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Comparison of Nutrition Compositions of Juvenile Paddlefish (*Polyodon spathula*) Fed with Live Feed and Formula Feed

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Abstract

Compositions of the amino acid and fatty acid in the muscle of the juvenile paddlefish (*Polyodon spathula*) were assessed after being fed with live feed and formula feed for 60 days. The crude fat content of formula feed group was significantly higher than that of live feed group (P<0.01). However, the muscle moisture and crude protein contents of formula feed group were significantly lower than those of live feed group (P<0.05). Seventeen kinds of amino acids were detected in the muscles of both groups. The total amino acids (TAA), essential amino acids (EAA), half-essential amino acids (HEAA), nonessential amino acids (NEAA), delicious amino acids (DAA) and essential amino acid index (EAAI) concentrations of live feed group were higher than those of formula feed group. Further, fifteen kinds of fatty acids were detected in both groups, including five kinds of saturated fatty acids (SFA), four kinds of monounsaturated fatty acids (MUFA) and six kinds of polyunsaturated fatty acids (PUFA). Concentrations of paddlefish muscle ∑MUFA, ∑UFA, ∑n-6PUFA, docosahexenoic acid (DHA), eicosapentaenoic acid (EPA)+DHA of formula feed group were higher than those of live feed group. Extremely significant differences were observed in the fatty acids (P<0.01) between groups except ∑n-6PUFA and EPA+DHA (P>0.05). Based on these comparative studies, our data provides better understanding of artificial culture, feed research and resource protection of paddlefishes

Keywords: Live feed, formula feed, juvenile Paddlefish **(***Polyodon spathula***),** muscle, nutrition composition.

Introduction

Fish muscle tissue is known for rich in essential amino acids (EAA), unsaturated fatty acids (UFA) and inorganic mineral elements (IME). It is considered as an important resource of animal protein and plays an important role in advancing physical and intellectual development of human being because of its high nutritional values, unique fragrance and good digestibility (Zhao *et al*. 2010; Ana *et al*. 2010).

Paddlefish (*Polyodon spathula*), which originated in the Mississippi River of North America , belonging to *Acipenseriformes*, *Polyodontida* and *Polyodon*. It is one of the only two living species of *Polyodontidae* (the other is the Chinese Paddlefish, *Psephurus gladius*) (Dillard 1986; Steven 1999). It mainly feeds on zooplankton (Carlson and Bonislawsky 1981; Liu and Yu 1990; Peng *et al*. 2007). Paddlefish is a promising aquaculture species among the sturgeon family (William *et al*. 1997), and particularly its roe can be processed into black caviar. In addition, the boneless white meat has shown high potential for consumer acceptance in both fresh and value-added products. So its culture becomes more and more popular in the world now (Wang *et al*. 1995). Since 1988, paddlefish was introduced and the artificial breeding was successful in China (Xiong *et al*. 2008; Yin *et al*. 2009), it has created enormous economic benefits (Xiong *et al*. 2008；Ji and Wang 2009). Paddlefish can be trained to accept a prepared diet, though they are obligated filter feeders of zooplankton in nature (Rosen and Hales 1981). At present, the paddlefish were cultured in several models (e.g. pond, cage and large water surface, etc) (Xiong *et al*. 2008). The muscle nutritional compositions of paddlefish cultured in different environments or with different feeds are different.

This nutrition composition differences in muscle could be due to internal factors (e.g. varieties and specifications and sexual maturity) and external factors (e.g. food, fishing season, salinity and water temperature) (Børresen 1991; Duyar 2000;

Wesselinova 2000). The difference in food composition can impact these properties as well (Gonza'leza *et al*. 2006).

The living conditions is yet another factor could influence the nutrition composition, for example, the farmed fish ,Compared with the wild fish, has softer muscle texture, lighter muscle flavor, and the nutrition compositions, taste, physical and chemical characteristics were significantly different (Yin *et al*. 2003; Johnston *et al*. 2006; Song *et al*. 2007). Evaluation of the muscle quality in the wild and farmed fish offers a way to discover the relationship between muscle nutrition and feed. Although muscle nutrition of the paddlefish has been intensively studied (Dong *et al*. 2007; Chen *et al*. 2008 ; Shen *et al*. 2009; Yin *et al*. 2010; Ji *et al*. 2011; Li *et al*. 2011), still little is known about the effects of live feed and formula feed on it. Moreover, the special paddlefish feeds have not been developed yet in the domestic and foreign markets. In the present study, a comparative study on the nutrition compositions of paddlefishes fed with live feed and formula feed was carried out, which provides basic data to artificial culture, feed research and resources protection of paddlefishes.

Materials and Methods

Paddlefishes were bought from an aquaculture base named '973 Experimental base', which was located at College of Fisheries, Huazhong Agricultural University (HZAU), Wuhan city, China. They were stocked in tanks and fed with live feed for two weeks prior to the 60 days of culture. Live feed was obtained from the high-yield ponds in the vicinity of HZAU. The analysis on nutrients of live feed was listed in Table 1.

The ingredients of formula feed are shown in Table 2. The formula feed is designed based on the nutrient composition of live feed and other sturgeon nutritional requirements. The buoyancy of the feed was appropriate (diameter 1.0-1.2 mm). The nutrition of formula feed was shown in Table 3.

The experiment was conducted at the Aquaculture Research Center in HZAU. Mean initial weight of 72 paddlefishes was 65.93±6.94 g, and all the fishes were randomly stocked at six tanks (160cm diameter×100cm deep) with 12 fishes in each. Two groups, each comprises three tanks were set up to compare the effects of living and formula food on

Table 1. Analysis on nutrients of live feed

Proximate composition (g/100g)		Amino acid composition (g/100g)		Fatty acid composition (g/100g fatty acids)	
Moisture	90.87±0.42	Asp	0.48±0.04	C14:0	2.90±0.36
Crude protein	4.17±0.17	Thr	0.26±0.02	C16:0	21.30±0.24
Crude fat	0.91±0.15	Ser	0.23±0.04	C16:1	13.20±0.10
Crude ash	0.81±0.12	Glu	0.63±0.03	C17:0	3.30±0.17
		Gly	0.24±0.03	C17:1	0.90±0.10
		Ala	0.33±0.04	C18:0	8.30±0.36
		Cys	0.02±0.01	C18:1	14.20±0.52
		Val	0.25±0.03	C18:2n-6	9.50±0.10
		Met	0.12±0.02	C18:3n-3	10.00±0.52
		Ile	0.19±0.03	C20:0	0.30±0.10
		Leu	0.40±0.02	C20:2	0.20±0.10
		Tyr	0.21±0.03	C20:4n-6	5.00±0.40
		Phe	0.23±0.03	C20:5n-3	10.00±0.53
		Lys	0.43±0.02	C22:6n-3	0.30±0.10
		Pro	0.21±0.03	C24:0	0.50±0.26
		His	0.12±0.02		
		Arg	0.38±0.01		

Table 2. Ingredients of formula feed

ingredients	diet (g kg^{-1})
Fish meal	300.0
Soybean meal	450.1
Wheat starch	221.1
Soybean oil	18.8
Vitamin premix	5.0
Mineral premix	5.0

Mineral premix (per kg diet): $ZnSO_4·7H_2O$: 180 mg; $CuSO_4·5H_2O$: 28 mg; $MnSO_4·7H_2O$: 104 mg; KI: 12 mg; $CoSO_4·7H_2O$: 22 mg.
Vitamin premix (per kg diet): retinol acetate 15 000 IU; vitamin D 25000 IU; a-tocopherol 200 mg; niacin 100 mg; thiamine-Cl 15 mg; riboflavin 35 mg; pyridoxine 10 mg; biotin 150 mg; menadione 60 mg; folic acid 5.2 mg; vitamin B_{12} 8 mg; ascorbyl-monophos-phate 2.0 g.

Table 3. Analysis on nutrients of formula feed

Proximate composition (g/100g)		Amino acid composition (g/100g)		Fatty acid composition (g/100g fatty acids)	
Moisture	6.19±0.29	Asp	3.60±0.03	C10:0	0.10±0.00
Crude protein	43.65±0.64	Thr	1.67±0.06	C12:0	0.10±0.00
Crude fat	6.31±0.13	Ser	1.92±0.08	C14:0	4.90±0.26
Crude ash	7.24±0.11	Glu	6.46±0.09	C16:0	24.00±0.66
		Gly	2.38±0.07	C16:1	5.90±0.46
		Ala	2.30±0.06	C17:0	1.60±0.17
		Cys	0.51±0.06	C17:1	0.90±0.10
		Val	2.06±0.08	C18:0	5.50±0.46
		Met	0.98±0.06	C18:1	19.40±0.36
		Ile	1.60±0.08	C18:2n-6	8.70±0.36
		Leu	3.00±0.05	C18:3n-3	1.70±0.17
		Tyr	1.27±0.04	C20:0	0.60±0.10
		Phe	1.75±0.05	C20:1	2.70±0.30
		Lys	2.51±0.10	C20:2	0.30±0.10
		Pro	2.26±0.04	C20:4n-6	1.40±0.17
		His	0.82±0.04	C20:5n-3	9.30±0.26
		Arg	2.36±0.06	C22:6n-3	12.90±0.53

muscle nutrition. During the experimental period, fish were fed twice a day (at 9:00 am and 4:00 pm, respectively). The excess feed and feces in tanks were cleaned daily before feeding in the morning. The culture water was continuously changed by circulation after treatment through filtration and purification system. Water temperature ranged from 18 to 23 ℃, with dissolved oxygen (DO) 6.5 to 8.2 mg/L, pH 7.1 to 7.9, ammonia nitrogen 0.3 to 0.5 mg/L and nitrite nitrogen 0.04 to 0.07 mg/L. The trial continued for 60 days.

The fish for each tank were randomly selected to be weighed and measured at the end of the experiment. Mean weight of the 36 paddlefishes fed with live feed and the other 36 fed with formula feed were 163.30±14.75 g and 147.72±7.92 g, respectively. All cultured fish were sacrificed with an overdose of tricaine methanesulphonate and rinsed in de-ionized water. The skins of both sides of the fish from the head to the caudal peduncle were removed, and the under muscles were taken and mixed to prepare for the samples. A total of nine samples for each group were tested. Muscle samples were kept under -80 ℃ prior to analysis. The muscle tissues of proximate analysis consisted of determining moisture, crude protein, crude fat and crude ash. Moisture content was determined by drying the sample in an oven at 105℃ until a constant weight 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 content was determined using the Soxhlet extraction method (AOAC, 1990). Crude ash content was determined by incineration in a muffle furnace at 550℃ for 24 h (AOAC, 1990). Amino acids analyses were determined by GB/T 5009.124-2003, in China, and the samples were hydrolyzed in 6 N HCl under a nitrogen atmosphere for 24 h. The hydrolyzed solution was subjected to Eppendorf LC 3000 (Eppendorf, Germany) automatic amino acid analyzer. Fatty acids analyses were determined (GB/T 17377-2008, in China) by gas chromatography (Agilent, Hewlett-Packand 6890N, USA). The proximate composition analysis of each sample was performed in triplicate, while the amino acid and fatty acid compositions analysis was done in duplicate.

Nutrition Evaluation Method

According to the assessment standards mode (%, dry) suggested by the FAO/WHO in 1973 and the amino acid mode of whole egg protein respectively, we calculated the mode of amino acid score (AAS), chemical score (CS) and essential amino acid index (EAAI) according to the following formula (Pellett and Yong 1980; Qiaoben 1980).

$$\text{AAS}=\frac{\text{aa}}{\text{AA}_{(\text{FAO/WHO})}}\times 100$$

$$\text{CS}=\frac{\text{aa}}{\text{AA}_{(\text{Egg})}}\times 100$$

$$\text{EAAI}=\sqrt[n]{\frac{100\text{A}}{\text{A}_\text{E}}\times\frac{100\text{B}}{\text{B}_\text{E}}\times\frac{100\text{C}}{\text{C}_\text{E}}\times\cdots\times\frac{100\text{I}}{\text{I}_\text{E}}}$$

In the above formula, aa means content of amino acids (%) of the samples. $\text{AA}_{(\text{FAO/WHO})}$ means the same amino acid content of FAO/WHO score standard mode (%). $\text{AA}_{(\text{Egg})}$ means content of the whole eggs in the same protein amino acid content (%). n denotes the number of the comparative essential amino acids. A, B, C,.. I represent content of essential amino acids for samples of muscle protein, and A_E, B_E, C_E,.. I_E are the measurement of the essential amino acids for the whole eggs protein content.

Data were analyzed in Excel (Microsoft office

2003) and STATISTICA 10.0 (StatSoft, Inc.) using t-test for independent sample to compare the parameters between two study groups. Differences were considered statistically significant when P<0.05 and extremely significant when P<0.01.

Results and Discussion

Proximate Compositions

The proximate compositions of paddlefish of live feed group and formula feed group were shown in Table 4. The muscle crude fat content of formula feed group was significantly higher than that of live feed group (P<0.01). The muscle crude ash content of formula feed group was significantly higher than that of live feed group (P<0.05). However, the muscle moisture and crude protein contents of formula feed group were significantly lower than those of live feed group (P<0.05).

This result is consistent with the previous reports (Yin *et al*. 2003; Ma *et al*. 2006; Chen *et al*. 2007; Luo *et al*. 2008; Song *et al*. 2007; Song *et al*. 2009). Compared the wild fish which had higher content of the moisture and lower content of the crude fat, the farmed fish showed the opposite pattern. This might related to the high efficiency of protein and energy of the feed and low energy consumption of the fish (Alasalvara *et al*. 2002; Grigorakis *et al*. 2007; Ana *et al*. 2010).

The muscle protein content of live feed group was higher than that of formula feed. This conclusion is consistent with some of the previous reports (Ma *et al*. 2006; Song *et al*. 2007), but contradicted with other reports (Yin *et al*. 2003; Chen *et al*. 2007; Luo *et al*. 2008; Song *et al*. 2009). Thus the crude protein content of fish muscle has not positive correlation with the farming methods and the type of feed.

Amino Acid Compositions

The paddlefish muscle amino acid compositions of both groups were summarized in Table 5. Seventeen kinds of amino acids (Trp was not detected because of acid hydrolysis) were detected, including seven kinds of human body essential amino acids

Table 4. Proximate compositions of paddlefish in both groups

Group	Moisture	Crude protein	Crude fat	Crude ash
live feed group	78.52±0.83*	17.20±0.30*	4.22±0.17**	0.95±0.09*
formula feed group	76.22±0.89	15.49±0.84	6.02±0.35	1.23±0.13

Notes: **means extremely significant difference at *P*<0.01. *means significant difference at *P*<0.05. (mean±SD, n=9, g/100g)

Table 5. Amino acid contents of both groups

Amino acid	Live feed group	Formula feed group	α
Asp	7.36±0.49	6.48±0.19	*
Thr	3.35±0.37	2.93±0.24	ns
Ser	3.13±0.03	2.79±0.21	*
Glu	11.93±0.33	10.67±0.45	*
Gly	3.10±0.40	2.87±0.16	ns
Ala	3.82±0.61	3.55±0.47	ns
Cys	0.25±0.07	0.32±0.09	ns
Val	3.54±0.21	3.11±0.23	ns
Met	2.33±0.08	2.02±0.19	ns
Ile	3.35±0.21	2.90±0.28	ns
Leu	6.15±0.16	5.31±0.20	**
Tyr	2.72±0.19	2.37±0.25	ns
Phe	3.82±0.44	3.06±0.21	ns
Lys	7.18±0.34	6.28±0.49	**
Pro	2.22±0.28	1.28±0.28	*
His	2.53±0.22	1.86±0.13	*
Arg	4.52±0.20	4.02±0.14	*
TAA	71.29±0.75	61.82±0.82	**
EAA	29.72±0.37	25.61±0.30	**
HEAA	7.05±0.35	5.89±0.15	**
NEAA	34.53±0.70	30.32±0.74	**
DAA	30.73±0.66	27.59±0.26	**
W_{EAA} / W_{TAA}	41.69±0.49	41.43±0.56	ns
W_{EAA} / W_{NEAA}	86.10±2.45	84.50±2.41	ns
W_{DAA} / W_{TAA}	43.10±0.70	44.63±0.19	*

Notes: **means extremely significant difference at *P*<0.01. *means significant difference at *P*<0.05. ns means non-significant. And it is the same in the following tables. (Mean±SD (n=9), g/100g dry muscle)

(EAA) (Thr, Val, Met, Phe, Ile, Leu and Lys), two kinds of human body half essential amino acids (HEAA) (His and Arg), and eight kinds of the human body non-essential amino acids (NEAA) (Asp, Glu, Ser, Gly, Ala, Tyr, Cys and Pro). In both groups, the sequence of the amino acids content from highest to lowest was: Glu (10.67 w/% and 11.93 w/%), Asp, Lys, Leu, Ala and Cys (0.32 w/% and 0.25 w/%). This characteristic of component was consistent with the amino acid composition rule of *Huso dauricus* (Yin *et al*. 2004), *Acipenser schrencki* (Yin *et al*. 2004) and *Xenocypris davidi Bleeker* (Zhang *et al*. 2002). Except Cys, other amino acid contents of formula feed group were lower than those of the live feed group. The contents of Asp, Ser, Glu, Pro, His and Arg were significantly different (P<0.05), and the contents of Leu and Lys showed extremely significant difference (P<0.01) while the others showed no significant differences (*P*>0.05) between the two groups.

Contents of total amino acids (TAA), total essential amino acids (TEAA), total half essential amino acids (THEAA), total non-essential amino acids (TNEAA), total delicious amino acids (TDAA), ∑EAA/∑TAA and ∑EAA/∑NEAA of formula feed group were lower than those of live feed group. No significant difference was observed in TEAA/TAA and TEAA/TNEAA (*P*>0.05), the rest of those were significantly different (P<0.01). Contents of ∑DAA/∑TAA of formula feed group were higher than those of live feed group (P<0.05).

Evaluation of Nutrition Quality

The data were converted into AA/protein (mg/g), and were compared with standard mode suggested by the FAO/WHO and amino acid mode of the egg protein. Then AAS, CS and EAAI of both groups were calculated, respectively (Table 6).

The paddlefish muscle amino acids content and proportion of both groups were basically the same, which was similar to the reports of Chen *et al* (2008) and Shen *et al* (2009). Compared to other fishes such as *Sinilabeo decorus* (Liang *et al*. 2009) and *Glossogobius giuris* (Zhuang *et al*. 2010), which also had a similar amino acid composition. Thus, the majority amino acid compositions of paddlefish muscle protein had a conservative pattern, which was in accordance with the findings of Yin *et al* (2004).

The evaluation of protein nutrition value must be based on the type of content and composition of amino acids, in particular, the eight kinds of essential amino acids in proportion to the level and composition of the evaluation (Bing *et al*. 2005). According to FAO / WHO amino acid standard mode, the better quality of its constituent amino acids of the protein EAA / TAA was about 0.40, and the protein EAA / NEAA was more than 0.60 (Bing *et al*. 2005). In this study, the protein EAA / TAA of live feed group and formula feed group were 41.69 and 41.43, and the protein EAA / NEAA were 86.10 and 84.50, respectively, which indicated that the muscle proteins of both groups had better balance in amino acid compositions and higher protein quality.

Lysine (Lys), as one of the most important AA involved in protein synthesis is called “growth of the amino acids” (Song *et al*. 2007). The Lys contents of live feed group and formula feed group were the highest among the essential amino acids, and both were 1.32 times and 1.15 times higher than that of the amino acid standard mode of FAO/WHO, respectively. This could compensate for the Lys lacking in grain foods which enhanced the protein utilization of the body (Yan *et al*. 1995). Besides, Lys was the first limiting amino acid in human milk. So paddlefish is also a superior prolactin food (Ma *et al*. 2003).

The flavor of animal protein depends on its tasty amino acids (Glu, Asp, Gly and Ala) composition and content. Glu and Asp were the determiners of the delicious flavor of amino acids Glu exerted stronger effects. Sweet taste of amino acids is mainly determined by Gly and Ala (Bing and Zhang 2006). Glu is not only delicious Amino acid, but also involves in the synthesis of a variety of physiologically active substances (Zhang *et al*. 1988). The total delicious amino acid of live feed group was

Table 6. Comparison of AAS, CS and EAAI between groups

Amino acid	Evaluation mode		Amino acid/protein		AAS		CS	
	FAO/WHO	Egg protein	Live feed group	Formula feed group	Live feed group	Formula feed group	Live feed group	Formula feed group
Ile	250	331	209	181	0.84	0.73	0.63	0.55
Leu	440	534	384	332	0.87	0.75	0.72	0.62
Lys	340	441	449	392	1.32	1.15	1.02	0.89
Thr	250	292	209	183	0.84	0.73	0.72	0.63
Val	310	411	221	194	0.71	0.63	0.54	0.47
Met+Cys	220	386	161	146	0.73	0.67	0.42	0.38
Phe+Tyr	380	565	408	339	1.07	0.89	0.72	0.60
EAAI							65.89	57.37

AAS results showed that among all the AA contents in both groups, Lys was the highest, followed by Phe + Tyr, and Val. According to the CS, Lys was the highest, followed by Thr, and Met + Cys. Based upon AAS, the first and second restrictive amino acids of both groups were Val and Met + Cys, respectively. The CS measure suggests that the first and second restrictive amino acids of both groups were Met + Cys and Val, respectively. mg/g, on protein basis.

significantly higher than that of formula feed group (P<0.01). Therefore, in theory, the muscle flavor of live feed group was better than that of formula feed group, which was in consistent with the other reports (Luo *et al*. 2008; Gu and Zhao 2008; Peng *et al*. 2008).

The paddlefish muscle essential amino acid indexes (EAAI) of live feed group and formula feed group were 65.89 and 57.37, respectively, which indicated the muscle quality of live feed group was superior to that of formula feed group. This finding was also consistent with another report (Song *et al*. 2007).

Analysis of Fatty Acid Compositions

There were 15 kinds of fatty acids detected in the muscle of both groups (Table 7), including five kinds of saturated fatty acids (SFA), four kinds of monounsaturated fatty acids (MUFA) and six kinds of polyunsaturated fatty acids (PUFA). In this study, the paddlefish muscle had high levels of C16:0 and C18:0, and low levels of C20:0, which is similar to the previous report (Haliloglu *et al*. 2004). Ibeas *et al* (1996) found out that C16:0 and C18:0 were of important function for the organism as not only the energy resource, but also the critical components of membrane phospholipids. C16:1 and C18:1 are the major ingredients of the four types of monounsaturated fatty acids detected in this study. High level of C16:1 is one of the main features of freshwater fish muscle (Gutierrez and Silva 1993; Oliveira *et al*. 2003). The highest content of fatty acids detected in monounsaturated fatty acids was C18:1. Since C18:1 was regarded as "security fatty acids" in nutriology, the number of C18:1 is an important indicator of food quality assessment. Rey *et al* (2004) also found that C18:1 could reduce blood total cholesterol and low density lipoprotein cholesterol but not high density lipoprotein cholesterol. Polyunsaturated fatty acids were mainly C20: 5n-3 (EPA) and C22: 6n-3 (DHA) in this study.

The nutrition values of fatty acid in paddlefish muscle of both groups were shown in Table 7. In this study, the ∑MUFA, ∑UFA, ∑n-6PUFA, DHA and EPA+DHA of formula feed group were higher than those of live feed group. No significant difference was found in ∑n-6PUFA and EPA+DHA between two groups (*P*>0.05). However, extremely significant differences were observed in other fatty acids (P<0.01). The ∑SFA, ∑PUFA, ∑SFA/∑UFA, ∑n-3PUFA, ∑n-3PUFA/∑n-6PUFA, EPA, EFA and HEFA of formula feed group were lower than those of live feed group. No significant differences were found in ∑PUFA, ∑n-3PUFA/∑n-6PUFA and HEFA between two groups (*P*>0.05). While significant difference was observed in ∑n-3PUFA (P<0.05), and extremely significant differences were observed in

Table 7. Fatty acid compositions in both groups

Fatty acids	Live feed group	Formula feed group	P
C14:0	1.20±0.17	1.50±0.10	ns
C16:0	27.40±0.53	26.60±0.35	ns
C17:0	1.20±0.10	0.60±0.10	**
C18:0	8.30±0.20	6.20±0.17	**
C20:0	0.10±0.00	0.10±0.00	ns
∑SFA	38.20±0.26	35.00±0.26	**
C16:1	7.10±0.26	4.30±0.17	**
C17:1	0.70±0.10	0.50±0.10	ns
C18:1	22.20±0.20	28.70±0.61	**
C20:1	0.30±0.10	1.30±0.26	**
∑MUFA	30.30±0.00	34.80±0.66	**
C18:2n-6	3.40±0.10	3.60±0.17	ns
C18:3n-3	3.10±0.17	0.40±0.10	**
C20:2	0.40±0.10	0.80±0.20	ns
C20:4n-6	4.70±0.10	4.60±0.17	ns
C20:5n-3(DHA)	13.30±0.35	7.10±0.30	**
C22:6n-3(EPA)	6.50±0.36	13.50±0.80	**
∑PUFA	31.40±0.26	30.00±0.98	ns
∑UFA	61.70±0.26	64.80±0.35	**
∑	99.90±0.00	99.80±0.10	ns
∑SFA/∑UFA	0.62±0.01	0.54±0.01	**
∑n-6PUFA	8.10±0.20	8.20±0.30	ns
∑n-3PUFA	22.90±0.40	21.00±0.96	*
∑n-6PUFA/∑n-3PUFA	0.35±0.01	0.39±0.02	ns
EPA	13.30±0.35	7.10±0.30	**
DHA	6.50±0.36	13.50±0.80	**
EPA+DHA	19.80±0.26	20.60±0.98	ns
EFA	6.50±0.10	4.00±0.10	**
HEFA	4.70±0.10	4.60±0.17	ns

(g/100g fatty acids).

other fatty acids (P<0.01).

Effects of live feed and formula feed on the muscle fatty acid compositions of paddlefish have not been reported. In this study, significant differences were observed in the muscle fatty acid composition and proportion between live feed group and formula feed group (P<0.05). Overall, the MUFA content of formula feed group was higher, while the SFA and PUFA content of live feed group was higher. This result is similar to the muscle fatty acid composition of *Hemibarbus maculate* cultured in wild or farm (Chen *et al*. 2007). Compared with other sturgeons, the SFA and PUFA contents of both groups were higher than that of *Acipenser sinensis*, while the content of MUFA was lower (Zhuang *et al*. 2010).

The proportion of C18: 3n-3 (ALA) and C20: 5n-3 (EPA) in formula feed group was lower than that of live feed group according to Table 7. The paddlefish with live feed possess a higher proportion of n-3PUFA, which is the same to the muscle fatty acids compositions of wild and farmed sea bass (Alasalvar 2002; Ana *et al*., 2010). Fat is the essential aroma component, and the high content of PUFA could significantly increase the flavor. It also reflected the degree of juiciness of the muscles to a certain extent (Mao *et al*. 2000). The fatty acid compositions were closely related to fat food source, season, water temperature, water physical and chemical factors, light etc (Codier *et al*., 2002). In recent years, studies suggested that monounsaturated fatty acids possess lipid-lowering effect (Mattson, 1990). Other studies also found that polyunsaturated fatty acids could significantly reduce blood lipid, inhibit platelet aggregation, lower blood pressure, and improve biofilm liquid, anti-tumor and immunomodulatory effects, which could significantly reduce the incidence of cardiovascular disease (Hang *et al*., 2001).

High level of dietary n-6PUFA could cause many health disorders while n-3PUFA could eliminate the adverse effects of it to some extent such as lowering serum triglycerides and cholesterol etc (Badiani *et al*. 1996; Guler *et al*. 2011). In recent years, studies have shown that EPA and DHA of n-3 series, which had been found in diatoms, red algae and brown algae, etc., that might own synthesis capability of EPA and DHA in nature, were a typical type of polyunsaturated fatty acids found mainly in fatty tissues of fish. Fish could build up EPA and DHA through the food chain enrichment. Clinical studies have found EPA and DHA were essential fatty acids of human and animal growth (Zhang, 1996), and could effectively prevent human cardiovascular disease (Lees *et al*., 1990; Zimmer *et al*., 2000).

In this study, the EPA + DHA contents of formula feed group were higher than those of live feed group, which indicated the paddlefish of formula feed group had a higher food value and health effects. Generally, it is believed that the content and composition of fatty acid of the feed might directly affect the fatty acid content and composition of fish muscle (Hansen *et al*. 2008). Therefore, in order to improve the food value and health effects, selecting the appropriate oil raw materials to increase the PUFA levels of the feed could improve the muscle PUFA ratio of farming paddlefish. The paddlefish formula feed should increase the content of PUFA which could improve the nutrition quality of the cultured fish (Orban *et al*. 2002).

In the present study, the same nutrition composition of paddlefish muscle in both groups reflects the stability of the species, while the different nutrition contents reveal the adaptability of the paddlefish to food. All the experimental subjects in the study were the offsprings of a particular group. They were raised in the same environment and shared the equal raising time. Thus we propose that the different ingredients in the feed may be one of the main reasons for the different contents and compositions of paddlefish muscle nutrition.

The nutrition quality of fish muscle is closely related to the fish bait, the physical condition, the living environment and the genes etc. But for the same species of fish, it seems that food and physical condition have more influence on the nutrition quality. In this study, since samples were taken from the same culture water, different muscle and nutrition compositions might be resulted from the different compositions of the feed (Alasalvar *et al*., 2002). Genetic and environmental effects on the nutrition quality of paddlefish would be further researched.

Conclusions

The paddlefishes fed with two kinds of feeds were rich in high-quality protein. But EAAI and DAA of live feed group were significantly higher than those of formula feed group. The paddlefish muscle contents of crude fat, MUFA and UFA of formula feed group were significantly higher than those of live feed group. Thus we propose that the development of paddlefish formula feed should be aimed at the amino acid balance and an appropriate proportion of polyunsaturated fatty acids.

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