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Nutritional Components and Quality Evaluation of *Coilia nasus* Muscle from Offshore of the Yangtze Estuary

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ABSTRACT

Background: *Coilia nasus* was one of the important economic fish in the Yangtze Estuary. The meat of *C. nasus* is tender and delicious, which is deeply loved by people. With the ban on fishing in the Yangtze River, a large number of "*C. nasus* from the sea" have appeared in the market. At present, the nutritional status and its true source are not clear. Therefore, the nutritional composition and quality of offshore *C. nasus* were analyzed to identify its source and evaluate its development and utilization potential according to its nutritional quality in the future.

Methods: The muscle nutritional components and quality of offshore *C. nasus* were analyzed according to the methods of national standards of China.

Result: The content of essential amino acids (EAA) in dry sample was 57.06%±7.39%. The first limited amino acid was tryptophan (Trp), the essential amino acids index (EAAI) was 83.05 and the F-value was 2.37. The total content of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in fatty acids were 10.67%±0.46%, the ratio of DHA/EPA was 1.74%±0.05%. This investigation indicates that the muscle of *C. nasus* from offshore of the Yangtze Estuary contained rich amino acid such as glutamate (Glu) and lysine (Lys) and sufficient polyunsaturated fatty acids such as DHA and EPA.

Key words: *Coilia nasus*, Muscle, Nutritional composition, Offshore of the Yangtze Estuary, Quality evaluation.

INTRODUCTION

Coilia nasus, as a kind of migratory fish, usually live in the sea and migrate from the sea to the river for reproduction during the breeding season from March to June (Zhuang *et al.*, 2018). *C. nasus* was one of the important economic fish in the Yangtze Estuary. However, with the impact of water conservancy projects' construction along the river, environmental pollution and overfishing, *C. nasus* resources in the Yangtze River are on the verge of extinction. Therefore, in recent years, a large number of studies have been carried out on the protection and management of *C. nasus* resources (Ma *et al.*, 2020; Xue *et al.*, 2020), migratory habits (Wang *et al.*, 2020; Xu *et al.*, 2020) and genetic diversity (Jo *et al.*, 2021; Xuan *et al.*, 2021). But, there are relatively few studies on the offshore *C. nasus* outside the No fishing line (Fig 1). The meat of *C. nasus* is tender and juicy and tastes delicious, which is deeply loved by people. Especially near the Qingming Festival, *C. nasus* from the Yangtze River is regarded as an important delicacy. It is generally believed that *C. nasus* has the highest nutritional value and the freshest taste in this period.

For a long time, the research on *C. nasus* nutrition has mainly focused on the individuals from the Yangtze River (Wen *et al.*, 2008; Liu *et al.*, 2009; Xu *et al.*, 2009a; Tang *et al.*, 2011; Teng *et al.*, 2016) and there are also some studies on the nutritional status of *C. mystus* in the Yangtze Estuary (Song *et al.*, 2020 a, c), while there is a lack of research on the nutritional status of offshore *C. nasus*. With the prohibition of fishing in the Yangtze River, a large number of "*C. nasus* from the sea" have gradually appeared in the market near the Qingming Festival. At present, the nutritional status and its real source are not clear. Therefore, this study analyzes the nutritional composition and quality of offshore *C. nasus* from outside the No fishing line, in order to provide a basic reference for the discrimination of *C. nasus* from different sources in market supervision and serve as a theoretical basis for rational development and utilization for the management of the offshore *C. nasus* outside the No fishing line in the future.

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MATERIALS AND METHODS

Sample collection and pretreatment

The offshore *C. nasus* was collected from Shengsi (SS) of Zhejiang Province in April 2020. The location is outside the No fishing line of the Yangtze River (Fig 1). Thirty individuals of *C. nasus* were randomly sampled and divided into 6 groups. A total of 200 g fresh muscle samples were taken from the back of 5 individuals in each group to form one sample. The six parallel samples were dried at 60°C, ground and mixed evenly. The six treated samples were divided into two subgroups, one of which was determined for amino acid and fatty acid, the other was dried to the constant weight at 105°C for determination of proximate composition of protein, fat and ash.

Determination of nutritional composition

The nutritional composition was determined according to the national standard methods in East China Sea Fisheries Research Institute. The contents of moisture, ash, protein and fat in the muscle of the offshore *C. nasus* were determined according to GB 5009.3-2016. The contents of amino acids were estimated according to GB 5009.124-2016 using Biochrom-20 amino acid analyzer. The contents of fatty acids were determined according to GB 5009.168-2016 using Agilent-6890 capillary gas chromatograph (Song *et al.*, 2019).

Amino acids evaluation

The amino acids score (AAS), chemical score (CS) and essential amino acids index (EAAI) were calculated with the formulas as follows: (Pellett and Yong, 1980; Yang, 2005; Jiang and Yang, 2020).

$$AAS = \frac{aa}{AA\ (FAO\ /WHO)}$$

$$CS = \frac{aa}{AA\ (Egg)}$$

$$EAAI = \sqrt[n]{\frac{100A}{AE} \times \frac{100B}{BE} \times \frac{100C}{CE} \times \ldots \times \frac{100H}{HE}}$$

Where,

aa is the amino acid content (%) of muscle protein in the dry sample; AA (FAO /WHO) and AA (Egg) are the FAO/WHO scoring mode and the same amino acid content (%) in the whole egg protein respectively; *n* is the number of essential amino acids; A, B, …, H and AE, BE, … and HE are the essential amino acid content (%) of the sample muscle protein and the whole egg protein respectively.

The F value was calculated according to the following formula (Tang *et al.*, 2011).

$$F = \frac{\text{Valine + leucine + isoleucine}}{\text{Phenylalanine + tyrosine}}$$

Data statistics and processing

The data were analyzed with IBM SPSS statistics 24.0 software and the descriptive statistical values were expressed by mean ± standard deviation (X ± SD).

RESULTS AND DISCUSSION

Proximate composition

The proximate composition in fresh muscle of offshore *C. nasus* from SS (Fig 1) was shown in Table 1. The moisture content (69.80%) was higher than that from Shanghai (SH) (68.06%) (Teng *et al.*, 2016), while lower than that from the other comparison sources. The protein content (18.18%) was lower than that from Dayang River (DYR) (18.43%♂) (Jiang and Yang, 2020), while higher than that from the other comparison sources. The fat content (10.52%) was lower than that from SH (16.54%) (Teng *et al.*, 2016), while significantly higher than that from the other comparison sources. The ash content (1.41%) was lower than that from Changshu (CHS) (1.49%) (Liu *et al.*, 2009), while significantly higher than that from SH (0.90%) (Teng *et al.*, 2016). In fresh muscle of offshore *C. nasus*, the content of protein was moderate and the fat was higher, indicating that the protein nutrition of offshore *C. nasus* was moderate and the fat nutrition was better.

Amino acid composition

Eighteen amino acids were detected in the offshore *C. nasus* muscle from SS (Table 2). In dry samples, the content of total amino acids (TAA) was 57.06%, which was higher than that from Jiangyin (JY) (52.74%) (Wen *et al.*, 2008), SH (37.35%) (Teng *et al.*, 2016) and DYR (54.34%♂ and 52.54%♀) (Jiang and Yang, 2020). The content of glutamic acid (Glu) was the highest (2.73%), which is not only delicious amino acids (DAA), but also plays an important role in intestinal energy supply and nutritional regulation (Qin *et al.*, 2019). The content of lysine (Lys) was 1.72%, which was the highest essential amino acid (EAA). In this study, the ratio of EAA to TAA (EAA/TAA) was 42.10% and the ratio of EAA to nonessential amino acids (NEAA) (EAA/NEAA) was 84.84%, which was clear that, the content of different amino acids was stable and the constitutional rate of the essential amino acids met the FAO/WHO Standard (Teng *et al.*, 2016). The balance effect of amino acid composition in muscle of offshore *C. nasus* is good, which is a high-quality protein source.

Amino acids evaluation

According to the method of Jiang and Yang (2020), the AAS, CS, EAAI and F values of offshore *C. nasus* muscle were calculated, respectively. Among the AAS and CS scores, the Lys was the highest, while tryptophan (Trp) was the lowest (Table 3). Lys had the highest score in AAS and CS and its content had exceeded the FAO/WHO standard and egg protein standard 1.74 and 1.34 times, respectively (Table 3). It can be used to make up for the lack of Lys in cereal food, enhance the absorption and utilization of protein and promote development (Wang and Zhao, 2018).

Table 1: Proximate composition (%) in fresh muscle of *C. nasus* from offshore of the Yangtze Estuary.

Proximate	Content
Moisture	69.80±2.56
Protein	18.18±0.89
Fat	10.52±2.27
Ash	1.41±0.65

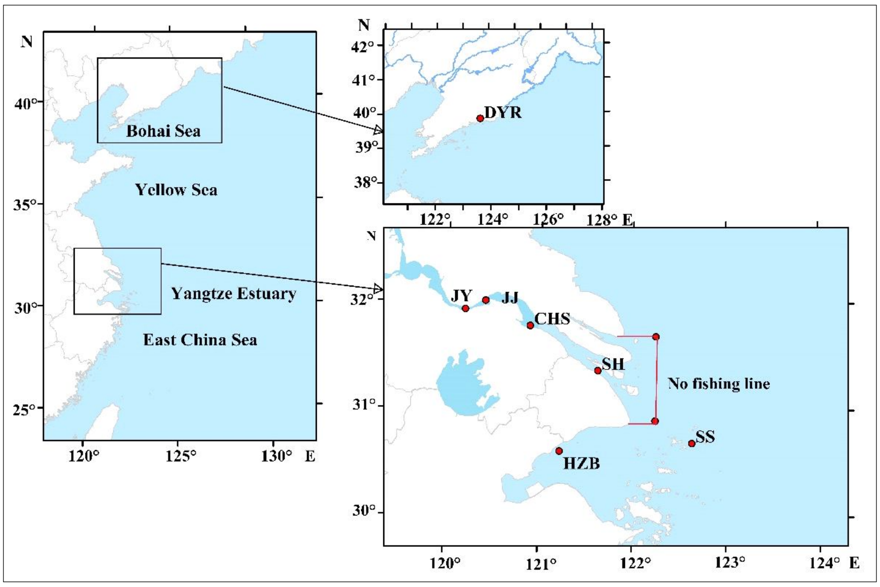

Fig 1: Map of the offshore *C. nasus* sample source of SS (Shengsi, 30.61°N 121.23°E) and the other six comparison sources of DYR (Dayang River), JY (Jiangyin), JJ (Jingjiang), CHS (Changshu), SH (Shanghai) and HZB (Hangzhou Bay); No fishing line (the frame area line formed by 122°15′ E, from 30°54′ N to 31°41′36″ N, bounded by the boundary between water and land to the West).

The EAAI was 83.05 (Table 3), which was significantly higher than that from CHS (70.49%) (Liu *et al.*, 2009) and DYR (59.82%♂ and 65.44%♀) (Jiang and Yang, 2020). The F value was 2.37 (Table 3), which closed to the normal range of human and other mammals (3.0 - 3.5), higher than that of JY (2.17) (Wen *et al.*, 2008) and CHS (2.17) (Liu *et al.*, 2009), significantly higher than that of liver injury (1.0 - 1.5). It has the effects of protecting liver and reducing cholesterol (Xu *et al.*, 2009 b; Tang *et al.*, 2011). In terms of DAA (21.64%), it was slightly lower than that from CHS (23.74%) (Liu *et al.*, 2009) and Jingjiang (JJ) (22.60%) (Tang *et al.*, 2011), while higher than that from the other comparison sources, which tasted delicious.

Fatty acid composition

Thirty-one kinds of fatty acids were detected in the muscle of offshore *C. nasus* (Table 4). The highest content of the saturated fatty acid (SFA) was 16:0 (23.70%), which was significantly higher than that from CHS (18.75%) (Liu *et al.*, 2009) and Hangzhou Bay (HZB) (18.54%) (Xu *et al.*, 2009b). The highest content of the monounsaturated fatty acid (MUFA) was 18:1n9c (45.50%), which was significantly higher than that from HZB (41.73%) (Xu *et al.*, 2009 b) and DYR (40.83%♂ and 39.70%♀) (Jiang and Yang, 2020). The highest content of the polyunsaturated fatty acid (PUFA) was docosahexaenoic acid (DHA), followed by eicosapentaenoic acid (EPA). PUFA has many excellent physiological functions, such as enhancing immunity, preventing cancer, promoting blood circulation, softening cardiovascular and cerebrovascular vessels and reducing cholesterol (Li and Zhang, 2009). PUFA accounted for 15.20% in the muscle of offshore *C. nasus*, which was higher than that from HZB (13.20%) (Xu *et al.*, 2009 b) and JY

Table 2: Amino acids composition (%) in muscle of *C. nasus* from offshore of the Yangtze Estuary.

Amino acids	Fresh matter	Dry matter
Serine (Ser)▲	0.67±0.05	2.25±0.30
Tyrosine (Tyr)▲	0.58±0.06	1.95±0.30
Cystine (Cys)▲	0.19±0.02	0.65±0.12
Proline (Pro)▲	0.54±0.02	1.81±0.19
Aspartic acid (Asp)▲*	1.81±0.15	6.03±0.79
Glutamic acid (Glu)▲*	2.73±0.22	9.11±1.31
Glycine (Gly)▲*	0.84±0.04	2.79±0.18
Alanine (Ala)▲*	1.11±0.07	3.71±0.44
Histidine (His)▸	0.32±0.05	1.07±0.22
Arginine (Arg)▸	1.10±0.09	3.66±0.49
Methionine (Met)▼	0.56±0.05	1.87±0.26
Phenylalanine (Phe)▼	0.78±0.07	2.60±0.34
Isoleucine (Ile)▼	0.84±0.07	2.81±0.35
Leucine (Leu)▼	1.43±0.12	4.76±0.63
Lysine (Lys)▼	1.72±0.16	5.74±0.80
Threonine (Thr)▼	0.78±0.06	2.60±0.33
Valine (Val)▼	0.96±0.07	3.19±0.38
Tryptophan (Trp)▼	0.14±0.01	0.46±0.07
TAA	17.10±0.32	57.06±7.39
EAA	7.20±0.61	24.02±3.14
HEAA	1.42±0.13	4.73±0.70
NEAA	8.48±0.59	28.30±3.57
DAA	6.48±0.44	21.64±2.68
EAA/TAA (%)	42.10	42.10
EAA/NEAA (%)	84.84	84.84
DAA/TAA (%)	37.96	37.96

delicious amino acids (DAA), ▲ non-essential amino acids (NEAA), ▸half-essential amino acids (HEAA), ▼ essential amino acids (EAA).

Table 3: Evaluation of essential amino acids composition in muscle of *C. nasus* from offshore of the Yangtze Estuary.

Essential amino acid	Amino acid content (mg/g)	FAO scoring mode	Egg protein pattern	Amino acid score (AAS)	Chemical score (CS)	Essential amino acid index (EAAI)	F value
Ile	289.47	250	379	1.16	0.87	83.05	2.37
Leu	490.26	440	568	1.11	0.92		
Lys	591.32	340	442	1.74	1.34		
Thr	267.89	250	315	1.07	0.92		
Val	328.90	310	368	1.06	0.80		
Trp	47.06	60	105	0.78	0.48		
Met+Cys	260.02	220	258	1.18	0.67		
Phe+Tyr	468.02	380	626	1.23	0.83		

Table 4: Fatty acids profile in muscle of *C. nasus* from offshore of the Yangtze Estuary.

Fatty acids	Content (%)	Fatty acids	Content (%)
12:0	0.15±0.02	18:2n6c▲	0.65±0.05
13:0	0.03±0.01	20:2	0.45±0.06
14:0	2.40±0.09	22:2	0.23±0.03
15:0	0.42±0.02	18:3n6▲	0.07±0.04
16:0	23.70±0.70	18:3n3(ALA)★	0.47±0.05
17:0	0.32±0.02	20:3n6▲	0.24±0.25
18:0	3.11±0.25	20:3n3★	0.10±0.01
20:0	0.28±0.02	20:4n6(ARA)▲	1.05±0.06
21:0	0.05±0.01	20:5n3(EPA)★	3.90±0.21
22:0	0.05±0.02	22:5n3(DPA)★	1.23±0.08
24:0	0.04±0.02	22:6n3(DHA)★	6.77±0.28
14:1	0.06±0.01	SFA	30.54±0.50
16:1	7.65±0.37	MUFA	54.25±0.48
17:1	0.48±0.17	PUFA	15.20±0.63
18:1n9t	0.19±0.01	DHA+EPA	10.67±0.46
18:1n9c	45.50±0.78	n3 PUFA	12.48±0.50
20:1n9	0.20±0.02	n6 PUFA	2.05±0.18
22:1n9	0.04±0.01	DHA/EPA	1.74±0.05
24:1n9	0.13±0.03	n3 PUFA/n6 PUFA	6.12±0.48
18:2n6t▲	0.04±0.02	PUFA/SFA	0.50±0.03

SFA is saturated fatty acid; MUFA is monounsaturated fatty acid; PUFA is polyunsaturated fatty acid; ▲ n6 series polyunsaturated fatty acids; ★ n3 series polyunsaturated fatty acids.

(4.74%) (Wen *et al.*, 2008). By comparison, the content of C16:0, C18:1n9c, DHA and EPA in the muscle of offshore *C. nasus* was higher, which showed that, its muscle has juicy taste, fat reduction, anti-aging and anti-cancer effects.

Fatty acid evaluation

DHA and EPA are the n3 high unsaturated fatty acids (HUFA) with the total content of 10.67%, which was lower than that from DYR (13.51% ♂ and 18.89% ♀) (Jiang and Yang, 2020), but higher than that from the other comparison sources. They can prevent cardiovascular diseases, inhibit platelet aggregation, enhance memory, improve intelligence, prevent Alzheimer's disease, improve autoimmunity and anti-cancer activity (Bibus and Lands, 2015; Zárate *et al.*, 2017). Previous studies have found that DHA is more effective than EPA in the treatment of cardiovascular and metabolic diseases (Innes and Calder, 2018; Mori, 2018). In this study, the content of DHA was more than EPA, with the ratio (DHA/EPA) of 1.74, which was significantly greater than that from CHS (0.50) (Liu *et al.*, 2009) and HZB (0.44) (Xu *et al.*, 2009 b). Therefore, the DHA and EPA nutritional composition is more suitable for people with cardiovascular diseases. In the fatty acid composition of human diet, n3 PUFA is generally insufficient, while n6 PUFA exceeds the standard (Stark *et al.*, 2016), so it needs to be balanced by feeding rich n3 PUFA in fish. In this study, n3 PUFA was significantly higher than n6 PUFA with the ratio (n3 PUFA/n6 PUFA) of 6.12, higher than that from JY (1.47) (Wen *et al.*, 2008) and CHS (2.78) (Liu *et al.*, 2009), also higher than *Pterois volitans* (2.33) from the Alacranes reef, southern Gulf of Mexico (Aranda-González *et al.*, 2020). The ratio is a good index for comparing relative nutritional value of fish (Song *et al.*, 2020 b) and a higher ratio of n3 PUFA/n6 PUFA shows the higher nutritional value of offshore *C. nasus.* Generally speaking, offshore *C. nasus* muscle had high n3 PUFA nutrition, which can be used to balance the nutritional demand of human body for n3 PUFA, especially for people with cardiovascular diseases.

CONCLUSION

In this study, the muscle nutritional components of offshore *C. nasus* were analyzed and evaluated. The muscle fat content was higher. The content of EAA, DAA, Glu and Lys are higher and the essential amino acids composition was balanced. 16:0, 18:1n9c, DHA and EPA were rich and the ratios of DHA/EPA and n3 PUFA/n6 PUFA were reasonable. On the whole, the muscle taste is delicate and juicy. The essential amino acids are rich and delicious, the HUFA showed health care effects. Through the analysis of the nutritional quality of offshore *C. nasus*, the basic data can be provided for the exploration of the nutritional status of *C. nasus* in the coastal waters and the theoretical basis will be served for the management, rational development and utilization of *C. nasus* outside the No fishing line of the Yangtze River in the future.

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REFERENCES

Aranda-González, I., Aguilar-Perera, A., Chel-Guerrero, L., Gallegos-Tintoré, S., Betancur-Ancona, D. (2020). Chemical composition, amino acid and fatty acid profiles of Lionfish *Pterois volitans* from the Alacranes reef, southern Gulf of Mexico. Indian Journal of Animal Research. 54: 1246-1250.

Bibus, D. and Lands, B. (2015). Balancing proportions of competing omega-3 and omega-6 highly unsaturated fatty acids (HUFA) in tissue lipids. Prostaglandins, Leukotrienes and Essential Fatty Acids. 99: 19-23.

GB 5009.3-2016. (2017). Determination of Moisture in Foods of National Food Safety Standards. Standard Press of China, Beijing. 1-6. (in Chinese).

GB 5009.124-2016. (2017). Determination of Amino Acids in Foods of National Food Safety Standards. Standard Press of China, Beijing. 1-6. (in Chinese).

GB 5009.168-2016. (2017). Determination of Fatty Acids in Foods of National Food Safety Standards. Standard Press of China, Beijing. 1-20. (in Chinese).

Innes, J.K. and Calder, P.C. (2018). The differential effects of eicosapentaenoic acid and docosahexaenoic acid on cardiometabolic risk factors: A systematic review. International Journal of Molecular Sciences. DOI:10.3390/ijms1902 0532.

Jiang, X.H. and Yang, P.M. (2020). Nutritional composition analysis in muscle of *Coilia nasus* from Dayang River. Fisheries Science. DOI: 10.16378/j.cnki.1003-1111.20146. (in Chinese).

Jo, S.G. and Yoon, J.M. (2021). Genetic distances between tailfin anchovy (*Coilia nasus*) populations analyzed by PCR. Development and Reproduction. 25: 59-65.

Li, Q. and Zhang, X. (2019). Overview of physiological functions of polyunsaturated fatty acids. China Food Safety Magazine. DOI: 10.16043/j.cnki.cfs.2019.18.044. (in Chinese).

Liu, K., Duan, J.R., Xu, D.P., Zhang, M.Y., Shi, W.G. (2009). Biochemical components and energy density in muscles of *Coilia mystus*, *C. ectenes* and *C. ectenes taihuensis* in spawning season in the lower reaches of Yangtze River. Chinese Journal of Zoology. 44: 118-124. (in Chinese).

Ma, J., Li, B., Zhao, J., Wang, X.F., Hodgdon, C.T., Tian, S.Q. (2020). Environmental influences on the spatio-temporal distribution of *Coilia nasus* in the Yangtze River estuary. Journal of Applied Ichthyology. 36: 315-325.

Mori, T.A. (2018). Marine OMEGA-3 fatty acids in the prevention of cardiovascular disease. Fitoterapia. 126: 8-15.

Pellett, P.L. and Yong, V.R. (1980). Nutritional Evaluation of Protein Foods. United National University, Tokyo.

Qin, Y.C., Zhou, J.Y., Zhu, M., Wang, X.Q. (2019). Research progress of glutamate absorption and transport and its effects on intestinal development. Chinese Journal of Animal Nutrition. 31: 544-552. (in Chinese).

Song C., Hu C.S., Zhao F., Zhang T., Zhuang, P. (2019). Lipid and fatty acid profile in different tissues of wild adult female *Cynoglossus gracilis* Günther, 1873 in Yangtze Estuary. Indian Journal of Animal Research. 53: 1321-1325.

Song, C., Zhao, F., Feng, G.P., Wang, S.K., Zhuang, P. (2020a). Comparative study of nutritional composition of adults and juveniles of *Coilia mystus* collected from the Yangtze Estuary. Indian Journal of Animal Research. 54: 1103-1108.

Song, C., Zhao, F., Liu, J.Y., Wang, Y., Huang, X.R. and Zhuang, P. (2020b). Proximate composition and fatty acid profile in different tissues of juvenile *Siganus guttatus* fed with *Enteromorpha prolifera*. Indian Journal of Animal Research. 54: 1358-1362.

Song, C., Zhao, F., Zhang, T., Zhang, T.T., Huang, X.R., Yang, G., Zhuang, P. (2020c). Proximate composition and fatty acid profile in different tissues of wild adult female *Coilia mystus* in Yangtze Estuary. Indian Journal of Animal Research. DOI: 10.18805/IJAR.B-1255.

Stark, K.D., Van Elswyk, M.E., Higgins, M.R., Weatherford, C.A., Salem, N. (2016). Global survey of the omega-3 fatty acids, docosahexaenoic acid and eicosapentaenoic acid in the blood stream of healthy adults. Progress in Lipid Research. 63:132-152.

Tang, X., Xu, G.C., Xu, P., Gu, R.B., Yue, G.W. (2011). A comparison of muscle nutrient composition between wild and cultured *Coilia nasus*. Chinese Journal of Animal Nutrition. 23: 514-520. (in Chinese).

Teng, J., Tao, N.P., Li, Y.Q. (2016). Analysis and evaluation of nutritional composition of Yangtze River *Coilia* meat at different ovarian development stages. Modern Food Science and Technology. 32: 267-274. (in Chinese).

Wang, H. and Zhao, Y.J. (2018). Application of lysine and development prospect of food-grade lysine. Bulletin of Fermentation Science and Technology. 47: 236-239. (in Chinese).

Wang, M.Y., Xu, G.C., Tang Y.K., Xu, P. (2020). Transcriptome analysis of the brain provides insights into the regulatory mechanism for *Coilia nasus* migration. BMC Genomics. 21: 410. DOI: org/10.1186/s12864-020-06816-3.

Wen, H.B., Zhang, C.X., Xu, G.C., Gu, R.B., Yu, R.P. (2008). Evaluation of nutritive quality and nourishing ingredients in muscle of *Coilia ectenes* from Yangtse River. Journal of Guangdong Ocean University. 28:20-24. (in Chinese).

Xu, D.P., Liu, K., Zhang, M.Y., Duan, J.R., Shi, W.G. (2009a). Analysis of the muscle nutritive composition of *Coilia ectenes* spawning stock in Yangtze River. Journal of Yunnan Agricultural University. 24:850-855. (in Chinese).

Xu, G.C., Bian, C., Nie, Z.J., Li, J., Wang, Y.Y., Xu, D.P. *et al.* (2020). Genome and population sequencing of a chromosome-level genome assembly of the Chinese tapertail anchovy (*Coilia nasus*) provides novel insights into migratory adaptation. GigaScience. 9:1-13.

Xu, G.C., Gu, R.B., Zhang, C.X., Zheng, J.L., Wen, H.B., Xu, P. (2009b). Comparison and evaluation of nutrient composition of two ecological groups of Japanese grenadie ranchovy-river-anchovy and sea-anchovy. Marine Fisheries. 31: 401-409. (in Chinese).

Xuan, Z.Y., Jiang, T., Liu, H.B., Chen, X.B., Yang, J. (2021). Mitochondrial DNA and microsatellite analyses reveal strong genetic differentiation between two types of estuarine tapertail anchovies (*Coilia*) in Yangtze River Basin, China. Hydrobiologia. 848: 1409-1431.

Xue, D.X., Yang, Q.L., Zong, S.B., Gao, T.X., Liu, J.X. (2020). Genetic variation within and among range-wide populations of three ecotypes of the Japanese grenadier anchovy *Coilia nasus* with implications to its conservation and management. Journal of Oceanology and Limnology. 38: 851-861.

Yang, Y.X. (2005). China Food Composition 2004: Book 2. Peking University Medical Press, Beijing.

Zárate, R., Jaber-Vazdekis, N.E., Tejera, N., Pérez, J.A., Rodríguez. C. (2017). Significance of long chain polyunsaturated fatty acids in human health. Clinical and Translational Medicine. 6: 1-19.

Zhuang, P., Zhang, T., Li, S.F., Ni, Y., Wang, Y.H., Deng, S.M. (2018). Fishes of the Yangtze Estuary (2nd Edn). China Agriculture Press, Beijing. 127-131. (in Chinese).