01
Methionine	0.27 ± 0.01b	0.28 ± 0.01b	0.29 ± 0.02b	0.29 ± 0.01b	0.33 ± 0.00a
Phenylalaninens	0.37 ± 0.03	0.43 ± 0.01	0.41 ± 0.02	0.41 ± 0.10	0.41 ± 0.04
Prolinens	0.57 ± 0.01	0.61 ± 0.00	0.61 ± 0.00	0.58 ± 0.02	0.57 ± 0.03
Serinens	0.61 ± 0.00	0.61 ± 0.02	0.57 ± 0.04	0.57 ± 0.03	0.59 ± 0.01
Threoninens	0.48 ± 0.01	0.50 ± 0.02	0.49 ± 0.04	0.52 ± 0.01	0.53 ± 0.03
Tryptophanns	0.06 ± 0.00	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.07 ± 0.01
Tyrosinens	0.41 ± 0.01	0.47 ± 0.01	0.43 ± 0.01	0.42 ± 0.03	0.41 ± 0.01
Valinens	0.20 ± 0.01	0.23 ± 0.01	0.25 ± 0.01	0.18 ± 0.02	0.18 ± 0.02

[1] Means ± SD in the same column with different superscript letters are significantly different (P≤0.05)

The fatty acid composition of crab meats as a percentage of total fatty acid is shown in Table 5. The main observed difference was the higher content of stearic acid (C18:0) and lignoceric acid (C24:0) in crabs fed with *G. edulis*. However, there was a lower content of linoleic acid (C18:2) compared with those fed with chopped fish, moist pellets and moist pellets combined with seaweed, as well as with crabs from the sea. The fatty acid composition of crab meats in this study was higher than Wen *et al*. (2002), for Chinese mitten-handed crab (*E. sinensis*) that had contents of arachidonic acid at 3.0 to 4.9 and eicosapentaenoic acid at 7.3 to 10.2%.

Instrumental measurement

Toughness of the blue swimming crab meats is shown in Table 6. The crabs fed with the moist pellets had significantly higher levels of toughness than crabs fed with the other experimental diets (chopped fish, moist pellets with seaweed and *G. edulis* diet).

Differences in the color of crab meat, were observed in each different part of the crab as shown in Table 7. In the claw and leg meats, the value of redness was significantly higher in crabs fed with *G. edulis* than in crabs fed with the other experimental diets, but the lightness and yellowness values were lower. In the chunk and flake meats, the value of lightness was significantly higher in the crabs fed with a chopped fish diet than in the crabs fed with red seaweed.

Sensory evaluation

The multi-sample test indicated differences in the organoleptic characteristics of claw and leg meats but did not indicate any difference in chunk and flake meats. The chunk

Table 5 Fatty acid composition of the meat in blue swimming crab fed with various experimental diets[1].

Fatty acid (% of total fatty acid)	Treatments				
	Crabs from the sea	Crabs fed chopped fish	Crabs fed moist pellets	Crabs fed moist pellets with seaweed	Crabs fed *G. edulis*
C16:0 ns	23.55±0.54	24.14±0.16	23.49±1.43	24.15±3.37	20.78±0.51
C16:1 ns	1.96±0.11	2.24±0.15	2.29±0.16	2.36±0.51	2.43±0.10
C18:0	13.75±0.90b	13.45±0.29b	12.77±0.93b	13.08±0.49b	16.36±1.59a
C18:1 ns	16.90±0.65	19.21±1.58	18.65±1.51	17.24±1.65	18.82±1.16
C18:2	5.37±0.55b	8.24±0.57a	9.18±1.51a	8.81±0.07a	5.91±0.67b
C20:4 ns	8.99±0.62	7.57±0.62	7.41±0.09	8.71±0.30	8.05±1.24
C20:5 ns	13.45±0.37	11.40±0.51	12.85±0.52	12.20±0.34	12.69±2.16
C24:0	16.04±0.48a	13.78±0.81a,b	13.37±0.96b	13.46±1.29b	14.98±0.91a,b

[1] Means ± SD in the same column with different superscript letters are significantly different (P≤0.05)

Table 6 Toughness (Newton) of the meat in blue swimming crab fed with various experimental diets[1].

Treatments	Toughness (Newton)
1 (Chopped fish)	7.65 ± 0.12b
2 (Moist pellets)	9.35 ± 0.04a
3 (Moist pellets with seaweed)	7.58 ± 0.02b
4 (*G. edulis*)	6.00 ± 0.03c

[1] Means ± SD in the same column with different superscript letters are significantly different (P≤0.05)

and flake meat had a white color that made it difficult to classify differences, while the claw and leg meats had color tone (red-dark brown) that made it easy for the panel to classify.

A descriptive test revealed some significant differences among treatments. Claw and leg meat from crabs fed with moist pellets and seaweed, as well as only seaweed had higher juiciness, color and seaweed odor and less odor intensity in the crab meat, compared with crabs fed with chopped fish and moist pellets. However the firmness, saltiness and sweetness were not different. Chunk and flake meat from crabs fed with moist pellets and seaweed, as well as only seaweed had higher juiciness, seaweed odor and less odor intensity in the crab meat, compared with crabs fed with chopped fish and moist pellets, while, the color, firmness, saltiness and sweetness were not different. With regard to overall acceptance, there were no significant differences.

CONCLUSION

Crabs fed with the red seaweed *G. edulis* had the lowest growth and a lower chemical composition except moisture content compared to crabs fed with the other experimental diets. This was considered to be due to the fact that the red seaweed diet had lower protein amounts than other diets and consequently there was not enough protein for the crabs' growth. Nevertheless, red seaweed affected the color of the crab meat, because red seaweed contained phycobilin pigments and thus claw and leg meats of crabs

Table 7 Parameters of color in the meat in blue swimming crab meats fed with various experimental diets[1].

Treatments	Parameters of color		
	L*	a*	b*
Claw1			
(Chopped fish)	64.14 ± 0.49b	3.59 ± 0.87c	10.74 ± 0.99d
2 (Moist pellet)	65.27 ± 0.27a	5.92 ± 0.26b	13.86 ± 0.38b
3 (Moist pellet/seaweed)	65.23 ± 0.36a	6.26 ± 0.45b	18.45 ± 0.63a
4 (*G. edulis*)	61.40 ± 0.36c	10.28 ± 0.17a	11.92 ± 1.73c
Leg			
1 (Chopped fish)	65.40 ± 0.73a	1.40 ± 0.34c	10.28 ± 0.56c
2 (Moist pellet)	60.51 ± 1.23b	3.96 ± 0.68b	17.44 ± 1.43a
3 (Moist pellet/seaweed)	58.04 ± 0.48c	4.04 ± 1.61b	13.16 ± 1.10b
4 (*G. edulis*)	56.73 ± 2.46d	5.68 ± 0.62a	16.23 ± 3.23a
Chunk			
1 (Chopped fish)	79.77 ± 0.13a	-2.18 ± 0.11b	9.21 ± 0.36d
2 (Moist pellet)	77.49 ± 0.16b	-2.32 ± 0.18b	11.39 ± 0.49c
3 (Moist pellet/seaweed)	77.52 ± 0.24b	-1.28 ± 0.11a	13.33 ± 0.29b
4 (*G. edulis*)	65.61 ± 0.49c	-1.31 ± 0.12a	17.60 ± 0.47a
Flake			
1 (Chopped fish)	78.78 ± 0.10a	-0.62 ± 0.08b	11.20 ± 0.29c
2 (Moist pellet)	78.75 ± 0.06a	-1.31 ± 0.12c	12.22 ± 0.48b
3 (Moist pellet/seaweed)	77.64 ± 0.10b	-0.99 ± 0.06a,b	12.07 ± 0.38b
4 (*G. edulis*)	75.00 ± 0.11c	0.60 ± 0.15a	14.07 ± 0.46a

L*, a* and b* described the lightness, redness and yellowness

[1] Means ± SD in the same column with different superscript letters are significantly different ($P \leq 0.05$)

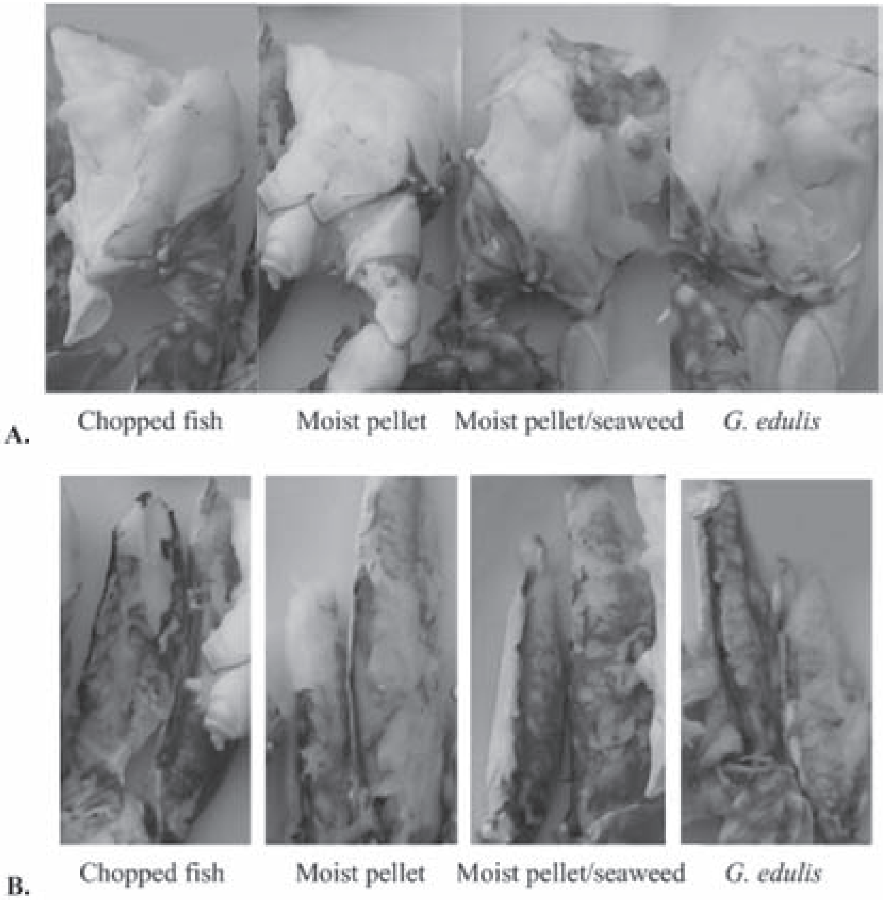

Figure 2 Appearance of cooked crab meat (A = Chunk portion and B = Claw portion) from crabs fed with various experimental diets.

fed with red seaweed had more redness compared to other diets. Therefore, red seaweed can be used as a supplementary food for blue swimming crab cultures to improve the quality of the meat.

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