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Biochemical composition and nutritional value analysis of Chinese mitten crab, *Eriocheir sinensis,* grown in pond

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Chinese mitten crab (*Eriocheir sinensis*) is an importantly economic species farmed in China and is becoming a commonly worldwide food due to its increasing export. The nutritional compositions of Chinese mitten crab of commercial size grown in pond with different genders were analyzed in this study. The results showed that total edible yield were ~40% for both male and female crabs. Meat from muscle contributed as much as 80% of the total protein, and can be considered as a low-fat and high-protein food with relative well-balanced essential amino acids, especially that from female crabs. While the edible viscera counting ~ 99% of the total fat with rich n-3 fatty acids, especially EPA and DHA, which together with the higher n-3/n-6 PUFA ratios, proved that Chinese mitten crab grown in pond is undoubtedly an n-3 PUFA-rich food for human. No significant differences were found in all parameters tested between male and female crabs though male crab has lower values of essential amino acids score than female crabs, indicating that male and female Chinese mitten crabs have equally nutritional values.

Keywords: Chinese mitten crab, nutrient, amino acids, fatty acids, crude protein, fat, pond

INTRODUCTION

Chinese mitten crab, *Eriocheir sinensis*, is a very importantly economic aquatic animal farmed in china with an annual production of 700,000 tons in 2012 and a culture area of more than 64,000 hectares in China. Chinese mitten crab is sweet, umami and has unique pleasant aroma (Chen and Zhang, 2007; Zhao, 2004). Since exports of this species increased significantly these years (Yuan, 2005), it has become a common food outside of China.

The quality and taste of the Chinese mitten crab is affected by rearing and environmental conditions (Li *et al*., 2012), and traditionally wild-caught crabs are preferred by local consumers because of its special taste. Due to the lack of wild resources of Chinese mitten crab and sharply increased demand for this crab recently, wild-caught crabs cannot longer satisfy the needs of consumers (Qin, *et al*., 2006). Therefore, pond grow of Chinese mitten crab has received much attention and developed extensively recently. But information on the nutritional quality of Chinese mitten crab grown in pond is still limited.

Whole body crude composition analyses have showed that Chinese mitten crab is of high quality protein with well-balanced essential amino acids and various fatty acids with high level of n-3 poly-unsaturated fatty acids (PUFA; Chen *et al*., 2007, Fei *et al*., 2006 and Li *et al*., 2000). Protein is important resources for human with essential amino acids as one of the most important nutritional qualities (Chen *et al*., 2007). Amino acid score is widely used for evaluating the nutritional quality of protein from various animals (Iqbal, *et al*., 2006), because it is calculated by comparing against the amino acid requirements of preschool-aged children, and if a protein effectively supports a young child's growth and development, it will meet or exceed the requirements of older children and adults (FAO/WHO/UNU, 1985).

Meanwhile, fatty acid analysis scan be also used to evaluate the quality of animal meat, especially the n-3 fatty acid that can benefit in reducing diseases of coronary artery (Skonberg and Perkins, 2002;), inflammation (Harwood and Caterson, 2006; Gil, 2002; Shoda, et al., 1996), coronary heart(Harper & Jacobson, 2005), cancer (Roynette, et al., 2004), neurological disorders (Falinska et al., 2012), and can guarantee neonatal health and normal development (Horrocks and Yeo, 1999; Innis, 2000; Voigt et al., 2000) and immune system (Sijben et al., 2009). Linolenic acid (LNA, 18:3n-3), linoleic acid (LA, 18:2n-6), eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) were essential for evaluate the nutritional quality of lipid (Gil, 2002).

Therefore, the nutritional qualities of Chinese mitten crab with different genders grown in pond were evaluated by determine the biochemical composition of muscle and edible viscera, including crude protein, lipid, moisture and ash contents, amino acids and fatty acids profiles and contents.

MATERIALS AND METHODS

Sample preparation

All crabs sample were obtained from a local farm in Jinshan district, Shanghai, China. Crabs were sampled from three ponds (0.5 hectare each) with six males (120.86±3.12g, mean±S.E.) and six females (163.64±1.01, mean±S.E.) in each pond. Three female and three male crabs in each pond were used to compare the body color before and after steamed at 100 ℃ for 20 min. Other three female and three male crabs in each pond were dissected to determine muscle meat and edible viscera (Hepatopancreas and gonads are defined as edible viscera since they are mixed in the abdomen and hard to be separated) yield. After calculating, muscle meat and edible viscera were separately homogenized, and stored at -80℃ prior to further analysis of proximate compositions, amino acids and fatty acids profile and contents.

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Proximate compositions analysis

All experimental samples were analyzed in triplicate for proximate composition following the standard methods (AOAC, 1990). Moisture was determined by oven drying at 105 ℃ to a constant weight. Samples used for dry matter were digested with nitric acid and incinerated in a muffle furnace at 600 ℃ overnight for ash content. Protein was measured by combustion method using an FP-528 Nitrogen Analyzer (Leco, USA). Lipid was determined by the ether extraction method using 2055 Soxtec System (Foss, Sweden).

Amino acids analysis score calculation

Amino acid content of samples were determined in triplicate by SYKAM S-433D Automatic Amino Acid Analyzer (Eresing, Germany) after acid digestion (6N HCl, 24h) in sealed glass tubes under a nitrogen atmosphere at 110 ℃. Essential amino acid score was calculated with respect to the FAO/WHO reference amino acid pattern of the preschool child (2–5 year) (FAO/WHO/UNU, 1985).

Amino acid score =Sample amino acid/Reference amino acid×100

Fatty acids analysis

Total lipid of triplicate samples of each finely ground meat and edible viscera samples were extracted using chloroform: methanol (2:1, v/v) according to the method of Folch *et al*. (1957). The saponifiable lipids were converted to their methyl esters by using the standard boron tri-fluoride-methanol method (Morrison and Smith, 1964). Fatty acids methyl esters (FAME) were analyzed on an Agilent 6890 gas chromatograph (Agilent Technologies, USA), equipped with a flame ionization detector (FID) and a SP-2560 fused silica capillary column (100 m, 0.25 mm i.d. and 0.20 µm film thickness). Injector and detector temperatures were 270 and 280 ℃, respectively. Column temperature was held at 120 ℃ for 5 min then programmed to increase at 3 ℃ /min up to 240 ℃ where it was maintained for 20 min. Carrier gas was helium (2 ml/min), and the split ratio was 30:1. Identification of fatty acids was carried out by comparing sample FAME peak relative retention times with those obtained for Sigma-Aldrich (St. Louis, MO, USA) standards. Concentration of the individual fatty acids were calculated and expressed as mass percentages of total identified fatty acids.

Statistical analyses

Results were expressed as mean± standard error (S.E., n = 3). The differences of means of all parameters between male and female crabs were determined by using t-test and a significance level $P < 0.05$ was used for all statistical tests.

RESULTS AND DISCUSSION

Edible yield and proximate composition

The proximate compositions of the Chinese mitten crab grown in pond are shown in Table 1. Total edible part yields for both male and female were all >41%, which is higher than the values reported by previous studies on Chinese mitten crab (Qin *et al*., 2006; Chen *et al*., 2007; Zhu and Bai, 2007). Chen *et al.* (2007) found that the total edible part yield of crabs obtained from an aquafarm located in Yangchenghu Lake (Suzhou, China) was 33.4%. Li *et al*. (2000) found that the total edible yield of Chinese mitten from Yangchenhu Lake is 36.72 %. For wild-caught crabs from Yangtze River, the edible part yields were 29.79 for male and 33.64% for female crab, respectively (Qin *et al*., 2006; Zhu and Bai, 2007). Higher total yield of this study was contributed mainly by the edible viscera, which are 18.79% and 14.73% for female and male crab. This can be explained partially by the differences of sampling time for different studies. Our crabs were sampled in mid-October

Table 1. The proximate compositions of the Chinese mitten crab grown in pond

Tissue	Gender	Yield (%) as wet body weight	Biochemical composition (%) as wet tissue weight			
			Protein	Lipid	Moisture	Ash
Edible viscera	female	18.79±0.27	7.01±1.01	52.45±4.44	31.99±1.50	1.13±0.23
	male	14.73±0.87	5.80±0.42	54.55±3.73	37.22±0.31	0.97±0.09
Muscle meat	female	23.37±1.19	18.85±0.34	0.53±0.02	71.61±1.22	1.51±0.09
	male	26.94±1.21	19.28±0.54	0.49±0.06	76.71±2.76	1.69±0.02

when the nutrients in edible viscera (Hepatopancreas and gonads) accumulated and reached its peak.

Crude protein of crab muscle meat were 18.85% and 19.28% as wet tissue weight for female and male crab, respectively, and crude fat lipid were 0.53% and 0.49%, respectively. This finding suggests that Chinese mitten crab muscle meat is a good meat source of protein with low fat, which is in agreement with the report of Chen *et al*. (2007), and even lower lipid content was found in this study (0.49-0.53 VS 0.9%). Similar findings were found in blue crab, *Callinectes sapidus*, swim crab, *Portumus pelagicus* (Gökoðlu and Yerlikaya, 2003; Saraswathy *et al*., 2006) and green crab, *Carcinus maenus* (Skonberg and Perkins, 2002). On the contrary, the edible viscera has as higher as >50% as wet tissue for both female and male crab, and lower protein contents as 5.01 % and 5.80%, respectively, suggesting that the edible viscera not only contribute the and creamy mouth-feel (Chen and Zhang, 2007), but also is a good source of beneficial fatty acids for human health. Edible viscera fat content in this study is as higher as two folds of that repotted by Chen *et al*. (2007). This could be also be explained by the differences of sampling time. Since lipid functions vitally important in the reproduction of Chinese mitten crab, higher lipid accumulation in hepantopancreas and gonads not only can provide adequate energy but also essential fatty acids for this crab (Cheng, 2003).

Amino acid and essential amino acid scores

According the proximate biochemical composition analysis, muscle meat contributes mainly the whole crab protein and amino acids, which count around 80% of the total whole body protein (Chen *et al*., 2007). Therefore, crab meat is the main tissue for amino acids other than edible viscera in Chinese mitten crab. Amino acid content in the crab meat and edible viscera of Chinese mitten crab are shown in the table 2. Obviously glutamic content is the highest, followed by aspartic, arginine, lysine in both muscle meat and edible viscera regardless genders. Similar findings were reported in blue swimmer crab *P. pelagicus* (Wu *et al*., 2010), green crab *C. mediterraneus* (Chrif *et al*., 2008), spider crab *Maja brachydactyla* (Marques *et al*., 2010), and wild-caught Chinese mitten crab (Qin *et al*., 2006; Zhu and Bai, 2007). The total essential amino acid (EAA) and non-essential amino acid (NEAA) contents were similar to those of spider crab (Marques *et al*., 2010), but were a little higher than those of blue swimmer crab (Wu *et al*., 2010), and were as higher as almost 2 times than those of wild-caught Chinese mitten crab (Qin *et al*., 2006; Zhu and Bai, 2007). Therefore, Chinese mitten crab grown in pond is of higher nutrition values in the respect of amino acids or protein among various edible crabs.

Essential amino acid score (EAAS) is used to evaluate

Table 2. Amino acid content in the crab meat and edible viscera of Chinese mitten crab grown in pond

	Edible viscera				Crab meat			
	Female		Male		Female		Male	
Amino acid	%	mg/g	%	mg/g	%	mg/g	%	mg/g
Asp	0.86±0.13	121.57±4.23	0.64±0.08	110.4±10.69	2.22±0.07	117.96±1.53	1.78±0.24	92.09±10.33
Thr	0.49±0.08	69.22±2.84	0.36±0.04	61.38±6.24	1.00±0.03	52.86±0.72	0.81±0.11	41.78±4.62
Ser	0.46±0.09	64.21±3.57	0.29±0.04	50.32±5.96	0.95±0.03	50.34±0.53	0.78±0.10	40.31±4.43
Glu	1.09±0.19	153.78±7.76	0.79±0.11	135.52±17.14	3.46±0.10	183.26±1.89	2.81±0.36	145.13±14.97
Gly	0.47±0.07	66.19±1.48	0.37±0.06	63.2±9.35	1.54±0.03	81.71±1.38	1.25±0.17	64.51±7.04
Ala	0.54±0.08	77.4±2.69	0.42±0.05	73.29±9.74	1.72±0.07	90.97±1.99	1.39±0.17	71.77±7.36
Val	0.50±0.09	71.01±3.38	0.35±0.04	60.28±5.45	0.98±0.03	52.23±0.73	0.80±0.11	41.18±4.49
Met	0.02±0.01	2.63±1.32	0.02±0.01	3.22±1.62	0.09±0.06	4.86±3.03	0.07±0.01	3.54±0.46
Ile	0.36±0.07	51.32±2.43	0.27±0.04	46.17±5.28	0.93±0.03	49.05±0.88	0.57±0.26	29.04±13.10
Leu	0.44±0.17	71.4±30.70	0.53±0.08	90.33±10.98	1.74±0.05	92.26±1.15	1.41±0.18	72.73±7.78
Tyr	0.36±0.06	50.83±3.45	0.25±0.04	43.52±5.16	0.73±0.05	38.58±2.05	0.69±0.15	35.56±6.88
Phe	0.44±0.07	62.39±1.72	0.32±0.04	55.49±5.90	0.95±0.03	50.55±0.78	0.77±0.10	39.91±4.16
His	0.25±0.03	35.82±0.93	0.20±0.03	33.98±3.07	0.57±0.01	30.30±0.23	0.47±0.06	24.15±2.67
Lys	0.62±0.10	88.36±2.47	0.47±0.06	80.63±8.55	1.84±0.06	97.35±1.38	1.47±0.20	76.03±8.62
Arg	0.68±0.10	96.4±2.80	0.5±0.10	86.28±15.43	2.34±0.07	123.92±1.44	1.88±0.26	97.17±11.08
Pro	0.56±0.09	79.38±3.26	0.44±0.07	75.15±12.13	1.21±0.05	63.9±1.63	0.94±0.12	48.49±5.21

Table 3. Essential amino acid score (EAAS) in the edible viscera and the muscle meat of Chinese mitten crab

Amino acid		Edible viscera				Muscle meat			
	reference	Female		Male		Female		Male	
	mg/g	mg/g	Score	mg/g	Score	mg/g	Score	mg	Score
Thr	47.00	69.22±2.84	147.28±6.04	61.38±6.24	130.60±13.28	52.86±0.72	112.47±2.67	41.78±4.62	88.89±9.83
Val	47.00	71.01±3.38	151.09±7.20	60.28±5.45	128.26±11.60	52.23±0.73	111.13±2.69	41.18±4.49	87.62±9.56
Ile	43.00	51.32±2.43	119.35±5.65	46.17±5.28	107.37±12.28	49.05±0.88	114.07±3.55	29.04±13.1	67.53±9.58
Leu	77.00	71.40±3.07	92.73±5.42	90.33±10.98	117.31±14.26	92.26±1.15	119.82±2.58	72.73±7.78	94.45±10.1
Tyr+Phe	78.00	113.22±5.16	145.15±6.61	99.01±11.06	126.94±14.03	89.13±2.82	114.27±5.83	75.47±11.03	96.76±13.62
Lys	81.00	88.36±2.47	109.09±3.04	80.63±8.55	99.54±10.56	97.35±1.38	120.19±2.95	76.03±8.62	93.86±10.64

the protein quality of Chinese mitten crab in this study, and are shown in table 3. Tryptophan and cysteine were not determined due to their special need for hydrolysis process. Other EAA, including threonine, valine, isoleucine, leucine, tyrosine+phenylalanine, and lysine EAAS were all calculated. According to the FAO/WHO reference amino acid requirement for preschool children (2-5-years old, FAO/WHO/UNU, 1985), when compared to the reference amino acid pattern, the EAAS of an amino acid is more than 100, it indicate that this amino acid will meet the requirement of children or adults. Otherwise, this amino acid will be considered as a limiting amino acid in food for human consumption. All amino acid scores of female crab muscle meat were higher than 100, while those of male crab were all lower than 100, but no significant differences were found when compared with those of female crab. Though crab edible viscera has lower protein content, higher EAAS (>100) were obtained in both female and male crabs except leucine in female (92.73) and lysine in male (99.54). Compared with the current study, average higher

Table 4. The fatty acid compositions of the edible viscera and the muscle meat of Chinese mitten crab

	Edible viscera %		Muscle meat %	
Fatty acids	Female	Male	Female	Male
C16:0	22.15±0.3	21.76±0.25	17.48±1.07	17.95±0.64
C18:0	2.69±0.13	2.89±0.07	9.61±0.2	9.53±0.71
C16:1	12.09±0.38	10.31±0.23	4.58±0.42	4.7±0.66
C18:1n9	32.34±0.21	32.79±0.61	30.61±1.75	30.97±0.41
C20:1n9	3.59±0.37	2.45±0.13	0.67±0.38	0.64±0.03
C18:2n6	10.08±0.58	11.39±0.83	7.94±0.61	8.52±0.05
C18:3n3	/	/	1.99±0.00	1.59±0.29
C20:5n3(EPA)	3.49±0.05	3.74±0.11	12.52±1.06	12.1±0.75
C22:5n3(DPA)	0.54±0.04	0.7±0.02	/	/
C22:6n3(DHA)	5.91±0.07	7.99±0.28	10.6±0.51	9.33±0.31
SFA	27.75±0.39	26.01±0.67	27.65±1.88	27.48±0.45
MUFA	49.29±1.18	46.69±0.99	35.86±5.61	36.61±0.25
PUFA	25.54±0.78	28.01±1.66	38.61±7.49	36.2±0.20
∑PUFA n-3/∑PUFA n-6	0.98	1.08	0.27	0.32

EAAS regardless genders were found in Chinese mitten crab obtained in aquafarm from Suzhou (Chen *et al*., 2007), and in both female and male blue swimmer crab *P. pelagicus* (Wu *et al*., 2010). But overall lower EAAS were found in Atlantic spider crab *M. brachydactyla* after re-calculating according the reference amino acid patter of preschool children (2-5 years, FAO/WHO/UNU, 1985). Therefore, the meat protein from Chinese mitten crab grown in pond are relative well-balanced in their essential amino acid compositions, especially from female crabs though no significant differences were found when compared with male crabs, indicating that meat from Chinese mitten crab can be regards as a high quality protein source for human consumption.

Fatty acid composition

The fatty acid compositions of edible viscera and muscle are shown in table 4. According the proximate biochemical composition analysis, edible viscera contributes mainly the whole crab fat and fatty acids, which count almost ~99% of the total whole body fat. Therefore, edible viscera are the main tissue other than muscle meat in Chinese mitten crab for providing fatty acids for human. In this study, monounsaturated fatty acids (MUFAs) were dominating fatty acids in Chinese mitten crab comprising about 50% the total fatty acids (Table 4). Among the MUFAs, oleic acid (18:1) was the dominant monounsaturated fatty acid accounting 32.55% of the total fatty acid, followed by palmitoleic acid (16:1, 11.20%). Saturated fatty acids (SFAs) and polyunsaturated fatty acids (PUFAs) counted 26.88% and 26.77%, respectively, and similar fatty acids profile were reported in previous studied on the snow crab *Chionoecetes bairdi* (Krzecekowski and Stone, 1974), blue swimmer crab *P. pelagicus* (Wu *et al*., 2010), green crab *C. maenus* (Naczk *et al*., 2004; Skonberg and Perkins, 2002), mud crab *Scylla serrata* (Tan *et al*., 2000), blue crab *C. sapidus* (Kuley *et al*., 2008). But higher PUFAs, lower SFAs were found in wild-caught Chinese mitten crab (Qin *et al*., 2006) and Chinese mitten crab grown in aquafarm (Chen *et al*., 2007; Li *et al*., 2012; Ying *et al*., 2006). Compared with other Chinese mitten crabs, our study has similar MUFAs. Therefore, the findings further proved that Chinese mitten crab grown in pond could be a good source of PUFAs for human.

Eicosapentaenoic acid (C20:5n3, EPA) and docosahexaenoic acid (C22:6n3, DHA) are the two most important fatty acids in PUFA, functioning as the key components of cell membrane phospholipids, and benefiting in preventing various diseases (Skonberg and Perkins, 2002; Harwood and Caterson, 2006; Gil, 2002;

Shoda, *et al*., 1996; Falinska *et al*., 2012; Horrocks and Yeo, 1999; Innis, 2000; Voigt *et al*., 2000; Sijben *et al*., 2009) . The DHA contents in female and male Chinese mitten crab edible viscera in this study were 5.91% and 7.99%, respectively, which are higher overall than those reported Chinese mitten crab either from aquafarms (Chen *et al*., 2007; Li *et al*., 2012) or wild-caught (Qin *et al*., 2006, Zhu and Bai, 2007) and are similar to other crabs species, including snow crab *C. bairdi* (Krzecekowski, Stone, 1974), blue swimmer crab *P. pelagicus* (Wu *et al*., 2010), green crab *C. maenus* (Naczk *et al*., 2004; Skonberg and Perkins, 2002), mud crab *S. serrata* (Tan *et al*., 2000), and blue crab *C. sapidus* (Kuley *et al*., 2008). While overall EPA contents in this study for both female and male crabs are similar to the findings in Chinese mitten crab (Chen *et al*., 2007; Li *et al*., 2012) and other various crabs (Krzecekowski, Stone, 1974; Naczk *et al*., 2004; Skonberg and Perkins, 2002; Tan *et al*., 2000; Kuley *et al*., 2008). But lake produced Chinese mitten crab had higher DHA and EPA content than the values in this study (Li *et al*., 2012). Higher DHA and EPA contents were found in both female and male Chinese mitten crab, which were 10.60% and 9.33% for DHA, and 12.52% and 12.10%, respectively. Therefore, muscle DHA and EPA in Chinese mitten crab can also benefit the human, though its lipid only contrite ~1% total lipid. The findings suggest that Chinese mitten crab grown in pond is a good source of higher DHA and EPA.

Linolenic acid (LNA, 18:3n-3) and linoleic acid (LA, 18:2n-6) contents are also used to evaluate the quality of animal meat. In this study, LNA was not determined in edible viscera for both female and male crabs, and its values found in muscle of female and male crabs were lower. Similar findings were found in the report (Chen *et al*., 2007; Li *et al*., 2012), indicating that the beneficial effects of n-3 fatty acids mainly from Chinese mitten crab meat come from EPA and DHA according the data in this study. The ratio of n-3/n-6 fatty acids is usually used as an index for evaluating the nutritional quality of aquatic products (Chen *et al*., 2007; Kuley *et al*., 2008), and a dietary ratio of n-3/n-6 at least 0.1-0.2, and higher ratio was considered more beneficial for human health (Wu *et al*., 2010; Celik *et al*., 2004: Dyerberg 1986; FAO/WHO 1994). In this study, the n-6 mainly came from the LA which was higher than 10% in edible viscera for both female and male crabs. But the n-3/n-6 ratio reached as high as 1.08 in male crab and 0.98 in female crab edible viscera, respectively, which is higher than the finding in Chinese mitten crab from aquafarm (n-3/n-6=0.45, Chen *et al*., 2007). Though muscle meat has low lipid in Chinese mitten carb, the n-3/n-6 ratio is still higher than 0.27. Therefore, Chinese mitten crab grown in pond is undoubtedly an n-3 PUFA-rich food for human consumption.

CONCLUSION

Pond grown Chinese mitten crab can considered as species with high nutritional values with total edible yield around 50% as wet weight gain. Meat from muscle contains as much as 80% of the total protein, and is a low-fat and high-protein food with relative well-balanced essential amino acid compositions, especially from female crabs. The edible viscera contain around 99% of the total fat with rich n-3 fatty acids, especially EPA and DHA. The higher n-3/n-6 PUFA ratios further controlled that Chinese mitten crab grown in pond is undoubtedly an n-3 PUFA-rich food for human consumption. Male and female Chinese mitten crabs have equally nutritional values, since no significant differences were found in all parameters tested. Besides, crab body color before and after being steamed also can satisfy the demand of human (see supplementation).

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