



Note

Comparison of nutrient composition in wild caught and cultured *Cirrhinus molitorella* (Valenciennes, 1844)

KE CUI^{1,2,4}, FALIN ZHOU^{2,3}, ZHENHUA MA^{2,3} AND SHIGUI JIANG^{2,3}

¹College of Fisheries and Life Science, Shanghai Ocean University, Shanghai - 200 090, P. R. China

²South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou - 510 300, P. R. China

³Key Laboratory of South China Sea Fishery Resources Exploitation and Utilisation, Guangzhou - 510 300, P. R. China

⁴College of Animal Science, South China Agricultural University, Guangzhou - 510 642, P. R. China

e-mail: zhenhua.ma@hotmail.com

ABSTRACT

Proximate body composition and amino acid profile of flesh of wild *Cirrhinus molitorella* (Valenciennes, 1844) from a reservoir and a river was compared with that of *C. molitorella* cultured in an aquaculture pond. The results showed the fat content to be highest in *C. molitorella* caught from reservoir followed by samples from river and lowest in pond cultured fishes. Protein content exhibited the opposite trend. Flesh of *C. molitorella* from river had optimum protein quality while flesh of fishes from reservoir had the best taste. Flesh of *C. molitorella* was found to be nutritionally rich and well balanced and its high glutamic acid as well as lysine content made it a superior forage fish for *Siniperca chuatsi*. Overall, *C. molitorella* flesh had a more balanced nutritional composition, but lower nutritional value than that of seven other reference fish species.

Keywords: Amino acids, *Cirrhinus molitorella*, Crude fat, Crude protein

Cirrhinus molitorella (Valenciennes, 1844) (Family: Cyprinidae) is widely distributed in South China and South-east Asian countries along the Mekong River and is an important species contributing to the commercial fishery as well as in pond culture. In Guangdong and Guangxi provinces in China, *C. molitorella* is pond cultured for commercial purposes and also as a forage food for other fish. Wild stocks of *C. molitorella* in natural water bodies have declined (Nguyen *et al.*, 2013) with a simultaneous increase in consumer demand and requirement for nutritional quality. Fish meat quality is affected by various factors including different cultivars, growing environments and natural food sources (Grigorakis, 2007). Fish flesh generally contains higher free amino acids than that of terrestrial animals (Haard, 1992). These amino acids are important contributors to taste (Solms, 1969) and plays important role in the quality of fish meat. The present study evaluated the composition of amino acids and other common nutritive components in the flesh of *C. molitorella* from three different water bodies in South China, aiming to provide basic data for the development of appropriate aquaculture models to improve flesh quality of *C. molitorella*.

The study was carried out in August 2012 in the laboratory of the South China Sea Fisheries Research Institute (SCSFI), Chinese Academy of Fishery Sciences, Guangzhou, China. Amino acid analysis was carried out

by the Guangzhou Institute of Entomology, Guangdong, China. *C. molitorella* samples used were collected from a controlled reservoir (Songtao Reservoir in Hainan Province), a natural river (Xijiang River in Shaoqing City, Guangdong Province) and an aquaculture pond in Foshan City, Guangdong Province, respectively. Five healthy fish were sampled from each site, euthanised by an overdose (60 mg l⁻¹) of AQYI-S® and transported to the laboratory with ice packs. After measurement of body length and weight (using an electronic balance OHAUS, USA), (Table 1) flesh from the fish were removed, along with the fishbone, using a boning knife. Flesh was then chopped to <1 cm using a scalpel and stored at -75°C until analysis. Moisture content in flesh was determined as:

$$\text{Percentage moisture content of flesh} = \frac{W1 - W2}{W1 - W0} \times 100$$

where W1= weight of the pre-dried pan and fresh fish meat before drying at 120°C; W2 = weight of the pre-dried pan and fish meat after drying at 120°C; W0 = constant weight of the pre-dried pan.

Crude ash was determined as per the method described in GB5009.4-2010 (2010).

Table 1. Body length and weight of *Cirrhinus molitorella* from three sampling sites

Parameters	Songtao Reservoir	Xijiang River	Aquaculture pond
Length (cm)	26.18±1.29	26.98±2.64	27.9±1.01
Weight (g)	507.2±70.22	495.8±51.01	510.2±28.85

$$\text{Percentage of crude ash} = \frac{W1 - W2}{W1 - W0} \times 100$$

where, W1=weight of pre-burned crucible and ash (g); W2=weight of pre-burned crucible (g); W0=weight of the pre-burned crucible and dried sample before burning (g).

Crude fat content was determined as described in GB5009.6-2003 (2003).

$$\text{Percentage crude fat} = \frac{W1 - W2}{W0} \times 100$$

where, W1=weight of aluminum cup and residue (g); W2= weight of aluminum cup (g); W0=weight of fresh fish meat (g).

Crude protein content was calculated as per GB5009.5-2010 (2010) from the nitrogen content using the following formula:

$$\text{Percentage of crude protein} = \frac{(V_2 - V_1) \times C \times 0.0140 \times 6.25}{m \times \frac{V'}{V}} \times 100\%$$

where, v_1 = volume of standard acid solution used in titration of the fish meat sample (ml); v_2 = volume of standard acid solution used in the titration of the control (ml); C = concentration of standard HCl solution (mol l⁻¹); m = weight of fresh fish sample (g); v = total volume of the sample digest (ml); v' = volume of the sample digest used for evaporation (ml); 0.014 = nitrogen milligram equivalent (mEq) (g) of 1 ml standard HCl (1 mol l⁻¹) solution; 6.25 = average conversion coefficient from nitrogen to protein.

Amino acid content was determined by hydrochloric acid hydrolysis, as described in GB/T5009.124-2003. (2003). The sample was dehydrated by drying, defatted by Soxhlet extraction, mashed, added 6 mol l⁻¹ analytical HCl, ultrasonicated, vacuum sealed and hydrolysed at 110°C for 24 h. The hydrolysate was then evaporated in a pan to remove the solvent. The residue was diluted with water to a constant volume and sent to the Institute of Entomology in Guangzhou for analysis of amino acids (excluding tryptophan) in a L-8800 automatic amino acid analyser (Hitachi Ltd., Japan) in triplicates.

Nutritive value of *C. molitorella* flesh were evaluated in comparison with the ratios and patterns of amino acids recommended by the Food and Agricultural Organization (FAO, 1973) and the ratios and patterns of amino acids in whole egg protein (Cai *et al.*, 1980). Amino acids scores

(AAS), chemical scores (CS) and the essential amino acid index (EAAI) were calculated following Tan *et al.* (2004):

AAS = content of single amino acid in the sample (mg gN⁻¹) / content of the same amino acid in FAO/WHO criteria (mg gN⁻¹);

CS = content of single amino acid in the sample (mg gN⁻¹) / content of the same amino acid in whole egg protein (mg gN⁻¹)

$$\text{EAAI} = \sqrt[n]{100a / A \times 100b / B \times \dots 100j}$$

where, n = number of amino acids used in the evaluation; a, b, c, ...j = contents of each amino acid in the fish meat proteins; A, B, C, ...J = contents of each amino acid in the whole egg protein.

The average contents of moisture, crude ash, crude protein and crude fat in the *C. molitorella* meat from the three sampling sites are given in Table 2. Moisture content was the highest, followed by protein, fat and ash. Among the three sampling sites, flesh moisture and crude protein content in *C. molitorella* from Songtao Reservoir was highest, followed by that from Xijiang River (p>0.05) and aquaculture pond (p<0.05). Crude fat content was highest in fish flesh collected from aquaculture pond, followed by that from Xijiang River (p>0.05) and Songtao Reservoir (p<0.05). Crude ash content was highest in fish from Xijiang River, followed by aquaculture pond (p>0.05) and Songtao Reservoir (p<0.05). Overall, the difference in basic nutritional composition was most significant between Songtao Reservoir and aquaculture pond.

The basic nutritional composition of *C. molitorella* (based on data from the present study) and of seven other cultured freshwater fish species are listed in Table 3 (Liu *et al.*, 2008; Yan *et al.*, 1995). The average protein content of *C. molitorella* was lower than that of *Mylopharyngodon piceus*, equal to that of *Siniperca chuatsi* and higher than that of the other five species. Fat content of *C. molitorella* was equal to that of *Hypophthalmichthys molitrix* and higher than that of the other five species. Variations in the nutritional composition between species could be attributed to the difference in their living environment.

Table 2. Basic nutritional composition of *C. molitorella* flesh from three sampling sites

Components	Percentage (% of wet weight)			p value		
	Songtao Reservoir	Xijiang River	Aquaculture pond	P ₁₂	P ₁₃	P ₂₃
Moisture	75.38 ± 0.83a	74.92 ± 0.92a	72.96 ± 0.44b	0.683	0.002	0.0086
Crude ash	0.96 ± 0.14b	1.16 ± 0.07a	1.08 ± 0.06ab	0.0267	0.1963	0.4904
Crude fat	3.70 ± 3.12b	5.60 ± 1.74b	9.72 ± 1.59a	0.4796	0.007	0.0588
Crude protein	18.59 ± 0.36a	17.67 ± 0.39b	17.22 ± 0.73b	0.0673	0.0076	0.4606

Table 3. Basic proximate composition of *C. molitorella* and seven other cultured freshwater fish species

	Moisture (%)	Crude ash (%)	Crude protein (%)	Crude fat (%)
<i>Mylopharyngodon piceus</i> *	79.63	1.23	18.11	1.02
<i>Ctenopharyngodon idella</i> *	81.59	1.22	15.94	0.62
<i>Hypophthalmichthys molitrix</i> *	76.48	1.17	15.8	5.54
<i>Aristichthys nobilis</i> *	78.89	1.16	16.26	3.04
<i>Cyprinus carpio</i> *	79.58	1.18	16.52	2.03
<i>Carassius auratus</i> *	80.28	1.64	15.74	1.58
<i>Siniperca chuatsi</i> **	79.76	1.06	17.56	1.504
<i>Cirrhinus molitorella</i> ***	75.2	1.05	17.83	6.34

*Data from Liu (1990); **Data from Yan *et al.* (1995); ***Present study (average from Table 2)

Eighteen amino acids in the fish flesh samples including seven essential amino acids (EAA) (threonine, valine, methionine, isoleucine, leucine, phenylalanine and lysine), two half-essential amino acids (HEAA) (histidine and arginine), eight nonessential amino acids (NEAA) (aspartic acid, serine, glutamic acid, proline, glycine, alanine, cystine and tyrosine) and one non-protein amino acid (taurine) were detected by acid hydrolysis (Table 4). Among them, aspartic acid, glutamic acid, glycine and alanine are flavour amino acids (FAA). In *C. molitorella*, the content of glutamic acid was highest, followed by aspartic acid, lysine and leucine, with cystine being the lowest among all amino acids. Glutamine and asparagine are converted to glutamate and aspartate due

to acid hydrolysis and cystine is generally destroyed due to acid hydrolysis. In addition, the contents of histidine, methionine and proline were relatively low. The content of EAA accounted for 40% of total amino acids and the ratio of EAA to NEAA was higher than 60% (Li *et al.*, 1988). *C. molitorella* samples from Songtao Reservoir had significantly higher threonine, glutamic acid, NEAA and FAA content ($p < 0.05$) and significantly lower methionine and valine content than that from Xijiang River and the aquaculture pond ($p < 0.05$). In addition, *C. molitorella* from Songtao Reservoir had significantly lower phenylalanine and lysine content than that from the aquaculture pond ($p < 0.05$). *C. molitorella* from Xijiang River had significantly lower cystine content than

Table 4. Amino acid composition in *C. molitorella* from three sampling areas

Amino acids	Percentage (% of FW)			p value		
	Songtao Reservoir	Xijiang River	Aquaculture pond	P ₁₂	P ₁₃	P ₂₃
Aspartate	1.707±0.04a	1.674±0.03a	1.646±0.04a	0.4238	0.0823	0.5413
Threonine	0.682±0.11a	0.661±0.01b	0.632±0.02ab	0.1974	0.0025	0.0666
Serine	0.567±0.03a	0.529±0.01c	0.477±0.03b	0.0895	0.0004	0.0202
Glutamic acid	2.572±0.04a	2.479±0.05b	2.444±0.05b	0.0551	0.0093	0.5936
Proline	0.530±0.03a	0.492±0.00ab	0.507±0.03b	0.1064	0.401	0.6576
Glycine	0.744±0.03a	0.694±0.00ab	0.697±0.04b	0.1003	0.127	0.9889
Alanine	0.981±0.03a	0.959±0.01a	0.952±0.04a	0.5334	0.3319	0.9211
Cystine	0.078±0.00a	0.074±0.00a	0.077±0.00b	0.0092	0.7467	0.0345
Valine	0.770±0.01c	0.843±0.01a	0.860±0.02b	<.0001	<.0001	0.2586
Methionine	0.447±0.00b	0.530±0.00a	0.537±0.00a	<.0001	<.0001	0.3166
Isoleucine	0.726±0.02b	0.762±0.01a	0.756±0.02a	0.0235	0.0613	0.8532
Leucine	1.275±0.03a	1.306±0.02a	1.296±0.03a	0.3071	0.5388	0.8937
Tyrosine	0.536±0.02a	0.514±0.00a	0.520±0.02a	0.1353	0.3495	0.8036
Phenylalanine	0.686±0.03b	0.715±0.00a	0.753±0.03b	0.2851	0.0081	0.133
Lysine	1.453±0.03b	1.489±0.02a	1.536±0.05b	0.3472	0.016	0.1941
Histidine	0.428±0.06a	0.436±0.01a	0.428±0.02a	0.9519	0.9999	0.9473
Arginine	0.964±0.06a	0.891±0.01a	0.895±0.03a	0.7576	0.8322	0.9898
Taurine	0.11±0.00b	0.11±0.00b	0.125±0.00a	1	0.0064	0.0064
W_{TAA}	15.347±0.31a	15.449±0.25a	15.408±0.46a	0.9124	0.9675	0.9852
W_{EAA}	6.038±0.20b	6.305±0.09a	6.370±0.15a	0.1602	0.0525	0.7892
W_{HEAA}	1.392±0.69a	1.327±0.02a	1.322±0.05a	0.9744	0.8745	0.9582
W_{NEAA}	7.714±0.14a	7.415±0.12b	7.320±0.24b	0.0763	0.0197	0.7296
W_{FAA}	6.004±0.09a	5.807±0.17a	5.739±0.12a	0.1231	0.0347	0.7487
W_{EAA}/W_{TAA} (%)	39.34	40.81	41.34			
W_{EAA}/W_{NEAA} (%)	78.27	85.03	87.02			

W_{EAA} - weight of EAA; W_{NEAA} - weight of NEAA; W_{TAA} - weight of TAA

that from Songtao Reservoir and the aquaculture pond ($p < 0.05$) and significantly higher isoleucine content than that from Songtao Reservoir ($p < 0.05$). *C. molitorella* from the aquaculture pond had significantly higher serine content and significantly lower taurine content than that from Songtao Reservoir and Xijiang River ($p < 0.05$).

A comparison of amino acid content of *C. molitorella* (present study) and *S. chuatsi* flesh (Yan *et al.*, 1995) is presented in Table 5. In *S. chuatsi*, glutamic acid accounted for the largest percentage of amino acids, followed by aspartate, lysine and leucine. Percentage of cystine was the lowest, with the percentages of histidine, methionine and tyrosine also relatively low. Percentages of each amino acid in *S. chuatsi* were very close to those in *C. molitorella*, with the maximum difference not higher than 0.7%. Percentage of total EAA in *C. molitorella* was higher than that in *S. chuatsi*. Except for arginine and threonine, which were ~0.3% lower than that in *S. chuatsi*, the percentages of all other EAA in *C. molitorella* were higher than those in *S. chuatsi*.

The data in Table 4 were converted to milligram amino acids per gram nitrogen (mg g N^{-1}) in dehydrated flesh [$62.5\% \times$ amino acids content in fresh flesh / (1 - average moisture content of flesh)]. We then referred to the ratios and patterns of amino acids recommended by FAO/WHO and to the ratios and patterns of amino acids in whole egg protein to determine AAS, CS and EAAI of *C. molitorella* flesh from the three sampling sites. Excluding tryptophan, the assessment score of lysine was

higher than that of the other EAAs, while methionine and cystine scores were relatively low in *C. molitorella* from all sampling sites (Table 6). In general, there were no significant differences in single amino acid scores among the *C. molitorella* samples from the three sites (tryptophan not included). Samples of *C. molitorella* from Xijiang River had the highest EAAI value, followed by those from Songtao Reservoir and the aquaculture pond (Table 6).

Amino acid content ratios of *C. molitorella* and seven other cultured freshwater fish (Liu, 1990; Yan *et al.*, 1995) are shown in Table 7. Total amino acid (TAA) and EAA contents in *C. molitorella* were only lower than those in *S. chuatsi*. The average $W_{\text{EAA}}/W_{\text{TAA}}$ value and average $W_{\text{EAA}}/W_{\text{NEAA}}$ value of *C. molitorella* were slightly higher and significantly higher, respectively, than that of the other seven fish species. The EAAI value of *C. molitorella* was significantly lower than that of the other seven fish species.

The difference in basic nutritive components of fish flesh among the three sampling sites was mainly in dry matter between samples from Songtao Reservoir and the aquaculture pond. Songtao Reservoir had higher water temperature (Ge and Yu, 2009) than Xijiang River or the aquaculture pond, while the aquaculture pond had superior nutritional conditions than those of Songtao Reservoir or Xijiang River. Fish in environments with higher accumulated temperature have higher metabolic rates, which makes it difficult to obtain sufficient energy for growth and development. In addition, naturally growing fish have to prey for food, which also results

Table 5. Amino acid composition in *C. molitorella* and *Siniperca chuatsi*

Amino acid		Percentage (% of wet weight)		Percentage (% of TAA)	
		<i>S. chuatsi</i> *	<i>C. molitorella</i>	<i>S. chuatsi</i> *	<i>C. molitorella</i>
NEAA	Aspartate	1.85	1.68	10.92	11.16
	Tyrosine	0.52	0.52	3.07	3.45
	Serine	0.68	0.52	4.01	3.45
	Glutamic acid	2.93	2.5	17.3	16.6
	Glycine	0.81	0.71	4.78	4.71
	Proline	0.69	0.51	4.07	3.39
	Alanine	1.09	0.96	6.43	6.37
	Cystine	0.17	0.08	1	0.53
EAA	Valine	0.88	0.82	5.19	5.44
	Methionine	0.51	0.5	3.01	3.32
	Isoleucine	0.84	0.75	4.96	4.98
	Leucine	1.44	1.29	8.5	8.57
	Phenylalanine	0.73	0.72	4.31	4.78
	Lysine	1.56	1.49	9.21	9.89
	Threonine	0.8	0.66	4.72	4.38
HEAA	Histidine	0.36	0.43	2.13	2.86
	Arginine	1.08	0.92	6.38	6.11
	W_{EAA}	8.2	7.58	48.41	50.33
	W_{TAA}	16.94	15.06		

*Data from Yan *et al.* (1995), W_{NEAA} - weight of NEAA; W_{TAA} - weight of TAA

Table 6. EAA composition in *C. molitorella* from three sampling sites

Indices	Amino acids	Milligram amino acids per gram nitrogen in dehydrated flesh (mg amino acids / g N)					Scores		
		FAO criteria	Whole egg protein criteria	Songtao Reservoir	Xijiang River	Aquaculture pond	Songtao Reservoir	Xijiang River	Aquaculture pond
AAS	Isoleucine	2.5		1.843	1.899	1.747	0.737	0.76	0.7
	Leucine	4.4		3.237	3.255	3	0.736	0.74	0.682
	Lysine	3.4		3.689	3.711	3.55	1.085	1.092	1.044
	Threonine	2.5		1.707	1.647	1.461	0.683	0.659	0.584
	Valine	3.1		1.955	2.1	1.987	0.631	0.677	0.641
	Tryptophan	0.6		/	/	/	/	/	/
	Methionine + Cystine	2.2		1.333	1.504	1.419	0.606	0.684	0.645
	Phenylalanine + Tyrosine	3.8		3.102	3.063	2.94	0.816	0.806	0.774
CS	Isoleucine		3.31	1.843	1.899	1.747	0.557	0.574	0.528
	Leucine		5.34	3.237	3.255	3	0.606	0.61	0.562
	Lysine		4.41	3.689	3.711	3.55	0.837	0.841	0.805
	Threonine		2.92	1.707	1.647	1.461	0.585	0.564	0.5
	Valine		4.1	1.955	2.1	1.987	0.477	0.512	0.485
	Tryptophan		0.99	/	/	/	/	/	/
	Methionine + Cystine		3.86	1.333	1.504	1.419	0.345	0.39	0.368
	Phenylalanine + Tyrosine		5.65	3.102	3.063	2.94	0.55	0.542	0.52
EAAI						54.86	56.32	52.56	

Table 7. Amino acid content ratio in *C. molitorella* and seven other cultured freshwater fish species

Species	W_{TAA}	W_{EAA}	W_{EAA}/W_{TAA}	W_{EAA}/W_{NEAA}	EAAI
<i>M. piceus</i> *	14.04	5.68	40.46	0.68	67.62
<i>C. idella</i> *	12.37	4.97	40.18	0.67	62.71
<i>H. molitrix</i> *	14.79	5.64	38.13	0.62	60.73
<i>A. nobilis</i> *	14.98	5.96	39.79	0.66	68.44
<i>C. carpio</i> *	13.94	5.58	40.03	0.67	68.96
<i>C. auratus</i> *	15.1	6.04	40	0.67	71.25
<i>S. chuatsi</i> **	16.94	6.76	39.91	0.66	81.02
<i>C. molitorella</i>	15.4	6.23	40.5	0.83	54.58

* Data from Liu (1990); ** Data from Yan *et al.* (1995)

in high metabolic rates and significant activity costs. Fat content of fish in Songtao Reservoir was lowest, followed by that in Xijiang River, with highest fat content in fish from aquaculture pond. Due to the long-term high metabolic costs, fish from Songtao Reservoir had lower fat content, but higher protein content than that of fish from the aquaculture pond.

Protein and fat are chief components and important indicators of fish flesh quality. Generally, high protein and fat content indicate high quality fish meat (Fu *et al.*, 2011). Compared with the seven other cultured freshwater fish, *C. molitorella* had higher average protein and fat content than all other species, except for *M. piceus*. Therefore the flesh quality of *C. molitorella* was found to be lower than that of *M. piceus*, while higher than that of *C. idella*, *H. molitrix*, *A. nobilis*, *C. carpio*, *C. auratus* and *S. chuatsi*.

Of the 18 amino acids in *C. molitorella*, glutamic acid content was the highest. Glutamic acid, which is one of the flavour amino acids (FAA) also plays an important

role in the biochemical metabolism of brain tissue and is involved in the synthesis of several physiologically active substances (Zhang *et al.*, 1988). Lysine content was also high in *C. molitorella*. As lysine, methionine and tryptophan are generally lacking in cereal, lysine is often classified as the main limiting amino acid in the human body (Chen, 1984). Cystine content was the lowest as well as a limiting amino acid in *C. molitorella*. In addition, *C. molitorella* flesh also contained taurine, a special amino acid that is functional in anti-oxidation and in improving immunity (Zhou *et al.*, 2009) and thus is important for human and animal health.

As to the difference in amino acid categories, the EAA content in *C. molitorella* from the aquaculture pond was higher than that from Songtao Reservoir, while the NEAA content from Songtao Reservoir was higher than that from the aquaculture pond. The W_{EAA}/W_{TAA} values for *C. molitorella* from Songtao Reservoir, Xijiang River and the aquaculture pond were 39.34, 40.81 and 41.34, respectively and the W_{EAA}/W_{NEAA} values were 78.27, 85.03 and 87.02 respectively. According to the FAO/WHO criteria, high quality proteins have W_{EAA}/W_{TAA} values of about 40% and W_{EAA}/W_{NEAA} values over 60%. The amino acid composition of *C. molitorella* from the three sampling sites met these requirements. Thus, *C. molitorella* from the three sampling sites showed well balanced amino acid composition.

The main FAAs found in fish are glutamic acid, aspartate, alanine and glycine. The content and composition of FAAs reflect the quality in terms of taste of animal

flesh. The FAA content in *C. molitorella* from the three sampling sites increased in the order from the aquaculture pond, Xijiang River and Songtao Reservoir, with the content from Songtao Reservoir significantly higher than that from the aquaculture pond which indicated that *C. molitorella* from Songtao Reservoir tasted better than that from the aquaculture pond.

Protein is the most important nutritional component in food. Furthermore, amino acid content and appropriate composition is important for high quality food. The proportion of amino acids in fish, especially the EAA, will be consistent with their natural food organisms. In *C. molitorella*, glutamic acid content was highest, followed by aspartate, lysine and leucine; cystine was the lowest, with histidine, methionine and proline also relatively low. With respect to amino acid proportion, *S. chuatsi* was very similar to *C. molitorella*, with the maximal difference lower than 0.7%, indicating similar nutritional composition for the two species. Essential amino acids are the most important determinant of the nutritive value of prey fish. In the present study, we found that the total and single EAA proportions of *C. molitorella* were higher than those of *S. chuatsi*, except for arginine and threonine, which were 0.3% lower. These results indicate that *C. molitorella* met the nutritional requirements of *S. chuatsi* as a food source with respect to EAA. The nutritional physiology and environmental adaptation of predator species, such as *S. chuatsi*, are influencing factors with regard to food/prey choice (Liang *et al.*, 1995). Our results showed that the EAA composition in *C. molitorella* satisfied the nutritional requirements of *S. chuatsi* and hence *C. molitorella* appears to be suitable as a high quality food organism for *S. chuatsi*.

In *C. molitorella* from all three sampling sites, the lysine score was higher than that of the other EAAs and methionine and cystine scores were relatively low. In general, no significant differences were observed in single amino acid scores among the *C. molitorella* samples from the three sampling sites (tryptophan excluded). These results indicate that *C. molitorella* had well-balanced amino acid composition and abundant lysine content. Furthermore, *C. molitorella* from Xijiang River had the highest EAAI value, followed by that from Songtao Reservoir and the aquaculture pond.

Amino acid content of *C. molitorella* was higher than that of *C. idella*, *H. molitrix*, *A. nobilis*, *C. carpio*, and *C. auratus* and lower than that of *S. chuatsi*. The average $W_{\text{EAA}}/W_{\text{TAA}}$ value of *C. molitorella* from the three sampling sites was slightly higher than that of the other seven fish species, while the average $W_{\text{EAA}}/W_{\text{NEAA}}$ value was

significantly higher. This indicated that the amino acids in *C. molitorella* were well-balanced, but protein quality was poorer.

Results of the present study indicated that the flesh of *C. molitorella* had rich and well-balanced nutrients compared to certain other freshwater species. Results from the present study provide basic practical data for the development of aquaculture models to improve flesh quality of *C. molitorella*.

Acknowledgements

This project was partially funded by the Guangdong Provincial Oceanic Fisheries Special Technology Promotion Project (B201400B01) and the Special Scientific Research Funds for Central Non-Profit Institutes, South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences (2014YJ01).

References

- Cai, W. Q. 1980. *Fisheries feed*. Agriculture Publishing Company, Beijing, China, p. 114-115.
- Chen, X. C. 1984. *Applied human nutrition*. People's Medical Publishing House, Beijing, China, p. 8-14.
- Fu, Z. R., Bai, X. H., Zhao, S. H., Li, J., Liang, C. H. and Li, W. W. 2011. *Quality and nutritive composition evaluation of three carp flesh*. *Hebei Fish*, 6: 5-58.
- Grigorakis, K. 2007. Compositional and organoleptic quality of farmed and wild gilthead seabream (*Sparus aurata*) and seabass (*Dicentrarchus labrax*) and factors affecting it: A review. *Aquaculture*, 272: 55-75.
- GB5009.6-2003, 2003. *Determination of fat in foods, National food safety standard*. Ministry of Health of the People's Republic of China, Beijing, China, 6 pp.
- GB/T5009.124-2003, 2003. *Determination of amino acids in foods, National food safety standard*. Ministry of Health of the People's Republic of China, Beijing, China, 6 pp.
- GB5009.4-2010, 2010. *Determination of ash in foods, National food safety standard*. Ministry of Health of the People's Republic of China, Beijing, China, 6 pp.
- GB5009.5-2010, 2010. *Determination of protein in foods, National food safety standard*. Ministry of Health of the People's Republic of China, Beijing, China, 6 pp.
- Ge, C. Y. H. 2009. Main environmental problems and countermeasures of Songtao Reservoir in Hainan Province. *J. Anhui. Agri. Sci.*, 37: 15948-15949.
- Haard, N. F. 1992. *Control of chemical composition and food quality attributes of cultured fish*. *Food Res. Int.*, 25: 289-307.
- Li, Z. Z. 1988. The determination and comparison of essential amino acids in pollen, ganoderma and pearl. *Amino Acids Biotic Resour.*, 4: 41-43.

- Liang, Y. Q., Liu, Y. L. and Cui, X. Q. 1995. The nutritional physiological analysis of *S. chuatsi* on the choice of forage fishes. *Reserv. Fish.*, 1: 9-11.
- Liu, J. K. 1990. *Ecological study of East Lake*. Science Press, Beijing, China, p. 307-311.
- Liu, L., Yu, H. X. and Xiao, W. 2008. Research progress on fish quality. *Inland Fish*, 9: 9-12.
- Nguyen, T. H. T., Van, N. S. and Thinh, D. V. 2013. *Cirrhinus molitorella*. *The IUCN Red list of threatened species 2013*: e.T166016A6168828. (Accessed 11 December 2015).
- Solms, J. 1969. Taste of amino acids, peptides and proteins. *J. Agr. Food Chem.*, 17: 686-688.
- Tan, D. Q., Wang, J. W., Dan, S. G. and Li, W. J. 2004. The ratio of muscle to body and analysis of the biochemical composition of muscle in *Megalobrama pellegrini*. *Acta Hydrobiol. Sin.*, 28(1): 17-22.
- Yan, A. S., Xiong, C. X., Qian, J. W. and Wang, X. D. 1995. A study on the rate of flesh content of mandarin fish and nutritional quality of the flesh. *J. Huazhong Agr. Univ.*, 14(1): 80-84.
- Zhang, C. Y., Li, L., Li, C. P. and Ren, B. Z. 1988. *Biochemistry*, 2nd edn. *People's Medical Publishing House*, Beijing, China, p. 305-561.
- Zhou, W. W., Chen, W., Zheng, X. L. and Su, S. 2009. Physiological function and clinical application of taurine. *Mod. Agr. Sci. Technol.*, 24: 303-309.