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Nutrient compositional differentiation in the muscle of wild, inshore and offshore cage-cultured large yellow croaker (*Pseudosciaena crocea*)

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Abstract

The proximate composition, amino acids and fatty acids composition in the muscle of wild, inshore and offshore cage-cultured large yellow croaker, *Pseudosciaena crocea* (Richardson, 1846), were determined to identify nutritional differences. Wild fish groups showed highest content of moisture and crude protein, but the lowest lipid content. Offshore cage-cultured fish showed significantly higher content of moisture and crude protein content, but lower crude lipid content than inshore cage-cultured fish. The content of aspartic acid, glutamic acid, and alanine was higher in wild large yellow croaker than inshore cage-cultured groups, but similar to offshore cage-cultured fish. Significant lower contents of total amino acids, essential amino acids, non-essential amino acids and flavor-enhancing amino acids content were recorded in two cultured fish groups than those in wild group. While no major differences in fatty acids composition were found between wild and cage-cultured groups except for linoleic acid. The fish from offshore cages has much better nutrient profile than inshore cage-cultured fish, but was still inferior compared to wild fish.

Keywords: Composition, Differences, Cultured, Wild, Inshore, Offshore, *Pseudosciaena crocea*

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Introduction

Large yellow croaker (*Pseudosciaena crocea*), has a favorite taste and firm texture that make high commercial value and has been highly demands for centuries in Asian countries such as China, South Korea and Japan (Lv *et al.*, 2008). However, over-exploitation and environmental deterioration has led to nearly depletion of wild populations (Liu and De Mitcheson, 2008). Significant breakthroughs in the commercial culture of large yellow croaker has occurred in the last 20 years and it has become one of the major fish species in marine aquaculture in China. This has been the result of the successful artificial hatchery in 1997 and increasing culture efforts from large companies and fish farmers to meet growing market demand (Hong and Zhang, 2002).

The large yellow croaker has been commercially cultured in small floating sea cages (typical size of 3×3×3 m) at inner bays with low current of seawater exchange for a long time. However, the farmed large yellow croaker has higher condition factor, and the appearance, flavor, texture and taste are inferior compared to wild croakers. The poor flesh quality of fish raised in small inshore cages and a major problem occurred for fish farmers because of its low consumer acceptability. The differences were mainly due to high amount of dietary fat intake, and relatively limited space and low activity of the fish (Lv *et al.*, 2008). Large offshore sea cages have been introduced for large yellow croaker as a new cage culture system. It is generally concluded that the cultured fish can adapt to the higher water current velocity with higher swimming activity (Hernández *et al.*, 2002). It might be represent one of the main factors that can influence the fitness and the quality of fish. The quality traits of fish are a complex set of parameters involving chemical composition, physical quality and sensory properties. The sensory quality of fish can partly depends on the chemical composition of the fish muscle tissues (Ehsani *et al.*, 2013). However, there are not detailed information about the nutrient compositional variation of the cultured croaker in offshore cages compared to croaker in the wild and cultured in traditional inshore cages. Regarding all mentioned reasons the present study was planned to quantify the nutrient differences in market-size wild caught, inshore and offshore cage-cultured large yellow croaker, in order to provide basic data to consumers, fish farmers and companies.

Materials and methods

Sample collection

Fifteen inshore cage-cultured fish (body weight 520.28±81.97 g body length 30.92±1.16 cm) and fifteen offshore cage-cultured fish (body weight 535.30±75.71 g, body length 31.26±3.10 cm) were collected from the inshore (3×3×3 m) and offshore (diameter = 10 m, depth = 10 m) cages, respectively along the Eastern Sea area of Ningde City, Fujian Province, China. The cultured fish from both sea cages were fed with mainly minced trash fish (*Ammodytes personatus*) and soft pellet feed. Five wild fish of similar size (body weight 558.46 ± 21.71 g, body length 35.90±1.15 cm) were captured from the area along the East China Sea of Ningde City as well. Individual wild fish from each group was separately skinned, filleted, and muscle from both sides of the fish was homogenized. Numbers of replicates was reduced for fish from cultured groups by pooling three fish from the same group to have same analyzed numbers as wild group. Each sample was freeze-dried for 48 h and then grounded to obtain fine powder. The homogenized samples were kept at -40 °C pending analysis.

Proximate composition analysis

Samples were analyzed for moisture, protein and lipid by using Association of Official Analytical Chemists standard methods (AOAC, 2005). Briefly, moisture was determined by drying the samples at 105 °C for 24 h. Crude protein content was measured by calculating nitrogen content (×6.25) using automated Kjeldahl analysis (Foss Tecator Kjeltec Auto 2200 analyzer, Warrington, U.K). Lipid was measured with the method of petroleum ether extraction using Soxtec method (Foss Tecator 148 Soxtec system 2043 Auto Extraction apparatus, Warrington, U.K). Ash was measured by combustion to a constant weight in a muffle furnace at 550 °C (Lindberg/Blue M, Thermo Fisher Scientific Inc., Waltham, USA).

Amino acids analysis

For amino acids analysis, the method was in accordance with Zhao *et al.* (2010). Freeze-dried samples were hydrolyzed with 6 mol L^{-1} HCl and determined by a Biochrom 20 amino acids analyzer (Biochrom Ltd., Cambridge, UK). For tryptophan, the samples were hydrolyzed with 5 mol L^{-1} NaOH and determined by Agilent 1100 Series system (Agilent Technologies, Palo Alto, CA, USA). The amino acids content was calculated by comparison with retention time and the peak areas of standard amino acids (Sigma-Aldrich, St. Louis, MO, USA).

Fatty acids analysis

For fatty acids analysis, total lipids of samples were extracted and fatty acids methyl esters were prepared in accordance with Metcalfe *et al.* (1966). Briefly, total lipids were extracted with chloroform-methanol solution (2:1, v v^{-1}). Fatty acid methyl esters (FAMEs) were prepared using a 15% (w v^{-1}) BF3-methanol reagent. FAMEs were measured by using HP-6890 GC series gas chromatograph (Agilent Technologies Inc., Santa Clara, USA) and a column (60 m×0.25 mm× 0.25 µm). Nitrogen was the gas carrier and the column temperature was set to increase from 130 °C to 230 °C, at a rate of 4 °C min^{-1}. The fatty acids composition was then determined by comparing the areas of the fatty acids analyzed to the areas of the concentration of stand FAME mixture (Nu-Chek-Prep Inc., Elysian, MN, USA).

Statistical analyses

The data were checked for normality and homogeneity of variance using

Levene's test. One-way ANOVA was used to determine the differences among these three groups. The significant differences were compared by using Tukey's multiple comparison tests. The differences among groups were considered significant at level of $p<0.05$. All statistics were performed using the SPSS 21.0 statistical software (SPSS Inc., Chicago, USA).

Results

Proximate composition

Differences were found in contents of moisture, protein and lipid (Table 1). Significant higher content of moisture was detected in wild group (79.77%) compared to inshore cage-cultured group (70.60%), while no differences were found in offshore cage cultured fish (76.33%). The results also showed that crude protein content of wild group was significantly higher (84.73% of dry weight), whilst crude lipid content (10.13% of dry weight) was significantly lower than the cultured groups (21.17%-34.47% of dry weight). Ash contents did not differ between the fish samples.

Table 1: Moisture (% of wet weight), crude protein and crude lipid (% of dry weight) in wild caught and cultured large yellow croaker (mean±standard deviation).

	Wild caught	Inshore cage-cultured	Offshore cage-cultured
Moisture	79.77±1.32^{a}	70.60±3.32^{b}	76.33±2.32^{ab}
Crude protein	84.73±2.99^{a}	58. 05±7.66^{c}	73.94±8.06^{b}
Crude lipid	10.13±3.70^{c}	34.47±10.43^{a}	21.17±5.78^{b}
Ash	5.78±0.59^{a}	4.14±1.06^{a}	5.40±1.04^{a}

Means in the same row with different superscripts are significantly different ($p<0.05$)

Amino acids composition

As shown in Table 2, the amino acids composition pattern of cultured large yellow croaker was found to be similar to the wild groups. Generally, the most two abundant amino acids in all fish samples were glutamic acid (9.50%-13.93%) and lysine (6.17%-7.75%). However, significant lower contents of total amino acids (AA), essential amino acids (EAA), non-essential amino acids (NEAA) and flavor-enhancing amino acids (FAA) content were recorded in cultured groups (61.07%-71.15%, 24.49%-29.14%, 31.21%-35.80% and 23.02%-26.58%, respectively) and the wild group content was recorded as (84.23%, 34.69%, 42.18% and 31.87%, respectively).

Table 2: Amino acid composition (% of dry weight) in wild caught and cultured large yellow croaker (mean±standard deviation).

Amino acids	Wild caught	Inshore cage-cultured	Offshore cage-cultured
Taurine	0.30±0.03	0.29±0.07	0.55±0.20
Aspartic acid	8.90±0.15^{a}	6.41±1.68^{b}	7.48±0.86^{b}
Glutamic acid	13.93±0.24^{a}	9.50±2.51^{b}	11.28±1.35^{ab}
Glycine	3.60±0.01	3.22±0.19	3.37±0.51

Table 2 continued:

Alanine	5.15±0.03^{a}	3.89±0.78^{b}	4.44±0.54^{ab}
Serine	3.02±0.13	2.26±0.62	2.61±0.28
Cysteine	1.13±0.12	1.35±0.90	1.25±0.57
Tyrosine	3.15±0.05	2.23±0.38	2.63±0.21
Proline	2.76±0.02	2.35±0.01	2.73±0.05
Phenylalanine	3.59±0.07	2.63±0.66	3.06±0.33
Lysine	7.70±0.24	6.17±1.74	7.75±0.98
Threonine	3.67±0.00	2.70±0.75	3.20±0.39
Valine	4.47±0.12	3.27±0.86	3.82±0.44
Methionine	2.14±0.27	1.28±0.52	1.49±0.30
Isoleucine	4.15±0.06	2.85±0.81	3.33±0.37
Tryptophan	0.90±0.06	0.56±0.22	0.58±0.08
Leucine	7.18±0.04	5.04±1.41	5.91±0.64
Arginine	5.35±0.04	3.93±0.64	4.55±0.31
Histidine	1.88±0.09	1.45±0.39	1.67±0.45
∑AA	84.23±0.88^{a}	61.07±15.04^{b}	71.15±8.30^{b}
∑EAA	34.69±0.32^{a}	24.49±6.96^{b}	29.14±3.29^{b}
∑NEAA	42.18±0.39^{a}	31.21±6.81^{b}	35.80±4.32^{b}
∑SEAA	7.36±0.17	5.38±1.28	6.21±0.77
∑DAA	31.87±0.41^{a}	23.02±5.16^{b}	26.58±3.25^{b}
∑EAA/∑AA	0.41±0.00	0.40±0.02	0.41±0.01
∑EAA/∑NEAA	0.82±0.00	0.78±0.05	0.81±0.03
∑DAA/∑AA	0.38±0.01	0.37±0.01	0.38±0.00

∑AA is total amino acids; ∑EAA is total essential amino acids; ∑NEAA is total non-essential amino acids; ∑SEAA is total semi-essential amino acids and ∑DAA is total delicious amino acids
Means in the same row with different superscripts are significantly different (p<0.05)

Fatty acids composition

The detailed fatty acids composition in the muscle of large yellow croaker is given in Table 3. The saturated fatty acids, SFA (40.15%-43.80%) were the main group of fatty acids in muscle samples, followed by monounsaturated fatty acids, MUFA (36.04%-36.34%) and polyunsaturated fatty acids, PUFA (18.90%-23.34%). No significant differences were observed in total SFA, MUFA or PUFA between the three fish groups. For individual fatty acid, the percentage of linoleic acid (C18:2n-6) was significantly higher in inshore cage-cultured large yellow croaker than cultured in wild or offshore cage cultured groups.

Table 3: Fatty acid composition (% of total fatty acids) in wild caught and cultured large yellow croaker (mean ± standard deviation).

Fatty acids	Wild caught	Inshore cage-cultured	Offshore cage-cultured
C8:0	0.13±0.12	0.02±0.01	0.03 ±0.02
C12:0	0.11 ±0.05	0.04 ±0.01	0.05 ±0.02
C13:0	0.01 ±0.02	0.03± 0.01	0.03 ±0.01
C14:0	3.39 ±0.37	3.54± 0.58	3.14 ±0.45
C14:1n-7	0.06 ±0.09	0.04± 0.05	0.00 ±0.00
C15:0	0.55 ±0.07	0.53± 0.13	0.54 ±0.09
C16:0	30.95 ±0.72	27.67± 0.10	29.64 ±2.58
C16:1n-7	12.71 ±1.01	10.27± 1.64	11.63 ±1.46
C17:0	1.17 ±0.04	1.30± 0.25	1.46 ±0.21
C17:1n-7	0.98 ±0.04	0.87 ±0.26	0.91 ±0.14
C18:0	6.00 ±1.71	5.13 ±0.06	5.43 ±0.39
C18:1n-9	21.47 ±0.85	21.97 ±3.25	21.86 ±1.90
C18:2n-6t	0.18 ±0.03	0.14 ±0.01	0.18 ±0.01
C18:2n-6c	0.98 ± 0.19^{b}	2.96 ± 0.20^{a}	1.23 ± 0.44^{b}
C18:3n-6	0.54 ±0.18	0.36 ±0.04	0.43 ±0.01
C18:3n-3	0.52 ±0.10	0.90 ±0.03	0.69 ±0.21
C20:1n-9	1.13 ±0.49	2.89 ±1.75	1.81 ±0.47
C21:0	0.42 ±0.19	0.84 ±0.55	0.33 ±0.30
C20:2n-6	0.21 ±0.00	0.20 ±0.01	0.19 ±0.02
C22:0	0.34 ±0.24	0.19 ±0.09	0.26 ±0.13
C20:4n-6	2.24 ±0.35	2.12 ±0.10	2.78 ±0.18
C23:0	0.55 ±0.19	0.74 ±0.31	0.59 ±0.16
C20:5n-3 (EPA)	5.00 ±1.11	5.04 ±0.96	4.39 ±1.37
C24:0	0.16 ±0.07	0.11 ±0.02	0.18 ±0.05
C24:1n-9	0.75 ±0.01	0.28 ±0.39	0.54 ±0.47
C22:6n-3 (DHA)	9.45 ±0.13	11.89 ±2.81	11.51 ±2.09
EPA+DHA	14.45 ±0.98	16.94 ±3.77	15.90 ±3.46
∑SFA	43.80 ±1.92	40.15 ±1.65	41.67 ±2.42
∑MUFA	36.34 ±2.48	36.04 ±2.82	36.21 ±3.27
∑PUFA	18.90± 0.54	23.34 ±1.58	21.21 ±4.03
∑n-3 PUFA	14.97±0.88	17.84 ±3.74	16.59 ±3.67
∑n-6 PUFA	3.94±0.34	5.50 ±2.16	4.62 ±0.58
PUFA/SFA	1.26±0.10	1.48±0.09	1.38±0.14
n-3/n-6 PUFA	3.83±0.55	3.66 ±2.12	3.59 ±0.65

∑SFA is total saturated fatty acids; ∑MUFA is total monounsaturated fatty acids; ∑PUFA is total poly unsaturated fatty acids; ∑n-3 PUFA is total n-3 poly unsaturated fatty acids; ∑n-6 PUFA is total n-6 poly unsaturated fatty acids

Means in the same row with different superscripts are significantly different ($p<0.05$)

Discussion

Higher lipid content from farmed fish compared to wild group have been found in some other fish species such as salmonids (Johnston *et al.*, 2006), Gilthead sea bream and sea bass (Orban *et al.*, 2003). The high lipid content of diet and the intensive feeding strategies were reported to the result in higher lipid content of fish muscle (Arechavala-Lopez *et al.*, 2013). The higher lipid content of farmed croaker may have a role in different sensory properties such as oily flavor and soft texture compared to wild group. Interestingly, fish from offshore cages also showed lower fat content (21.17% of dry weight) compared to fish from inshore cages (34.47% of dry weight). This could be mostly because of the restricted activities and lower water current in small cages but large space and higher current in offshore cages.

The glutamic acid and lysine showed the highest level in all groups of large yellow croaker. The high contents of these amino acids are found in the previous results described for other marine fish species (González *et al.*, 2006; Zhao *et al.*, 2010). Lower levels of total amino acids (AA), essential amino acids (EAA), non-essential amino acids (NEAA) and flavor-enhancing amino acids (FAA) content were recorded in cultured groups than wild fish. These results were same results of other reported literatures has also showed decreased levels of AA, EAA, NEAA and FAA in cultured fish compared to wild fish (Zhao *et al.*, 2010). The wild fish mainly feeds on variable feeds with the high levels of amino acids but cultured fish solely have the same diet. For individual amino acid, three flavor-enhancing amino acids (Aspartic acid, Glutamic acid and Alanine) illustrated significantly higher contents in wild groups compared to inshore cage-cultured fish, but only one amino acid (Aspartic acid) varied between wild fish and offshore cage-cultured fish. It is reported that certain amino acids can impart favorable sensory perception to feeds (Li *et al.*, 2009). Compared with cultured groups, wild fish are rich in these FAAs that lead to more favorable sensory perception.

The fatty acid composition of the fish analyzed in the present study was corresponds to previous reports of other marine fish species as well (Sales, 2010). There were no significant differences in total SFA, MUFA or PUFA among the three fish groups. For individual fatty acid, the content of linoleic acid (C18:2n-6) was significantly higher in inshore cage-cultured large yellow croaker than in wild group, while the amount of EPA and DHA was found to be similar in cage-cultured large yellow croaker compared to levels of wild group. Several studies have documented that the lower percentage of linoleic acid but similar level of EPA or DHA was found in wild fish, such as Atlantic salmon (Blanchet *et al.*, 2005), Rainbow trout (Ural *et al.*, 2017), turbot (Sérot *et al.*, 1998) and sea bream (Grigorakis *et al.*, 2002). The flesh fatty acids compositions in fish have been shown to be closely correlated with dietary fatty acids (Bell *et al.*, 2003). The different levels found in the current study could be largely due to the complement of dietary lipid from the fish fed. However, other metabolic regulators could also influence muscle fatty acid composition (Tocher, 2003; Saglik Aslan *et al.*, 2007). The effects of various dietary lipid sources, metabolic fates of the different fatty acids and biosynthesis of PUFA in large yellow croaker need to be conducted in the near future.

Present study was carried out to find out nutrient composition of large yellow croaker from different origins (wild caught, inshore and offshore cage-cultured). According to the results of this study, it can be concluded that nutrient quality differences were found among wild, inshore cage-cultured and offshore cage-cultured large yellow croaker. The fish from offshore cage has better nutrient profile than inshore cage-cultured fish, but is still inferior compared to wild fish. Future farming strategies and artificial feeds development for better fish quality are needed to have higher consumer acceptance.

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