Hindawi
Aquaculture Research
Volume 2023, Article ID 8143352, 9 pages
https://doi.org/10.1155/2023/8143352

Research Article

Impact of Overwintering Hoard on the Edible Tissues, Muscle Quality, Hepatopancreas Color, and Proximate Biochemical and Amino Acid Compositions of Male *Eriocheir sinensis*

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Received 3 May 2023; Revised 2 July 2023; Accepted 25 July 2023; Published 22 August 2023

Academic Editor: Liqiao Chen

The Chinese mitten crab, *Eriocheir sinensis*, is a popular food and an important breeding crab in China. In order to pursue higher sales prices and improve breeding efficiency, many farmers often hoard these crabs, until around the Spring Festival or even later, before selling them. Therefore, considering the time span of hoarding, the present study was designed to check the quality (edible tissues, muscle quality, hepatopancreas color, proximate biochemical and amino acid compositions) of *E. sinensis*, before and after overwintering hoard. The hepatosomatic index before hoarding in winter was higher than that of after hoarding in winter, but the gonadosomatic index, meat yield, total edible yield, and condition factor were significantly ($p < 0.05$) lower after hoarding in winter. The texture profile analysis (TPA) of muscle, the springiness, chewiness, and cohesiveness after hoarding in winter were significantly ($p < 0.05$) higher than those before hoarding in winter. The redness and yellowness of the hepatopancreas before hoarding in winter were lower than those after hoarding in winter. No significant difference ($p < 0.05$) was found in moisture, crude protein, and crude lipid in hepatopancreas, gonad, and muscle tissues of male *E. sinensis*. The contents of all amino acids (except methionine and histidine) in hepatopancreas, gonad, and muscle before hoarding in winter were higher than after hoarding, but there was no significant difference ($p < 0.05$) in hepatopancreas and gonad. While, in the muscle, the contents such as threonine, serine, glutamic acid, glycine, alanine, leucine, phenylalanine, histidine, and arginine, before hoarding in winter, were significantly ($p < 0.05$) higher than after hoarding. This study showed that, for the male *E. sinensis* after overwintering hoard, the edible tissues and muscle quality increased, and, moreover, the hepatopancreas color and proximate biochemical and amino acid compositions of hepatopancreas and gonad have no significant changes, but the content of many good amino acids, ΣNEAA and ΣDAA, in muscle all decreased.

1. Introduction

Eriocheir sinensis, also known as the Chinese mitten crab, became a popular food and an important breeding crab in China. In 2021, the total annual production of this crab was recorded approximately 808,274 tons [1]. According to Chinese tradition, the best time to eat male *E. sinensis* is November (this time corresponds to October of the lunar calendar). But during this time period, these crabs are found in abundance in the market, and often the rate becomes relatively low. Hence, the income of the crab farmers affected. Therefore, many farmers in northern Jiangsu Province often hoarded these crabs until around the Spring Festival or even later before selling them in order to obtain higher prices. The Suqian, a city in northern

Table 1: Comparisons on proximate nutrient biochemical composition of male *Eriocheir sinensis* before and after hoarding in winter (% wet weight).

	Corn	Hepatopancreas ($n = 4$)		Gonad ($n = 4$)		Muscle ($n = 4$)	
		Before hoarding	After hoarding	Before hoarding	After hoarding	Before hoarding	After hoarding
Moisture	10.87	50.08 ± 6.75	50.83 ± 3.46	71.18 ± 0.75	74.13 ± 2.04	75.39 ± 0.73	78.02 ± 1.63
Crude protein	8.16	9.35 ± 0.67	8.20 ± 0.96	15.48 ± 3.57	13.02 ± 3.52	13.86 ± 2.40	13.27 ± 1.67
Crude lipid	4.07	37.68 ± 6.53	39.85 ± 2.72	1.13 ± 0.29	1.24 ± 0.16	1.33 ± 0.18	0.90 ± 0.15

Jiangsu Province, has a plan to make it a tourist attraction to enjoy the Chinese mitten crab during the Spring Festival. Recently, some research studies were carried out on the nutrient composition changes of female *E. sinensis*, during hoarding of overwintering [2–4] and breeding technology [3, 5]. Results investigated that when female *E. sinensis* fed by corn, soybean (*Glycine max*), and iced trash fish, the nutrition lost to a certain extent, while the quality and edible flavor had been improved after overwintering cultivation [2]. On the other hand, the body meat lipid content was decreased [4]. The key to this breeding technology of hoarding of overwintering was transferred in the pond-grown crabs, *E. sinensis*, to cages. The female and male crabs were raised separately. The optimal stocking density of female crabs was around 21.88 kg/m^2 in case of overwintering cultivation for less than 90 days, while a medium density of 15.63 kg/m^2 was found more suitable for more than 90 days overwintering cultivation [3].

The main edible parts of crabs are the gonads, hepatopancreas, and muscle. The development of the gonads directly affects its quality, marketing, and economic value [6]. Condition factor (CF) is one of the criteria for judging the quality of live *E. sinensis* [7] and can also be intuitively felt by consumers. Hepatosomatic index (HSI), gonadosomatic index (GSI), edible yield (EY), and total edible yield (TEY) are commonly used to evaluate the edible tissues of the Chinese mitten crab [8–10]. Color of the fresh hepatopancreas of male *E. sinensis* is one of the important factors affecting consumers' attention for evaluation of crabs. The crabs with the yellow or red hepatopancreas are considered to be of high quality. Thus, the lighter color of the fresh hepatopancreas directly affects the market value of these crabs [11, 12].

Muscle is one of the main edible parts of *E. sinensis*, and its better texture is one of the concerns of consumers. Texture, as one of the evaluation elements of food quality, can be directly evaluated through human tasting. Further, it can also be used to measure related indicators such as hardness, chewiness, elasticity, resilience, cohesion, etc., for comprehensive evaluation of texture analysis [13, 14]. Although the method of human sensory tasting is simple and direct, it is easily affected by unstable factors such as the personal relish and taste of the evaluator, which reduce the reliability and comparability of the experimental results. The General Foods Texturometer is different that mainly reflects the texture characteristics of food related to mechanical properties. The general method is texture profile analysis (TPA), also known as double chewing test. It mainly compacts the sample twice by simulating the chewing movement of the human mouth and calculates the values of various indexes of texture according to the force required for compression and deformation of the sample. The degree of recovery after compression was objective and accurate. Using TPA, a number of studies have investigated on the muscle qualities of mud crab (*Scylla paramamosain*), eel (*Monopterus albus*), grass carp (*Ctenopharyngodon idellus*), tilapia (GIFT *Oreochromis niloticus*), black sea bream (*Acanthopagrus schlegelii*), golden pompano (*Trachinotus ovatus*), and red porgy (*Pagrus pagrus*) [13, 15–18, 19–23]. But, particularity, the muscle structure and texture in *E. sinensis* have not been reported yet. Therefore, the present study was designed to investigate the quality of *E. sinensis* during the hoarding period.

2. Materials and Methods

2.1. Animals and Experimental Setup. The hoarding in winter, present experiment, was carried out on a farmed crab in Gaochun, Jiangsu, China. The experimental pond covered an area of 0.4 hm^2 and was equipped with two paddlewheel aerators diagonally. One week before the start of experiment, the pond was drained to remove harmful organisms such as wild fish. Three experimental cages (length × width × depth = 2 m × 3 m × 1 m; mesh size: 0.85 mm) were setup. The cages were 40 cm from the bottom of the pond and plastic boards (height 20 cm) were setup surrounding the top of each cage to prevent crabs. Nets (mesh size: 0.25 mm) were installed to the water inlet and outlet of the experimental pond to exclude indigenous fishes and other aquatic animals. The water was added up to 1.2 m deep and maintained this depth by adding a small amount of water irregularly. The experimental cages were submerged about 80 cm deep in water, and the total water volume of each cage was 4.8 m^3.

On November 19, 2021, the healthy pond-reared adult male Chinese mitten crabs, *E. sinensis*, were obtained. The body weights of these crabs were between 200 and 230 g. A dozen crabs were randomly selected as the experimental individuals before hoarding in winter. In addition, 600 individuals were randomly selected for the experiment and put into three experimental cages on average. During the experiment period, these crabs were checked and the dead individuals were removed on daily basis. According to the feeding conditions, each cage was given an appropriate amount of yellow corn every 2 or 3 days to ensure adequate feed for crabs. The crude biochemical composition and amino acid composition are shown in Tables 1 and 2. For the water quality of the experimental pond, the temperature, pH, and dissolved oxygen were recorded between range of 5–20°C,

Table 2: Comparisons on amino acid composition of male *Eriocheir sinensis* before and after hoarding in winter (dry weight, mg/g).

Amino acid	Corn	Hepatopancreas ($n=4$)		Gonad ($n=4$)		Muscle ($n=4$)	
		Before hoarding	After hoarding	Before hoarding	After hoarding	Before hoarding	After hoarding
Threonine	2.70	3.66 ± 0.94	3.33 ± 0.31	15.06 ± 1.29	13.14 ± 2.56	7.70 ± 0.36^{a}	6.51 ± 0.51^{b}
Cysteine	0.90	1.20 ± 0.31	1.01 ± 0.05	3.88 ± 0.53	2.93 ± 1.07	1.68 ± 0.10	1.47 ± 0.18
Valine	3.35	3.91 ± 0.91	3.67 ± 0.30	6.04 ± 0.61	5.45 ± 0.26	7.45 ± 0.82	6.34 ± 0.50
Methionine	1.50	1.11 ± 0.44	0.87 ± 0.29	0.83 ± 0.23	1.10 ± 0.24	3.46 ± 0.55	3.09 ± 0.38
Isoleucine	2.63	3.11 ± 0.74	2.98 ± 0.26	7.89 ± 0.64	6.32 ± 1.59	7.35 ± 1.06	6.25 ± 0.43
Leucine	10.16	5.70 ± 1.33	5.33 ± 0.49	12.4 ± 0.81	10.48 ± 2.13	13.9 ± 1.03^{a}	11.86 ± 0.83^{b}
Tyrosine	2.66	3.10 ± 0.65	2.63 ± 0.18	5.58 ± 0.63	4.56 ± 1.05	6.44 ± 0.32	5.66 ± 0.49
Phenylalanine	4.01	3.57 ± 0.82	3.37 ± 0.27	7.31 ± 0.51	5.90 ± 1.46	7.84 ± 0.57^{a}	6.59 ± 0.49^{b}
Lysine	2.23	4.58 ± 1.11	4.41 ± 0.57	8.28 ± 0.77	8.20 ± 0.71	15.19 ± 1.39	13.13 ± 0.95
ΣEAA	30.15	29.93 ± 7.10	27.59 ± 2.50	67.28 ± 4.67	58.09 ± 10.25	71.01 ± 5.44	60.91 ± 4.41
Aspartic acid	6.54	5.26 ± 1.66	4.57 ± 0.45	20.69 ± 3.11	20.33 ± 3.45	17.18 ± 1.18	14.77 ± 1.30
Serine	3.26	2.99 ± 0.80	2.50 ± 0.34	8.98 ± 0.59	8.07 ± 1.40	7.47 ± 0.29^{a}	6.48 ± 0.50^{b}
Glutamic acid	14.20	7.28 ± 2.22	6.19 ± 0.66	23.48 ± 2.19	22.51 ± 2.26	30.32 ± 2.81^{a}	25.87 ± 1.54^{b}
Glycine	2.63	4.38 ± 1.55	3.53 ± 0.41	7.04 ± 0.61	5.81 ± 1.01	13.42 ± 0.52^{a}	10.13 ± 0.42^{b}
Alanine	6.39	6.27 ± 1.25	5.01 ± 0.63	13.38 ± 1.27	11.72 ± 2.26	17.62 ± 0.72^{a}	14.11 ± 1.29^{b}
Histidine	2.82	2.58 ± 0.77	2.27 ± 0.19	13.46 ± 1.61	14.05 ± 1.75	5.18 ± 0.27^{a}	4.27 ± 0.39^{b}
Arginine	3.05	5.35 ± 1.69	4.48 ± 0.53	7.81 ± 1.06	6.72 ± 0.42	16.97 ± 0.82^{a}	15.57 ± 1.39^{b}
Proline	6.02	4.29 ± 0.98	2.86 ± 0.31	24.77 ± 2.11	20.37 ± 6.98	6.28 ± 0.64	4.91 ± 0.67
ΣNEAA	44.92	38.42 ± 10.28	31.40 ± 3.13	119.60 ± 8.48	109.57 ± 18.56	114.44 ± 4.71^{a}	96.13 ± 6.79^{b}
Aspartic acid	6.54	5.26 ± 1.66	4.57 ± 0.45	20.69 ± 3.11	20.33 ± 3.45	17.18 ± 1.18	14.77 ± 1.30
Glutamic acid	14.20	7.28 ± 2.22	6.19 ± 0.66	23.48 ± 2.19	22.51 ± 2.26	30.32 ± 2.81^{a}	25.87 ± 1.54^{b}
Alanine	6.39	6.27 ± 1.25	5.01 ± 0.63	13.38 ± 1.27	11.72 ± 2.26	17.62 ± 0.72^{a}	14.11 ± 1.29^{b}
Tyrosine	2.66	3.10 ± 0.65	2.63 ± 0.18	5.58 ± 0.63	4.56 ± 1.05	6.44 ± 0.32	5.66 ± 0.49
Phenylalanine	4.01	3.57 ± 0.82	3.37 ± 0.27	7.31 ± 0.51	5.90 ± 1.46	7.84 ± 0.57^{a}	6.59 ± 0.49^{b}
Lysine	2.23	4.58 ± 1.11	4.41 ± 0.57	8.28 ± 0.77	8.20 ± 0.71	15.19 ± 1.39	13.13 ± 0.95
ΣDAA	36.04	30.06 ± 7.55	26.17 ± 2.60	78.72 ± 6.70	73.22 ± 10.32	94.60 ± 6.47^{a}	80.15 ± 5.71^{b}

Note. Different letters within the same row indicate significant differences between the same tissues ($p<0.05$). ΣEAA, total essential amino acids containing threonine, cysteine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, and lysine; ΣNEAA, total nonessential amino acids; ΣDAA, total delicious amino acids containing aspartic acid, glutamic acid, alanine, tyrosine, phenylalanine, and lysine.

7.5–8.4, and 4–6 mg/L, respectively, while the ammonia nitrogen concentration was found lower than 0.05 mg/L.

In order to ensure the exchange of water in the experimental cages, they were cleaned once a week. On January 13, 2022, 12 individuals were randomly selected as experimental crabs after hoarding in winter from three cages, i.e., four crabs per experimental cage.

2.2. Edible Tissues. Before and after hoarding in winter, six adult male *E. sinensis* were randomly selected, respectively. The average body weight of the crabs, before hoarding in winter, was 214.98 ± 8.00 g, while the crabs after hoarding in winter were recorded 219.49 ± 6.88 g. Upon arrival of these crabs to the laboratory, they were immediately dissected for determination of experimental indices. Before dissecting, these crabs were anesthetized in crushed ice for 10 min and then their surface moisture water was dried by clean towel. They were weighed (accuracy 0.01 g) and measured the body length (accuracy 0.001 cm) and calculated CF. Subsequently, all hepatopancreas and gonads were removed and weighed to calculate HSI and GSI. All muscles in abdomen and appendage were removed and meat yield (MY) and TEY were calculated after weighing. All removed tissues were stored in −79°C refrigerator for further biochemical analysis. The formulas for calculating the tissue indices and TEY were given as follows:

$$\mathrm{CF}\,(\mathrm{g/cm^3}) = \text{Body wet weight/body length}^3, \quad (1)$$

$$\mathrm{GSI}\,(\%) = \text{Gonad wet weight/body wet weight} \times 100, \quad (2)$$

$$\mathrm{HSI}\,(\%) = \text{Hepatopancreas wet weight/body wet weight} \times 100, \quad (3)$$

$$\mathrm{MY}\,(\%) = \text{Muscle wet weight/body wet weight} \times 100, \quad (4)$$

$$\mathrm{TEY}\,(\%) = \mathrm{GSI} + \mathrm{HSI} + \mathrm{MY}. \quad (5)$$

2.3. Texture Profile Analysis (TPA) of Muscle. To measure the TPA of muscle, six individuals were randomly selected from crabs of three experimental cages (two crabs per cage), and the propodus muscle of crab claw was dissected for TPA

measure. The propodus and merus segments of crab claw were removed from the junction of the propodus and carpus with a pair of dissecting scissors, and the outer shell of the propodus was carefully cut along its edge. The connection of the propodus muscle to shell was gently cut with a scalpel, and the propodus muscle was separated from the merus with a pair of dissecting scissors; then, the propodus muscle of crab claw was obtained successfully. The above propodus muscle samples were trimmed into a cube (length × width × depth = 25 mm × 22 mm × 10 mm) and the TPA of muscle was immediately measured. The mean measured value of the propodus muscle of two claws of a crab was used as the result of the TPA of muscle of this crab.

The Universal TA Texture Analyzer (Tengba, China) was used to analyze the experimental samples, including hardness, springiness, chewiness, cohesiveness, and resilience. A cylindrical probe was used with diameter and speed of 36 mm and 1 mm/s, respectively. The distance mode was selected, and the distance of movement was 1.5 mm. The contact induction force is 5 gf, and the interval between two depressions was 5 s.

2.4. Color of Hepatopancreas. Parameters such as lightness (L^*), redness (a^*), and yellowness (b^*) of hepatopancreas (fresh) were carried out using a NR10QC Precision Colorimeter (3nh, China). Six readings were taken on each sample surface over the level and averaged similar to the method described by Li et al. [24]. The fresh hepatopancreases were put into a clear plastic ziplock bag and put it on a white paper and ground before color measurement, and then measured the coloration. The background light intensity was 70–80 Lx.

2.5. Proximate Nutrient Composition Analysis. The contents of moisture, lipid, and protein in corn, hepatopancreas, gonads, and muscle were determined, respectively. Approximately 1 g of the sample was dried to a constant weight at a constant temperature of 60°C to determine the moisture [25]. The protein content of the hepatopancreas was determined by the Kjeldahl method with a conversion factor F of 6.25 [26, 27]. The crude lipids of the sample were extracted with a mixture of chloroform and methanol (V/V = 2 : 1) and the content was determined as previously described [28].

2.6. Amino Acid Analysis. Amino acid content of corn, hepatopancreas, gonads, and muscle was detected by acid hydrolysis method. Each sample (freeze-dried, approximately 0.12 g dry weight, accuracy 0.0001 g) was placed in a 40 mL hydrolyzation tube, and 5 mL of 6.0 M HCl solution was added. Then, the tube was put into liquid nitrogen to cool, removed after the solution solidified, and sealed after vacuum extraction. Samples were hydrolyzed at 110°C in a constant temperature drying oven for 13 hr. After cooling, the acid hydrolysate was titrated to 10 mL and filtered through a 0.45 μm filter membrane. 0.5 mL filtrate was withdrawn to a 1.5 mL centrifuge tube and evaporated, and the residue was dissolved in 1 mL deionized water and dried again, and repeated two times. Finally, 1 mL of pH 2.2 citrate buffer was added and dissolved and diluted to a tenth. The above diluents were filtered through a 0.22 μm filter membrane; then, the filtrate was analyzed using an amino acid autoanalyzer (Sykam S433D, Germany) with the chromatographic column (LCA K06/Na), and the injection volume was 0.05 mL. The amino acid content was expressed as milligram individual amino acid per gram dry tissue (mg/g dry weight).

2.7. Statistical Analysis. All results are presented as means ± standard deviation (SD). Homogeneity in variance of data was tested with Levene's test. Significant differences between two means were determined by Student's t-test and the level of significant difference was set at $p < 0.05$. All statistical analyses were performed with a SPSS package (version 16.0).

3. Results

3.1. Edible Tissues. Indicators of edible tissues, including HSI, GSI, MY, TEY, and CF, are shown in Figure 1. The HSI of male *E. sinensis* before hoarding in winter was higher (6.90% ± 0.23%) than that of after hoarding in winter (6.38% ± 1.05%), but there was no significant ($p > 0.05$) difference observed between them. In addition to HSI, GSI, MY, TEY, and CF of male *E. sinensis* before hoarding in winter (GSI: 2.63% ± 0.34%; MY: 16.83% ± 1.36%; TEY: 26.36% ± 1.21%; CF: 0.625 ± 0.027 g/cm^3) were significantly ($p < 0.05$) lower than those of after hoarding in winter (GSI: 3.58 ± 0.58; MY: 21.61 ± 1.27; TEY: 31.57 ± 1.90; CF: 0.671 ± 0.012).

3.2. Texture Profile Analysis (TPA) of Muscle. For TPA of muscle, all indexes of male *E. sinensis* after hoarding in winter were higher than those before hoarding in winter; however, only springiness (0.707 ± 0.030), chewiness (19.81 ± 3.03 gf), and cohesiveness (0.719 ± 0.032) of male *E. sinensis* after hoarding in winter were significantly higher than those before hoarding in winter (springiness: 0.773 ± 0.020; chewiness: 32.23 ± 7.91; cohesiveness: 0.793 ± 0.029) ($p < 0.05$), while in the case of hardness and resilience, there was no significant difference (Figure 2).

3.3. Color of Hepatopancreas. Lightness (L^*: 53.46 ± 3.58) of the hepatopancreas of male *E. sinensis* before hoarding in winter was higher than that (L^*: 51.59 ± 3.64) after hoarding in winter. On the contrary, redness (a^*: 10.46 ± 1.40) and yellowness (b^*: 44.16 ± 3.81) of the hepatopancreas of male *E. sinensis* before hoarding in winter were lower than those (a^*: 11.11 ± 0.99; b^*: 49.24 ± 5.64) after hoarding in winter, but for three indexes, the difference was not significant (Figure 3).

3.4. Proximate Nutrient Biochemical Analysis. The results of proximate nutrient biochemical analysis are summarized in Table 1. No any significant difference was found in moisture, crude protein, and crude lipid in hepatopancreas, gonad, and muscle tissues of male *E. sinensis*. To be specific, the content of moisture in hepatopancreas (50.08% ± 6.75% vs. 50.83% ± 3.46%), gonad (71.18% ± 0.75% vs. 74.13% ± 2.04%), and muscle (75.39% ± 0.73% vs. 78.02% ± 1.63%) of crab before hoarding was lower than after hoarding, but the content of crude protein in three tissues (hepatopancreas: 9.35% ± 0.67% vs. 8.20% ± 0.96%; gonad: 15.48% ± 3.57% vs. 13.02% ± 3.52%; muscle: 13.86% ± 2.40% vs. 13.27% ± 1.67%) of crab before

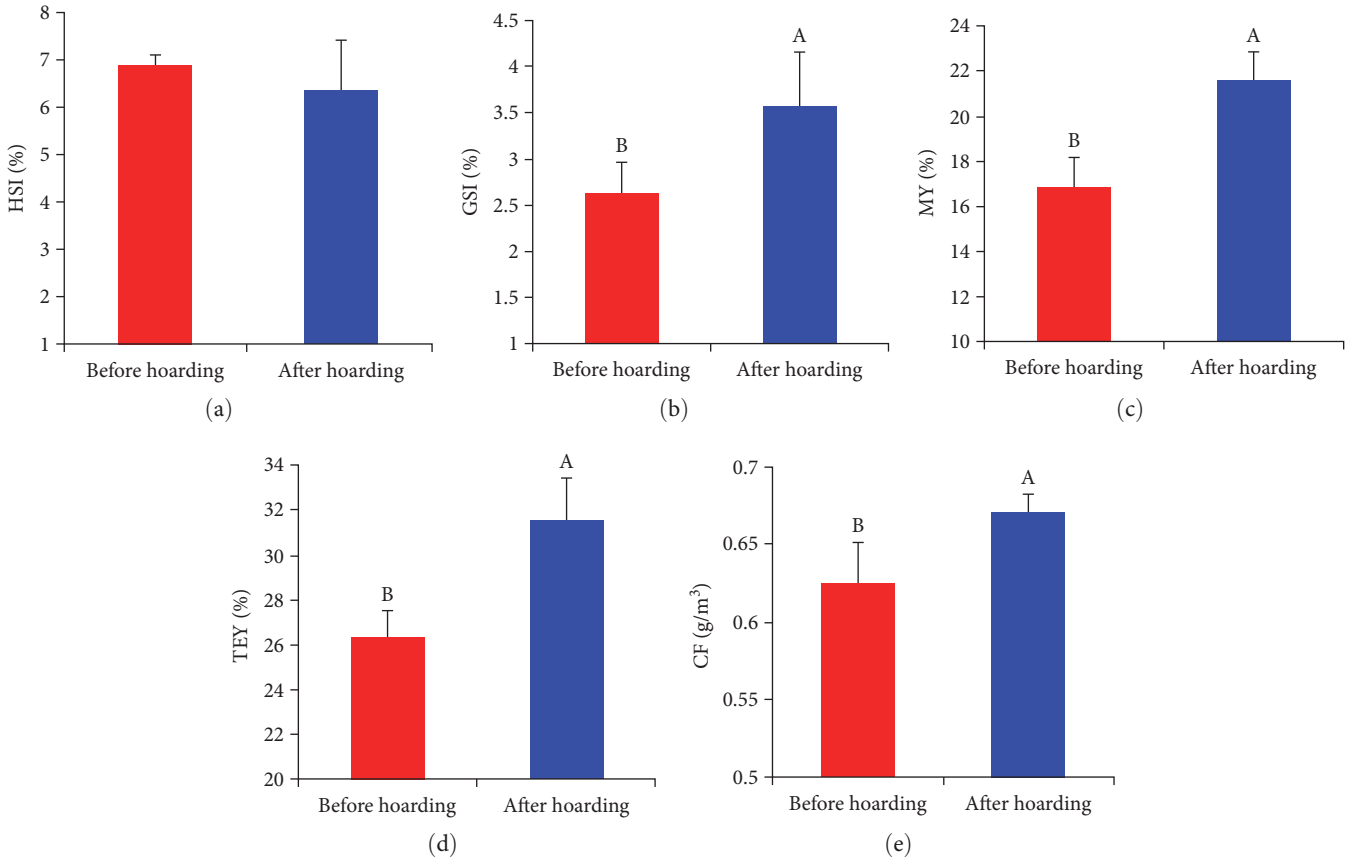

Figure 1: Impact of overwintering hoard on the edible tissues of male *Eriocheir sinensis* (a–e).

hoarding was higher than after hoarding. For crude lipid, the content in hepatopancreas (37.68% ± 6.53% vs. 39.85% ± 2.72%) and gonad (1.13% ± 0.29% vs. 1.24% ± 0.16%) of male *E. sinensis* before hoarding in winter was lower than after hoarding, but the content in muscle (1.33% ± 0.18% vs. 0.90% ± 0.15%) was the opposite.

3.5. Amino Acid Analysis. Except for methionine and histidine in gonad, the contents of all amino acids in hepatopancreas, gonad, and muscle of male *E. sinensis* before hoarding in winter were higher than after hoarding, but the differences were not significant in hepatopancreas and gonad ($p > 0.05$). For muscle, the contents such as threonine (7.70 ± 0.36 mg/g vs. 6.51 ± 0.51 mg/g), serine (7.47 ± 0.29 mg/g vs. 6.48 ± 0.50 mg/g), glutamic acid (30.32 ± 2.81 mg/g vs. 25.87 ± 1.54 mg/g), glycine (13.42 ± 0.52 mg/g vs. 10.13 ± 0.42 mg/g), alanine (17.62 ± 0.72 mg/g vs. 14.11 ± 1.29 mg/g), leucine (13.9 ± 1.03 mg/g vs. 11.86 ± 0.83 mg/g), phenylalanine (7.84 ± 0.57 mg/g vs. 6.59 ± 0.49 mg/g), histidine (5.18 ± 0.27 mg/g vs. 4.27 ± 0.39 mg/g), and arginine (16.97 ± 0.82 mg/g vs. 15.57 ± 1.39 mg/g) of crab before hoarding in winter were significantly higher than after hoarding ($p < 0.05$).

For ΣEAA, the contents in three tissues (hepatopancreas: 29.93 ± 7.10 mg/g vs. 27.59 ± 2.50 mg/g; gonad: 67.28 ± 4.67 mg/g vs. 58.09 ± 10.25 mg/g; muscle: 71.01 ± 5.44 mg/g vs. 60.91 ± 4.41 mg/g) of male *E. sinensis* before hoarding in winter were higher than after hoarding; however, no significant differences were found. The contents of ΣNEAA (hepatopancreas: 38.42 ± 10.28 mg/g vs. 31.40 ± 3.13 mg/g; gonad: 119.60 ± 8.48 mg/g vs. 109.57 ± 18.56 mg/g; muscle: 114.44 ± 4.71 mg/g vs. 96.13 ± 6.79 mg/g) and ΣDAA (hepatopancreas: 30.06 ± 7.55 mg/g vs. 26.17 ± 2.60 mg/g; gonad: 78.72 ± 6.70 mg/g vs. 73.22 ± 10.32 mg/g; muscle: 94.60 ± 6.47 mg/g vs. 80.15 ± 5.71 mg/g) in three tissues of male *E. sinensis* before hoarding in winter were higher than after hoarding. However, the significant ($p < 0.05$) difference was found only in the muscle.

4. Discussion

The investigations found that, during the hoarding period, most farmers used yellow corn (*Zea mays*) as bait for these crabs. In this study, the differences in edible and nutritional quality of male *E. sinensis* (fed with yellow corn), including the edible tissues, muscle quality, color of hepatopancreas, proximate biochemical and amino acid compositions, before and after hoarding in winter, were determined and compared.

For indicators of edible tissues, GSI, MY, TEY, and CF of male *E. sinensis* increased after hoarding in winter. The results showed that, although the water temperature was low (5–20°C) during the overwintering hoard, the gonad of these male crabs that feed on corn continued to develop, and nutrients in gonad and muscle were still accumulated. HSI of male *E. sinensis* decreased after hoarding in winter. This was because hepatopancreas was the nutrient absorption and

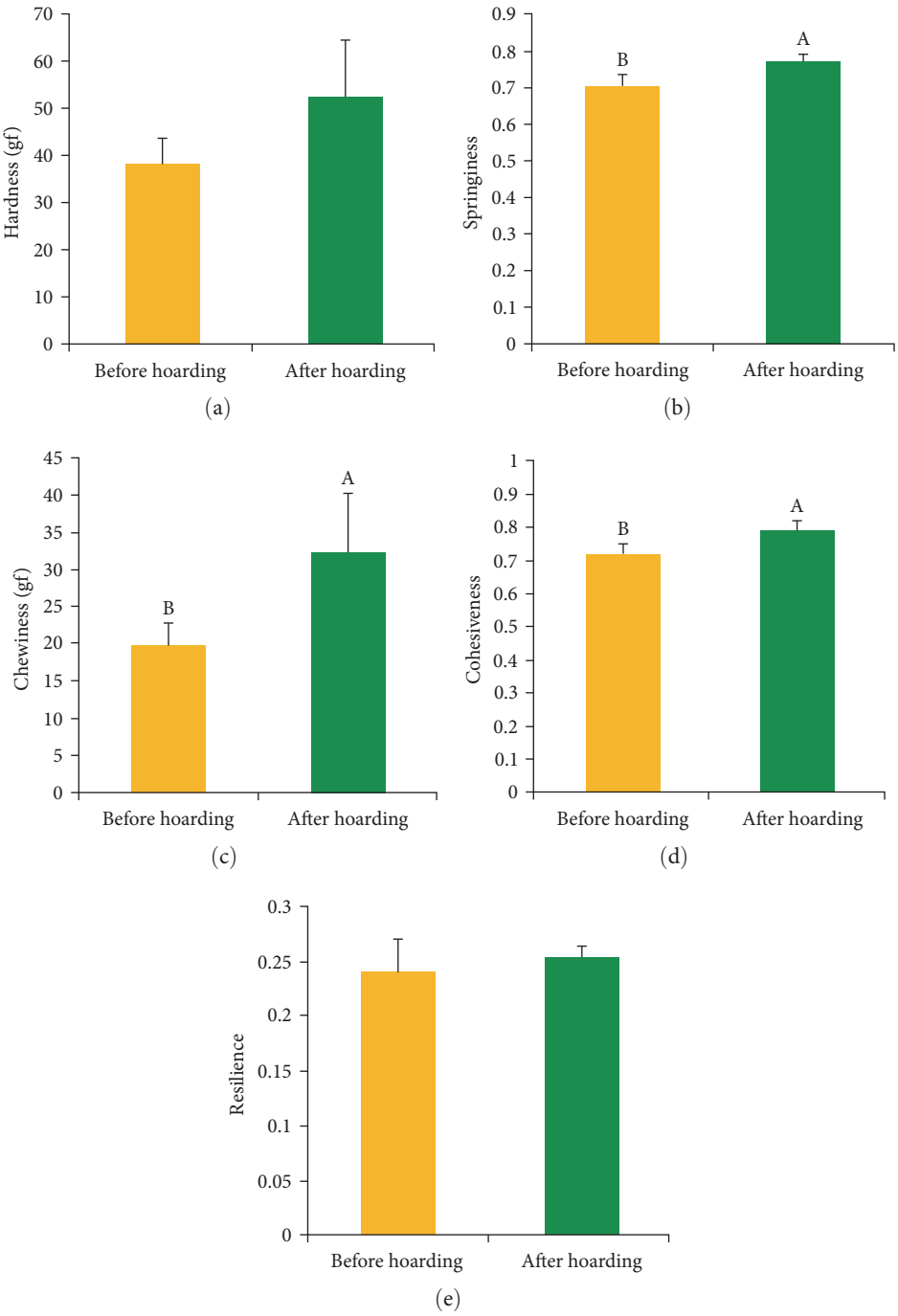

Figure 2: Impact of overwintering hoard on the muscle quality of male *Eriocheir sinensis* (a–e).

storage organs of *E. sinensis* [29, 30], and its nutrients supplied the development of gonads and muscles. Moreover, the results of this study were consistent with those of female *E. sinensis* fed on chilled fish, corn, and soybeans after overwintering hoard [2].

Muscle texture was one of the most crucial factors influencing meat quality. Although TPA had been used to analyze the muscle quality of a variety of aquatic animals [15, 16, 18, 19, 21], the muscle quality of *E. sinensis* has not been reported because of the particularity of muscle structure. In this study, a method for determining TPA of *E. sinensis* was developed, which showed good reproducibility in experiments. The results showed that the muscle quality of male *E. sinensis* was significantly improved after overwintering hoard. It was speculated that the reasons were closely related to the structural changes of muscle fibers. Studies have shown that the muscle fiber density and diameter were two crucial factors in muscle texture that closely correlated to the hardness, springiness, resilience, and chewiness of muscle [15, 31, 32].

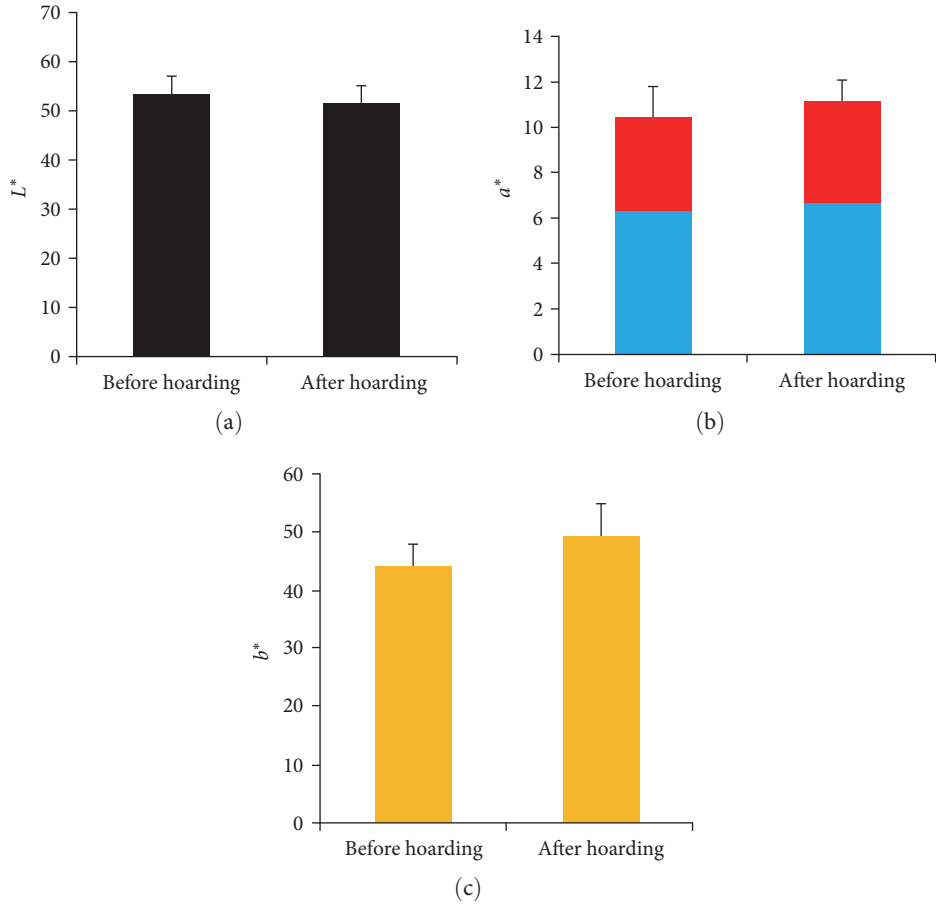

FIGURE 3: Impact of overwintering hoard on the hepatopancreas color of male *Eriocheir sinensis* (a–c).

Yellow hepatopancreas is not only an indicator of high quality, but also one of the characteristics of healthy *E. sinensis* [12, 33]. The color of *E. sinensis* is largely dependent on the amount of carotenoids present in the carapace, hepatopancreas, and ovaries [34, 35]. The crustacean cannot synthesize de novo carotenoids and must obtain them from dietary sources [36]. In this study, the male *E. sinensis* was fed with yellow corn during the hoarding period in winter, which is rich in carotenoids, mainly including lutein and zeaxanthin, but the redness and yellowness of the hepatopancreas of experimental crabs before hoarding in winter were lower than those after hoarding in winter; this indicated that it was related to less accumulation of carotenoids in the hepatopancreas. In order to improve the color of the hepatopancreas of *E. sinensis* by increasing the accumulation of carotenoids, it is feasible to increase the supply of carotenoids in the diet [35, 37].

At present, the effects of the overwintering hoard on biochemical components, nutritional quality, and flavor of *E. sinensis* were mainly concentrated in female crabs [4, 2, 3, 38]. These studies had shown that, after overwintering hoard, the body meat lipid content decreased [4, 38], and the essential amino acid content of muscle increased or kept steady [2, 3]. In this study, except for methionine and histidine in gonad, the contents of all amino acids in hepatopancreas, gonad, and muscle of male *E. sinensis* before hoarding in winter were higher than after hoarding. Especially for muscle, the contents of threonine, serine, glutamic acid, glycine, alanine, leucine, phenylalanine, histidine, arginine, ΣNEAA, and ΣDAA of male crabs before hoarding in winter were significantly higher than after hoarding. There were two main reasons for the inconsistency between the results of this study and those of previous studies. The first reason was the nutritional requirements of male and female *E. sinensis* are different, and another reason was the different baits were fed in these experiments. These experimental females were fed with soybean and chilled fish in addition to corn. The changes of amino acid contents in muscle of male crabs in this experiment were presumably related to the crude protein low content of corn (only 4.07%, Table 1) and the life style of crabs. During the period of hoarding in winter, the experimental crabs spent most of their time hanging on the net by walking feet, which may require more energy from their muscles. However, further experiments will be needed to investigate the specific reasons.

5. Conclusions

In the case of overwintering hoard fed on yellow corn, for the male *E. sinensis*, the edible tissues and muscle quality increased, and, moreover, the hepatopancreas color and proximate biochemical and amino acid compositions of hepatopancreas and

gonad have no significant changes, but the content of many good amino acids, ΣNEAA and ΣDAA, in muscle all decreased. Thus, in order to improve the amino acid composition in muscle of male *E. sinensis* after overwintering hoard, it is necessary to conduct in-depth research on the nutritional requirements of these crabs during overwintering hoard.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This study was supported by a general project (HSXT30323) of Jiangsu Collaborative Innovation Center of Regional Modern Agriculture & Environmental Protection, top-notch personnel of science and technology in Guizhou Province (2017) 096.

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