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Comparative study on muscle nutritional composition of juvenile bighead carp (*Aristichthys nobilis*) and paddlefish (*Polyodon spathula*) fed live feed

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Abstract: The contents of the proximate composition of amino acids and fatty acids in the muscle of juvenile bighead carp (*Aristichthys nobilis*) and paddlefish (*Polyodon spathula*) that were fed with live feed for 60 days were assessed in this investigation. The moisture, crude protein, and crude ash contents of bighead carp muscle were slightly higher than those of paddlefish ($P > 0.05$). The crude fat content of paddlefish muscle was significantly higher than that of bighead carp ($P < 0.01$). Seventeen amino acids were detected in the muscle of both bighead carp and paddlefish. The total concentrations of amino acids (TAAs), essential amino acids (EAAs), and delicious amino acids (DAAs) in the muscle of bighead carp were higher than in those of paddlefish. Fifteen fatty acids were detected in both bighead carp and paddlefish muscles, including 5 saturated fatty acids (SFAs), 4 monounsaturated fatty acids (MUFAs), and 6 polyunsaturated fatty acids (PUFAs). The concentrations of muscle ∑ SFAs, ∑ MUFAs, ∑ PUFAs, ∑ UFAs, ∑ SFAs/∑ UFAs, ∑ n-6 PUFAs, ∑ n-3 PUFAs, eicosapentaenoic acid (EPA), EPA + docosahexenoic acid (DHA), essential fatty acids (EFAs), and half–essential fatty acids (HEFAs) in bighead carp were significantly lower than those in paddlefish ($P < 0.01$). In addition, bighead carp possessed significantly lower muscle ∑ n-6 PUFAs/∑ n-3 PUFAs content than paddlefish did ($P < 0.05$). Muscle DHA content of bighead carp was higher than that of paddlefish ($P < 0.05$).

Key words: Bighead carp (*Aristichthys nobilis*), paddlefish (*Polyodon spathula*), muscle, nutritional composition, juvenile fish

1. Introduction

Fish muscle is rich in protein, unsaturated fatty acids, and mineral elements (Fuentes et al., 2010; Zhao et al., 2010). It is considered an important source of animal protein, and plays an important role in advancing the physical and intellectual development of humans due to its good nutritional values.

Bighead carp (*Aristichthys nobilis*) is widely distributed in East Asia, especially in China, where it is known as 1 of the 4 major Chinese carps, which include the black carp (*Mylopharyngodon piceus*), the grass carp (*Ctenopharyngodon idellus*), the silver carp (*Hypophthalmichthys molitrix*), and the bighead carp (Li and Fang, 1990). Bighead carp can also be found in some wild environments of Europe, South America, and North America (Naeem and Salam, 2010). Paddlefish (*Polyodon spathula*) is one of only 2 living species of polyodontidae. It is one of the world's rarest and most economically valuable species; it inhabits the Mississippi River in the United States (Carlson and Bonislawsky, 1981; Liu and Yu, 1990; Peng et al., 2007). Wang et al. (1995) reported that paddlefish meat was highly acceptable to consumers, indicating a promising potential market for consumption of its meat. Since 1988, paddlefish aquaculture in China has created enormous economic benefits (Xiong et al., 2008).

Bighead carp and paddlefish are ecologically similar species, as they live in the same aqueous layer and both are filter feeders (Liu and Yu, 1990; Zhou and Lin, 1990). The fast growth rate of paddlefish and its high market demand has resulted in paddlefish aquaculture becoming increasingly popular in China. The nutritive value of the muscle of bighead carp (Chen et al., 1983; Tong, 1997; Santiago et al., 2004; Cao et al., 2007; Guo et al., 2008; Hadjinikolova, 2008; Yang et al., 2010) and paddlefish (Dong et al., 2007; Chen et al., 2008; Shen et al., 2009; Ji et al., 2011; Li et al., 2011) has been reported by many researchers. However, the comparison of the muscle nutritional value between the 2 species based on previous studies is still incomplete, since muscle nutrition characteristics can be influenced by many intrinsic factors (for example, body size and sexual maturity) and extrinsic factors (for example, food resources, fishing season, water salinity, and temperature) (Børresen, 1992; Duyar, 2000; Wesselinova, 2000). Therefore, a comparative analysis of

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muscle nutrition between bighead carp and paddlefish cultured in a strictly controlled laboratory environment was performed in this study. This study provides nutritional information and basic data for the development of artificial culturing and compound feeding of these 2 important commercial fishes.

2. Materials and methods

The experimental fish were acquired from the 973 Experimental Base located at the College of Fisheries, Huazhong Agricultural University (HZAU), China. Fish were stocked in tanks (200 cm length × 200 cm width × 150 cm depth), and fed with live feed for 2 weeks of acclimation prior to the 60 days of the experiment. The live feed was acquired from high-yield ponds in the vicinity of HZAU. The live feed consisted of live zooplankton, such as cladocera, which accounted for more than 90% of the total.

The nutritional components of the live feed are shown in Table 1.

The experiment was carried out at the Aquaculture Research Center at the College of Fisheries of HZAU from 1 July to 30 September 2010. The mean initial weights of 45 bighead carps and 45 paddlefish were 7.56 ± 0.33 g and 6.97 ± 0.71 g, respectively. The 45 bighead carps were randomly stocked in 3 tanks (0.3014 m^3, 80 cm diameter × 60 cm deep), with 15 per tank. The same treatment was applied to the paddlefish. During the experimental period, the fish were fed with the same amount of live feed at 0900 and 1600 daily. The residual live feed was removed and weighed after 2 h, when the fish were finished feeding. The quantity of live feed fed to the experiment fish equals the total amount of live feed minus the amount of residual live feed. The culture water was treated through a filtration and purification system. Water temperature ranged from 20 to 26 °C, dissolved oxygen (DO) from 6.5 to 8.2 mg/L, pH from 7.1 to 7.9, ammonia nitrogen from 0.3 to 0.5 mg/L, and nitrite nitrogen from 0.04 to 0.07 mg/L.

All fish per tank were weighed and measured at the end of the study period. We did not know exactly how much food each fish consumed during the experiment; however, we calculated the average amount of live feed per fish. The average amount of feed for each juvenile paddlefish and bighead carp was 190.09 g and 162.87 g, respectively. Mean terminal weights of 45 bighead carps and 45 paddlefishes were 18.16 ± 1.23 g and 20.88 ± 1.55 g, respectively. The muscle of paddlefish was directly obtained since it is a

Table 1. Analysis of nutrients of the live feed used in this study.

Proximate composition (g/100 g fresh muscle)		Amino acid composition (g/100 g fresh muscle)		Fatty acid composition (g/100 g fatty acid)	
Moisture	91.18 ± 0.84	Asp	0.48 ± 0.02	C14:0	2.70 ± 0.26
Crude protein	5.35 ± 0.15	Thr	0.25 ± 0.03	C16:0	21.40 ± 0.17
Crude fat	0.99 ± 0.13	Ser	0.24 ± 0.02	C16:1	13.40 ± 0.44
Crude ash	0.79 ± 0.02	Glu	0.62 ± 0.03	C17:0	3.40 ± 0.17
		Gly	0.24 ± 0.02	C17:1	0.80 ± 0.10
		Ala	0.34 ± 0.02	C18:0	8.40 ± 0.36
		Cys	0.02 ± 0.01	C18:1	14.30 ± 0.44
		Val	0.26 ± 0.02	C18:2 n-6	9.60 ± 0.20
		Met	0.12 ± 0.01	C18:3 n-3	10.20 ± 0.36
		Ile	0.20 ± 0.02	C20:0	0.30 ± 0.10
		Leu	0.40 ± 0.02	C20:2	0.20± 0.10
		Tyr	0.22 ± 0.03	C20:4 n-6	4.90 ± 0.36
		Phe	0.24 ± 0.03	C20:5 n-3	9.70 ± 0.44
		Lys	0.42 ± 0.02	C22:6 n-3	0.30 ± 0.17
		Pro	0.22 ± 0.03	C24:0	0.30 ± 0.10
		His	0.12 ± 0.01		
		Arg	0.36 ± 0.01		

cartilage fish without any scales. Because bighead carp is a bony fish, and any mix of the fish bones would compromise the measurement of the results, the intermuscular bones were carefully removed from the muscle. Nine fish per tank were randomly selected; boneless muscle was obtained from 3 fish and ground together as a mixed sample. Nine mixed samples each of paddlefish and bighead carp juveniles were obtained prior to analysis. Muscle samples were kept at –80 °C prior to analysis. The muscle proximate analysis consisted of determining moisture, crude protein, crude fat, and crude ash. Moisture content was determined by drying samples in an oven at 105 °C until a constant weight was obtained (AOAC, 1990). Crude protein content was determined by the Kjeldahl method (AOAC, 1990), and a conversion factor of 6.25 was used to convert total nitrogen to crude protein. Crude fat was determined by using the Soxhlet extraction method (AOAC, 1990). Crude ash was determined by incineration in a muffle furnace at 550 °C for 24 h (AOAC, 1990). For amino acid analysis (GB/T5009.124-2003, China), the samples were hydrolyzed in 6 N HCl in a nitrogen atmosphere for 24 h. The hydrolyzed solution was subjected to an Eppendorf LC 3000 (Eppendorf, Germany) automatic amino acid analyzer. Fatty acids were determined (GB/T17377-2008, China) by gas chromatography (Agilent, Hewlett–Packard 6890N, USA). The assessment of proximate composition contents of each sample was performed in triplicate, while the amino acid and fatty acid contents were analyzed in duplicate.

Data were analyzed in Excel (Microsoft Office, 2003) and STATISTICA 6.0 statistical software (StatSoft, Inc.), using Student's t-test to compare the parameters between the 2 study groups.

3. Results and discussion

3.1. Proximate compositions

Proximate compositions of the bighead carp and paddlefish samples are shown in Table 2. The moisture, crude protein, and crude ash contents of the bighead carp muscle were slightly higher than those of the paddlefish, but no significant differences were observed ($P > 0.05$). However, the crude fat content of the paddlefish was significantly higher than that of the bighead carp ($P < 0.01$).

The muscle contains most of the nutritional value of fish. Muscle nutritional compositions mainly include crude protein, crude fat, amino acid, fatty acid, and trace elements, whose types and contents were typical of fish nutritional value. In this study, the moisture, crude protein, and crude ash contents of the bighead carp muscle were similar to those of the paddlefish muscle ($P > 0.05$). The levels of moisture, crude protein, and crude ash contents in the samples could have been affected by a variety of factors. Carpenè et al. (1999) reported that trace element concentrations in fish muscle varied with ages, life histories, and species. Hall and Ahmad (1997) reported an inverse relationship between moisture and protein content. Crude fat content of the bighead carp was significantly lower than that of the paddlefish ($P < 0.01$). Stansby (1973) classified fish species into 5 categories (A to E) based on the fat and protein contents in the muscle. The bighead carp was assigned to category A (<5% lipids and 15% to 20% proteins) based on our results. The protein content in the muscle of the paddlefish was less than 15%, probably because it was at the juvenile stage, with a lower accumulation of nutrients. According to Ackman's classification based on fat content (Ackman, 1989), bighead carp is considered a lean fish (<2% fat), whereas paddlefish is considered a medium-fat fish (4% to 8% fat).

Among the 4 major Chinese carps, the bighead carp has relatively low muscle crude protein content (Cai et al., 2004; Li et al., 2007; Liu, 2009). The bighead carp's muscle crude fat content is higher than that of the silver carp (Liu, 2009) and the grass carp (Li et al., 2007), but lower than that of the black carp (Cai et al., 2004). Compared with several sturgeons, the crude protein content of the paddlefish was higher than those of *Acipenser sinensis* (Yin et al., 2004), *Acipenser guldenstadti* (Yang et al., 2005), and *Acipenser ruthenus* (Yin et al., 2004), but lower than those of *Acipenser schrencki* (Yin et al., 2004; Wang, 2006), and *Huso dauricus* (Yin et al., 2004). The crude fat content of paddlefish was higher than those of *A. sinensis* (Yin et al., 2004), *A. guldenstadti* (Yang et al., 2005), *A. ruthenus* (Yin et al., 2004), *A. schrencki* (Yin et al., 2004; Wang et al., 2006), and *H. dauricus* (Yin et al., 2004). The crude fat content of paddlefish muscle was significantly higher than

Table 2. Proximate composition in muscles of juvenile bighead carp and paddlefish (mean ± SD, n = 9, g/100 g fresh muscle).

Fish	Moisture	Crude protein	Crude fat	Crude ash
Juvenile bighead carp	78.87 ± 0.67	15.89 ± 0.68	1.69 ± 0.06	1.24 ± 0.08
Juvenile paddlefish	78.86 ± 1.03	13.98 ± 0.72	4.94 ± 0.35**	0.86 ± 0.09

Notes: ** denotes significant level at $P < 0.01$.

that of bighead carp. This might be due to differing levels of fat absorption and different expressional levels of the fatty acid synthase gene (FASN) of the 2 species.

3.2. Analysis of amino acids composition

Amino acid profiles of bighead carp and paddlefish are summarized in Table 3. Seventeen amino acids (Trp was not detected because of acid hydrolysis) were detected, including 7 human-body essential amino acids (EAAs) (Thr, Val, Met, Phe, Ile, Leu, and Lys), 2 human-body half-essential amino acids (HEAAs) (His and Arg), and 8 human-body non-essential amino acids (NEAAs) (Asp, Glu, Ser, Gly, Ala, Tyr, Cys, and Pro). All of the amino acid levels of the bighead carp muscle were higher than those of the paddlefish muscle. An extremely significant difference was found in His content between the 2 species ($P < 0.01$), while significant differences among Asp, Glu, Val, Lys, and Arg contents were found between the 2 species ($P < 0.05$), and no significant differences were found in the rest of the detected amino acids ($P > 0.05$). In both species, the sequence of the amino acid contents from the highest to the lowest was as follows: Glu (2.42 w/% in bighead carp muscle and 2.13 w/% in paddlefish muscle), Asp, Lys, Leu, Arg, Ala, and Cys. Iwasaki and Harada (1985) reported that the main amino acids in fish muscle were Asp, Glu, and Lys. Glu is not just a delicious amino acid (DAA), but an important amino acid that has an important role in brain metabolism and the synthesis of many physiological substances (Zhang et al., 1988).

Among the measurements of the contents of total amino acids (TAAs), total essential amino acids (TEAAs), total half-essential amino acids (THEAAs), and total nonessential amino acids (TNEAAs), no significant difference was observed in TDAAs/TAAs between the 2 species ($P > 0.05$), a significant difference was found in TNEAAs ($P < 0.05$), and extremely significant differences were found in TAAs, TEAAs, THEAAs, and TDAAs ($P < 0.01$). Concentrations of TEAAs/TAAs and TEAAs/TNEAAs of bighead carp muscle were similar to those of the paddlefish ($P > 0.05$).

Our study indicates that the types and proportion of amino acids in the muscles of the bighead carp and the paddlefish were similar. Characteristics of types and proportion of muscle amino acids in the paddlefish are consistent with previous studies about the nutritive value of paddlefish (Chen et al., 2008; Shen et al., 2009), as well as that of sturgeons (Yin et al., 2004). Therefore, it is likely that most paddlefish have a similar formation rule of amino acids. Protein quality is primarily based upon the content and composition proportions of 8 essential amino acids. According to the FAO/WHO standard model of amino acids, high-quality protein's EAAs/TAAs is about 0.40, and its EAAs/NEAAs exceeds 0.60 (Zhuang et al., 2010). In this study, the EAAs/TAAs in the bighead carp muscle and the

Table 3. Amino acid composition and content of bighead carp and paddlefish muscle (g/100 g fresh muscle).

Amino acid	Juvenile bighead carp	Juvenile paddlefish	α
Asp	1.58 ± 0.09	1.29 ± 0.10	*
Thr	0.67 ± 0.05	0.60 ± 0.07	ns
Ser	0.63 ± 0.07	0.58 ± 0.05	ns
Glu	2.42 ± 0.10	2.13 ± 0.13	*
Gly	0.74 ± 0.06	0.62 ± 0.08	ns
Ala	0.94 ± 0.11	0.74 ± 0.10	ns
Cys	0.12 ± 0.02	0.12 ± 0.04	ns
Val	0.74 ± 0.04	0.58 ± 0.08	*
Met	0.46 ± 0.04	0.38 ± 0.04	ns
Ile	0.65 ± 0.06	0.58 ± 0.10	ns
Leu	1.24 ± 0.05	1.06 ± 0.15	ns
Tyr	0.52 ± 0.04	0.48 ± 0.08	ns
Phe	0.66 ± 0.03	0.65 ± 0.06	ns
Lys	1.50 ± 0.09	1.27 ± 0.08	*
Pro	0.59 ± 0.14	0.44 ± 0.06	ns
His	0.48 ± 0.04	0.37 ± 0.02	**
Arg	1.03 ± 0.09	0.84 ± 0.05	*
TAAs	14.97 ± 0.40	12.72 ± 0.36	**
EAAs	5.92 ± 0.11	5.10 ± 0.21	**
HEAAs	1.52 ± 0.08	1.22 ± 0.04	**
NEAAs	7.54 ± 0.43	6.40 ± 0.11	*
DAAs	6.71 ± 0.32	5.62 ± 0.16	**
W_{EAA}/W_{TAA}	39.55 ± 1.74	40.11 ± 0.55	ns
W_{EAA}/W_{NEAA}	78.70 ± 5.94	79.72 ± 1.97	ns
W_{DAA}/W_{TAA}	44.80 ± 1.04	44.21 ± 0.04	ns

Mean ± SD (n = 9) with different letters in the same row are significantly different. Level of significance (α): $^{**}P < 0.01$; $^{*}P < 0.05$; ns: nonsignificant.

Notes: TAAs, total amino acids; EAAs, essential amino acids; HEAAs, half-essential amino acids; NEAAs, nonessential amino acids; DAAs, delicious amino acids.

paddlefish muscle were 0.3955 and 0.4009, respectively, while the EAAs/NEAAs in bighead carp muscle and paddlefish muscle were 0.7870 and 0.7972, respectively. This suggests that bighead carp and paddlefish are sources of high-quality protein.

Lys is directly bound up with protein synthesis and animal growth. Thus it is called the "growth amino acid" (Song, 2007). Lys is an amino acid of limited availability for children living in developing countries with cereal-based diets (Kim and Lall, 2000). Lys content is low in cereals but high in bighead carp and paddlefish muscle, which implies that bighead carp and paddlefish meat might make up for the Lys shortage in cereals in such areas.

Some amino acids are related to the flavor of fish meat, such as Glu, Asp, Gly, and Ala (Ruiz-Capillas and Moral, 2004). Glu and Asp are the 2 main kinds of DAA. Moreover, Glu is considered to be closely tied to many important biological functions (Jones et al., 1999). Ala and Gly are the 2 sweet amino acids (Wang et al., 2006). The flavorful amino acid content of bighead carp is significantly higher than that of paddlefish; therefore, in theory, the flavor of bighead carp muscle should be better than that of paddlefish.

3.3. Analysis of fatty acids composition

Fifteen fatty acids were detected in bighead carp and paddlefish muscles (Table 4), including 5 saturated fatty acids (SFAs), 4 monounsaturated fatty acids (MUFAs), and 6 polyunsaturated fatty acids (PUFAs). Compared to marine fish, bighead carp and paddlefish muscle had higher levels of C16:0 and C18:0, and lower levels of C20:0 (Haliloğlu et al., 2004). C16:1 and C18:1 are 2 predominant MUFAs in both species. High levels of C16:1 have been described as one characteristic of freshwater species (Gutierrez and Silva, 1993; Oliveira et al., 2003). C20:5 n-3 (EPA) and C22:6 n-3 (DHA) are 2 predominant PUFAs. Freshwater fish are usually rich in the n-6 family acids, whereas marine fish are rich in n-3 family acids (especially DHAs and EPAs) (Haliloğlu et al., 2004; Mnari et al., 2007).

Table 4 shows the types and contents of muscle fatty acids in bighead carp and paddlefish. Concentrations of Σ SFAs, Σ MUFAs, Σ PUFAs, Σ UFAs, Σ SFAs/Σ UFAs, Σ n-6 PUFAs, Σ n-3 PUFAs, Σ n-6 PUFAs/Σ n-3 PUFAs, EPAs, EPAs + DHAs, essential fatty acids (EFAs), and half-essential fatty acids (HEFAs) of the bighead carp were lower than those of the paddlefish. No significant difference was found in Σ n-6 PUFAs/Σ n-3 PUFAs between these 2 species ($P > 0.05$); however, extremely significant differences were observed in other fatty acids ($P < 0.01$). The bighead carp had significantly higher DHA content than the paddlefish ($P < 0.05$). The ratio of the n-6 family and the n-3 family (that is, n-6/n-3) is one important standard for assessing the lipid quality of foods. According to nutritional recommendations (Santos-Silva, 2002), the

Table 4. The fatty acid composition and content of bighead carp and paddlefish muscle (g/100 g fatty acid).

Fatty acid	Juvenile bighead carp	Juvenile paddlefish	A
C14:0	0.12 ± 0.02	1.43 ± 0.20	**
C16:0	3.60 ± 0.11	11.41 ± 0.34	**
C17:0	0.22 ± 0.03	1.04 ± 0.10	**
C18:0	1.72 ± 0.15	3.16 ± 0.17	**
C20:0	0.05 ± 0.02	0.05 ± 0.00	ns
Σ SFAs	5.71 ± 0.20	17.09 ± 0.30	**
C16:1	0.76 ± 0.07	5.14 ± 0.37	**
C17:1	0.12 ± 0.03	0.54 ± 0.09	**
C18:1	3.45 ± 0.09	10.08 ± 0.26	**
C20:1	0.12 ± 0.03	0.10 ± 0.05	ns
Σ MUFAs	4.44 ± 0.07	15.86 ± 0.47	**
C18:2 n-6	0.88± 0.08	3.26 ± 0.35	**
C18:3 n-3	0.51± 0.09	3.11 ± 0.26	**
C20:2	0.07 ± 0.02	0.20 ± 0.05	*
C20:4 n-6	1.20 ± 0.07	2.82 ± 0.49	**
C20:5 n-3(EPA)	2.08 ± 0.14	5.53 ± 0.30	**
C22:6 n-3(DHA)	2.01 ± 0.06	1.48 ± 0.23	*
Σ PUFAs	6.74 ± 0.13	16.40 ± 0.28	**
Σ UFAs	11.19 ± 0.20	32.26 ± 0.30	**
Σ	16.90 ± 0.00	49.35 ± 0.00	**
Σ SFAs/Σ UFAs	0.51± 0.03	0.53 ± 0.01	ns
Σ n-6 PUFAs	2.08 ± 0.13	6.08 ± 0.18	**
Σ n-3 PUFAs	4.60 ± 0.25	10.13 ± 0.18	**
Σ n-6 PUFAs Σ n-3 PUFAs	0.45 ± 0.05	0.60 ± 0.02	*
EPAs	2.08 ± 0.14	5.53 ± 0.30	**
DHAs	2.01 ± 0.06	1.48 ± 0.23	*
EPAs + DHAs	4.09 ± 0.18	7.01 ± 0.43	**
EFAs	1.39 ± 0.08	6.37 ± 0.60	**
HEFAs	1.20 ± 0.07	2.82 ± 0.49	**

Mean ± SD (n = 9) with different letters in the same row are significantly different. Level of significance (α): $^{**}P < 0.01$; $^{*}P < 0.05$; ns: nonsignificant.
EFAs, essential fatty acids, HEFAs, half-essential fatty acids.

n-6/n-3 ratio in the human diet should not exceed 4.0, in order to reduce cardiovascular risks (Williams, 2000). The n-6/n-3 ratios in both species studied here were below the recommended limit.

Fatty acids produced by heating fat are indispensable components of flavor. High levels of PUFA may significantly increase the flavor, and to some extent make the muscles juicier (Mao and Zhao, 2007). EPA and DHA are known as "brain gold," and may be effective in preventing cardiovascular disease in humans (Lees et al., 1990; Zimmer et al., 2000). The fatty acid composition of the 2 species was closely related to fat in food sources, season, water temperature, physical and chemical factors of the water, light, and so on (Codier et al., 2002). Levels of PUFAs, EPA, and n-3 series fatty acids of the bighead carp were significantly lower than those of the paddlefish ($P < 0.01$), which meant that paddlefish have higher nutritional quality than bighead carp.

The discrepancy in nutritional quality between the muscles of the 2 fish was closely linked with diet, physical conditions, living environments, expressional levels of genes, and so on. In the 2 studied species, it seemed that the nutritional quality of muscle was mainly influenced by food and gene expression (Alasalvar, 2002). Periago et al. (2005) suggested that genetic factors and environmental factors have a significant impact on muscle structure and quality. Since these fish were raised in similar environments, the differences in muscle qualities of bighead carp and paddlefish were likely due to gene expression. The crude fat content of paddlefish was significantly higher than that of bighead carp, and polyunsaturated fatty acids (PFAs), EFAs, and EPAs + DHAs in the muscle of bighead carp were significantly lower than in paddlefish ($P < 0.01$). This might be explained by bighead carp and paddlefish being different species, or possibly they have different feeding efficiencies. The specific mechanisms remain unknown and merit further investigation.

Based on our data from mixed muscle samples, bighead carp and paddlefish may be considered good protein sources. Seventeen amino acids and 15 fatty acids were detected in both species. Levels of EAAs and DAAs of the bighead carp are higher than those of the paddlefish. However, the paddlefish have higher lipid and other fatty acids than the bighead carp.

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