

Meat Quality of Blue Swimming Crab (*Portunus pelagicus*, Linnaeus 1758) Fattened with Different Diets

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ABSTRACT

The research aim was to study the growth and meat quality of blue swimming crab fattened with different diets: chopped fish; live blue mussels; moist pellets; chopped fish and red seaweed; blue mussel and red seaweed; moist pellets and red seaweed; and red seaweed. The results of fattening crabs, measured by the change from an average initial weight of 100 g for 4 weeks, showed that crabs fed blue mussel had the highest weight gain (38.79%), followed by: crabs fed moist pellets; chopped fish; and chopped fish and red seaweed (32.16, 32.13 and 32.06%, respectively). Crabs fed blue mussel and red seaweed had the highest survival rate (88.33 %). Crabs fed only red seaweed had not only the lowest weight gain (23.12%) and survival rate (75%), but also had the lowest protein, fat, amino acid and fatty acid contents. Feeding with red seaweed or supplemented with red seaweed gave the highest methionine, EPA, DHA and astaxanthin content (0.37 g/100g, 20.93, 2.50% and 10.32 mg/g, respectively), but the lowest cholesterol content (63.50 mg/100g). The color of the crab meat in each part affected by the various diets was significantly different. Toughness of the crab meat fed blue mussel was the highest (11.45 N). A sensory evaluation revealed coincidental results between the chemical/physical measurement and the organoleptic perception of the panelists in firmness, juiciness, odor, color and overall acceptance. Claw and leg meats had significant differences in color while feeding with red seaweed gave more brown to red coverage meat color.

Key words: blue swimming crab, *Portunus pelagicus*, feeding, fattening, meat quality, diets

INTRODUCTION

The blue swimming crab (*Portunus pelagicus*, Linnaeus 1758), an economically important crustacean, has been distributed abundantly up until the last few years in the Andaman Sea and the Gulf of Thailand. It has been consumed locally and used as a raw material in the processing industry. Due to an excess demand recently, heavy harvesting has caused a decreasing trend in the production of blue swimming crabs. In 2004, the total catch was 29,500 tons, an 8.67%

decrease from 2003 (Department of Fisheries, 2005), with most of the crabs caught being small in size and sometimes under marketable quality. Culturing of blue swimming crab has been seen as a desirable way to increase production and compensate for reduced catches from the sea (Tiensongrasamee, 2004).

Culture conditions and suitable feed to promote good growth and quality of meat have been studied in previous research including: different feed ingredients for the mud crab (*Scylla serrata*) by Prinpanapong and Youngwanichsaed

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(1992) and also by How-Cheong *et al.* (1992); the effect of feeding the Chinese hairy crab (*Eriocheir sinensis*) with different protein levels and different sources of lipid on growth performance and reproduction by Mu *et al.* (1998) and Wen *et al.* (2002); and the effect of feeding *Gracilaria edulis* on growth and meat quality of small crabs (25 g on average size) raised for 8 weeks by Chaiyawat *et al.* (2008).

Fattening crab is an alternative process to improve the texture quality of the postmolt stage or soft-meat crab. From one to four crabs per kilogram in size, that have been fed for 10-20 days before being sold have already been studied (Prinpanapong and Youngwanichsaed, 1992). Information on the culturing and fattening of the blue swimming crab (*Portunus pelagicus*) has also been extensively investigated (Jiampreecha and Chantarasri, 1980; Yoodee, 1981; Tuntikul, 1983; Singhagraiwan, 1989; and Ngansakul and Pimoljinda, 1994). However, information on the chemical, physical and sensory quality of meat from fattened crab is rare. The aim of this experiment was to study the growth and meat quality of the blue swimming crab (*Portunus pelagicus*) following fattening (short period feeding) with different diets. In addition, the feasibility of using red seaweed as a foodstuff or partial supplement for improving crab meat quality was also studied.

MATERIALS AND METHODS

Diets

Seven diets were tested consisting of: chopped fish (*Caranx leptolepis*); live blue mussels (*Perna veridis*); moist pellets; chopped fish and red seaweed (*Gracilaria edulis* (Gmelin) Silva); live blue mussels and red seaweed; moist pellets and red seaweed; and only red seaweed. The feeding amount was 5% of the crab's total weight, twice a day. Growing red seaweed was supplemented in those treated crabs exceedingly. The proximate composition of the diets was analyzed prior to being used and is shown in Table 1.

Growth trials

Blue swimming male crabs at the post-molted stage, with an average weight of 100 g and a carapace width of 10 cm, were used in the experiment and provided by a crab-catching farmer in Chumporn province. Thirty crabs were fattened in experimental concrete tanks (2×4×1 m³), filled to a depth of 60 cm with aerated seawater. Water temperature, salinity, dissolved oxygen, pH and alkalinity were measured daily and maintained within a desired range. Each group was hand-fed with its respective diet twice daily at 9.00 a.m. and 4.00 p.m. All tanks were cleaned daily in the morning, waste materials and scum were discarded and the visible dead crabs were immediately

Table 1 Proximate composition of the experimental diets.

Diet	Proximate composition (% dry weight)					Moisture (%)	Energy (kcal/100g DM)
	Protein	Lipid	Fiber	Ash	NFE		
Chopped fish	68.95	2.92	-	11.66	15.94	75.72	345.30
Blue mussel	62.30	11.00	-	8.90	17.80	80.90	387.04
Moist pellet	45.95	9.69	-	14.52	29.84	31.67	344.87
Chopped fish/red seaweed	63.00	2.67	0.69	13.08	20.57	76.71	330.90
Blue mussel/red seaweed	57.01	9.94	0.69	10.60	21.77	81.37	368.49
Moist pellet/red seaweed	42.30	8.76	0.69	15.66	32.60	37.06	330.54
Red seaweed	9.40	0.37	6.87	25.88	57.48	85.60	201.50

removed and recorded, while about 10-20% of the seawater was renewed. The crabs in each tank were weighed every week and the growth was calculated per feed intake. After the crabs were removed for checking, the tanks were thoroughly cleaned, drained out and refilled. The duration of the experiment was 28 days. At the end of the growth trial, differences in growth, specific growth rate (SGR), protein efficiency ratio (PER) and feed conversion ratio (FCR) were analyzed. Seven crabs sampled from the initial batch were used as an initial control. Another seven crabs sampled from the crab farmer, with a similar size and weight to the experimental crabs at feed termination were used as a final control.

Chemical composition analysis

At the termination of the experiment, seven representative crabs from each treatment were sacrificed for tissue composition analysis of: moisture content, crude protein, ash and lipid according to AOAC (2000). The fatty acid composition and cholesterol content were analyzed by gas chromatography (Variance, Model 3800, USA), the amino acid composition was analyzed by an amino acid analyzer and astaxanthin was analyzed according to Kobayashi *et al.* (1991).

Physical characteristic measurement

Seven representative crabs were sampled based on four meat parts (claws, legs, chunks and flakes) from each treatment by colorimetric measurement using a chromameter (Minolta, Model CM-3500d, Japan). Data were expressed using an $L^* a^* b^*$ system, representing lightness, redness and yellowness (CIE, 1986). Meat from the claw of each crab was sampled for texture analysis using a texture analyzer (Stable Micro System Model TA-HD, UK) with a Warner-Bratzler blade (speed: 5 mm/s) cutting the claw into two pieces. The measurement parameter of toughness was expressed as Newton (N).

Sensory evaluation

Cooked meat from seven representative crabs from each treatment were sensory evaluated by seven trained panelists. Following a multi-sample descriptive test, crab meat was discriminated for the attributes: appearance (color, meat character), texture (firmness, juiciness), odor, taste (salty, sweet) and overall acceptance.

Statistical analysis

Data were analyzed using a one way ANOVA and Duncan's multiple range test. Results were tested for a statistically significant difference at the 0.05 level using SPSS software version 14.0.

RESULTS AND DISCUSSION

Growth

The average final weight gain, specific growth rate, survival rate and feed utilization are shown in Table 2. Crabs fed with blue mussel had the highest weight gain (38.79%) and specific growth rate (1.09%/day), while the lowest weight gain (23.12%) and specific growth rate (0.69%/day) were found in crabs fed only red seaweed. No significant differences ($p > 0.05$) were found among the weight gain and specific growth rate of crabs fed with: chopped fish; moist pellets; chopped fish and red seaweed; and blue mussel and red seaweed.

Crabs fed mussel and red seaweed had the highest survival (88.33%), however this was not significantly different from crabs fed chopped fish, mussel or moist pellets (78.33, 83.33 and 80.00% respectively). Crabs fed chopped fish and red seaweed and only red seaweed had the lowest survival (75.00%), but these results were not significantly different from crabs fed: chopped fish; blue mussel; moist pellets; and moist pellets and red seaweed diets (78.33, 83.33, 80.00 and 76.67% respectively).

The highest protein efficiency ratio was found in crabs fed either with blue mussel (1.65)

Table 2 Mean weight gain, specific growth rate (SGR), survival rate and utilization of blue swimming crab fed various experimental diets¹.

diet	Weight gain (%)	SGR ² (% day ⁻¹)	Survival ³ (%)	PER ⁴	FCR ⁵
Chopped fish	32.13±1.40 ^{a,b}	0.93±0.04 ^{a,b}	78.33±7.07 ^{a,b}	1.32±0.16 ^{a,b}	5.48±0.68 ^b
Blue mussel	38.79±0.88 ^a	1.09±0.02 ^a	83.33±4.71 ^{a,b}	1.65±0.08 ^a	4.56±0.23 ^b
Moist pellet	32.61±2.06 ^{a,b}	0.94±0.05 ^{a,b}	80.00±4.71 ^{a,b}	1.23±0.01 ^{a,b}	5.59±0.03 ^b
Chopped fish/red seaweed	32.06±5.44 ^{a,b}	0.93±0.14 ^{a,b}	75.00±2.36 ^b	1.21±0.16 ^{a,b}	5.98±0.77 ^b
Blue mussel/red seaweed	37.22±1.51 ^a	1.06±0.04 ^a	88.33±2.36 ^a	1.53±0.06 ^a	4.68±0.17 ^b
Moist pellet/red seaweed)	26.84±4.64 ^{b,c}	0.79±0.12 ^{b,c}	76.67±4.71 ^b	1.21±0.24 ^{a,b}	6.35±1.25 ^b
Red seaweed	23.12±0.60 ^c	0.69±0.02 ^c	75.00±2.36 ^b	1.05±0.30 ^b	9.80±2.75 ^a

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

² SGR = $100 \times [(\ln \text{ final body weight} - \ln \text{ initial body weight}) / \text{duration}]$

³ Survival = (number of crabs left × 100)/number of crabs initially

⁴ PER = wet weight gain/crude protein intake

⁵ FCR = dry feed intake/wet weight gain

or blue mussel and red seaweed (1.53), but these ratios were not significantly better than those fed with: chopped fish (1.32); moist pellets (1.23); chopped fish and red seaweed (1.21); blue mussel and red seaweed (1.53); and moist pellets and red seaweed (1.21). Crabs fed only red seaweed had the lowest protein efficiency ratio (1.05) which was significantly lower than crabs fed the other diets ($p \leq 0.05$).

The best feed conversion ratio was found in crabs fed blue mussel (4.56). However, it was not significantly better than those fed with: chopped fish; moist pellets; chopped fish and red seaweed; blue mussel and red seaweed; and moist pellets and red seaweed (5.48, 5.59, 5.98, 4.68 and 6.35, respectively). Crabs fed only red seaweed had the lowest feed conversion ratio (9.80) which was significantly higher than crabs fed the other diets ($p \leq 0.05$). The feed conversion ratio from this experiment was rather high compared to a previous report which showed that the feed conversion of crab fed with chopped fish was 3 – 3.5 (Tiensongrasamee, 2004).

Chemical composition

The chemical composition of crab meat from the initial control sample which was analyzed

at the beginning and the final control sample at the end of the experiment and crabs from the experiment are shown in Table 3. The crabs fed only red seaweed had significantly lower protein (10.09%) and lipid (0.09%) content than the control samples, both at the beginning (14.93% protein, 0.3% lipid) and the end (15.12% protein, 0.43% lipid). Crabs fed the other diets were not significantly different in protein and lipid content. However, the crabs fed only a red seaweed diet had significantly higher moisture (80.04%) and ash (1.83%) content. No significant differences were observed in crab meat samples among the experimental diets. The result of proximate composition was similar to that reported for the chemical composition of the blue crab (*Portunus pelagicus*); with values of 78.06, 12.35, 1.02 and 1.78 g/100 g, for moisture, protein, lipid and ash respectively (Siddiquie *et al.*, 1987). However, the values are lower in protein (17.8 %) and ash content (2.6%) than those reported for the Dungeness crab (*Cancer magister*) by King *et al.*, (1990). Skonberg and Perkins (2001) reported that the average protein and ash contents of the green crab (*Carcinus maenus*) were 17.1 and 2.2 g/100 g, respectively. Crabs fed only red seaweed or moist pellets and red seaweed had the lowest

Table 3 Mean proximate composition of blue swimming crab meat samples fed with various experimental diets¹.

Treatment	Chemical composition (% wet weight)					
	Moisture	Protein	Lipid	Ash	Carbohydrate NS	Cholesterol (mg/100g)
Control (initial)	74.84±0.34 ^b	14.93±0.06 ^a	0.30±0.07 ^{a,b}	1.50±0.13 ^b	8.42±0.38	60.02±0.03 ^b
Chopped fish	74.85±0.75 ^b	13.99±0.91 ^a	0.54±0.18 ^{a,b}	1.64±0.22 ^{a,b}	8.98±0.55	62.93±0.13 ^a
Blue mussel	74.77±0.42 ^b	13.35±2.50 ^a	0.83±0.65 ^a	1.78±0.07 ^a	7.97±1.83	63.16±0.64 ^a
Moist pellet	75.84±0.77 ^b	14.65±0.70 ^a	0.40±0.44 ^{a,b}	1.72±0.10 ^{a,b}	8.00±2.85	60.57±0.76 ^b
Fish/seaweed	75.79±0.26 ^b	13.93±1.02 ^a	0.40±0.47 ^{a,b}	1.73±0.16 ^{a,b}	8.16±1.39	60.27±0.04 ^b
Mussel/seaweed	75.22±0.41 ^b	14.00±0.75 ^a	0.67±0.61 ^{a,b}	1.75±0.09 ^a	8.36±1.86	63.50±0.37 ^a
Moist	75.89±1.37 ^b	13.29±2.27 ^a	0.23±0.01 ^{a,b}	1.70±0.22 ^{a,b}	8.57±1.07	57.67±0.16 ^c
pellet/seaweed	80.04±1.16 ^a	10.09±2.40 ^b	0.09±0.01 ^b	1.83±0.30 ^a	7.96±3.87	57.16±1.15 ^c
Red seaweed	74.81±0.58 ^b	15.12±0.38 ^a	0.43±0.06 ^{a,b}	1.77±0.35 ^a	7.88±0.28	62.51±0.22 ^a
Control (final)						

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

NS means data was not significant (P>0.05)

cholesterol content (57.16 and 57.67 mg/100g). Crabs fed: chopped fish; blue mussel; blue mussel and red seaweed; or the control samples contained higher cholesterol content (62.93, 63.16, 62.51 mg/100g, respectively). The results from this study indicated that the cholesterol content of crab meat ranged from 57.16 to 63.50 mg/100g which was similar to the cholesterol content of the green crab, *C. maenus*, that ranged from 57.20 to 64.80 mg/100g (Skonberg and Perkins, 2001).

The amino acid composition of crab meat in the 100 g samples are shown in Table 4. For the majority of experimental crabs, the amino acid composition was not significantly different (P>0.05), but the arginine and methionine content were significantly different (P≤0.05) from each other. The arginine content among the experimental crabs was not significantly different, but it was significantly higher than the initial control. Crabs fed only red seaweed and red seaweed with other diets had higher methionine content than crabs fed the normal diets without seaweed and also the control crabs.

The fatty acid composition of crab meat as a percentage of the total fatty acid is shown in Table 5. The linoleic acid content (C18:2) of all

study groups was not significantly different (P>0.05) with the oleic acid (C18:1) content of crabs fed red seaweed the lowest. The arachidonic acid (C20:4) content of crabs fed red seaweed was as high as that for crabs fed red seaweed and other diets, while crabs fed diets without red seaweed and the control showed a significantly lower content. The EPA (C20:5) content of crabs fed red seaweed and moist pellets with red seaweed was significantly higher than for crabs on other diets. The DHA (C22:6) content was found only in the crabs fed red seaweed and red seaweed with blue mussel and chopped fish.

The astaxanthin content of the crab meat from the controls and experimental crabs is shown in Table 6. Crabs fed with red seaweed tended to produce significantly higher astaxanthin content in their meat, with crabs fed only red seaweed having the highest astaxanthin content (10.32 µg/g meat). Crabs fed red seaweed with other diets had a lower astaxanthin content (9.30-9.36 µg/g meat), but it was higher than those fed no red seaweed and the control samples (7.37-7.68 µg/g meat). This was confirmed by the redness value (*a**) measured by a chromameter.

Table 4 Mean amino acid composition of blue swimming crab meat sample fed with various experimental diets¹.

Amino acid (g/100 g meat)	Treatment							
	Control (initial)	Chopped fish	Blue mussel	Moist pellet	Chopped fish/seaweed	Mussel/ seaweed	Moist pellet/ seaweed	Seaweed (final)
Alanine ^{ns}	0.45 ± 0.05	0.49 ± 0.02	0.52 ± 0.02	0.46 ± 0.05	0.49 ± 0.03	0.50 ± 0.02	0.50 ± 0.01	0.47 ± 0.04
Arginine	1.02 ± 0.01 ^b	1.49 ± 0.02 ^a	1.57 ± 0.12 ^a	1.60 ± 0.18 ^a	1.42 ± 0.12 ^a	1.52 ± 0.03 ^a	1.50 ± 0.02 ^a	1.38 ± 0.16 ^a
Aspartic acid ^{ns}	1.89 ± 0.03	2.01 ± 0.03	2.18 ± 0.07	2.00 ± 0.24	1.90 ± 0.16	2.16 ± 0.18	1.88 ± 0.15	1.82 ± 0.20
Cystine ^{ns}	0.59 ± 0.12	0.80 ± 0.18	0.64 ± 0.10	0.51 ± 0.05	0.64 ± 0.08	0.67 ± 0.12	0.65 ± 0.14	0.73 ± 0.07
Glutamic acid ^{ns}	1.47 ± 0.03	1.83 ± 0.14	1.77 ± 0.13	1.70 ± 0.21	1.52 ± 0.22	1.66 ± 0.07	0.61 ± 0.22	1.56 ± 0.04
Glycine ^{ns}	1.11 ± 0.03	1.21 ± 0.03	1.20 ± 0.05	1.22 ± 0.07	1.20 ± 0.02	1.20 ± 0.03	1.19 ± 0.08	1.17 ± 0.02
Histidine ^{ns}	0.56 ± 0.06	0.54 ± 0.08	0.45 ± 0.11	0.46 ± 0.05	0.57 ± 0.03	0.59 ± 0.00	0.53 ± 0.04	0.56 ± 0.12
Isoleucine ^{ns}	0.24 ± 0.02	0.23 ± 0.03	0.24 ± 0.03	0.22 ± 0.07	0.23 ± 0.01	0.23 ± 0.04	0.24 ± 0.01	0.22 ± 0.02
Leucine ^{ns}	0.75 ± 0.00	0.69 ± 0.05	0.68 ± 0.02	0.68 ± 0.03	0.66 ± 0.03	0.69 ± 0.01	0.70 ± 0.07	0.67 ± 0.06
Lysine ^{ns}	0.96 ± 0.04	0.94 ± 0.00	0.96 ± 0.05	0.94 ± 0.01	0.87 ± 0.05	0.92 ± 0.07	0.96 ± 0.02	0.89 ± 0.02
Methionine	0.22 ± 0.07 ^b	0.15 ± 0.01 ^b	0.18 ± 0.00 ^b	0.22 ± 0.06 ^b	0.36 ± 0.06 ^a	0.37 ± 0.02 ^a	0.35 ± 0.02 ^a	0.37 ± 0.03 ^a
Phenylalanine ^{ns}	0.41 ± 0.05	0.42 ± 0.00	0.45 ± 0.01	0.37 ± 0.08	0.46 ± 0.03	0.45 ± 0.02	0.44 ± 0.04	0.44 ± 0.03
Proline ^{ns}	0.59 ± 0.02	0.64 ± 0.00	0.67 ± 0.08	0.62 ± 0.00	0.59 ± 0.03	0.67 ± 0.09	0.69 ± 0.08	0.58 ± 0.09
Serine ^{ns}	0.59 ± 0.03	0.56 ± 0.02	0.51 ± 0.04	0.53 ± 0.13	0.49 ± 0.03	0.47 ± 0.06	0.50 ± 0.03	0.50 ± 0.03
Threonine ^{ns}	0.46 ± 0.02	0.48 ± 0.00	0.45 ± 0.04	0.47 ± 0.02	0.48 ± 0.02	0.46 ± 0.05	0.45 ± 0.06	0.46 ± 0.04
Tryptophan ^{ns}	0.06 ± 0.01	0.07 ± 0.01	0.08 ± 0.00	0.06 ± 0.01	0.06 ± 0.00	0.08 ± 0.01	0.06 ± 0.01	0.06 ± 0.00
Tyrosine ^{ns}	0.43 ± 0.03	0.46 ± 0.04	0.46 ± 0.05	0.46 ± 0.03	0.41 ± 0.10	0.50 ± 0.05	0.49 ± 0.00	0.45 ± 0.02
Valine ^{ns}	0.22 ± 0.04	0.26 ± 0.05	0.26 ± 0.04	0.27 ± 0.02	0.24 ± 0.03	0.24 ± 0.03	0.21 ± 0.04	0.22 ± 0.04

¹ Means ± SD in the same row with different superscript letters are significantly different (P≤0.05)^{ns} means data was not significant (P>0.05)

Table 5 Mean fatty acid composition of blue swimming crab meat samples fed with various experimental diets¹.

Fatty acid (%)	Treatment							
	Control (initial)	Chopped fish	Blue mussel	Moist pellet	Chopped fish/seaweed	Mussel/seaweed	Moist pellet/seaweed	Seaweed Control (final)
C14:0	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b
C16:0	23.04±0.40 ^a	23.36±0.16 ^a	22.54±0.52 ^a	22.56±0.38 ^a	17.11±0.80 ^b	17.01±0.42 ^b	16.90±0.37 ^b	23.01±0.18 ^a
C16:1	3.76±0.02 ^b	2.68±0.46 ^{b,c}	3.34±0.28 ^{b,c}	3.64±0.24 ^b	2.31±0.95 ^c	2.36±0.76 ^c	0.00±0.00 ^d	3.77±0.17 ^b
C18:0	14.82±0.04 ^{a,b}	14.91±1.22 ^{a,b}	15.16±0.11 ^{a,b}	14.95±0.18 ^{a,b}	14.98±0.33 ^{a,b}	14.41±0.02 ^b	14.24±0.12 ^b	15.36±0.25 ^{a,b}
C18:1	16.39±1.46 ^a	17.71±0.87 ^a	16.74±1.60 ^a	16.02±0.91 ^a	17.59±1.70 ^a	17.13±0.13 ^a	18.10±0.43 ^a	16.91±0.11 ^a
C18:2 ^{ns}	3.72±0.06	4.74±0.13	4.09±0.08	3.98±0.06	4.71±0.34	4.75±1.12	4.67±0.05	3.61±0.22
C20:4	8.49±0.08 ^b	8.57±0.79 ^b	8.58±1.34 ^b	8.19±0.06 ^b	12.52±0.54 ^a	12.52±0.10 ^a	12.50±0.04 ^a	8.66±0.01 ^b
C20:5	15.22±0.06 ^c	15.40±0.91 ^c	15.07±1.16 ^c	15.79±0.05 ^c	16.18±0.64 ^c	18.74±0.24 ^b	20.33±0.24 ^a	15.18±0.19 ^c
C22:6	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	1.64±0.43 ^a	2.03±0.95 ^a	0.00±0.00 ^b	0.00±0.00 ^b
C24:0	14.58±1.73 ^a	12.65±2.03 ^a	14.49±0.64 ^a	14.88±0.93 ^a	12.98±0.49 ^a	12.56±0.42 ^a	13.28±1.00 ^a	14.23±0.41 ^a

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

^{ns} means data was not significant ($P > 0.05$)

Astaxanthin and its derivative esters is the major constituent of carotenoids in marine crustaceans (Shahidi *et al.*, 1998). This agreed with observations by Sachindra *et al.* (2005), who reported that the meat of the marine crab, *C. cruciata*, had a total carotenoids content of 3.4 µg/g (wet weight basis) of which astaxanthin and its ester constituted 67.6 g/100g of the total carotenoids. Matsuno and Maoka (1988) reported that astaxanthin contributed 33 – 39 g/100g of the total carotenoids in the meat and shell of the marine crab, *Paraalithodes brevipes*, from Japanese waters.

Physical characteristic measurement

The toughness of the crab claw meat samples is shown in Table 7. The crabs fed blue mussel had the highest toughness value (11.45 N), followed by crabs fed chopped fish (9.70 N) and moist pellets (9.35 N). Crabs fed red seaweed with chopped fish or blue mussel or moist pellets in addition to the final control sample had low toughness values ranging from 7.59 to 8.14 N). Crabs fed red seaweed and also the initial control sample recorded the lowest toughness values (6.00–6.03 N). The results were confirmed by sensory evaluation; crabs fed red seaweed produced the softest meat while crabs fed blue mussel produced the toughest meat.

Differences in the color of crab meat were observed in samples taken from different parts of the crab as shown in Table 8. In the claw and leg meat parts, where the pigment was obvious, crabs fed only red seaweed or red seaweed with other diets had a significantly higher redness value (a^*) than in the crabs fed not fed red seaweed. The redness value was confirmed by the color classifications recorded by the panelists. The yellowness value (b^*) could not be used to definitely classify the yellowish brown color

Table 6 Mean astaxanthin content of blue swimming crab meat samples fed with various experimental diets¹.

Treatment	Astaxanthin (µg/g sample)
Control (initial)	7.37 ± 0.00 ^d
Chopped fish	7.63 ± 0.05 ^c
Blue mussel	7.68 ± 0.00 ^c
Moist pellet	7.63 ± 0.02 ^c
Fish/seaweed	9.30 ± 0.00 ^b
Mussel/seaweed	9.36 ± 0.05 ^b
Moist pellet/seaweed	9.30 ± 0.05 ^b
Seaweed	10.32 ± 0.05 ^a
Control (final)	7.65 ± 0.05 ^c

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

Table 7 Mean toughness of blue swimming crab claw meat samples fed with various diets¹.

Treatment	Toughness (Newton, N)
Control (initial)	6.03 ± 0.05 ^d
Chopped fish	9.70 ± 0.03 ^b
Blue mussel	11.45 ± 0.03 ^a
Moist pellet	9.35 ± 0.04 ^b
Fish/seaweed	7.66 ± 0.09 ^c
Mussel/seaweed	7.90 ± 0.03 ^c
Moist pellet/seaweed	7.59 ± 0.02 ^c
Seaweed	6.00 ± 0.03 ^d
Control (final)	8.14 ± 0.06 ^c

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

of the claw and leg meat samples as the color of the meat was not consistent. Chunk and flake samples, which were white when cooked, were defined by lightness (L^* values). Crabs fed red seaweed tended to have lower L^* values especially in the chunk samples.

Sensory evaluation

The multi-sample test indicated differences in the organoleptic characteristics of claw and leg meat among the samples. As claw and leg meat samples were red to dark brown and yellowish brown, they could be easily classified by the panelists. Chunk and flake meats were white and therefore differences could not be detected.

Consequently, a descriptive test revealed some significant differences among groups. Claw and leg meat samples from crabs fed red seaweed had more juiciness, defined color intensity and seaweed odor. Crabs fed diets without red seaweed had less color intensity and odor, but tougher meat. Nevertheless, firmness and crab taste were not different. In overall acceptance, the crabs fed diets with red seaweed had higher liking scores on color and taste than the crabs fed without red seaweed.

CONCLUSION

Crab meat quality was affected by the diets fed. Fattening crabs in a short period could produce a difference in the quality attributes of

Table 8 Mean color of blue swimming crab meat samples (L^* a^* b^*) fed with various experimental diets¹.

Treatment	Parameter of color		
	L^*	a^*	b^*
Claw			
Control (initial)	65.20 ± 0.06 ^a	3.30 ± 0.55 ^d	14.06 ± 1.14 ^a
Chopped fish	64.89 ± 0.48 ^a	3.60 ± 0.82 ^d	14.18 ± 0.38 ^a
Blue mussel	65.14 ± 0.30 ^a	4.89 ± 0.16 ^c	14.12 ± 0.52 ^a
Moist pellet	65.04 ± 0.26 ^a	5.24 ± 0.60 ^c	12.22 ± 0.00 ^b
Fish/seaweed	61.00 ± 0.09 ^c	6.34 ± 0.14 ^b	13.61 ± 1.83 ^a
Mussel/seaweed	60.97 ± 0.28 ^c	6.83 ± 0.33 ^b	12.43 ± 0.25 ^b
Moist pellet/seaweed	59.13 ± 0.32 ^d	6.26 ± 0.41 ^b	12.72 ± 0.20 ^b
Seaweed	59.48 ± 0.02 ^d	10.29 ± 0.09 ^a	11.20 ± 0.13 ^c
Control (final)	62.32 ± 0.30 ^b	3.36 ± 0.42 ^d	13.62 ± 0.21 ^a
Leg			
Control (initial)	61.95 ± 0.60 ^{b,c}	1.06 ± 0.03 ^d	10.01 ± 0.18 ^d
Chopped fish	64.86 ± 0.37 ^{a,b}	1.34 ± 0.15 ^d	10.33 ± 0.42 ^d
Blue mussel	66.05 ± 0.53 ^a	2.54 ± 0.17 ^c	12.62 ± 0.73 ^c
Moist pellet	64.93 ± 5.19 ^{a,b}	2.72 ± 0.54 ^c	13.46 ± 0.06 ^b
Fish/seaweed	59.45 ± 0.43 ^c	4.56 ± 0.13 ^b	15.50 ± 0.63 ^a
Mussel/seaweed	62.22 ± 0.06 ^{b,c}	4.52 ± 0.02 ^b	12.43 ± 0.25 ^c
Moist pellet/seaweed	60.27 ± 0.21 ^c	4.75 ± 0.15 ^b	13.68 ± 1.12 ^b
Seaweed	59.40 ± 01.26 ^c	5.30 ± 0.27 ^a	13.07 ± 0.24 ^{b,c}
Control (final)	61.99 ± 0.56 ^{b,c}	2.80 ± 0.48 ^c	10.06 ± 0.31 ^d
Chunk			
Control (initial)	79.66 ± 0.05 ^a	-1.85 ± 0.50 ^d	9.38 ± 0.21 ^d
Chopped fish	76.89 ± 1.08 ^b	-1.64 ± 0.43 ^d	9.41 ± 0.47 ^d
Blue mussel	77.49 ± 0.12 ^b	-1.30 ± 0.02 ^c	10.40 ± 0.87 ^c
Moist pellet	77.54 ± 0.01 ^b	-1.34 ± 0.06 ^c	10.82 ± 0.15 ^c
Fish/seaweed	67.30 ± 0.39 ^c	-0.96 ± 0.06 ^{a,b}	13.38 ± 0.18 ^b
Mussel/seaweed	66.25 ± 0.06 ^d	-0.99 ± 0.08 ^b	13.42 ± 0.17 ^b
Moist pellet/seaweed	67.23 ± 0.32 ^c	-0.98 ± 0.01 ^b	17.78 ± 0.21 ^a
Seaweed	65.68 ± 0.44 ^d	-0.75 ± 0.02 ^a	17.53 ± 0.26 ^a
Control (final)	77.35 ± 0.11 ^b	-1.00 ± 0.06 ^b	9.38 ± 0.10 ^d
Flake			
Control (initial)	77.86 ± 0.96 ^a	-0.81 ± 0.44 ^b	11.81 ± 0.67 ^d
Chopped fish	77.93 ± 0.51 ^a	-0.98 ± 0.33 ^b	11.76 ± 0.77 ^d
Blue mussel	77.61 ± 0.19 ^a	-1.10 ± 0.14 ^b	11.91 ± 0.05 ^d
Moist pellet	77.43 ± 0.10 ^a	-0.91 ± 0.15 ^b	11.76 ± 0.13 ^d
Fish/seaweed	75.18 ± 0.10 ^b	-0.30 ± 0.04 ^a	13.37 ± 0.18 ^c
Mussel/seaweed	74.46 ± 0.13 ^c	-0.35 ± 0.00 ^a	14.58 ± 0.11 ^b
Moist pellet/seaweed	75.34 ± 0.15 ^b	-0.36 ± 0.02 ^a	13.53 ± 0.09 ^c
Seaweed	74.09 ± 0.26 ^c	-0.23 ± 0.09 ^a	15.55 ± 0.19 ^a
Control (final)	77.30 ± 0.66 ^a	-1.04 ± 0.25 ^b	12.15 ± 0.33 ^d

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

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

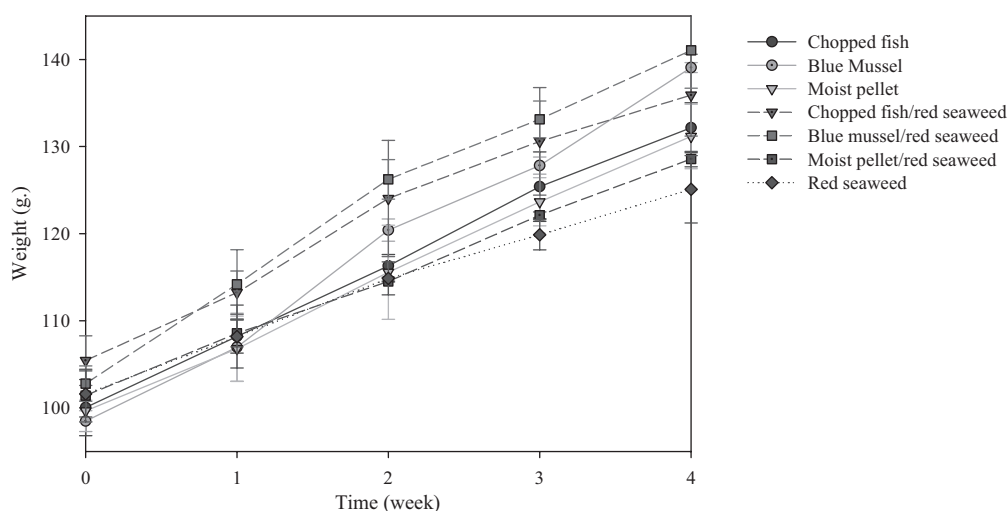


Figure 1 Body weight changes in blue swimming crab fed various experimental diets.

the meat, as well as by feeding for a longer time as reported by Chaipayat *et al.* (2008). Crabs fed red seaweed had the lowest growth, lower protein and lipid content, low cholesterol and high arginine and methionine. Red seaweed produced more astaxanthin, red color, seaweed odor and more taste in the crab meat. Therefore, red seaweed could be a partial supplement diet for improving the meat quality of crabs during short periods of feeding.

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LITERATURE CITED

- AOAC. 2000. **Official Methods of Analysis**. 17th ed., Association of Official Analytical Chemists, Arlington, Virginia.
- Chaipayat, M., I. Eunggrasme, and N. Raksakulthai. 2008. Quality characteristics of blue swimming Crab (*Portunus pelagicus*, Linnaeus 1758) meat fed *Gracilaria edulis* (Gmelin) Silva. **Kasetsart J. (Nat. Sci.)** 42: 522-530.
- CIE (International Commission on Illumination). 1986. **Colorimetry**. 2nd ed. Publication CIE, vol. 15.2. Central Bureau of the CIE, Vienna, Austria. 23 p.
- Department of Fisheries. 2005. **Fisheries Statistics of Thailand 2003**. Fishery Information Technology Center, Department of Fisheries, Ministry of Agriculture and Cooperatives, No. 6/2005. 91 p.
- How-Cheong, C., U.P.D. Gunasekera and H.P. Amandakoon. 1992. Formulation of artificial feeds for mud crab culture: a preliminary biochemical, physical and biological evaluation, pp.179-184. In C.A. Angell, (ed.). **Report of the seminar on The Mud Crab Culture and Trade Held in Thailand, 5–8 November 1991**. Bay of Bengal Programme Report No. BOBP/REP/51. Project GCP/RAS/118/MUL. Madras, India.
- Jiampreecha, B. and T. Chantarasri. 1980. **Larval rearing and mass produce of blue swimming crab (*Portunus pelagicus* Linnaeus)**. Marine Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives, Technical paper No. 20/1980.

- King, M.T. Childs, C. Dorsett, J.G. Ostrander and E.R. Monsen. 1990. Shellfish: proximate composition, minerals, fatty acids and sterols. **J. American Diet. Assoc.** 90: 677-685.
- Kobayashi, M., T. Kakizono and S. Nagai. 1991. Astaxanthin production by a green algae, *Haematococcus pluvialis*, accompanied with morphological changes in acetate medium. **J. Ferment. Bioeng.** 74: 61-63.
- Matsuno, T. and T. Maoka. 1988. The carotenoid of crab *Paralithodes brevipes*. **Bull. Jap. Soc. Sci. Fish.** 54: 1437-1442.
- Mu, Y.Y., K.F. Shim and J.Y. Guo. 1998. Effects of protein level in isocaloric diets on growth performance of juvenile Chinese hairy crab, *Eriocheir sinensis*. **Aquaculture** 165: 139-148.
- Ngansakul, P. and J. Pimoljinda. 1994. Experiment on nursing blue swimming crabs (*Portunus pelagicus* Linnaeus) by different types of feeds, pp. 11-17. In **Proceedings of the Seminar on Fisheries 1994, 19-21 September 1994**. Thailand,
- Prinpanapong, S. and T. Youngwanichsaed. 1992. Rearing of mud crab (*Scylla serrata*), pp. 191-194. In C.A. Angell, (ed.). **Report of the seminar on The Mud Crab Culture and Trade Held in Thailand, 5-8 November 1991. Bay of Bengal Programme Report No. BOBP/REP/51. Project GCP/RAS/118/MUL**, Madras, India,
- Sachindra N.M., N. Bhaskar and N.S. Mahendrakar. 2005. Carotenoids in crab from marine and fresh waters of India. **LWT.** 38: 221-225.
- Shahidi, F., Metusalach, and J.A. Brown. 1998. Carotenoid pigments in seafood and aquaculture. **CRC Critical Reviews in Food Science** 38: 1-67.
- Siddiquie, P.J.A., Z. Akbar and R. Qasim. 1987. Biochemical composition and caloric values of three edible species of Portunidae crabs from Karachi, Pakistan. **J. Sci.** 30: 119-121.
- Singhagraiwan, T. 1989. **The Experiment on Net Cage Culture of Blue Swimming Crab (*Portunus pelagicus* Lin.)**. Eastern Marine Fisheries Development Center, Marine Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives, Technical paper No. 13.
- Skonberg, D.I. and B.L. Perkins. 2001. Nutrient composition of green crab (*Carcinus maenas*) leg meat and claw meat. **Food Chem.** 77: 401-404
- Tiensongrasamee, B. 2004. **Technology of Blue Swimming Crab Culture**. Star team manage group, Bangkok. 132 p.
- Tuntikul, S. 1983. **Growth of Blue Swimming Crabs Reared in the Laboratory**. Marine Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 11 p.
- Wen, X.B., L.Q. Chen, Z.L. Zhou, C.X. Ai and G.Y. Deng. 2002. Reproduction response of Chinese mitten-hand crabs (*Eriocheir sinensis*) fed different sources of dietary lipid. **Comp. Biochem. Physiol.** 131: 675-681.
- Yoodee, K. 1981. **Age and Growth of Blue Swimming Crab (*Portunus pelagicus* Linn.) from the Eastern Coast of the Gulf of Thailand**. Marine Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives, Technical paper No. 13/1981.