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Fatty Acid Composition in Freeze-Dried Chinese Mitten Crabs (*Eriocheir sinensis*)

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ABSTRACT

Freeze drying is reported to be the best method of dehydration. Live fresh Chinese mitten crabs (*Eriocheir sinensis*) were freeze dried. The moisture content, rehydration ratio, and fatty acid composition of freeze-dried crabs were analysed. The applicability of using freeze drying to process high-value *E. sinensis*, so as to prolong the time duration of their storage and marketing, were discussed. After lyophilisation, the average moisture content was 6%. The physical properties (shape, size, and colour) of the musculature and viscera were maintained well during freeze drying. The rehydration ratio was 2.15 when rehydrated for 30 min at room temperature. The levels of polyunsaturated fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid, were higher in female freeze-dried crabs than in male crabs. After full rehydration, the fatty acid composition of freeze-dried crabs showed no significant differences to that of frozen crabs after thawing. In conclusion, freeze drying can well preserve the physical properties of the edible parts and fatty acid composition of the viscera in high-value *E. sinensis*. Rehydration has no destruction of the nutritional value regarding to the fatty acid composition. Therefore, freeze drying is a suitable technique for the processing of high-value *E. sinensis*.

Keywords: *Eriocheir sinensis*; Fatty Acid Composition; Freeze Drying; Frozen Storage; Rehydration Ratio; Viscera

1. Introduction

Eriocheir sinensis, commonly called Chinese mitten crab, is native to freshwater and estuarine habitats in China. It is favoured by consumers in China and some other Asian countries because of its taste and high nutritional value. Mature crabs that weigh > 150 g are a high-value commodity, and crabs from Yangcheng Lake and Taihu Lake in Suzhou, Jiangsu Province are the most expensive and popular both in China and abroad. In recent years, the increased market demand for Chinese mitten crab has led to rapid expansion in its culture, and it is now a promising freshwater fisheries industry in China. Production has increased from 3305 tonnes in 1989 to 416,000 tonnes in 2004, and this increase has contributed greatly to the income of rural farmers in many areas of China [1].

As a popular aquaculture species, Chinese mitten crabs are generally marketed live. Every autumn from middle September to November is the most concentrated time for Chinese mitten crabs to market. Because the shelf life of Chinese mitten crabs is relatively short, it is difficult for the market to cope with large production in a short period of time. This can lead to over-supply and price reduction, which can have a significant negative impact on the economic return for farmers. In order to relieve market pressure and increase the income of farmers, techniques must be developed to process and store large numbers of Chinese mitten crabs.

Chinese mitten crabs can be kept alive for 1 - 2 weeks at 4˚C and 70% relative humidity without feeding. Their metabolism is decreased at 4˚C, but they still consume nutrients, which can have a negative effect on taste and nutritional quality. Moreover, preservation at 4˚C cannot significantly prolong the sale time or relieve market pressure. As a consequence, more effective processing techniques must be developed. At present, two commercially processed products are made from small and low-value Chinese mitten crabs: “drunken crab” (which is preserved in a sauce with a high alcohol content), and “crystallized crab powder” (used in cooking as a seasoning agent) [2]. However, these methods are not suitable for large and high-value crabs due to the changed taste and lower value of the processed products.

Drying is one of the oldest and most efficient methods for food processing and preservation. It produces dehydrated products and can significantly extend the preservation time. Freeze drying is reported to be the best method of dehydration. It freezes samples and then reduces the surrounding pressure to allow frozen water in

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the samples to sublime directly from the solid phase to the gas phase. The ice inside the samples and the low temperature required during freeze drying protects the products from deterioration and microbiological reactions, which results in the final products having excellent physical and biological qualities [3]. We assume that freeze drying may be a promising method for high-value Chinese mitten crab processing, so, we evaluated the physical changes, rehydration ability and fatty acid composition of freeze dried Chinese mitten crabs.

2. Materials and Methods

2.1. Chemicals

All the chemicals used in this study were of analytical grade and were obtained from Merck (Darmstadt, Germany), Sigma-Aldrich Corporation (St. Louis, MO, USA) and Shanghai Chemical Reagent Company (Sinopharm Chemical Reagent Co., Ltd., China). All the reagents were prepared freshly before use.

2.2. Freezing and Freeze Drying of Chinese Mitten Crabs

Live Chinese mitten crabs (individual weight 140 - 160 g) were purchased in November from an aquatic farm in Taihu Lake, which is one of the best-known locations for Chinese mitten crabs in Suzhou, Jiangsu Province, China, and transported live to the laboratory. The live crabs were cut vertically into two halves from the middle of the carapace, and marked as 1L (left half of No. 1), 1R (right half of No. 1), 2L (left half of No. 2), 2R (right half of No. 2), and so on. The crabs were then frozen and stored at –80˚C before freeze drying and fatty acid analysis.

The frozen right or left half of one crab was taken out at random and lyophilized under high-vacuum conditions in a FreeZone 6 Liter Freeze Dry System (Labconco Corp., Kansas City, MO, USA) to produce freeze dried samples. The freeze dried samples were kept in sealed bags at room temperature until biochemical analysis. The remaining frozen halves were used as controls.

2.3. Rehydration of Freeze-Dried Chinese Mitten Crabs

Three freeze-dried Chinese mitten crabs that had been preserved at room temperature for 2 months were dried at 70˚C, until they reached a constant weight, to estimate their water content. Another three male and three female freeze-dried samples were immersed in distilled water at room temperature and rehydrated for 30 min or 60 min respectively. Then, they were weighed after gently removing the superficial water with tissue paper. The rehydration ratio was calculated as the ratio of the mass of the rehydrated sample to that of the dried sample.

2.4. Analysis of Fatty Acid Composition

Total lipid was extracted with chloroform/methanol (2:1, v/v) as described by Folch *et al*. [4]. Fatty acid methyl esters (FAMEs) were prepared by transesterification by boiling with 14% borontrifluoride /methanol (w/w), in accordance with the method of Morrison and Smith [5]. FAMEs were analysed using an Agilent 6890 Gas Chromatograph fitted with an Omegawax 320 fused silica capillary column (30 m × 0.32 mm ID; Supelco, Billefonte, PA, USA). The temperature of the column was held initially at 60˚C, increased to 170˚C at a rate of 50˚C·min^{-1}, increased to 180˚C at a rate of 2˚C·min^{-1} and held for 2 min, increased to 230˚C at a rate of 2˚C·min^{-1} and held for 1 min, and finally increased to 240˚C at a rate of 1˚C·min^{-1} and held for 1 min. The total analysis time was 46.2 min. The carrier gas was helium with a flow velocity of 25 mL·min^{-1}. The injection port and the flame ionisation detector were maintained at 250˚C. Identification was made by comparing retention time with those of known standards (Sigma-Aldrich Co., St. Louis, MO, USA). Fatty acid composition was expressed as the percentage of each fatty acid relative to the total fatty acids.

2.5. Statistical Analysis

All data presented in the tables are means ±standard deviation (SD). The paired *t*-test was used to assess differences in the composition of fatty acids between the freeze-dried crabs and the control crabs that were kept frozen before analysis.

3. Results

3.1. Lyophilisation and Rehydration of Chinese Mitten Crabs

Three male and three female Chinese mitten crabs were lyophilized. Upon lyophilisation, the carapace turned red, the meat was white, and the edible viscera were pale red in female crabs and pale yellow in male crabs. The meat and viscera were brittle and maintained their physical structure. There was no significant reduction in volume or change in shape, such as shrinkage, wrinkling or deformation. This indicated that physical destruction during freeze drying was minimal.

When preserved in sealed bags at room temperature for 2 months, the average moisture content was approximately 6.14%. No destruction of pigment, such as discolouration or browning, was observed in the meat or viscera. When immersed in distilled water at room temperature for 30 min, the rehydration ratio reached 2.15, which was very close to that for 60 min (**Table 1**), indicating good rehydration ability of freeze-dried crabs.

Table 1. Average rehydration ratio of freeze-dried *E. sinensis* after rehydration for different time (n = 6).

Rehydration time	30 min	60 min
Rehydration ratio (±SD)	2.15 ± 0.11	2.21 ± 0.12

3.2. Fatty Acid Composition

One of the most favored parts of high-value Chinese mitten crabs lies in the edible viscera, so we particularly analyzed the nutritional value of freeze-dried crabs concerning the fatty acid composition of viscera. As shown in **Table 2**, thirty-one fatty acids were identified from lyophilized Chinese mitten crabs. Monounsaturated fatty acids (*MUFA*s) were the most abundant and accounted for 46% - 48% of the total fatty acids, followed by polyunsaturated fatty acids (*PUFA*s), which accounted for 26% - 36% of the total. Oleic acid (C18:1) was the predominant fatty acid (29% - 32%), followed by palmitic acid (C16:0, 13% - 19%), palmitoleic acid (C16:1, 10%) and linoleic acid (C18:2n-6, 8% - 15%). The major n-3 *PUFA*s were eicosapentaenoic acid (*EPA*, 20:5n-3) and docosahexaenoic acid (*DHA*, 22:6n-3); both of which were more abundant in female than in male crabs (**Table 2**). The contents of *EPA* and *DHA* in lyophilized female Chinese mitten crabs were comparable to that reported in marine crabs [6-8]. In addition, some monomethyl and multiple methyl branched fatty acids were also detected in our study, among which monomethyl hexadecanoic acid [C16:0(15ME), C16:0(14ME)] and 3,7,11,15-tetramethyl-hexadecanoic acid [C16:0(3,7,11,15ME)] were predominant (**Table 2**). These branched fatty acids could be converted to branched carbohydrates *in vivo*.

The FAO/WHO recommend that the ratio of n-3 *PUFA* to n-6 *PUFA* in the diet should be at least 0.1 - 0.2, and a higher ratio (>0.2) is more beneficial to human health [9]. A higher ratio of n-3 *PUFA* to n-6 *PUFA* in the food indicates a much higher nutritional value [10,11]. In this study the ratio of n-3 to n-6 *PUFA*s was 0.44 in male and 1.92 in female crabs (**Table 2**), indicating that both the male and female lyophilized Chinese mitten crabs have high nutritional value.

Considering that lyophilized crabs must be rehydrated fully before cooking, so, we further analysed the fatty acid profiles of the lyophilized crabs after full rehydration. As shown in **Table 3**, the major contents of fatty acid after rehydration were similar to that before rehydration (**Table 2**): the most prevalent fatty acid was oleic acid (C18:1, 18% - 25%), followed by palmitic acid (C16:0, 12% - 21%), linoleic acid (C18:2n-6, 5% - 18%), and palmitoleic acid (C16:1, 6% - 12%). *EPA* and *DHA* were the major n-3 *PUFA*s and accounted for 2% - 6% of the total fatty acids. The ratio of n-3 to n-6 *PUFA*s was 0.33 - 0.86, which was higher than that recommended by the FAO/WHO [9]. Differences of most fatty acid contents, except that of C15:0 and C22:5n3, were not significant between lyophilized and frozen crabs after full rehydration and thawing (paired t-test, $p < 0.05$, **Table 3**). The results suggest that lyophilisation and full rehydration have no destruction to the fatty acid composition of viscera in Chinese mitten crabs. Therefore, lyophilisation is a proper technique for high-value Chinese mitten crab processing.

Yet the contents of some fatty acids were significantly different between male and female crabs (paired t-test, $p < 0.05$, **Table 3**), indicating that the composition of fatty acid was different between male and female crabs.

Table 2. Fatty acid composition (% of the total fatty acids) of viscera from freeze-dried *E. sinensis*.

Fatty acids	Female (n = 3)	Male (n = 3)
C12:0	0.03 ± 0.01	0.06 ± 0.01
C14:0	0.74 ± 0.09	0.86 ± 0.25
C15:0	0.43 ± 0.08	0.54 ± 0.15
C16:0	12.72 ± 1.67	19.02 ± 1.73
C17:0 (2-hexyl)	1.09 ± 0.17	1.61 ± 0.15
C14:0(13ME)	0.16 ± 0.02	0.32 ± 0.07
C14:0(12ME)	0.06 ± 0.02	0.16 ± 0.06
C15:0(14ME)	0.12 ± 0.04	0.22 ± 0.13
C16:0(15ME)	0.48 ± 0.17	0.76 ± 0.26
C16:0(14ME)	0.19 ± 0.04	0.38 ± 0.14
C16:0(3,7,11,15ME)	0.58 ± 0.11	0.23 ± 0.07
C23:0	0	0.22 ± 0.12
C24:0	0	0.15 ± 0.01
∑*SFA*	16.60 ± 1.21	24.53 ± 2.26
C14:1n5	0.01 ± 0	0.01 ± 0
C14:1n3	0.07 ± 0.02	0.15 ± 0.1
C16:1n7	9.92 ± 1.43	9.67 ± 0.13
C16:1n10(7ME)	0.12 ± 0.07	0.07 ± 0.04
C18:1n9	28.56 ± 4.31	31.7 ± 1.1
C18:1n5	5.99 ± 1.52	3.92 ± 0.58
C20:1n9	1.08 ± 0.19	1.61 ± 0.03
C22:1n9	0.47 ± 0.19	0.71 ± 0.28
C24:1n9	0	0.13 ± 0.06
∑*MUFA*	46.22 ± 1.46	47.97 ± 1.63
C18:2n6	8.48 ± 0. 35	14.45 ± 1.5
C18:2n7	0.11 ± 0.05	0.27 ± 0.07
C20:2n7	0.70 ± 0.3	1.58 ± 0.3
C18:3n3	2.69 ± 0.43	1.72 ± 0.95
C20:3n3	0.41 ± 0.06	0.50 ± 0.13
C20:4n6	3.48 ± 1.64	2.53 ± 0.58
C21:4n7	0.10 ± 0.02	0.15 ± 0.03
C20:5n3	9.92 ± 2.12	1.88 ± 0.87
C22:6n3	9.90 ± 0.51	3.26 ± 1.87
Unknown 1	0.64 ± 0.15	0.42 ± 0.24
Unknown 2	0.75 ± 0.27	0.74 ± 0.17
∑*PUFA* (≥18:2*n*)	35.79 ± 2.89	26.34 ± 4.06
∑*n*-3*PUFA*	22.92 ± 2.02	7.36 ± 3.50
∑*n*-6*PUFA*	11.96 ± 1.31	16.98 ± 1.23
n-3/*n*-6	1.92 ± 0.11	0.43 ± 0.18
DHA/EPA	1.00 ± 0.21	1.73 ± 0.52
∑*HUFA* (≥20:3*n*)	23.81 ± 3.89	8.32 ± 2.06

ME: methyl; *SFA*: saturated fatty acid; *MUFA*: monounsaturated fatty acid; *PUFA*: polyunsaturated fatty acid; *HUFA*: highly unsaturated fatty acid; *DHA*: docosahexaenoic acid; *EPA*: eicosapentaenoic acid.

Table 3. Fatty acid contents (% of the total fatty acids, mean ± SD, *n* = 3) of viscera in the lyophilized half of crabs after full rehydration, fatty acid contents in the corresponding frozen half of crabs after full thawing were used as control.

Fatty acids	Lyophilized crabs		Frozen crabs	
	Female	Male	Female	Male
C14:0	0.75 ± 0.02$^{\#}$	1.14 ± 0.01$^{\#}$	0.54 ± 0.04$^{\#}$	0.92 ± 0.01$^{\#}$
C15:0	0.37 ± 0.04$^{*\#}$	0.62 ± 0.09$^{*\#}$	0.24 ± 0.03$^{*\#}$	0.39 ± 0.02$^{*\#}$
C16:0	14.66 ± 1.32$^{\#}$	16.47 ± 2.31$^{\#}$	12.19 ± 0.75$^{\#}$	14.73 ± 1.09$^{\#}$
C17:0	0.40 ± 0.07$^{\#}$	1.01 ± 0.29$^{\#}$	0.31 ± 0.02$^{\#}$	0.91 ± 0.15$^{\#}$
C18:0	8.46 ± 1.88$^{\#}$	12.66 ± 2.89$^{\#}$	6.82 ± 3.14$^{\#}$	13.22 ±5.59$^{\#}$
C23:0	0.04 ± 0.07	0	0.08 ± 0.07	0.10 ± 0.14
∑*SFA*	24.68 ± 3.13$^{\#}$	31.91 ± 2.45$^{\#}$	20.19 ± 3.03$^{\#}$	30.28 ± 4.48$^{\#}$
C14:1n7	1.73 ± 1.01$^{\#}$	4.32 ± 0.46$^{\#}$	2.46 ± 0.06$^{\#}$	4.91 ± 0.03$^{\#}$
C16:1n7	11.27 ± 1.15$^{\#}$	5.76 ± 1.29$^{\#}$	9.7 ± 0.15$^{\#}$	6.95 ± 0.37$^{\#}$
C16:1n5	0.61 ± 0.10	0.64 ± 0.16	0.44 ± 0.12	3.10 ± 0.21
C17:1	0.47 ± 0.06	0.42 ± 0.05	0.40 ± 0.03	0.55 ± 0.23
C18:1n9	24.82 ± 1.81$^{\#}$	18.48 ± 1.64$^{\#}$	24.61 ± 1.11$^{\#}$	17.6 ± 4.56$^{\#}$
C18:1n7	3.24 ± 0.52	2.89 ± 0.81	3.12 ± 0.35	3.04 ± 1.52
C20:1n9	0.88 ± 0.14$^{\#}$	1.95 ± 0.24$^{\#}$	0.84 ± 0.10$^{\#}$	2.58 ± 0.53$^{\#}$
C20:1n7	0.39 ± 0.13$^{\#}$	2.33 ± 0.61$^{\#}$	0.22 ± 0.12$^{\#}$	1.96 ± 2.05$^{\#}$
∑*MUFA*	43.40 ± 2.29	36.78 ± 3.82	41.83 ± 1.31	40.71 ± 8.97
C18:2n6	15.06 ± 2.30$^{\#}$	8.43 ± 1.26$^{\#}$	18.16 ± 2.67$^{\#}$	7.60 ± 0.54$^{\#}$
C18:3n4	2.37 ± 0.93$^{\#}$	0.17 ± 0.19$^{\#}$	2.71 ± 1.03$^{\#}$	0.19 ± 0.27$^{\#}$
C18:3n3	0	0	0.08 ± 0.15	0
C18:4n3	0.24 ± 0.05$^{\#}$	0$^{\#}$	0.30 ± 0.04$^{\#}$	0.14 ± 0.20$^{\#}$
C20:2n6	0.96 ± 0.06	0.99 ± 0.25	1.14 ± 0.18	1.20 ± 0.13
C20:3n6	0.15 ± 0.04	0.36 ± 0.25	0.19 ± 0.06	0.29 ± 0.11
C20:4n6	2.30 ± 0.11$^{\#}$	3.43 ± 0.45$^{\#}$	3.00 ± 0.48$^{\#}$	5.49 ± 0.65$^{\#}$
C20:4n3	0.17 ± 0.02	0.10 ± 0.15	0.19 ± 0.04	0.12 ± 0.17
C20:5n3	3.30 ± 0.09	4.34 ± 1.50	4.45 ± 0.63	5.49 ± 1.52
C22:2n6	0.11 ± 0.20	0	0.06 ± 0.06	0.20 ± 0.28
C22:5n3	0.41 ± 0.03$^{*\#}$	0.33 ± 0.05$^{*\#}$	0.66 ± 0.09$^{*\#}$	0.59 ± 0.13$^{*\#}$
C22:6n3	2.84 ± 0.56	3.34 ± 1.62	3.53 ± 0.89	3.611 ± 0.50
∑*PUFA*	27.89 ± 1.74$^{\#}$	21.44 ± 4.83$^{\#}$	34.48 ± 1.82$^{\#}$	24.88 ± 3.34$^{\#}$
∑*n*-3*PUFA*	6.95 ± 0.65	8.12 ± 1.23	9.22 ± 1.22	9.91 ± 2.12
∑*n*-6*PUFA*	18.58 ± 2.29$^{\#}$	13.21 ± 3.94$^{\#}$	22.55 ± 1.96$^{\#}$	14.78 ± 1.49$^{\#}$
n-3/*n*-6	0.38 ± 0.06$^{\#}$	0.62± 0.15$^{\#}$	0.41 ± 0.06$^{\#}$	0.67 ± 0.08$^{\#}$
DHA/EPA	0.86 ± 0.16	0.74 ± 0.12	0.80 ± 0.20	0.67 ± 0.09
∑*HUFA* (≥20:3*n*)	9.13 ± 0.68	11.55 ± 3.68	12.02 ± 0.93	15.55 ± 2.85

*Differences were significant between freeze-dried and frozen crabs after full rehydration and thawing (paired *t*-test, $p < 0.05$). $^{\#}$Differences were significant between male and female crabs (paired *t*-test, $p < 0.05$).

4. Discussion

Freeze drying dehydrates by freezing samples and then reducing the surrounding pressure to allow frozen water in the samples to sublime directly from the solid phase to the gas phase. It usually causes little shrinkage or toughening of the dehydrated samples, and can better preserve the chemical composition and nutritional value. It was first developed to preserve serum and vaccines, and now it has been used for processing of foods. Recently it has been applied in processing dry *Stichopus japonicus*. Results showed that the nutrient, color, shape and taste of freeze-dried sea cucumbers were the same as those of traditionally processed sea cucumbers [12].

In this study we observed that there were no significant shrinkage and toughening in the meat and viscera of freeze-dried crabs, indicating that freeze drying process causes very little destruction to the physical structure and volume of the edible parts. We also observed good rehydration ability of freeze-dried crabs. It has been reported that insufficient uptake of water during rehydration is related to the irreversible rupture and dislocation of cells, which results in a dense, collapsed and greatly shrunken structure during drying [13]. In other words, rehydration ability could reflect the structural changes that have occurred in dried products. In this study, the good rehydration ability of freeze-dried crabs from another hand confirms that freeze drying process causes very little effect

to the physical structure of the edible parts. This agrees with the results of Ratti and Marques *et al*. [14-16].

The average moisture content of freeze-dried crabs was about 6.14%. It has been reported that when the moisture in aquatic products falls below 40%, the proliferation of bacteria and fungi and decomposition by enzymes are inhibited, which can prevent deterioration and prolong storage time duration. The storage time of lyophilized products can be several years [14]. Therefore, lyophilized Chinese mitten crabs can be preserved at room temperature for a longer time, which could be more advantageous and convenient for storage, transport and sale than that of live crabs.

High-value Chinese mitten crabs usually are mature with well developed gonads. Their edible viscera, including gonads and hepatopancreas, are most favored because of the high nutrition value, lovely taste and flavor of fatty acids. It has been reported that *MUFA*s comprised about half of the total fatty acids in live Chinese mitten crabs and oleic acid (18:1) was the predominant [10]. We got similar composition of *MUFA*s and oleic acid in freeze-dried Chinese mitten crabs (**Table 2**). The *PUFA*s were significantly higher than *SFA*s in freeze-dried female crabs due to the much higher contents of C20:5n-3 and C22:6n-3, but in freeze-dried male crabs the contents of *PUFA*s and *SFA*s were approximately equal and the contents of C20:5n-3 and C22:6n-3 were significantly lower than those in female crabs (**Table 2**). This may be related to the differences of fatty acid composition between ovary and testis, suggesting that C20:5n-3 and C22:6n-3 may play important role in ovary development. Ying *et al*. (2007) reported that the contents of C20:5 and C22:6 increased when the ovary was mature and the female began to spawn, which suggested that C20:5 and C22:6 were important for embryo development [17].

We also detected some monomethyl and multiple methyl branched saturated fatty acids, such as monomethyl hexadecanoic acid and 3,7,11,15-tetramethyl-hexadecanoic acid (**Table 2**). 3,7,11,15-tetramethyl-hexadecanoic acid has been supposed to be the precursor of some volatile compounds, such as 3,7,11,15-tetramethyl-2-hexadecene and 2,6,10,14-tetramethyl-hexadecane. 2,6,10,14-tetramethyl-hexadecane was reported to contribute a green, sweet aroma to crayfish processing waste [18].

Intake of *PUFA*s, especially n-3 *PUFA*s could lower the risk of developing cardiovascular disease and are beneficial to human health. Besides, n-3 *PUFA*s are beneficial to the development of retina and brain of infants and children. N-6 *PUFA*s play a similar role as n-3 *PUFA*s in normal growth. But high levels of n-6 *PUFA*s may promote many inflammatory diseases, and n-3 *PUFA*s are less inflammatory than n-6 *PUFA*s. As the contents of n-3 *PUFA*s are commonly lower than that of n-6 *PUFA*s in normal diets, the n-3/n-6 ratio has been regarded as a good index of nutrition value. Higher ratio of n-3/n-6 *PUFA*s indicates higher nutrition value. The ratios of n-3/n-6 *PUFA*s reported in this study, no matter in crabs of male or female, freeze-dried or frozen, rehydrated or dehydrated, all were higher than that recommended by the FAO/WHO, indicating that Chinese mitten crabs have high nutritional value. The n-3/n-6 ratios of freeze-dried crabs were much lower than those of frozen crabs after full rehydration and thawing, but the differences were not significant (**Table 3**). The results indicate that freeze-drying and full rehydration have no destruction to the nutrition value of Chinese mitten crabs with regard to the fatty acid composition.

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REFERENCES

[1] China Society of Fisheries, "China Fisheries Statistic Yearbook 2004," Bureau of Fisheries, Beijing, 2005.

[2] Y. Q. Zeng, "New Technology in Chinese Mitten Crab Processing", *Scientific Fish Farming*, Vol. 6, No. 6, 2003, pp. 60-61 (in Chinese).

[3] C. Ratti, "Hot Air and Freeze-Drying of High-Value Foods: A Review," *Journal of Food Engineering*, Vol. 49, No. 4, 2001, pp. 311-319. doi:10.1016/S0260-8774(00)00228-4

[4] J. Folch, M. Lees and G. H. S. Stanley, "A Simple Method for the Isolation and Purification of Total Lipids from Animal Tissues," *Journal of Biological Chemistry*, Vol. 266, No. 1, 1957, pp. 497-509.

[5] W. R. Morrison and L. M. Smith, "Preparation of Fatty Acid Methyl Esters and Dimethyl Acetals from Lipids with Boron Trifluoride-Methanol," *Journal of Lipid Research*, Vol. 5, 1964, pp. 600-608.

[6] M. Çelik, C. Türeli, M. Çelik, Y. Yanar, E. Ünal and K. Aygül, "Fatty Acid Composition of the Blue Crab (*Callinectes sapidu* Athbun, 1896) in the North Eastern Mediterranean," *Food Chemistry*, Vol. 88, No. 2, 2004, pp. 271-273. doi:10.1016/j.foodchem.2004.01.038

[7] S. Cherif, F. Frikha, Y. Gargouri and N. Miled, "Fatty Acid Composition of Green Crab (*Carcinus mediterraneus*) from the Tunisian Mediterranean Coasts," *Food Chemistry*, Vol. 111, No. 4, 2008, pp. 930-933. doi:10.1016/j.foodchem.2008.05.007

[8] X. G. Wu, B. Zhou, Y. X. Cheng, C. S. Zeng, C. L. Wang and L. Feng, "Comparison of Gender Differences in Biochemical Composition and Nutritional Value of Various Edible Parts of the Blue Swimmer Crab," *Journal of Food Composition and Analysis*, Vol. 23, No. 2, 2010, pp. 154-159. doi:10.1016/j.jfca.2009.08.007

[9] FAO/WHO, "Fats and Oils in Human Nutrition," Report of a Joint FAO/WHO Expert Consultation, FAO Food

and Nutrition Paper 57, Rome, 1994, pp. 168.

[10] D. W. Chen, M. Zhang and S. Shrestha, "Compositional Characteristics and Nutritional Quality of Chinese Mitten Crab (*Eriocheir sinensis*)," *Food Chemistry*, Vol. 103, No. 4, 2007, pp. 1343-1349. doi:10.1016/j.foodchem.2006.10.047

[11] E. Kuley, F. öZogul, Y. ÖZogul and A. I. Olgunoglu, "Comparison of Fatty Acid and Proximate Compositions of the Body and Claw of Male and Female Blue Crabs (*Callinectes sapidus*) from Different Regions of the Mediterranean Coast," *International Journal of Food Sciences and Nutrition*, Vol. 59, No. 7-8, 2008, pp. 573-580. doi:10.1080/09637480701451201

[12] X. Yun, X. H. Han, S. Z. Nong and H. Yang, "Technological Condition of Vacuum Freeze-Drying in *Stichopus japonicus*," *Journal of Fishery Sciences of China*, Vol. 13, No. 4, 2006, pp. 662-666 (in Chinese with English Abstract).

[13] K. S. Jayaraman, D. K. D. Gupta and N. B. Rao, "Effect of Pretreatment with Salt and Sucrose on the Quality and Stability of Dehydrated Cauliflower," *International Journal of Food Science & Technology*, Vol. 25, No. 1, 1990, pp. 47-60. doi:10.1111/j.1365-2621.1990.tb01058.x

[14] C. Ratti, "Hot Air and Freeze-Drying of High-Value Foods: A Review," *Journal of Food Engineering*, Vol. 49, No. 4, 2001, pp. 311-319. doi:10.1016/S0260-8774(00)00228-4

[15] L. G. Marques, A. M. Silveira and J. T. Freire, "Freeze-Drying Characteristics of Tropical Fruits," *Drying Technology*, Vol. 24, No. 4, 2006, pp. 457-463. doi:10.1080/07373930600611919

[16] L. G. Marques, M. M. Prado and J. T. Freire, "Rehydration Characteristics of Freeze-Dried Tropical Fruits," *LWT—Food Science and Technology*, Vol. 42, No. 7, 2009, pp. 1232-1237. doi:10.1016/j.lwt.2009.02.012

[17] X. P. Ying, W. X. Yang and Y. P. Zhang, "Comparative Studies on Fatty Acid Composition of the Ovaries and Hepatopancreas at Different Physiological Stages of the Chinese Mitten Crab," *Aquaculture*, Vol. 256, No. 1-4, 2006, pp. 617-623. doi:10.1016/j.aquaculture.2006.02.045

[18] D. W. Chen and M. Zhang, "Analysis of Volatile Compounds in Chinese Mitten Crab (*Eriocheir sinensis*)," *Food and Drug Analysis*, Vol. 14, No. 3, 2006, pp. 76-82.

