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Quality Differences of Large Yellow Croaker (*Pseudosciaena crocea*) Cultured in Deep-Water Sea Cages of Two China Regions

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Abstract

Environmental factors, i.e. geographic sites and regions, can affect the nutritional values and organoleptic properties of fish products. Therefore, this paper aims to study the quality (e.g. biometric and physicochemical parameters) of large yellow croaker (*Pseudosciaena crocea*) cultured in two regions (Zhoushan and Taizhou) during grow-out phase in deep-water sea cages. The cultured fish would be compared to its wild counterpart as well. Generally, wild fish was characterized by significantly higher values of protein content and shear force in texture assessment, but lower total polyunsaturated fatty acids (PUFAs), compared to the cultured fish. Between the two cultured regions, the significantly higher values of length/height ratio, condition factor and protein content were observed in fish from Taizhou, whilst higher values of total weight, lipid content were observed in fish from Zhoushan. In addition, fish from Zhoushan was characterized by higher value of yellowness in skin colour, whilst fish from Taizhou was characterized by higher value of lightness. Texture profile showed higher values of gumminess and chewiness in fish from Zhoushan. Moreover, significantly higher values of total amino acids, total non-essential amino acids, and total semi-essential amino acids were observed in fish from Zhoushan. By contrast, the significantly higher total PUFAs, EPA (eicosapentaenoic acid), and DHA (docosahexaenoic acid) values were found in fish from Taizhou culture. In conclusion, our study emphasizes the quality differences between aquaculture regions of large yellow croaker.

Keywords: Large yellow croaker; Deep-water sea cages; Fish quality; Regional effect

Introduction

Nutritional values and organoleptic properties are two important sets of characteristics of fish quality [1], which can influence the perception and consumption of consumers [2]. Both characteristics are affected by intrinsic and extrinsic factors, such as species [3] age [4] sex [5] environmental conditions [6] feeding diets [7] geographic sites [8] etc.

Large yellow croaker (*Pseudosciaena crocea*) is a type of marine fish that mainly inhabits in the coastal waters of continental East Asia [9]. Large yellow croaker has three main putative geographic stocks initially identified in coastal waters of China, i.e. the Daiquyang, MinYuedong and Naozhou stocks. The suitable rearing temperature of large yellow croaker is between 20~28°C [10]. If the water temperature is lower than 13°C or higher than 30°C, the feed intake will be significantly reduced [10].

In keeping with the high quality and quantity requirements of consumers, large yellow croaker has been cultured for more than three decades in China [11]. The sea-cage farming mode is the mostly used culturing mode for large yellow croaker [12]. Recently, segmented-phase cultivation is applied as an effective culture method for large yellow croaker [10]. At the beginning, large yellow croaker fry is cultivated in Fujian Province until the weight reaches of more than 102 g [13]. In the grow-out phase fish can be transferred to deep-water sea cages or seine culture by July [14] to other cooler regions, such as Zhejiang, Jiangsu [15]. The reason is based on the migratory requirements and ecological habitats of large yellow croaker, wherein the fish usually migrate to cooler waters in the summer [10]. Moreover, this artificial migration can promote the fish growth, reduce the outbreak of diseases and fish mortality [10].

To date, there are reports about the biochemical composition [4,16,17] and flesh quality [18] of large yellow croaker. In addition, the nutrition of fatty acid and amino acid analysis of different stocks had been studied [19]. However, there is little literature reported on the quality of one stock of large yellow croaker grown-out in different seacoast regions.

The aim of this study is to compare the quality of MinYuedong stock grown-out in deep-water sea cages of two different regions in Zhejiang province, Zhoushan and Taizhou. The cultured large yellow croaker would be compared to its wild counterpart as well. The biometric measurement, proximate composition, mineral contents, physico-chemical parameters, color, texture, fatty acid profiles, amino acid profiles and would be analyzed.

Materials and Methods

Study design

In April 2015, juvenile fish (3-5 cm size, initial weight 1.5-2.1 g) were purchased in Fujian (southeast coast of mainland China) and stocked in cages (0.8 × 0.8 × 1.0 m; 0.8 cm mesh). After acclimating for 15 days, the fish were moved to intermediate cages (3.3 × 3.3 × 4.0 m size, 1.0 cm mesh). After 15 days, the fish were transferred and reared in small sea cages (3.3 × 3.3 × 6.0 m size, 1.5~1.8 cm mesh). After one month, the fish were transferred and reared in large sea cages (3.3 × 3.3 × 9.0 m size, 2.0~2.5 cm mesh). When the fish weight reached approximately 200 g in

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July 2016, they were divided into two regions, Zhoushan and Taizhou, and reared in deep-water sea cages (50 m perimeter, 8 m depth). Fish were fed to apparent satiation (50 g fishmeal: 700 g fish body weight) twice a day (at 5:00 and 17:00 respectively) with a trashed-fish fishmeal and commercial powder combination. The commercial feed used contained 42% protein, 11% fat, 15% ash, 4% fiber, 2% available phosphate, 11% moisture, which satisfied the nutrient requirements of large yellow croaker [11]. The experiment trial was harvested in October 2016 when the fish weights were approximately 300~350 g.

Wild large yellow croaker was captured off the coast of Ningde City (Fujian Province) in August 2016. All other factors during capture were not controlled or assessed.

All fish samples (Zhoushan (n=29), Taizhou (n=29), and wild fish (n=19)) were packed in separate insulated polystyrene boxes with slurry ice and delivered to the laboratory within 24 h of harvesting or catching. In the lab, fish were surrounded by flake ice and assessed for biometric measurements, pH, water holding capacity, TVBN, color, texture and proximate composition immediately. Then, fish were frozen and stored at -18°C for later use in determination of minerals, fatty acids and amino acids contents.

All chemicals were purchased from Sino pharm chemical reagent company (Shanghai, China). Fatty acid and amino acid standards were supplied by Sigma- Aldrich Company Ltd. (St. Louis, MO, USA).

Aquatic environments

The geography sites of Zhoushan and Taizhou (Figure 1) and physico-chemical characteristics of rearing conditions are described as below.

Zhoushan (29.99°N, 122.2°E) is a prefecture-level city in the northeastern Zhejiang Province in eastern China. The physico-chemical characteristics of the Zhoushan rearing conditions are pH 7.8~8.0, salinity 25.6~26.2%, the highest temperature between July to October was 23~31°C, and the lowest temperature between July to October was 17~24°C.

Taizhou (28.65°N, 121.42°E) is a city on the eastern coast of the Zhejiang province in eastern China, facing the East China Sea. The physico-chemical characteristics of the Taizhou rearing conditions are pH 7.7~8.0, salinity 24.5~32.0‰, the highest temperature between July to October was 25~33°C, and the lowest temperature between July to October was 18~26°C.

Biometric measurements

Upon arrival to the lab, the fish of all groups were immediately measured for total weight, body length and height, and condition factor. Total weight (g) is the fish weight with internal organs. The total body length (cm) was measured from the tip of fish mouth to the upper lobe of the caudal fin end. The body height (cm) was measured as the largest vertical line between the first dorsal fin and pelvic fin. Length/height ratio (LHR) was calculated as:

LHR=total body length/ body height. Condition factor (CF) (g/100 cm^3) was calculated as: CF=(body weight/body $length^3$) × 100

Here, the body weight is the weight after removing the internal organs [20].

Proximate composition and mineral content

Lipid and protein contents of the fish flesh samples.

Amino acids (AAs)

Amino acid analysis was undertaken by HPLC with pre-column derivatization using phenylisothiocyanate (PITC), according to Chinese standard GB 5009.124-2016. All analyses described above were performed in triplicate.

PUFAs damage and nutritional quality

The measurement of PUFAs damage was expressed using the polyene index (PI) [21].

$$PI = \frac{C20:5 + C22:6}{C16:0}$$

The nutritional quality of large yellow croaker was calculated by the atherogenic index (AI) and thrombogenic index (TI), according to Ulbricht and Southgate [22]:

$$AI = \frac{C12:0 + 4 \times C14:0 + C16:0}{\sum MUFA + \sum PUFAs}$$

$$TI = [\frac{C14:0 + C16:0 + 18:0}{0.5 \times \sum MUFA + 0.5 \times \sum n-6\,PUFAs + 3 \times \sum n-3PUFAs + (\mathrm{n}-3/\mathrm{n}-6}]$$

Statistical analysis

Statistical analysis in this study was conducted using the SPSS Statistics software version 20.0 (IBM Analytics, USA). Significant differences between the fish samples were computed by one-way

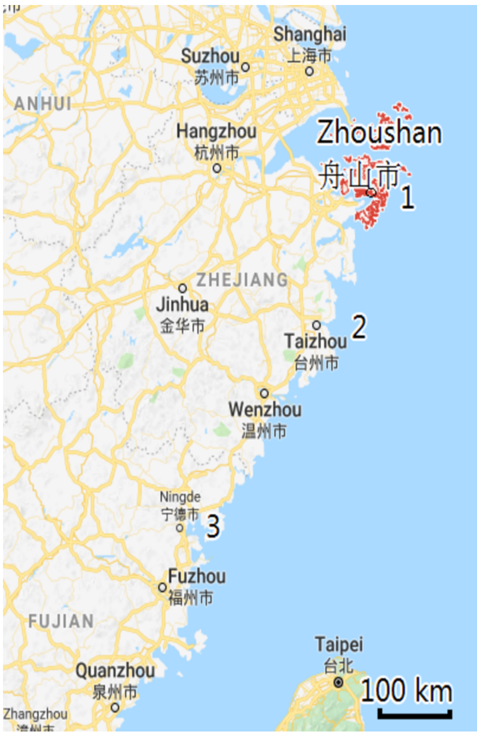

Figure 1: The geography sites of sampling large yellow croaker. Each site is coded with number: 1. Zhoushan (29.99°N, 122.21°E), the first cultivation region; 2. Taizhou (28.65°N, 121.42°E), the second cultivation region; 3. Ningde (26.66°N, 119.54°E), the wild-caught region.

analysis of variance (ANOVA)-LSD (least significant difference) with a significance level of α=0.05 (p<0.05).

Results

Biometric measurements

The biometric measurements of cultured and wild large yellow croaker are shown in Table 1. There was no significant difference in the body length between fish groups. However, the total weight of cultured fish were significant higher than that of the wild counterpart (p<0.05), due to the overfishing and lacking of the wild fish in the natural environment now-a-days. Among the fish groups, wild fish significantly had a higher value of length/height ratio and lower value of condition factor. Among the cultured fish groups, fish from Taizhou culture slightly had lower values of total weight and condition factor, and higher values of body length and length/height ratio than that of fish from Zhoushan culture (not statistical significance, except for CF value).

Proximate composition and mineral content

The proximate compositions of large yellow croaker are shown in Table 1. The moisture contents of large yellow croaker in this study is represented between 64.90 to 66.21 g/100 g, wet basic; and there were no significant differences in moisture contents in the three fish groups. The highest lipid value was found in fish from Zhoushan (15.54 g/100 g), compared to fish from Taizhou culture (14.13 g/100 g) and the wild fish (9.76 g/100 g). Additionally, the protein content of wild fish (20.80 g/100 g) was significantly (p<0.05*)* higher than fish from Zhoushan and Taizhou cultures (15.97 and 16.40 g/100 g, respectively). There was no significant difference in the protein contents between the two fish cultures, but fish from Taizhou culture slightly had a higher protein content than fish from Zhoushan culture (not significantly). The ash content of fish from Taizhou culture was significantly higher than that of fish from Zhoushan culture and wild fish (p<0.05*)*; meanwhile, there was no significant difference in the ash content of fish from Zhoushan and wild fish (p>0.05).

The mineral contents (macro minerals and micro minerals) and heavy metals of large yellow croaker are shown in Table 1. There were significant differences in the macro mineral contents (Na, Mg, Ca, and K) between fish groups (p<0.05). The highest contents of Na and Mg were observed in the fish from Taizhou, compared to other fish groups. The highest content of K was observed in the fish from Zhoushan (335.00 mg/100 g), compared to fish from Taizhou (315.00 mg/100 g) and wild fish (301.00 mg/100 g). The highest content of Ca was significantly found in the wild fish (649.00 mg/100 g), compared to fish from Zhoushan and Taizhou (304.00 and 376.00 mg/100 g, respectively). Micro mineral contents (Fe, Cu) of the two fish cultures were not significantly different (p>0.05); and cultured fish were found to be significantly lower in Fe content and higher in Cu content compared to wild fish (p<0.05). There was no significant difference in the Zn content among the three fish groups (p>0.05). Additionally, the heavy metals contents (Hg, As, Pb and Cd) of the three fish groups were not significantly different (p>0.05) and were lower than the Chinese legislative limits (GB 2762- 2017).

Physico-chemical parameters of large yellow croaker

The physico-chemical values of large yellow croaker are shown in Table 2. There were no significant differences in the pH and water activity values between the two studied cultures (p>0.05). However, cultured fish were found to have significantly lower pH and higher water activity values than those of the wild fish. In addition, the highest value of WHC was found in fish from Taizhou culture (p<0.05), and there was no significant difference in the WHC values of fish from Zhoushan and the wild fish (p>0.05). Moreover, no significant differences in TVB-N values were found in the cultured and wild large yellow croaker.

In term of the muscle color, there was no significant difference in L^*, a^* and b^* values in these three groups of large yellow croaker (p>0.05). However, there were significant differences in the skin color between the wild and cultured large yellow croaker. The skin color of wild large yellow croaker was significantly higher in L^* and b^* values, and lower in a^* value compared to the cultured fish groups (p<0.05). Among the studied fish cultures, the higher L^* and a^* values were observed in the fish from Taizhou, the highest value of b^* was observed in fish from Zhoushan.

In the compression test of texture assessment, the highest values of cohesiveness and springiness were found in the wild fish, followed by the values of fish from Taizhou (p<0.05). The highest values of gumminess and chewiness were found in the fish from Zhoushan, and there was no significant difference in the gumminess and chewiness values between the fish from Taizhou and wild fish. Additionally, the maximum shear force value of wild fish (14.01 ± 0.35 N) was significantly higher than that of the fish cultured in Zhoushan and Taizhou (8.00 ± 1.21 and 7.75 ± 1.51 N, respectively).

Fatty acid profile

The fatty acid profiles of the large yellow croaker from Zhoushan, Taizhou and wild counterpart are shown in Table 3. In this study, there were nine saturated fatty acids (SFAs), five monounsaturated fatty acids (MUFAs) and seven polyunsaturated fatty acids (PUFAs) found in large yellow croaker. Moreover, the amounts of SFAs and MUFAs were significantly higher than the amounts of PUFAs in all fish groups.

The total SFAs amount of wild large yellow croaker was significantly higher than that of the cultured fish, which was similar to other research in cultured sea bass [20]. Palmitic acid 16:00 (highest in wild fish) was the most predominant SFA in all fish groups, followed by stearic acid 18:0 (highest in fish from Zhoushan) and myristic acid 14:0 (highest in fish from Taizhou). Palmitic acid and stearic acid were also the predominant SFAs of large yellow croaker [4] and different types of fish such as sea bass [20].

In the MUFAs profile, there was no significant difference in the total MUFAs amount between the fish from Zhoushan and wild fish (37.87 and 37.88 g/100 g fatty acid, respectively), and the values were significantly higher than that of fish from Taizhou (29.70 g/100 g fatty acid). In our study, the major MUFAs in all fish groups were oleic acid (18:1 n-9) and palmitoleic acid (16:1 n-7), both fatty acids amounts were significantly highest in the fish from Zhoushan (p<0.05). In addition, the amounts of erucic acid (22:1 n-9) and nervonic acid (24:1 n-9) were significantly higher in cultured fish than that of the wild fish, and the values were slightly higher in fish from Taizhou compared to Zhoushan culture (not significantly).

In the PUFAs profile, the total PUFAs amounts were found to be significantly higher in cultured fish than that of wild fish (p<0.05). The significantly higher value of total PUFAs was observed in fish from Taizhou than that of fish from Zhoushan culture (29.65 and 23.73 g/100 g, respectively).

The total n-6 fatty acids of the cultured fish were significantly higher than in the wild fish; this trend was consistent with other different

Variables	Zhoushan	Taizhou	Wild	α
Biometric measurement				
Total weight (g)	325.27 ± 10.21[a]	306.25 ± 92.65[a]	149.18 ± 22.37[b]	*
Body length (cm)	27.22 ± 2.04[a]	28.79 ± 1.40[a]	26.00 ± 1.10[b]	ns
Length/ height ratio	3.54 ± 0.19[a]	3.67 ± 0.14[a]	3.94 ± 0.14[b]	*
Condition factor	1.60 ± 0.20[a]	1.29 ± 0.10[b]	1.16 ± 0.20[b]	*
Proximate composition (g/100 g, wet basic)				
Moisture	66.21 ± 0.34	64.90 ± 0.03	65.24 ± 0.58	ns
Lipid	15.54 ± 0.02[a]	14.13 ± 0.01[b]	9.76 ± 0.01[c]	*
Protein	15.97 ± 0.21[a]	16.40 ± 0.12[a]	20.80 ± 0.11[b]	*
Ash	1.26 ± 0.07[a]	1.96 ± 0.09[b]	1.24 ± 0.03[a]	*
Mineral composition				
Macro minerals (mg/100 g)				
Na	61.50 ± 7.96[a]	88.80 ± 8.64[b]	75.70 ± 7.56[b]	*
Mg	29.40 ± 0.69[a]	32.20 ± 0.82[b]	31.10 ± 0.77[b]	*
Ca	304.00 ± 0.93[a]	376.00 ± 0.79[b]	649.00 ± 0.98[c]	*
K	335.00 ± 10.05[a]	315.00 ± 8.45[b]	301.00 ± 9.03[b]	*
Micro minerals (mg/100 g)				
Fe	0.50 ± 0.07[a]	0.76 ± 0.08[a]	0.90 ± 0.07[b]	*
Cu	0.36 ± 0.01[a]	0.37 ± 0.01[a]	0.14 ± 0.01[b]	*
Zn	0.68 ± 0.08	0.74 ± 0.06	0.74 ± 0.07	ns
Heavy metals (mg/Kg)				
Hg	0.02 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	ns
As	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	ns
Pb	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	ns
Cd	0.04 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	ns

Mean ± standard deviation (n=9). Different letters in the same row denote statistically significant difference between fish groups (p<0.05). Level of significance (α), *p<0.05; ns: non-significant.

Table 1: Biometric measurement, proximate composition, and mineral concentration of large yellow croaker from Zhoushan, Taizhou and wild counterpart.

Variables	Zhoushan	Taizhou	Wild	α
pH	6.27 ± 0.02[a]	6.24 ± 0.01[a]	6.98 ± 0.01[b]	*
a_w	0.98 ± 0.01[a]	0.98 ± 0.01[a]	0.95 ± 0.01[b]	*
WHC (%)	80.10 ± 0.05[a]	83.96 ± 0.02[b]	80.51 ± 1.22[a]	*
TVB-N (mg N/100g)	10.78 ± 0.59	9.10 ± 1.38	8.18 ± 0.78	ns
Muscle color				
L*	51.02 ± 1.85	52.48 ± 2.86	50.28 ± 0.55	ns
a*	-1.50 ± 0.49	-1.39 ± 0.39	-0.85 ± 0.06	ns
b*	3.08 ± 1.2	2.16 ± 1.18	4.95 ± 1.36	ns
Skin color				
L*	72.18 ± 0.77[a]	79.66 ± 0.75[b]	80.40 ± 1.21[b]	*
a*	0.78 ± 2.09[ab]	2.89 ± 0.31[a]	-0.14 ± 0.86[b]	*
b*	26.87 ± 1.84[a]	23.96 ± 1.43[b]	31.73 ± 1.96[c]	*
Texture				
Compression test				
Cohesiveness	0.24 ± 0.03[a]	0.28 ± 0.03[a]	0.38 ± 0.06[b]	*
Springiness (mm)	1.38 ± 0.17[a]	1.42 ± 0.21[a]	6.72 ± 0.22[b]	*
Gumminess (N)	7.04 ± 0.56[a]	5.12 ± 0.83[b]	4.64 ± 0.28[b]	*
Chewiness (mJ)	9.87 ± 1.22[a]	7.22 ± 0.71[b]	7.71 ± 1.15[b]	*
Shear force test				
F_{max} (N)	8.00 ± 1.21[a]	7.75 ± 1.51[a]	14.01 ± 0.35[b]	*

Mean ± standard deviation (n=9). Different letters in the same row denote statistically significant difference between fish groups (p<0.05). Level of significance (α), *p<0.05; ns: Non-Significant.

Table 2: Physico-chemical, color, and textural parameters of large yellow croaker from Zhoushan, Taizhou and wild counterpart.

types of cultured fish [20]. Moreover, the significantly higher value of total n-6 fatty acids was found in fish from Zhoushan than that of fish from Taizhou (9.68 and 6.68 g/100 g fatty acid, respectively). The same pattern was observed in linoleic acid value (18:2 n-6) since linoleic acid is one primary dietary fatty acid in n-6 PUFAs of large yellow croaker in this study. Differently, the amount of arachidonic acid (20:4 n-6) was found to be significantly highest in wild fish (1.38 g/100 g fatty acid), followed by fish from Taizhou (0.74 g/100 g fatty acid).

In term of n-3 fatty acids, the highest level of total n-3 fatty acids was observed in fish from Taizhou (22.97 g/100 g fatty acid), and there was no significant difference in total n-3 fatty acids levels between the fish from Zhoushan and the wild fish ($p>0.05$). The amounts of EPA and DHA were observed to be highest in fish from Taizhou, followed by the wild fish, and lowest in fish from Zhoushan ($p<0.05$). The ratio of n-3/n-6 fatty acids was higher in wild fish (6.61) than those of two-cultured large yellow croaker from Zhoushan and Taizhou (1.45 and 3.44, respectively).

The damage of PUFAs, as measured by PI, was found to be highest in fish from Taizhou (0.77), and there was no significant difference in the PI values of fish from Zhoushan and the wild fish (0.42 and 0.41, respectively). In this study, PI values of large yellow croaker was found to be lower than sardines (0.88~0.93) [21] and farmed bogue (0.79~0.99) [23]. The nutritional quality of large yellow croaker, through AI and TI indices, was significantly higher in wild fish than that of the cultured fish. This result is consistent to health lipid indices of bogue [23]. Furthermore, there were variations between the two fish cultures in the AI and TI values, where AI value was higher in fish from Taizhou, and TI value was higher in fish from Zhoushan. The AI and TI indices of cultured large yellow croaker in this study were found to be higher than bogue [23], brown crab [24] and shrimp [25].

Amino acid (AA) analysis

The amino acids (AAs) profiles of the three fish groups of large yellow croaker are listed in Table 4. Unfortunately, there was no regional variation observed in the total amount of essential amino acids (EAAs) between the two fish cultures, and both values were significantly lower than that of the wild fish. The same pattern was generally found in the amounts of three major EAAs, lysine, leucine and valine; and other minor EAAs, isoleucine, threonine, and methionine. However, the total non-essential amino acids (NEAAs) differed significantly depending on the cultivation places. The highest amount of NEAAs was observed in fish from Zhoushan, and there was no significant difference in the fish from Taizhou and the wild fish ($p>0.05$). The same pattern was observed in other abundant NEAAs components were glycine, alanine and proline. However, the amounts of two major NEAAs, glutamic acid and aspartic acid, were significantly highest in the wild fish. On the other hand, there were no significant differences in glutamic acid and aspartic acid amounts from two fish cultures. Additionally, fish from Zhoushan confirmed the regional variation existed in the semi-essential amino acids (SEAAs) profile, when the amount of total SEAAs (arginine and histidine) were significantly obtained the highest value among the three fish groups ($p<0.05$).

There was no significant difference in the total AAs of fish from Zhoushan and the wild fish, which values were significantly higher than that of fish from Taizhou. Among the fish groups, the percentage of

Fatty acid	Zhoushan	Taizhou	Wild	α
4:0	ND	ND	0.17 ± 0.00	
14:0	2.05 ± 0.08[a]	3.17 ± 0.11[b]	1.89 ± 0.02[a]	*
15:0	0.32 ± 0.07[a]	0.63 ± 0.02[b]	0.26 ± 0.01[a]	*
16:0	24.40 ± 1.27[a]	23.60 ± 0.68[a]	31.70 ± 1.20[b]	*
17:0	0.92 ± 0.03[a]	1.69 ± 0.05[b]	0.90 ± 0.03[a]	*
18:0	7.01 ± 0.29[a]	5.16 ± 0.15[b]	6.67 ± 0.21[ab]	*
20:0	0.42 ± 0.01	0.53 ± 0.02	ND	--
21:0	0.52 ± 0.02	0.06 ± 0.00	ND	--
24:0	ND	ND	0.32 ± 0.01	--
ΣSFAs	35.64 ± 0.35[a]	34.25 ± 0.29[a]	41.91 ± 1.26[b]	*
16:1 n-7	8.38 ± 0.34[a]	7.47 ± 0.23[a]	11.20 ± 0.53[b]	*
17:1 n-7	0.62 ± 0.02[a]	1.00 ± 0.03[b]	0.60 ± 0.02[a]	*
18:1 n-9	27.30 ± 0.39[a]	18.70 ± 0.56[b]	25.30 ± 0.76[a]	*
22:1 n-9	1.06 ± 0.02[a]	1.30 ± 0.04[b]	0.28 ± 0.01[c]	*
24:1 n=9	0.51 ± 0.01[a]	1.23 ± 0.04[b]	0.50 ± 0.02[a]	*
ΣMUFAs	37.87 ± 0.16[a]	29.70 ± 0.89[b]	37.88 ± 1.14[a]	*
18:2 n-6	8.96 ± 0.35[a]	5.61 ± 0.17[b]	0.59 ± 0.02[c]	*
18:3 n-3	2.91 ± 0.17[a]	3.22 ± 0.10[a]	1.11 ± 0.03[b]	*
20:2 n-6	0.27 ± 0.03	0.33 ± 0.07	0.18 ± 0.01	*
20:3 n=3	0.94 ± 0.01[a]	1.53 ± 0.05[b]	0.27 ± 0.01[c]	*
20:4 n-6	0.45 ± 0.05[a]	0.74 ± 0.02[a]	1.38 ± 0.04[b]	*
20:5 n-3 (EPA)	2.98 ± 0.43[a]	4.92 ± 0.15[b]	4.04 ± 0.12[b]	*
22:6 n-3 (DHA)	7.22 ± 0.95[a]	13.30 ± 0.40[b]	8.80 ± 0.26[a]	*
ΣPUFAs	23.73 ± 0.29[a]	29.65 ± 0.89[b]	16.37 ± 0.49[c]	*
Σn-3	14.05 ± 0.39[a]	22.97 ± 0.69[b]	14.22 ± 0.43[a]	*
Σn-6	9.68 ± 0.16[a]	6.68 ± 0.20[b]	2.15 ± 0.06[c]	*
n-3/n-6	1.45 ± 0.27[a]	3.44 ± 0.22[b]	6.61 ± 0.20[c]	*
EPA/DHA	0.41 ± 0.09[ab]	0.37 ± 0.07[a]	0.46 ± 0.05[b]	*
PI	0.42 ± 0.01[a]	0.77 ± 0.01[b]	0.41 ± 0.00[a]	*
AI	0.53 ± 0.01[a]	0.61 ± 0.02[b]	0.72 ± 0.02[c]	*
TI	0.49 ± 0.00[a]	0.35 ± 0.01[b]	0.58 ± 0.02[c]	*

Mean ± standard deviation (n=9). Different letters in the same row denote statistically significant difference between fish groups ($p<0.05$). Level of significance (α), *$p<0.05$; ns: non-significant. ND: Not Detected.
ΣSFAs: Sum of saturated fatty acids; ΣMUFAs: Sum of monounsaturated fatty acids; ΣPUFAs: Sum of polyunsaturated fatty acids; PI: Polyene Index; AI: Atherogenic Index; TI: Thrombogenic Index.

Table 3: Fatty acids concentrations of large yellow croaker from Zhoushan, Taizhou and wild counterpart (g/ 100 g fatty acid).

Amino acid	Zhoushan	Taizhou	Wild	α
Lysine	1.20 ± 0.01[a]	1.23 ± 0.00[a]	1.36 ± 0.01[b]	*
Leucine	1.05 ± 0.02[a]	1.10 ± 0.05[a]	1.20 ± 0.02[b]	*
Valine	0.73 ± 0.01[a]	0.72 ± 0.02[a]	0.81 ± 0.02[b]	*
Isoleucine	0.61 ± 0.22[a]	0.66 ± 0.02[b]	0.72 ± 0.02[c]	*
Threonine	0.70 ± 0.02[ab]	0.68 ± 0.02[a]	0.72 ± 0.02[b]	*
Phenylalanine	0.61 ± 0.02	0.60 ± 0.02	0.62 ± 0.02	ns
Methionine	0.44 ± 0.02[a]	0.45 ± 0.01[a]	0.50 ± 0.02[b]	*
Total EAA	5.34 ± 0.14[a]	5.44 ± 0.16[a]	5.93 ± 0.18[b]	*
Glutamic acid	2.12 ± 0.09[ab]	2.09 ± 0.06[a]	2.24 ± 0.07[b]	*
Aspartic acid	1.42 ± 0.01[a]	1.42 ± 0.04[a]	1.47 ± 0.04[b]	*
Glycine	1.03 ± 0.02[a]	0.82 ± 0.02[b]	0.79 ± 0.02[b]	*
Alanine	0.98 ± 0.04[a]	0.88 ± 0.03[b]	0.90 ± 0.03[b]	*
Serine	0.66 ± 0.15	0.63 ± 0.02	0.64 ± 0.02	ns
Tyrosine	0.53 ± 0.02[a]	0.54 ± 0.02[ab]	0.57 ± 0.02[b]	*
Cysteine	0.11 ± 0.01[a]	0.08 ± 0.00[b]	0.09 ± 0.00[ab]	*
Proline	0.93 ± 0.08[a]	0.65 ± 0.02[b]	0.70 ± 0.02[b]	*
Total NEAA	7.78 ± 0.07[a]	7.11 ± 0.21[b]	7.40 ± 0.22[b]	*
Arginine	1.10 ± 0.08[a]	0.97 ± 0.03[b]	0.96 ± 0.03[b]	*
Histidine	0.41 ± 0.09[a]	0.35 ± 0.01[b]	0.35 ± 0.01[b]	*
Total SEAA	1.51 ± 0.07[a]	1.32 ± 0.04[b]	1.31 ± 0.04[b]	*
TAA	14.63 ± 0.37[a]	13.87 ± 0.28[b]	14.64 ± 0.44[a]	*
EAA/TAA×100%	36.50 ± 1.19[a]	39.23 ± 1.18[b]	40.51 ± 1.22[b]	*
NEAA/ TAA×100%	53.18 ± 1.50[a]	51.26 ± 1.54[ab]	50.55 ± 1.52[b]	*

Mean ± standard deviation (n=9). Different letters in the same row denote statistically significant difference between fish groups ($p<0.05$). Level of significance (α), *$p<0.05$; ns: non-significant.

Table 4: Amino acid concentrations of large yellow croaker from Zhoushan, Taizhou and wild counterpart (g/100 g, wet basis).

NEAAs were significantly higher than EAAs. The percentage of EAAs of fish from Taizhou was similar to that of wild fish ($p<0.05$), which values were significantly higher than that of fish form Zhoushan. No significant difference was observed in the NEAAs percentage from two fish cultures, which values were significantly higher than that of wild fish ($p<0.05$).

Discussion

The differences in origin (cultured vs wild) and regions with variations in environmental conditions, such as water temperature, the water current capacity, etc., can be considered as the factors influenced the fish sensory, physical, and chemical characteristics. We observed the quality variations depending on the fish origin (cultured or wild) and cultivation regions (Zhoushan or Taizhou).

Fish origin (cultured or wild) differed significantly in some biometrics parameters and proximate compositions. Although there was no significant difference in the body length of the three fish groups, the body weight values of cultured fish were significantly higher than the wild counterpart, the same pattern happened to commercial and wild fish of different species [26]. In this study, wild fish significantly had higher protein and lower lipid contents than cultured fish; this trend is consistent with other species reported before [20,27,28]. The reason may mainly due to the high dietary fat level in the fishmeal and the reduced level of activity of cultured fish in sea cages compared to when they are in nature. In previous research, the moisture content of cultured fish was lower than wild fish [28], this pattern is not the same in our study, when there were no significant differences among three fish groups.

In this study, the regional variations existed between the two cultivation regions in the biometric parameters and proximate compositions. Firstly, fish from Taizhou slightly had lower values of body weight, lipid and condition factor; and higher values of protein, body length and length/height ratio than those of the fish from Zhoushan (not significantly, except for CF and lipid content). Secondly, these biometric parameters (LHR, CF) and proximate composition (lipid, protein) values of fish from Taizhou were more likely similar to the wild counterpart. From the reasons above, it was revealed that fish from Taizhou during the deep-water sea-cage cultivation process had dramatically adapted to the environment and transformed its biological and nutritional status similarly to the wild counterpart.

In general, mineral contents are affected by the environmental conditions and daily diets [29]. Levels of Na, Mg, and K in large yellow croaker in our study were not as high as other species of fish (yellowtail, yellow perch) [28,30]. However, level of Ca in large yellow croaker of our study was higher than other fish (yellow perch, sea bass) [30,31]. The regional variations were reflected through the mineral concentrations between the fish from Zhoushan and Taizhou cultures. Fish from Taizhou had significantly higher contents of macro and micro minerals (Na, Mg, Ca, Fe, Cu) than those of fish from Zhoushan. Meanwhile, the highest content of K was observed in fish from Zhoushan, and there were no significant differences in Zn and heavy metals contents between the fish cultures.

In term of physical parameters, cultured fish in our study were found to have lower pH value than that of wild fish, which is consistent to different fish species [20,32]. Moreover, the pH values of large yellow croaker growing in deep-water sea-cage in our study were lower than that of large yellow croaker growing in enclose culture and sea-cage culture modes in other studies [18]. The highest value of WHC in our study was found in fish Taizhou, which does not agree to the study about sea bass, where the WHC of wild fish was observed to be higher than in the cultured fish [20].

Color is one key indicator of fishing products quality [33]. Large yellow croaker has a typical golden yellow in the dorsal area, which is very important for the quality evaluation and product consumption of consumers. Color parameters showed significantly higher L* value in the wild fish, this observation is in the agreement to other species of fish [20,34]. Moreover, color measurements showed higher values of b* than a* in both wild and cultured fish. The absolute value of b*/a* ratio of wild fish (226.64) was significantly higher than cultured fish from Zhoushan and Taizhou (34.45 and 8.29, respectively). In addition, the b* values (located between the ventral fin and anal fin, ranged from 23.96 to 31.73) of large yellow croaker in our study were higher than those of large yellow croaker (on the ventral skin behind the ventral fin, ranged from 11.35 to 17.64) in previous study [18]. In the two studied regions, the higher L* and a* values were observed in fish from Taizhou, the higher b*value was observed in fish from Zhoushan. Hence, the regional differences or cultivation conditions can affect the skin color of large yellow croaker.

There were variations on the texture parameters between the three fish groups in our study. The wild fish was characterized by significantly higher value of shear force value that those of cultured fish. This pattern is in agreement to the study on wild and cultured blackspot seabream [34]. The significantly higher values of gumminess and chewiness were observed in fish from Zhoushan compared to fish from Taizhou and even to the wild counterpart. This result contributed to the limited literature about the effects of regions on the texture of fish muscle.

The fatty acids profiles of large yellow croaker in this study differed depending on the cultivation regions, particularly in the MUFAs and PUFAs profile. The significantly higher value of total MUFAs was found in fish from Zhoushan, while the significantly higher value of total PUFAs was found in fish from Taizhou. In general, the significantly higher values of fatty acids were mostly observed in fish from Taizhou, such as 17:1 n-7, 22:1 n-9, 24:1 n=9, 18:3 n-3, 20:4 n-6, 20:5 n-3 (EPA), and 22:6 n-3 (DHA). Those variations may due to the differences in the aquatic environments of the two regions. The average temperature of Taizhou region is slightly higher than that of Zhoushan, which results in a higher water temperature in sea- cages. The salinity range of Taizhou region (24.5~32.0‰) is larger than that of Zhoushan region (25.6~26.2‰). In our study, the significantly higher values of total n-3 fatty acids (mostly EPA and DHA) were found in Taizhou, slightly higher average temperature region than Zhoushan. This observation was not consistent to the results found in carp [35] and whitefish [8], which reported that the lower temperature resulted in higher total n-3 fatty acids. However, it is notable that the average temperature in Taizhou is not far higher than Zhoushan; therefore, the observation needs to be considered more in the next study.

In all fish groups, the most predominant amino acid was glutamic acid (ranged from 2.09 to 2.24 g/100 g), then followed by aspartic acid, lysine, leucine and glycine. This observation was consistent with previous report on large yellow croaker [16]. These AAs (mentioned above) are reported to be abundant in aquatic organisms [20] and create the characteristics of fish flavor [36]. Among them, lysine is the amino acid which is limited in cereal-based diets [37]. Leucine is considered to be important in muscle growth [38]. Our results showed that large yellow croaker is rich in amino acids, which provides the special flavor of fish and benefits to human health.

The amino acids profile differed highly significantly depending on the cultivation regions of large yellow croaker. Fish from Zhoushan was characterized by the higher values of TAAs, total NEAAs, and total SEAAs. As a result, the significantly higher levels of abundant amino acids were observed in fish from Zhoushan than those of fish from Taizhou, such as glycine, alanine, cysteine, proline, arginine, and histidine. Therefore, the higher quality of fish flavor is highly expected in from Zhoushan, which needs more work to prove in further study.

Conclusion

There were regional variations existed between large yellow croaker *(Pseudosciaena crocea)* from Zhoushan and Taizhou cultures in biometrics, proximate compositions, physico-chemical parameters, color, texture, fatty acids and amino acids profiles. During the experimental time, fish from Zhoushan culture had significantly higher values of weight and yellowness (b*), and better amino acids profile; we revealed that fish from Zhoushan culture is suitable for commercial market, and Zhoushan region is a felicitous cultivation region. Although fish from Taizhou culture had a lower value of weight, other parameters (except for amino acids profile) were high qualitied compared to fish from Zhoushan. For example, LHR, CF, lipid and protein values of fish from Taizhou were similar to the wild counterpart. Moreover, the significantly higher values of mineral contents (Na, Mg, and Ca), EPA, and DHA were observed in fish from Taizhou. From the results, we have some suggestions for the future studies: firstly, flavor variations of the fish from different regions; secondly, fatty acids diversification depending on the rearing temperature; lastly, how to gain fish weight but maintain good LHR, CF values and flavor.

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