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ORIGINAL ARTICLE

Nutritional quality of different grades of adult male chinese mitten crab, *Eriocheir sinensis*

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Abstract This study mainly investigated the composition of adult male Chinese mitten crab (*Eriocheir sinensis*) from four grades/sizes (Grade I: 200–249 g; Grade II: 175–199 g; Grade III: 150–174 g; Grade IV: ≤ 150 g). The results showed that the grade III crabs had the largest gonadsomatic index (GSI), which was significantly higher than the grade I and grade II crabs, no significant difference was found with the grade IV crab. Significant differences in moisture and total lipid contents were observed among various edible parts from different grades of male *Eriocheir sinensis*. In particular, grade II crabs had the highest total lipid and dry matter content for hepatopancreas. A balanced amino acids composition and a high essential amino acids score (EAAS) were found in the muscle and gonads of grade III crabs. The levels of poly-unsaturated fatty acids (PUFA), n-3 PUFA, n-6 PUFA and docosahexaenoic acid (DHA) in the hepatopancreas, as well as the contents of PUFA, highly-unsaturated fatty acids (HUFA), n-3 PUFA, arachidonic acid (ARA), and eicosapentaenoic acid (EPA) in the gonads were significantly increased in the grade II crabs. Taken together, it can generally be concluded that adult male *Eriocheir sinensis* of 150–200 g (Grade II–III) weight have the highest nutritional quality even though they are not the largest crabs.

Keywords Chinese mitten crab · Grade/size difference · Various edible parts · Food composition · Nutritional quality

Introduction

The Chinese mitten crab, *Eriocheir sinensis*, a fresh water culture crab, is known as one of the most important economically aquacultured species in China and other east Asian countries, which is distributed geographically from Korea in the north to the south area of China (Sun et al. 2013). The Chinese mitten crabs as a catadromous species are widely found in fresh water when they are juveniles and adults. To mate and spawn, the crabs reach reproduction maturity and migrate downstream into estuary regions between autumn and winter. Then, they return to freshwater habitats once they have completed breeding. With the improvement of reproduction technology in the recent decades since the 1990s, production of *E. sinensis* has been continuously increasing. Annual production of *E. sinensis* can be approaching 729,900 tonnes in 2013 (Chinese Fishery Statistical Yearbook, 2014) and economic output is exceeding tens of billions of yuan in China, which is maintained mainly by the artificial breeding way in the fresh water, including ponds, rivers and lakes.

It is well-known that *E. sinensis* is a traditional and common savory food in China due to its delicious taste and

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high nutritional value. It not only is an excellent source of essential amino acids (EAA) and highly-unsaturated fatty acids (HUFA), particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), but also contains higher content of minerals, such as calcium, iron, zinc, potassium and phosphorus (Wu et al. 2007a; Chen et al. 2007; Guo et al. 2015). Over the past two decades, studies on nutritional quality of *E. sinensis* have been concentrated on several aspects, mainly including early individual development stage (Ying et al. 2006), gonadal development special period (Ying et al. 2006), appropriate levels of dietary functional substance (Sun et al. 2013; Wu et al. 2007a, b, 2011), such as HUFA, phospholipid and Cu, and comparison with the crabs of other species or different places of origin (Jiang et al. 2014; Wang et al. 2016).

The effects of variational levels of dietary DHA/EPA ratios and phospholipid on growth, biochemical composition and osmotic stress tolerance of *E. sinensis* were studied successively (Wu et al. 2007a, b). Supplementation of DHA, EPA and phospholipid with the appropriate dosage in the feed is especially important for growth and development of *E. sinensis.* Wang et al. (2016) reported that the flavor qualities of *E. sinensis* from different areas in China, respectively, wild-caught crabs (fishing from Yangtze river), Yangcheng crabs (pond-reared crabs from Yangcheng) and Chongming crabs (pond-reared crabs from Shanghai), and then flavor quality of wild-caught crabs was obviously better than those of the other two crabs. Along with the previously mentioned the aspects, biochemical composition was also considered at different physiological stages of *E. sinensis*. A total of 18 types of fatty acids were found in the ovary during the early development period. It was noteworthy from these results that several fatty acids were not found in certain period; however, arachidonic acid (ARA) was only detectable in the egg-losing crabs. The authors believed that composition and amount of fatty acids in the ovaries has a direct relationship to abortion or egg loss of *E. sinensis* (Ying et al. 2006).

To the best of our knowledge, it has being an focus issue in China that the annual price of the large *E. sinensis.* Generally speaking, the price of fattened males *E. sinensis* of more than 250 g can approach roughly 440 yuan/kg in the best market time, whereas the price falls sharply to approximate 200 yuan/kg for the weight ranges of 175–199 g males, and 50 yuan/kg for less than 125 g males (He et al. 2014), these data revealed huge differences presented in the price and the weight of *E. sinensis.* Up until now, little information is available about the comparison of nutritional quality in the *E. sinensis* from different grades/sizes, even though large differences of their price truly exist in the present market of China. Moreover, the consumers really have no idea why the weight of the crab is heavier, means that the market price is higher, although they do have a relatively larger consumption for *E. sinensis*.

The Chinese mitten crab is widely known as being nutritious; however, the precise nutritional value of its edible tissues in crabs of different size has not been sufficiently reported. Information on the relationship between the nutritional value and weight grade of *E. sinensis* is still quite scarce. Therefore, this paper aimed to provide more detailed knowledge concerning the nutritional value of the adult *E. sinensis* from male crabs of different sizes, especially, proximate composition, amino acids content, and fatty acids profile of the edible parts, which were investigated and compared in this study. Therefore, this work is more meaningful for consumers, and it also provides new insights for the nutritional assessment of the male *E. sinensis*.

Materials and methods

Source of the crabs and sampling procedure

Adult *E. sinensis* was gave as a present by Shanghai Bright Special Aquaculture Co. LTD. (Chongming, Shanghai, China). According to body weight, the grade of male crab was defined as four grades, there were 200–249 g (Grade I), 175–199 g (Grade II), 150–174 g (Grade III), $\leq$ 150 g (Grade IV). The healthy and intact crabs were individually weighed and classified as listed in Table 1; 10 males were selected randomly in the four grades, and then measured for carapace width and length with a vernier caliper. The crabs were then dissected to obtain hepatopancreas and gonads tissues, while the meat from the claw and leg was carefully picked by hands. Subsequently, the wet weight of the meat, hepatopancreas and gonads from each crab were recorded and stored separately at $-$ 80°Cfor later biochemical analysis. The meat yield (MY), total edible yield (TEY), hepatosomatic index (HSI), GSI and condition factor (CF) of the crabs were calculated using the following formulas:

HSI (%) = 100 $\times$ hepatopancreas wet weight/body wet weight;

GSI (%) = 100 $\times$ gonad wet weight/body wet weight;

CF (%) = 100 $\times$ body wet weight/carapace length^3;

MY (%) = 100 $\times$ meat wet weight/body wet weight;

TEY (%) = MY + HSI + GSI.

In this study, hepatopancreas, meat, and gonad tissues were sampled from one crab and pooled from three crabs to form a replicate for the subsequent chemical analyses, because the male gonad from a single crab had a relatively low total weight. All of the samples were then analyzed as at least three replicates.

Table 1 Tissue indices and proximate composition in the hepatopancreas, gonads and muscle of different grades of male *E. sinensis*

	Grade I	Grade II	Grade III	Grade IV
Tissue indices and total edible yield				
Average weight (g)	219.152 ± 25.83	180.616 ± 8.76	153.346 ± 1.80	133.468 ± 7.55
HSI (%)	5.20 ± 0.27	5.43 ± 0.25	4.54 ± 0.13	5.13 ± 0.44
GSI (%)	4.00 ± 0.20^{b}	3.98 ± 0.24^{b}	5.23 ± 0.43^{a}	4.43 ± 0.13^{ab}
MY (%)	28.87 ± 0.73	27.24 ± 1.07	27.42 ± 1.00	28.40 ± 0.37
TEY (%)	38.07 ± 0.51	36.56 ± 1.21	37.20 ± 1.10	37.96 ± 0.45
CF (%)	0.70 ± 0.01^{a}	0.69 ± 0.02^{a}	0.64 ± 0.01^{b}	0.66 ± 0.00^{b}
Proximate composition in the hepatopancreas				
Moisture (%)	66.17 ± 2.21^{ab}	60.44 ± 3.23^{b}	67.87 ± 1.17^{ab}	70.38 ± 2.98^{a}
Crude protein (%)	10.70 ± 0.93	10.59 ± 0.95	9.35 ± 0.49	8.30 ± 0.86
Total lipid (%)	20.01 ± 1.71^{ab}	24.16 ± 2.13^{a}	21.00 ± 1.05^{ab}	16.33 ± 1.89^{b}
Total carbohydrate (%)	1.31 ± 0.03	1.32 ± 0.16	1.54 ± 0.13	1.37 ± 0.19
Proximate composition in the gonads				
Moisture (%)	74.06 ± 0.43	75.70 ± 1.03	73.78 ± 0.2	73.88 ± 0.75
Crude protein (%)	17.37 ± 0.31	16.89 ± 0.81	17.25 ± 1.14	17.06 ± 0.89
Total lipid (%)	1.14 ± 0.14^{ab}	0.87 ± 0.06^{b}	0.93 ± 0.06^{ab}	1.22 ± 0.09^{a}
Total carbohydrate (%)	0.77 ± 0.03	1.12 ± 0.03	1.01 ± 0.05	0.88 ± 0.22
Proximate composition in the muscle				
Moisture (%)	79.23 ± 0.33^{b}	77.27 ± 0.52^{b}	77.89 ± 0.16^{b}	80.30 ± 0.33^{a}
Crude protein (%)	18.20 ± 0.42	18.13 ± 0.23	18.14 ± 0.41	17.78 ± 0.26
Total lipid (%)	0.81 ± 0.03^{ab}	0.74 ± 0.09^{b}	0.94 ± 0.04^{a}	0.78 ± 0.02^{ab}
Total carbohydrate (%)	0.97 ± 0.13^{a}	0.67 ± 0.01^{b}	0.27 ± 0.01^{c}	0.15 ± 0.02^{c}

Data were presented as mean ± SE. Data in a same line that do not share the same superscript were significantly different ($P < 0.05$)

Proximate composition analysis

A proximate composition analysis of the sample was conducted. The contents of moisture and total lipid were determined using standard Association of Official Agricultural Chemists (AOAC) methods 932.06 and 925.09, respectively (AOAC 2000). Crude protein was calculated by micro-Kjeldahl method with a 6.25 nitrogen-to-protein conversion coefficient (AOAC 2000). The determination of total carbohydrate content was carried out according to the phenol sulfuric acid method (Kochert 1978).

Amino acids analysis and essential amino acids score

The free amino acids content of the crabs was determined by referring to the method described by Chen et al. (2007). Each sample was freeze-dried firstly and then homogenized separately. A total of 100 mg dry weight of the sample was weighed and transferred into the 40 mL hydrolyzation tube. A total of 8 mL HCl solution (6.0 M) was added simultaneously. Then, the hydrolyzation tube was vacuumed and filled with enough nitrogen at 110 °C for 24 h. The final reaction volume was controlled to 50 mL with the distilled water and centrifuged at 2659 × g, then the hydrolyzate was filtered using filter paper. To remove the HCl, 1 mL of hydrolyzate was taken to dry in a vacuum condition at 50 °C. The hydrolyzate was then dissolved in 2–5 mL of 0.02 M HCl, and the supernatant (1 mL) was sampled for amino acid analysis using a Hitachi 835–50 automatic amino acid analyzer. For tryptophan analysis, the processing of per-treatment samples was conducted through the alkaline hydrolysis method. Briefly, each freeze-dried sample was treated with 5 M NaOH containing 5% $SnCl_2$ (w/v) at 110 °C for 20 h. In a different manner than previously mentioned, before centrifugation and filtration, the hydrolyzate was neutralized with 6 M HCl. The next analysis procedure was similar to the methods previously described. The identity and quantity of the individual amino acids were assessed by referring to the retention times and peak areas of the standard amino acids (Sigma-Aldrich, St. Louis. MO, USA). The amount of amino acids was expressed as milligram amino acids per gram wet tissue (mg/g wet weight).

The essential amino acids score (EAAS), was evaluated for the individual essential amino acids with the following formula (Food and Agriculture Organization of the United Nations/World Health Organization/United Nations University, FAO/WHO/UNU 1985), which was based on a

FAO/WHO reference to the amino acid requirement for preschool children (2–5 years of age). The formula EAAS = 100 × individual EAA content/FAO was used as a reference for the corresponding EAA content, and the amino acids content in this study was expressed as milligram individual amino acids per gram total protein (mg/g).

Fatty acids analysis

The method of fatty acids analysis was mainly based on the previous report by Wu et al. (2007b) and it was slightly improved in this study. First, the processing of fatty acids methyl esters was conducted with transesterification by boiling 14% orontrifluoride/methanol (w/w), and following the method described by Morrison and Smith (1964). Fatty acids methyl esters were analytically verified through flame ionization detection (FID) after injecting the sample into an Agilent 7890B/5977A GCMS. An Omegawax L × I.D.30 m × 0.25 mm × 0.25 μm fused silica capillary column (Supelco, Billefonte, PA, USA) was fitted in the GCMS. The injector temperature was controled at 240 °C. The initial column temperature was kept at 40 °C for 2 min, using a set of procedures, and the temperature was increased to 230 °C until all of the fatty acid methyl esters had been absolutely eluted. The total time of the procedure was set at 49 min. The carrier gas was the helium with the flow velocity of 58.825 cm/s. The available peaks were identified though comparing the retention times with known standards (Nu-Chek-Prep Inc., Elysian, MN, USA). The amount of fatty acids of each sample was expressed as a percentage of the total fatty acids (%).

Statistics

All of the data were presented as mean ± standard error (SE). Homogeneity of variance of data was tested with Levene's test. The collected data were analyzed by SPSS 13.0 (SPSS Inc., Chicago, IL, USA). The statistical significance of differences among treatments was measured using one-way analysis of variance (ANOVA). When the overall treatment effect was significantly different, Duncan's multiple range test was conducted to compare the means of the individual treatments. ($P < 0.05$; n = 3).

Results and discussion

Tissue indices and total edible yield

The tissue indices and total edible yield of different grade crabs are shown in Table 1. The average weight of four grade *E. sinensis* used in this study were 219.15 ± 25.83 g (grade I), 180.62 ± 8.76 g (grade II), 153.35 ± 1.80 g (grade III), 133.47 ± 7.55 g (grade IV), respectively. The trends of HSI, MY and TEY were similar among all of the treatments. However, the GSI of grade III crabs was significantly higher than those of grade I and grade II crabs ($P < 0.05$), and no significant difference was found with the grade IV crabs ($P > 0.05$). The CF indices of grade I and grade II crabs were significantly increased when compared with the grade III and grade IV crabs ($P < 0.05$).

In the current study, the relationship was first established between the wet weight of *E. sinensis* and nutritional quality. It seems that the tissue indices and total edible yield did not gradually improve with the increasing of the grades. The crucial indicator, total edible yield, also did not display statistically differences, although the highest one was grade I (38.07%). Chen et al. (2007) reported that the male Chinese mitten crabs had a wet weight of 150–160 g, and the mean value of TYE was 33.4%, which was slightly lower than grade III (37.20%) in our experiment. The smaller value of MY (24.2%) was the main reason for this result. The yield of the edible viscera of *E. sinensis* was 9.2% and 9.04% in their studies by Chen et al. (2007), which was slightly lower than our data shown in Table 2. The effects of natural and formulated diets on hepatopancreas and gonads quality of *E. sinensis* had also been compared (Shao et al. 2013). The results showed that the GSI and HSI of the male *E. sinensis* (wet weight: 105–115 g) was 2.10–0.58% and 6.53–1.32%, respectively. The corresponding value of grade IV in the current study was 5.13 and 4.43% for GSI and HSI, respectively. There were some differences between the two results, and the differences were likely due to the food discrepancy and individual differences. Taken together, the grade II crabs should be recommended according to the Chinese diet habits, because they have the highest GSI, regardless of the face that the TEY of the grade II crabs was not the best of the four grades of crabs.

Proximate composition

The chemical composition of hepatopancreas, gonads, and muscle is shown in Table 1. The moisture of the hepatopancreas, as expected, was the smallest in the grade II crabs, in which it was significantly lower than that of the grade III and grade IV crabs ($P < 0.05$). On the contrary, the highest content of the total lipid was also found in the grade II crabs, and it was significantly increased when compared with the grade IV crabs ($P < 0.05$), although no differences were observed between the grade II crabs and either the grade I or grade III crabs ($P > 0.05$). The different sizes of *E. sinensis* did not significantly impact the levels of the crude protein and the total carbohydrate of the hepatopancreas ($P > 0.05$).

Table 2 Amino acids composition in the gonads and muscle of different grades of male *E. sinensis* (mg/g wet weight)

	Amino acids composition of the gonads				Amino acids composition of the muscle			
	Grade I	Grade II	Grade III	Grade IV	Grade I	Grade II	Grade III	Grade IV
Isoleucine	6.96 ± 0.27	6.52 ± 0.45	6.86 ± 0.10	6.69 ± 0.17	6.92 ± 0.26^{b}	7.09 ± 0.10^{ab}	7.58 ± 0.03^{a}	6.73 ± 0.12^{b}
Leucine	10.47 ± 0.33	9.88 ± 0.67	10.41 ± 0.12	10.08 ± 0.24	10.20 ± 1.90	11.91 ± 0.19	12.72 ± 0.02	11.36 ± 0.23
Lysine	7.17 ± 0.18	6.96 ± 0.42	7.17 ± 0.11	7.25 ± 0.14	9.91 ± 2.09	13.01 ± 0.22	13.36 ± 0.21	12.87 ± 0.45
Methionine	3.46 ± 0.15	3.01 ± 0.25	3.35 ± 0.16	3.29 ± 0.06	4.03 ± 0.11^{ab}	4.03 ± 0.07^{ab}	4.33 ± 0.11^{a}	3.61 ± 0.20^{b}
Cystine	3.03 ± 0.36^{a}	2.20 ± 0.20^{b}	3.36 ± 0.24^{a}	3.21 ± 0.10^{a}	0.70 ± 0.12^{ab}	0.69 ± 0.13^{ab}	0.90 ± 0.16^{a}	0.35 ± 0.09^{b}
Valine	5.76 ± 0.11	5.66 ± 0.34	5.92 ± 0.06	5.92 ± 0.06	7.33 ± 0.27	7.55 ± 0.11	8.13 ± 0.01	7.11 ± 0.13
Phenylalanine	6.26 ± 0.16	5.98 ± 0.44	6.25 ± 0.11	5.99 ± 0.17	6.52 ± 0.27^{b}	6.70 ± 0.12^{ab}	7.22 ± 0.02^{a}	6.39 ± 0.12^{b}
Tyrosine	5.87 ± 0.21	5.61 ± 0.42	5.68 ± 0.10	5.61 ± 0.19	6.45 ± 0.33^{ab}	6.60 ± 0.13^{ab}	6.99 ± 0.64^{a}	6.21 ± 0.13^{b}
Threonine	13.48 ± 0.59	12.63 ± 0.81	13.47 ± 0.11	12.84 ± 0.31	7.04 ± 0.29^{ab}	7.16 ± 0.10^{ab}	7.51 ± 0.06^{a}	6.78 ± 0.15^{b}
Tryptophan	1.62 ± 0.02^{a}	1.52 ± 0.01^{b}	1.57 ± 0.00^{ab}	1.42 ± 0.04^{c}	1.63 ± 0.02^{b}	1.74 ± 0.01^{a}	1.72 ± 0.01^{a}	1.57 ± 0.02^{c}
Serine	7.34 ± 0.21	6.84 ± 0.42	7.39 ± 0.06	7.05 ± 0.13	6.29 ± 0.25^{ab}	6.38 ± 0.11^{ab}	6.72 ± 0.05^{a}	6.03 ± 0.15^{b}
Glutamic acid	20.74 ± 0.56	19.78 ± 1.20	21.06 ± 0.17	20.71 ± 0.46	23.57 ± 1.02^{ab}	24.12 ± 0.35^{ab}	25.58 ± 0.08^{a}	23.06 ± 0.54^{b}
Glycine	6.57 ± 0.22	6.42 ± 0.46	7.02 ± 0.06	6.92 ± 0.07	10.72 ± 0.43^{b}	10.74 ± 0.44^{b}	12.24 ± 0.20^{a}	11.12 ± 0.22^{ab}
Alanine	11.26 ± 0.26	10.73 ± 0.88	11.18 ± 0.14	11.02 ± 0.33	13.56 ± 0.71^{ab}	14.20 ± 0.17^{a}	13.31 ± 0.26^{ab}	12.32 ± 0.51^{b}
Aspartic acid	18.06 ± 0.59	17.06 ± 1.20	18.57 ± 0.45	17.98 ± 0.55	14.43 ± 0.59^{b}	14.73 ± 0.39^{b}	16.17 ± 0.02^{a}	14.49 ± 0.35^{b}
Histidine	4.17 ± 0.10	4.11 ± 0.27	4.43 ± 0.08	4.25 ± 0.06	3.54 ± 0.15^{b}	3.76 ± 0.06^{ab}	4.05 ± 0.04^{a}	3.49 ± 0.06^{b}
Arginine	7.59 ± 0.20	7.48 ± 0.40	7.57 ± 0.14	7.85 ± 0.11	11.20 ± 0.40	14.89 ± 0.48	15.56 ± 0.10	14.27 ± 0.31
Proline	21.64 ± 1.07	20.05 ± 1.61	21.87 ± 0.27	20.82 ± 0.63	8.48 ± 0.48	8.05 ± 0.27	8.16 ± 0.11	7.31 ± 0.50
EAA	64.06 ± 2.12	59.96 ± 3.99	64.03 ± 0.51	62.27 ± 1.40	60.75 ± 5.42	66.47 ± 1.07	70.47 ± 0.33	62.97 ± 0.89
NEAA	97.35 ± 3.12	92.40 ± 6.34	99.09 ± 1.05	96.60 ± 2.23	91.80 ± 7.50	96.87 ± 1.26	101.78 ± 0.22	92.09 ± 2.11
EAA/TAA	0.40 ± 0.00	0.39 ± 0.01	0.39 ± 0.00	0.39 ± 0.00	0.40 ± 0.00^{b}	0.41 ± 0.00^{a}	0.41 ± 0.00^{a}	0.41 ± 0.01^{a}

Data were presented as mean ± SE. Values in the same line of the same tissue with different superscripts were significantly different ($P < 0.05$)

EAA essential fatty acids, *NEAA* non-essential fatty acids, *TAA* total amino acids

The change trend of the total lipid of the gonads was different from that of the hepatopancreas. The lowest total lipid value of the gonads was shown in the grade II crabs, whereas the value of the total lipid in the grade IV crabs was the highest, and a significant difference was found between two treatments ($P < 0.05$). However, for all of the treatments, the three indices of the moisture, the crude protein and the total carbohydrate in the gonads had no significant difference ($P < 0.05$). Compared with the hepatopancreas and the gonads, the muscle had a relatively high moisture level. The content of moisture was significantly increased in the grade IV crabs, although the moisture of the other treatments was significantly reduced ($P < 0.05$). The significant differences of the total lipid level of the muscle in the four grade crabs were detected in this study. The largest value (0.94 ± 0.04 g) was the grade III crabs ($P < 0.05$), whereas the smallest one (0.74 ± 0.09 g) was the grade II crabs ($P < 0.05$), and the total lipid contents of the grade I crabs and the grade IV crabs were in the middle level (0.81 ± 0.03 g; 0.78 ± 0.02 g), respectively. With the decreasing of the average weight of male *E. sinensis*, the content of the total carbohydrate in the muscle was significantly reduced ($P < 0.05$). In a similar manner to the hepatopancreas and the gonads, no significant differences were observed in the muscle for the crude protein among the four grade crabs ($P > 0.05$).

The chemical composition and nutritive value of the edible parts had been extensively investigated in various regions of the world. Guo et al. (2015) had assessed the nutrient and nonvolatile taste compound contents of edible viscera and the remaining tissues of *E. sinensis*. The results suggested that the moisture of edible viscera and remainder tissues were 60.88 and 76.39%, which was lower than 61.17–76.53%, and 77.27–80.30% shown in Table 3 of this study. Based on the results of Shao et al. (2013), the moisture content of the gonads was basically consistent; however, the dry matter of the hepatopancreas was smaller. The reasons may be contributed to the food factor, because the hepatopancreas moisture content of all of grade crabs was larger than others' results. However, there was an accordance of the crude protein content of the three edible parts between our data and the results of Shao et al.(2013). Additionally, the total lipid content (16.33–24.16%) in the hepatopancreas and gonads (0.87–1.14%) was similar to that (20.2 and 0.9%) reported by Chen et al. (2007). Wu et al. (2007a) had demonstrated that the total lipid content of 140 g male *E. sinensis* was 15.74% of hepatopancreas, 1.75% of gonads, and 1.8% of muscle.

In our experiment, grade IV crabs had a little higher total lipid content of hepatopancreas (16.33%), but also had a somewhat lower total lipid content of the gonads (1.22%) and muscle (0.78%). To the best of our knowledge, a few studies had concentrated on the total carbohydrate of *E. sinensis*. It is worthy to pay attention to the face that the total carbohydrate level of muscle was progressively reduced with the decreasing of the grades, which was the most obvious characteristics among the four grades of crabs. Overall, it seems difficult to select the best grade for the proximate composition of the edible part. Despite this, most of the protein resided in the meat, whereas the fat is predominant in the hepatopancreas (Chen et al. 2007).

Amino acids contents and EAA scores

In the present research, the contents of the 18 free amino acids of the muscle and the gonads were also analyzed, and the results are shown in the Table 2. The amino acids scores were summarized in Table 3. In the gonads, the content of the amino acids did not differ for the male *E. sinensis* of grade I through grade IV, except for Cys and Try, whereas the content of amino acids of the muscle was affected by the crab's size and exhibited a significant interaction. The content of EAA in the muscle displayed the trend of first increasing and then being reduced with the decreasing grade; interestingly, the highest point was in the grade III crabs, and the lowest point was in the grade IV crabs except for Ieu and Lys. The contents of Thr, Met, Cys, Ile, Tyr, Try and Phe in the grade III crabs significantly increased compared to the grade IV crabs ($P < 0.05$). However, no statistical differences were found in the content of Val, Lys, and Leu between grade III and grade IV ($P > 0.05$). The value of the remainder of non-essential amino acids (NEAA), including Ser, Glu, Ala, and His, was also significantly decreased in the grade IV crabs ($P < 0.05$); on the contrary, the highest value was detected in the grade II or grade III crabs. Moreover, EAA scores showed that Try was the limited amino acids for the muscle, because its score was lower than 100. Compared to the muscle, the limited amino acids of the gonads were Leu, Lys, Try, and Val, respectively.

Protein represents the most important fundamental component of the nutrient composition for humans, which plays a crucial role in the aspects of basic framework and physiological function of the cells. The composition of EAA can reflect the nutritional qualities of protein. The amino acids score is an approved method for assessing protein quality by comparing it against the amino acids requirements of preschool-aged children. In addition, the appearance of a diet's flavor was contributed by the amino acids, especially the strong umami and pleasant sweetness in the *E. sinensis*, which was an attractive flavor for Asian people. Therefore, the amino acids composition and amino acids scores were also evaluated in the edible parts of four grade male *E. sinensis.*

Table 3 Essential amino acids score (EAAS) of the gonads and muscle of different grades of male *E. sinensis*

	Grade I	Grade II	Grade III	Grade IV
EAA scores of the gonads				
Isoleucine	143	138	143	141
Leucine	91	88	92	90
Lysine	71	71	72	74
Methionine + Cystine	149	123	157	153
Phenylalanine + Tyrosine	111	109	111	108
Threonine	228	200	232	222
Tryptophan	84	82	83	76
Valine	95	96	99	99
Average score	127	121	130	127
EAA scores of the muscle				
Isoleucine	140	140	149	139
Leucine	88	100	106	99
Lysine	97	124	127	128
Methionine + Cystine	107	104	115	91
Phenylalanine + Tyrosine	117	116	124	115
Threonine	117	116	122	115
Tryptophan	84	87	86	82
Valine	119	119	128	117
Average score	112	117	125	115

EAAS = 100 × one essential fatty acid content in sample/one essential fatty acid content in FAO reference protein (FAO/WHO/UNU 1985)

Chen et al. 2007 had reported that *E. sinensis* protein contained a high level of Glu (151 mg/g), Asp (99 mg/g), Arg (99 mg/g), Lys (81 mg/g) and Leu (77 mg/g). Gly and Ala contributed to the major sweet taste, whereas Glu acid contributed to the strong umami taste. Wang et al. (2016) had compared the flavour qualities of three sourced *E. sinensis*, and Arg, Gly and Ala were the major free amino acids, accounting for more than 70% of the total free amino acids. Overall, the content of amino acids in the present experiment was in normal range (Chen et al. 2007; Wang et al. 2016).

When compared with the results of the amino acids scores of meat provided by Chen et al. 2007, only the S-containing amino acids score (cysteine and methionine) was less than 100 and seemed to be the limiting amino acids in *E. sinensis.* However, our data from all of the grade crabs in both of the muscle and the gonads was more than 100, except for the grade IV in the muscle. Moreover, the scores of Lys, Leu and Val in the gonads were lower than 100, but there was an inverse results in the muscle in our present study and the research by Chen et al. (2007). Taken together, these results of amino acids content and EAA scores indicated or confirmed that: 1) the differences of amino acid content always existed among the individuals although they grew and developed under the same condition (Chen et al. 2007); 2) the balance of essential amino acids in the muscle was better than gonads for male *E. sinensis* (Chen et al. 2007); 3) the grade II and the grade III crabs have the excellent qualities for amino acids among four grade *E. sinensis*, and the grade III is the best one for the two tissues of muscle and gonads, which can be as good a source of protein.

Fatty acids composition

The proportion of fatty acids in the three edible parts was calculated by the gas chromatography-mass spectrometry (GC–MS) method (Tables 4, 5, 6). The three tissues of male *E. sinensis* had a similar fatty acids composition. Twenty-four types of free fatty acids were detected including 8 saturated fatty acids (SFA), 6 monounsaturated fatty acids (MUFA) and 9 polyunsaturated fatty acids (PUFA), with the carbon chain length started from 14–22 C.

In the hepatopancreas, the levels of SFA and MUFA were quite closed in all of the treatments. However, the PUFA, n-3/n-6, and DHA/EPA had been affected by the different sizes. The smallest value of the PUFA was found in the grade III crabs, and was significantly lower than those of the other treatments ($P < 0.05$); however, the PUFA content did not differ from the other three treatments, although the highest PUFA content was the grade II

Table 4 Fatty acids composition in the hepatopancreas of different grades of male *E. sinensis* (% total fatty acids)

Fatty acids	Grade I	Grade II	Grade III	Grade IV
C14:0	0.92 ± 0.15^{a}	0.54 ± 0.01^{b}	0.64 ± 0.06^{b}	0.48 ± 0.02^{b}
C15:0	0.95 ± 0.07	0.69 ± 0.09	0.58 ± 0.11	0.78 ± 0.15
C16:0	14.14 ± 0.72	15.28 ± 0.30	14.59 ± 1.62	12.24 ± 1.30
C17:0	0.78 ± 0.15	0.63 ± 0.12	0.45 ± 0.05	0.76 ± 0.09
C18:0	3.09 ± 0.03	2.98 ± 0.36	3.41 ± 0.14	3.47 ± 0.30
C20:0	0.26 ± 0.02	0.21 ± 0.01	0.20 ± 0.02	0.27 ± 0.03
C22:0	0.22 ± 0.01^{ab}	0.20 ± 0.00^{b}	0.26 ± 0.04^{a}	0.25 ± 0.04^{a}
SFA	20.36 ± 0.68	20.52 ± 0.37	20.14 ± 1.52	18.26 ± 1.88
C16:1n7	5.38 ± 0.29^{a}	3.25 ± 0.09^{b}	4.14 ± 0.15^{ab}	4.68 ± 0.69^{a}
C17:1n7	0.83 ± 0.73	0.63 ± 0.02	0.70 ± 0.07	0.79 ± 0.09
C18:1n7	3.19 ± 0.13	3.16 ± 0.42	3.58 ± 0.22	3.21 ± 0.22
C18:1n9	24.74 ± 1.63	25.51 ± 1.55	27.49 ± 3.99	21.86 ± 0.50
C20:1n9	2.07 ± 0.28	2.14 ± 0.35	3.27 ± 0.53	2.15 ± 0.27
C22:1n9	0.45 ± 0.04^{b}	0.48 ± 0.10^{ab}	0.69 ± 0.07^{a}	0.35 ± 0.03^{b}
MUFA	36.67 ± 1.59	35.18 ± 0.94	39.86 ± 4.26	33.03 ± 1.69
C18:2n6	14.57 ± 2.40^{a}	17.02 ± 0.07^{a}	6.90 ± 0.61^{b}	8.49 ± 0.98^{b}
C20:2n6	3.41 ± 0.42^{b}	2.83 ± 0.29^{b}	3.19 ± 0.28^{b}	5.70 ± 0.80^{a}
C18:3n3	1.50 ± 0.14^{a}	1.40 ± 0.22^{a}	0.76 ± 0.12^{b}	0.69 ± 0.02^{b}
C20:3n3	0.38 ± 0.05^{b}	0.23 ± 0.06^{b}	0.50 ± 0.04^{a}	0.33 ± 0.01^{b}
C20:3n6	0.30 ± 0.02	0.36 ± 0.08	0.31 ± 0.04	0.42 ± 0.07
C20:4n6	3.80 ± 0.58^{ab}	2.50 ± 0.33^{b}	3.10 ± 0.58^{a}	6.62 ± 0.66^{a}
C20:5n3	2.10 ± 0.10^{ab}	2.66 ± 0.52^{a}	1.60 ± 0.19^{b}	4.30 ± 0.06^{a}
C22:5n3	0.94 ± 0.01^{ab}	1.07 ± 0.09^{a}	0.76 ± 0.04^{b}	0.85 ± 0.05^{b}
C22:6n3	4.81 ± 0.02^{b}	5.97 ± 0.40^{a}	3.48 ± 0.22^{b}	4.42 ± 0.29^{b}
PUFA	31.18 ± 1.81^{a}	34.04 ± 0.38^{a}	21.89 ± 1.41^{b}	31.57 ± 1.10^{a}
HUFA	12.34 ± 0.60^{b}	12.79 ± 0.30^{b}	11.04 ± 0.86^{b}	16.70 ± 0.34^{a}
n-3 PUFA	9.73 ± 0.25^{b}	11.46 ± 0.23^{a}	8.20 ± 0.42^{c}	10.43 ± 0.33^{b}
n-6 PUFA	22.08 ± 1.57^{a}	22.58 ± 0.61^{a}	13.68 ± 1.24^{b}	21.15 ± 1.33^{a}
n-3 PUFA/n-6 PUFA	0.44 ± 0.02^{b}	0.51 ± 0.02^{ab}	0.61 ± 0.05^{a}	0.50 ± 0.05^{ab}
DHA/EPA	2.31 ± 0.10^{a}	2.44 ± 0.52^{a}	3.06 ± 0.32^{a}	0.97 ± 0.07^{b}

Data were presented as mean ± SE. Values in the same line with different superscripts were significantly different ($P < 0.05$)

SFA saturated fatty acids, *MUFA* mono-unsaturated fatty acids, *PUFA* poly-unsaturated fatty acids, *HUFA* highly-unsaturated fatty acids, *n-3/n-6* the ratio of ∑n-3PUFA/∑n-6PUFA

crabs ($P > 0.05$). The opposite result of the HUFA content was observed: the grade IV crabs had the highest level and reached the significance level when compared with the other treatments ($P < 0.05$). The composition of total fatty acids showed that the three most important HUFA, DHA and EPA, as well as ARA were significantly increased in the grade II crabs ($P < 0.05$), although the highest ratio of DHA/EPA was not found in the grade II crabs but rather in the grade III crabs.

The fatty acids composition of the gonads in the different grade crabs are shown in Table 5. Compared to the MUFA content of grade II crabs, the MUFA content of the grade IV crabs was significant increased ($P < 0.05$), and there were no significant differences with the grade I and grade III crabs ($P > 0.05$). On the contrary to the MUFA content, the gonads of the grade III crabs had the significantly higher contents of PUFA and HUFA, as well as the ratios of n-3/n-6 PUFA ($P < 0.05$). Despite the ratios of DHA/EPA having no significant differences in the gonads among the four treatments ($P > 0.05$), the DHA and EPA contents were abundant in the grade II crabs. Additionally, the content of the ARA in the grade II crabs was significantly larger than that of the grade IV crabs ($P < 0.05$).

Twenty-four fatty acids were found in the edible tissues of *E. sinensis*. The fatty acids profiles of the hepatopancreas were dominated by MUFA and SFA, while the muscle and gonads were richer in PUFA fatty acids (Tables 5, 6). SFA is the main supplier of energy for *E. sinensis* during the β-oxidation processing. In this study, the odd-numbered fatty acids, including C15:0, C17:0 and

Table 5 Fatty acids composition in the gonads of different grades of male *E. sinensis* (% total fatty acids)

Fatty acids	Grade I	Grade II	Grade III	Grade IV
C14:0	0.36 ± 0.02^{b}	0.25 ± 0.00^{b}	0.30 ± 0.06^{b}	0.53 ± 0.03^{a}
C15:0	0.34 ± 0.04^{b}	0.25 ± 0.01^{b}	0.27 ± 0.05^{b}	0.48 ± 0.04^{a}
C16:0	10.28 ± 1.47^{ab}	7.75 ± 0.17^{b}	8.68 ± 0.49^{b}	11.89 ± 0.86^{a}
C17:0	0.65 ± 0.03	0.78 ± 0.15	0.51 ± 0.04	0.58 ± 0.04
C18:0	4.84 ± 0.24^{b}	6.78 ± 0.85^{a}	5.23 ± 0.51^{ab}	4.28 ± 0.39^{b}
C20:0	0.37 ± 0.04^{b}	0.69 ± 0.10^{a}	0.39 ± 0.03^{b}	0.41 ± 0.00^{b}
C22:0	0.50 ± 0.04^{b}	0.88 ± 0.07^{a}	0.65 ± 0.01^{b}	0.59 ± 0.05^{b}
SFA	17.33 ± 1.20	17.38 ± 1.03	16.03 ± 0.21	18.76 ± 0.52
C16:1n7	2.74 ± 0.13^{b}	2.27 ± 0.47^{b}	3.24 ± 0.74^{b}	6.93 ± 1.76^{a}
C17:1n7	0.43 ± 0.04^{b}	0.32 ± 0.10^{bc}	0.38 ± 0.03^{ab}	0.60 ± 0.03^{a}
C18:1n7	3.46 ± 0.08^{a}	3.35 ± 0.19^{ab}	3.07 ± 0.30^{c}	3.72 ± 0.11^{a}
C18:1n9	18.30 ± 1.10	15.15 ± 1.31	17.14 ± 0.56	18.85 ± 1.36
C20:1n9	1.63 ± 0.06	2.59 ± 0.38	2.33 ± 0.26	1.78 ± 0.34
C22:1n9	0.69 ± 0.12^{c}	1.26 ± 0.05^{a}	0.98 ± 0.04^{b}	0.60 ± 0.06^{c}
MUFA	27.26 ± 1.11^{ab}	24.94 ± 2.11^{b}	27.14 ± 1.37^{ab}	32.48 ± 2.84^{a}
C18:2n6	9.03 ± 1.63^{a}	4.66 ± 0.38^{b}	5.84 ± 0.08^{b}	7.18 ± 0.24^{ab}
C20:2n6	3.86 ± 0.60	3.18 ± 0.29	4.46 ± 0.30	3.28 ± 0.19
C18:3n3	0.63 ± 0.02^{b}	0.49 ± 0.06^{ab}	0.39 ± 0.04^{c}	0.97 ± 0.10^{a}
C20:3n3	0.27 ± 0.01^{a}	0.25 ± 0.00^{b}	0.21 ± 0.01^{b}	0.30 ± 0.03^{a}
C20:4n6	13.76 ± 0.65^{a}	16.38 ± 0.83^{a}	13.34 ± 1.14^{a}	9.83 ± 1.25^{b}
C20:5n3	7.97 ± 0.08^{c}	9.63 ± 0.22^{a}	8.75 ± 0.22^{b}	5.74 ± 0.35^{d}
C22:5n3	0.85 ± 0.02	0.72 ± 0.01	0.81 ± 0.04	0.81 ± 0.08
C22:6n3	11.64 ± 0.75^{bc}	14.57 ± 1.40^{ab}	15.12 ± 0.86^{a}	9.59 ± 0.16^{c}
PUFA	48.01 ± 2.03^{a}	49.87 ± 1.58^{a}	48.93 ± 1.80^{a}	37.70 ± 1.70^{b}
HUFA	34.49 ± 1.45^{b}	41.54 ± 1.69^{a}	38.23 ± 1.88^{ab}	26.26 ± 1.55^{c}
n-3 PUFA	21.37 ± 0.82^{b}	25.66 ± 1.34^{a}	25.28 ± 1.00^{a}	17.40 ± 0.36^{c}
n-6 PUFA	26.64 ± 1.39^{a}	24.22 ± 0.74^{ab}	23.65 ± 1.22^{ab}	20.29 ± 1.36^{b}
n-3 PUFA/n-6 PUFA	0.80 ± 0.03^{b}	1.06 ± 0.06^{a}	1.07 ± 0.06^{a}	0.86 ± 0.05^{b}
DHA/EPA	1.46 ± 0.08	1.52 ± 0.16	1.73 ± 0.06	1.69 ± 0.12

Data were presented as mean ± SE. Values in the same line with different superscripts were significantly different ($P < 0.05$)

SFA saturated fatty acids, *MUFA* mono-unsaturated fatty acids, *PUFA* poly-unsaturated fatty acids, *HUFA* highly-unsaturated fatty acids, *n-3/n-6* the ratio of ∑n-3PUFA/∑n-6PUFA

C19:0, had been detected in different edible parts of *E. sinensis*, despite the contents being lower. Rumpold and Schlüter (2013) mentioned that the odd-numbered fatty acids were also found for some insects, and the two dominant components of the SFA were palmitic acid (C16:0) and stearic acid (C18:0) as reported by O'Connor et al. (1968). Compared with the previously mentioned results, our data of the three tissues in this experiment displayed the accordant conclusion. As we all known, hepatopancreas is the most important organ for decapod crustacean, which has the primary role of nutrition digestion and energy metabolism, and the function may be a consequence of the SFA content of the hepatopancreas being higher than the other tissues.

A balanced composition of essential fatty acids, namely a-linolenic acid (18:3n3) and (18:2n6) is essential for human health, whereas ARA, EPA and DHA are indispensable for special treatments for people, in particular fetuses, infants, adolescents, and pregnant or lactating women (Muskiet et al. 2006). The consumption of foods containing DHA and EPA can reduce cardiovascular disease risk (Hall 2009); suppress inflammation (Capela et al. 2015), and be beneficial for bone health (Nakanishi and Tsukamoto 2015) and therapeutic action of diabetes (Bhaswant et al. 2015). Moreover, EPA and DHA had an irreplaceable role for larval *E. sinensis*, which can accelerate the molting cycle of the crabs and facilitate the improvement of growth performance (Wu et al. 2007b; Suprayudi et al. 2004). In this study, the greatest percentages of PUFA in three edible parts of *E. sinensis* were the muscle, followed by the gonads and the hepatopancreas. Among the different grades of male crabs, the grade II

Table 6 Fatty acids composition in the muscle of different grades of male *E. sinensis* (% total fatty acids)

Fatty acids	Grade I	Grade II	Grade III	Grade IV
C14:0	0.24 ± 0.01[a]	0.16 ± 0.02[b]	0.16 ± 0.02[b]	0.16 ± 0.01[b]
C15:0	0.28 ± 0.03	0.24 ± 0.01	0.24 ± 0.07	0.28 ± 0.03
C16:0	9.38 ± 0.10	8.64 ± 0.42	8.63 ± 0.18	9.01 ± 0.09
C17:0	0.74 ± 0.05	0.72 ± 0.03	0.71 ± 0.13	0.83 ± 0.01
C18:0	6.11 ± 0.18	6.26 ± 0.07	6.53 ± 0.23	6.40 ± 0.15
C19:0	0.15 ± 0.02	0.14 ± 0.02	0.17 ± 00	0.19 ± 0.02
C20:0	0.35 ± 0.03	0.35 ± 0.02	0.38 ± 0.02	0.36 ± 0.01
C22:0	0.28 ± 0.02[b]	0.33 ± 0.02[b]	0.39 ± 0.01[a]	0.33 ± 0.02[b]
SFA	17.52 ± 0.27	16.84 ± 0.49	17.27 ± 0.35	17.55 ± 0.09
C16:1n7	2.28 ± 0.27	2.17 ± 0.05	1.93 ± 0.18	2.20 ± 0.26
C17:1n7	0.53 ± 0.03	0.48 ± 0.02	0.46 ± 0.05	0.57 ± 0.04
C18:1n7	2.87 ± 0.04	2.88 ± 0.31	2.76 ± 0.09	2.87 ± 0.42
C18:1n9	17.76 ± 0.63	15.96 ± 0.60	17.45 ± 0.91	16.63 ± 1.25
C20:1n9	0.99 ± 0.05[ab]	2.02 ± 0.30[a]	1.71 ± 0.09[a]	1.52 ± 0.17[ab]
C22:1n9	0.32 ± 0.03[ab]	0.33 ± 0.07[ab]	0.25 ± 0.01[b]	0.44 ± 0.04[a]
MUFA	24.75 ± 0.75	23.85 ± 0.91	24.56 ± 0.89	24.32 ± 1.00
C18:2n6	9.19 ± 0.41	8.20 ± 0.71	7.80 ± 0.16	7.32 ± 0.79
C20:2n6	2.82 ± 0.17	3.34 ± 0.65	3.40 ± 0.37	4.11 ± 0.91
C18:3n3	1.12 ± 0.13	1.10 ± 0.08	1.08 ± 0.27	1.01 ± 0.22
C20:3n3	0.28 ± 0.03	0.27 ± 0.03	0.35 ± 0.07	0.31 ± 0.04
C20:4n6	8.02 ± 0.77	7.52 ± 0.67	7.28 ± 0.61	7.65 ± 0.09
C20:5n3	14.93 ± 0.23	15.81 ± 0.55	15.95 ± 0.27	15.76 ± 0.36
C22:5n3	0.86 ± 0.07	0.86 ± 0.10	0.74 ± 0.13	0.73 ± 0.04
C22:6n3	13.38 ± 0.04	14.83 ± 0.41	14.38 ± 0.88	13.84 ± 0.41
PUFA	50.60 ± 0.77	51.92 ± 0.76	50.99 ± 0.51	50.78 ± 0.53
HUFA	37.47 ± 0.97	39.28 ± 0.70	38.70 ± 0.76	38.34 ± 0.63
n-3 PUFA	30.57 ± 0.36[b]	32.87 ± 0.29[a]	32.50 ± 0.43[a]	31.70 ± 0.47[ab]
n-6 PUFA	20.03 ± 0.57	19.06 ± 0.95	18.49 ± 0.76	19.08 ± 0.14
n-3 PUFA/n-6 PUFA	1.53 ± 0.04	1.73 ± 0.09	1.77 ± 0.09	1.66 ± 0.02
DHA/EPA	0.90 ± 0.01	0.94 ± 0.06	0.90 ± 0.06	0.88 ± 0.02

Data were presented as mean ± SE. Values in the same line with different superscripts were significantly different ($P < 0.05$)

SFA saturated fatty acids, *MUFA* mono-unsaturated fatty acids, *PUFA* poly-unsaturated fatty acids, *HUFA* highly-unsaturated fatty acids, *n-3/n-6* the ratio of ∑n-3PUFA/∑n-6PUFA

crabs had more numbers of the PUFA. Considering the sum of the percentages of five PUFA, the highest content was grade II in the hepatopancreas (29.55%) and in the gonads (46.91%), whereas the lowest content was in the hepatopancreas (15.84%) of grade III and in the gonads (33.31%) of grade IV, respectively.

The levels of n-3 PUFA and n-6 PUFA, as well as n-3/n-6 ratio are the good indicators for comparing the relative nutritional value, and a higher n-3/n-6 PUFA ratio has often been cited as an index of a better nutritional value (Chen et al. 2007; Coetzee and Hoffman, 2002). The experts had recommended that dietary n-3/n-6 PUFA ratio in the diets should be at least 0.1–0.2 (FAO/WHO 1994). Dyerberg (1986) noted that an increase of n-3/n-6 PUFA ratio improved the availability of n-3 PUFA, which was beneficial for human health. The ratio of n-3/n-6 PUFA had a certain change within different tissues. Generally, meat had the higher ratio of n-3/n-6 PUFA than the hepatopancreas, according to our data, and the results of *Callinectes sapidus* from Mehmet et al. (2004) exhibited similar trends. Therefore, the maximum of n-3 PUFA level of the three edible parts was the grade II; meanwhile, the grade II displayed a relatively better ratio of n-3/n-6 PUFA. The current results indicated that the PUFA profiles of the grade II crabs were abundant and well-balanced when compared with the other grades. Overall, in terms of the fatty acids, it was concluded that the best nutritional value for the edible parts was still the grade II crabs.

Up until now, the research is extremely rare concerning the nutrition composition of *E. sinensis* at different

physiological stages or sizes, especially, regarding male crabs. A few studies had been concentrated on the development periods of ovary and larva (Ying et al. 2006; Xu et al. 2014; Li et al. 2012). In summary, these previous results suggested that the composition and proportion of various nutritional factors were not entirely consistent, and this inconsistency reflected the inherent characteristics of the organization or may be explained as food factor and aquaculture environment. However, the results of the current study also confirmed the analogous principle that the nutrition composition of *E. sinensis* could still be changed with the increased grade apart from the conservation tissue of nutrition composition. The different grades of crabs were considered to give rise to this variety.

Conclusion

This is the first study to address the effects of different grades on the proximate chemical composition, and the fatty acids and amino acids contents of male *E. sinensis*. The results from the three representative edible tissues, including hepatopancreas, gonads, and muscle, revealed that the grade III male *E. sinensis* (150–174 g) was rich in well-balanced EAA compositions and meet amino acids requirements for humans. Furthermore, the grade II male *E. sinensis* (175–199 g) had the best fatty acids nutrition. Considering the tissue indices, total edible yield, and proximate chemical, there were no obvious differences for the crabs from different grades. Taken together, it can generally be concluded that the male *E. sinensis* of 150–200 g weight has the highest nutritional quality, even though they are not the largest size. This knowledge from our study confirmed that the Chinese mitten crab is a nutritious food for human health, and contributes to the better data for chemical composition of male *E. sinensis.* Based on these results, the 150–200 g weight for male *E. sinensis* (Grade II–III) should be recommended because it displays a better nutritional quality. However, the mineral and vitamin contents of edible parts are necessary for fully assessing the nutritional quality, and this should be investigated through further research.

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