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Differentiate the fatty acids profiles of large yellow croaker (*Pseudosciaena crocea*) fed with trash, commercial and formulated diets

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Abstract
Studies regarding the diets of large croaker (*Pseudosciaena crocea*) have dominated research in recent years. However, few literatures has documented the differences between the fatty acids profiles of large yellow croaker (LYC) fed with trash-fish, commercial and formulated diets. This paper aims to differentiate these three fish groups based on the principal component analysis (PCA) and non-metric multidimensional scaling (NMDS) techniques. Literature compilation of fatty acid profiles of large yellow croaker was encompassed all papers published from 14 studies and 51 fatty acid profiles. The findings showed that the cumulative percentage of variance accounted for PC1 and PC2 showed rather low proportion (52.1%) to total variance; therefore the PCA analysis resulted in the deficient intuition to differentiate the fatty acids profiles of LYC fed with different sources of diets. In contrast, NMDS could discriminate the fatty acids profiles of LYC fed with formulated and trash/commercial diets with the stress value of 0.164.

Keywords: Fatty acids discrimination, principal component analysis, non-metric multidimensional scaling, nutrition sources

1. Introduction
Large yellow croaker (*Pseudosciaena crocea*) is one of the most important economical marine fishes of China. Large yellow croaker (LYC) diets have been extensively sought for decades in China [1]. Particularly, the studies about the protein/lipid ratio [1-2], the dietary protein sources [3] and other supplements (methionine, phosphorus, astaxanthin and xanthophylls) [4-6] have been investigated for the larvae (initial weight 1.93-7.36 mg) and juvenile (initial weight 0.57-36.80 g) LYC. A number of authors have posited the studies about the diets for the marketed-sized (initial weight 245.29 g) LYC [7].
Dietary protein and lipid play an important role in the growth performance and flesh quality of LYC. The dietary protein and lipid levels can affect the survival, weight gain, feed conversion ratio and protein efficiency ratio [1]. In addition, the dietary protein sources can be replaced without negative effects on growth performance, flesh fatty acids composition and nutrient utilization in large yellow croaker [3, 8].
Commercial diet has been abundantly used due to its convenience and availability, which warrant the stable quality for fish growth [9]. However, in order to reduce the cost of fish production, trash fish is still used as an alternative of protein source for diet in aquaculture [10-12]. Besides that, prior research has thoroughly investigated into the formulated diets for large yellow croaker throughout the laboratories of China [6, 13-14].
To present, the prevailing method for identify or discriminate the differences among various seafood products, has evolved to species, geographic populations, wild and farmed seafood identification, etc. [15-17]. Some commonly implemented methods are the molecular markers (such as proteins and/or DNA), trace elements and/or stable isotopes, protein markers and fatty acids profiles [18-20]. Frequently, the successful identification methods replies on a variety of markers in combination with different analytical techniques [18]. However, there is little published research about the methods to differentiate the fatty acids profiles of large yellow croaker fed with trash, commercial and formulated diets.
This paper aims to (1) compare the fatty acids profiles from muscles/tissues of large yellow croaker fed with trash, commercial and formulated diets in the fishery market, and (2)

discriminate the fatty acids profiles from those three groups of fish. Some algorithms were used, such as the principal component analysis (PCA) and non-metric multidimensional scaling (NMDS) technique, to discriminate the differences between fish groups.

2 Materials and Methods

2.1 Methods

The database from web of science was collected in December 2019 using the search term "fatty acids", "wild", "cultured", "farm" and "large yellow croaker". Among the 224 returned articles, 53 papers were reported of wild and/or cultured large yellow croakers. After screening the abstract and reading the relevant articles in detail, we chose among published fatty acids profiles of large yellow croaker, shortlisted 14 studies and constructed a large enough database for this paper's work. The database consisted in 51 fatty acids profiles of LYC in total, 9 profiles of trash fed, 3 profiles of commercial and 39 profiles of formulated diets, distributed in Ningbo City (Zhejiang Province), Ningde City (Fujian Province) and Guanjinyang (Fujian Province).

The details of all identified fatty acids profiles are listed in Supplementary data. It was limited the data for lipid extraction and fatty acids profiles reported from fish muscle/flesh of large yellow croakers only.

Some adaptions were taken to encourage the comparison of fatty acids profiles. First, it was just considered the fatty acids that were quantified in at least 80% of profiles; as a result, lists of 11 fatty acids were re-calculated to reach 100% (as Table 1). Second, when only the number of unsaturation, but not its first position of a given fatty acid was reported, it was converted to the generally most abundant corresponding fatty acid. Thus, FA16:1 was converted to FA16:1 n-7, and FA18:1 was converted to FA18:1 n-9. Additionally, some profiles of FA16:1 n-9 was converted as FA16:1 n-7, in order to quantifying the amount of 80% of the profiles was covered.

2.2 Statistical analysis

The probability predictions and significance between each fatty acids profile were calculated based on the means and standard deviations according normal distribution laws and one-way ANOVA (LSD Post Hoc Test, $P < .05$) using IMP SPSS Statistics Data Editor version 20.0. The principal component analysis (PCA) was used to estimate the eigenvector and eigenvalue of the fatty acids indicators (used R function "prcomp"). The non-metric multidimensional scaling (NMDS) technique based on Bray-Curtiss distance matrix was used to differentiate the fatty acids profiles of trash, commercial and formulated diets fed large yellow croaker (used R package "vegan").

3. Results

The fatty acids profiles of LYC fed with trash, commercial and formulated diets were listed in Table 1, including 4 saturated fatty acids SFAs, 2 mono-unsaturated fatty acids MUFAs, and 5 poly-unsaturated fatty acids PUFAs. There were significant differences in FA18:0, FA20:0, 16:1n-7, 18:2n-6, 22:6n-3 and ΣPUFAs ($p<.05$). LYC fed with formulated diets had significantly higher proportions in F18:0, FA20:0, 18:2n-6 and ΣPUFAs (Table 1) among three fish groups. In addition, there were no significant differences in F18:0, FA20:0, 18:2n-6 and ΣPUFAs between trash and commercial diet-fed LYC. In contrast, LYC fed with trash fish had significantly higher proportions of 16:1n-7 and 22:6 n-3 (DHA) among the three fish groups (Table 1).

Table 1: Average proportion of the eleven most frequently quantified fatty acids in trash fed and commercial/formulated fed large yellow croaker

Fatty acids (%)	Trash	Commercial	Formulated	Sig
FA 14:0	2.81 ± 0.91	2.36 ± 1.24	2.64 ± 1.25	ns
FA 16:0	24.19 ± 11.14	16.46 ± 13.19	22.77 ± 6.54	ns
FA 18:0	4.86^{a} ± 1.94	3.59^{a} ± 2.86	6.27^{b} ± 1.12	*
FA 20:0	0.48^{a} ± 0.21	0.05^{a} ± 0.07	1.22^{b} ± 0.74	*
ΣSFAs	32.18 ± 13.12	22.46 ± 4.34	32.91 ± 2.41	ns
16:1 n-7	8.08^{a} ± 2.38	5.68^{b} ± 1.31	5.72^{b} ± 1.36	*
18:1 n-9	19.31 ± 8.72	17.04 ± 11.03	19.89 ± 5.46	ns
ΣMUFAs	27.39 ± 10.83	22.72 ± 6.17	25.62 ± 3.41	ns
18:2 n-6	2.19^{a} ± 1.38	3.57^{a} ± 2.74	14.53^{b} ± 5.70	*
18:3 n-3	1.19 ± 0.78	1.31 ± 0.88	1.91 ± 1.63	ns
20:4 n-6	0.89 ± 0.63	0.28 ± 0.13	1.74 ± 1.57	ns
20:5 n-3 [21]	4.72 ± 3.09	3.34 ± 3.26	4.11 ± 0.92	ns
22:6 n-3 (DHA)	11.22^{a} ± 5.49	5.56^{b} ± 2.94	8.09^{b} ± 2.50	*
ΣPUFAs	20.20^{a} ± 7.96	14.08^{a} ± 1.99	30.38^{b} ± 2.46	*

Note: *, p-value refers to ANOVA significance of trash, commercial and formulated diets fed LYC ($p<0.05$).

Different letters in the same row denote statistically significant difference between fish groups ($p<0.05$). SD, standard deviation; ns, non-significant; ΣSFAs, sum of saturated fatty acids; ΣMUFAs, sum of monounsaturated fatty acids; ΣPUFAs, sum of polyunsaturated fatty acids; EPA, eicosapentaenoic acid, and DHA, docosahexaenoic acid.

Based on the 11 quantified fatty acids, the bi-plot of principal component analysis (PCA) displayed the most significant variances of PC1 and PC2 (Fig. 1). The axes are seen as arrows originating from the center point (Fig. 1). PC1 explained 21.8% of the total variance (proportion of variance 0.218), which means that nearly one-fourth of the information in the dataset (11 variables) could be encapsulated by just the first principal component. Meanwhile, the PC2 explained 20.3% of the variance (proportion of variance 0.203). Therefore, PC1 and PC2 could explain 52.1% of the variance. In addition, the fatty acids components FA18:0 and 18:1n-9 contributed most to PC1, with higher values in those variables moving the samples to the right on this plot (Fig. 1). Moreover, the PCA also gave the information about the clustering characteristics of the three groups of diets in LYC (trash, commercial and formulated components). However,

the result was not very ideal, the ellipse of commercial diet group scattered in a large space; while, the fatty acids components of LYC fed with formulated diet was overlapped in trash diet group (Fig. 1).

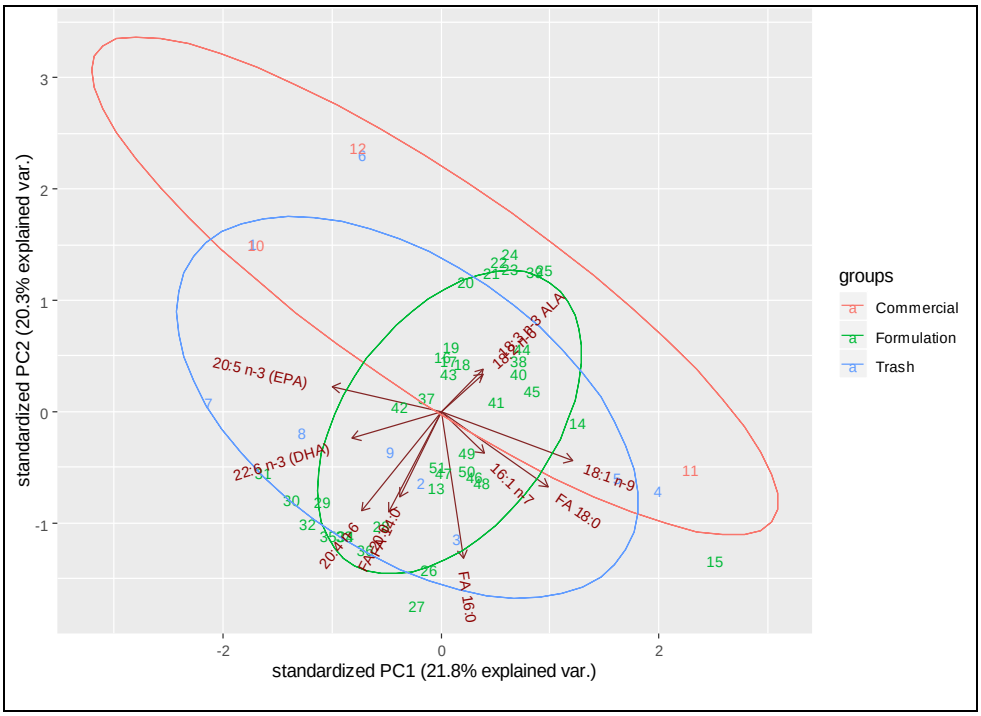

Fig 1: Principal component analysis (PCA) of the fatty acids profiles of large yellow croaker fed with trash, commercial and formulated diets

Note: PC1, PC2, the first and second principal components, respectively. Numbers in the graph were the identity of the paper profile listed in literature compilation in Supplementary data. Color code: trash diet = blue, commercial diet = red, and formulated diet = green (color fig. soft copied version).

The PCA is successful when most of the variance is accounted for by the largest two components. In this study, however, the cumulative percentage of variance accounted for PC1 and PC2 showed rather low proportion (52.1%) to total variance (Fig. 1). In addition, there was no clear identification between fatty acids profiles of the three groups of diets. Therefore, PCA analysis is not an ideal technique to identify the fatty acids profiles of LYC fed with trash, commercial and formulated diets.

Compared to PCA, the NMDS based on the 11 quantified fatty acids of LYC shows a clear differentiation between fatty acids profiles of LYC fed with formulated and trash/commercial diets (Fig. 2). The NMDS-stress value (0.164) was considered generally acceptable; however, the visualization or interpretation still had some misleading points. Particularly, there were two exceptions (13th and 15th profiles) that did not fall into the expected category of formulated diets (Fig. 2). The reason may be due to the low proportions of FA20:0 and 18:2n-6 were measured in these two profiles [22].

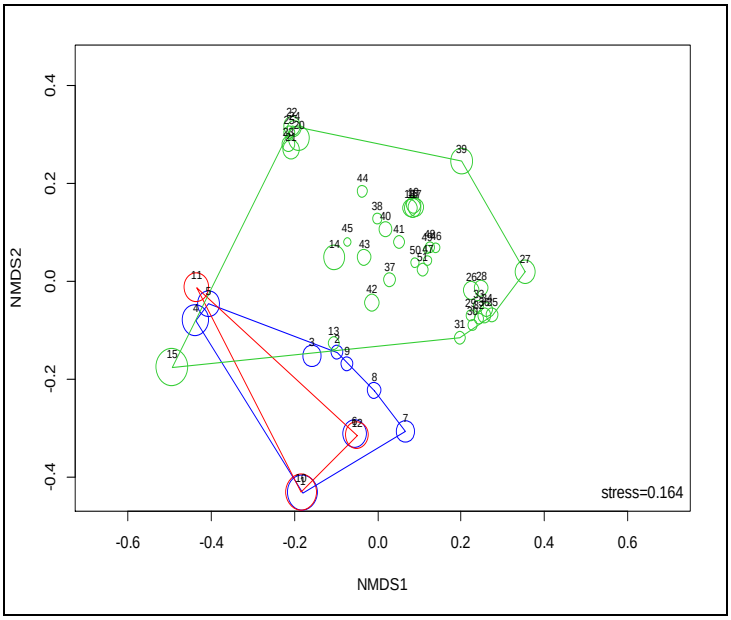

Fig 2: Non-metric multidimensional scaling (NMDS) of large yellow croaker fed with trash, commercial and formulated diets based on relative proportions of the 11 most commonly quantified fatty acids.

Note: Numbers in the graph were the identity of the paper profile listed in literature compilation in Supplementary data. Color code: trash diet = blue, commercial diet = red, and formulated diet = green (color fig. soft copied version). The sizes of the bubbles represented the reversion of the Goodness of fit in NMDS.

In addition, the fatty acids proportions of trash and commercial diets fed LYC were almost overlapped (Fig. 2). Hence, there was no discrimination between the fatty acids profiles of LYC fed with trash and commercial diets (Fig. 2), but only the discrimination between formulated diets existed. It has reflected the fact that there is still the difference between the formulated diets for LYC in laboratories and the real situations in the aquaculture market. The expositions may be explained by the variations in the dietary proteins, lipids, or fatty acids sources that fish are regularly fed.

For example, the alternative protein sources and fish meal replacement can advocate to the lower feeding rate, digestibility and the imbalance of essential amino acids [3]. Therefore, the replacement should be conducted with care. The effects of the replacement of fish meal by meat and bone meal (MBM) were investigated by Q. Ai, *et al*. [3]. The authors suggested that the maximum inclusion level of MBM was 54.3% to maintain the normal physiological function of large yellow croaker. Other protein source, like dietary krill meal, can replace up to 75% of the fish meal (40% in diet) of LYC without negative effects on fish growth performance and feed utilization [23].

In addition, the variety of lipid sources also affects the lipid digestibility and growth rate of fish [24]. Indeed, high content of SFAs such as 18:0, which is rich in beef tallow, performs a low apparent digestibility coefficient and slower growth rate of fish [22, 24]. Moreover, the n-3 and n-6 highly unsaturated fatty acids (HUFA) such as arachidonic acid (ARA; 20:4n-6), eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3) have essential physiological roles in survival and normal growth of fish [25]. Similarly, dietary lipid sources not only influence the fatty acid composition in fish tissue, growth performance, but also the enzyme activities and gene expression related to the lipid metabolism of LYC [26].

Moreover, fatty acids proportions of fish tissues are affected by fish species, fish size, age, seasons, environmental factors and diets [27-28]. Among them, diet is the main factor influencing the compositions of LYC body lipids and fatty acids [22, 29]. For example, LYC fed with 6.5% of palm oil had significant increased levels of ΣSFA, ΣMUFA, and Σn-6 PUFA and decreased levels of Σn-3 PUFA in both liver and muscle, compared the relevant percentage of fish oil diets [13].

It is acknowledged that marine fish usually lack the bioconversion capacity to elongate and desaturase C18 PUFA to n-3 and n-6 highly unsaturated fatty acid (HUFA) such as arachidonic acid (ARA; 20:4n-6), eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3) [25, 30-31]. Therefore, some n-3 HUFA must be adequately provided by fish diets. Studies on marine fish larvae have shown that higher DHA/EPA level in diets can be more optimal for specific growth rate of fish [32-33]. The higher ratio of DHA/EPA (2.17–3.04) was reported to improve the growth performance, nonspecific immunity, as well as disease resistance at the early parasite infection stage of juvenile large yellow croaker [33]. The reason was believed to be due to the different physiological role and metabolism pathway of DHA and EPA [33].

4. Conclusion

The significantly higher proportions in F18:0, FA20:0, 18:2n-6 and ΣPUFAs were found in large yellow croaker fed with formulated diets. In contrast, LYC with trash-fish diets had significantly higher proportions of 16:1n-7 and 22:6 n-3 (DHA) among the three fish groups. Compared to principal component analysis, the non-metric multidimensional scaling was observed to have a higher capacity to cluster the fatty acids profiles of LYC fed with formulated and trash/commercial diets. Further research would be needed to understand the contributions of the final body weight and the dietary fatty acids compositions on the fatty acids profiles of fish muscles/tissues.

Supplementary data

Supplementary data: Literature compilation of large yellow croaker fatty acids profile in Ningbo City (Zhejiang Province), Ningde City (Fujian Province) and Guanjinyang (Fujian Province) of China.

Id	Authors	DOI	Final body weight (g)	Feed	Place	FA 14:0	FA 16:0	FA 18:0	FA 20:0	16:1 n-7	18:1 n-9	18:2 n-6	18:3 n-3	20:4 n-6	20:5 n-3 (EPA)	22:6 n-3 (DHA)
1	Tang et el	10.1111/j.1745-4557.2008.00206.x	289.17	Trash	Ningbo	3.93	10.61	1.82	0.00	5.13	14.22	2.73	1.45	0.35	8.02	9.83
2	Tang et el	10.1111/j.1745-4557.2008.00206.x	168.3	Trash	Ningbo	3.00	27.90	5.70	0.40	9.60	23.00	1.10	0.70	1.50	5.30	12.10
3	Tang et el	10.1111/j.1745-4557.2008.00206.x	283.5	Trash	Ningbo	2.50	30.30	6.40	0.40	10.10	30.30	1.40	0.60	1.80	4.30	17.90
4	Li Xiaoqin	10.1007/s11802-017-3338-0 ISSN	432.7	Trash	Guanjinyang	2.78	37.58	6.50	0.00	8.93	29.27	4.63	2.31	0.13	0.64	4.17
5	Li Xiaoqin	10.1007/s11802-017-3338-0 ISSN	484.6	Trash	Guanjinyang	2.08	36.65	6.41	0.00	10.47	25.58	4.07	2.48	0.10	1.10	8.15
6	Ma Rui	10.1007/s00343-019-8353-0	501.3	Trash	Ningbo	0.87	3.88	1.55	0.16	4.73	5.21	0.47	0.14	0.49	1.41	3.33
7	Xi-Quan Shen	10.1016/j.bse.2018.02.003	7.5	Trash	Ningbo	3.30	21.30	6.10	0.70	5.10	9.70	2.10	1.00	1.30	8.80	19.20
8	Xi-Quan Shen	10.1016/j.bse.2018.02.003	310	Trash	Ningbo	3.50	24.10	4.70	0.70	8.80	15.40	1.60	0.90	1.10	7.40	14.00
9	Xi-Quan Shen	10.1016/j.bse.2018.02.003	780	Trash	Ningbo	3.30	25.40	4.60	0.50	9.90	21.10	1.60	1.10	1.20	5.50	12.30
10	Tang et el	10.1111/j.1745-4557.2008.00206.x	302.14	Commercial	Ningbo	3.92	11.22	1.69	0.00	4.89	14.95	2.62	1.52	0.34	7.93	9.72
11	Li Xiaoqin	10.1007/s11802-017-3338-0 ISSN	416.9	Commercial	Guanjinyang	2.28	34.60	7.63	0.00	7.52	31.47	7.31	2.26	0.10	0.67	3.71
12	Ma Rui	10.1007/s00343-019-8353-0	518.5	Commercial	Ningbo	0.88	3.57	1.44	0.16	4.63	4.70	0.80	0.14	0.41	1.43	3.27
13	Xin-Xia Wang	10.1111/j.1365-2109.2011.02826.x	380.83	Formulation	Ningbo	2.57	28.87	5.89	0.73	9.64	25.50	0.58	0.54	0.93	5.72	12.03
14	Xin-Xia Wang	10.1111/j.1365-2109.2011.02826.x	364.86	Formulation	Ningbo	2.69	23.74	5.96	0.48	4.28	37.45	11.80	0.29	0.78	3.20	5.37
15	Xin-Xia Wang	10.1111/j.1365-2109.2011.02826.x	355.04	Formulation	Ningbo	3.70	32.03	10.52	0.26	4.47	40.62	0.39	0.26	0.47	1.62	2.29
16	Renlei Ji	10.1111/are.13574	36.71	Formulation	Ningde	3.88	18.59	4.64	1.17	6.62	16.93	22.68	2.30	0.70	4.63	4.62
17	Renlei Ji	10.1111/are.13574	37.96	Formulation	Ningde	3.81	18.08	4.81	1.29	6.51	17.17	22.56	2.27	0.77	4.41	4.24
18	Renlei Ji	10.1111/are.13574	37.53	Formulation	Ningde	3.81	18.62	5.06	1.15	6.68	17.45	22.82	2.23	0.77	4.25	4.28
19	Renlei Ji	10.1111/are.13574	36.8	Formulation	Ningde	3.59	17.90	4.81	1.19	6.17	17.04	23.00	2.33	0.73	4.46	4.17
20	Qinghui Ai	10.1016/j.aquaculture.2006.06.043	18.67	Formulation	Ningbo	0.00	19.00	6.50	0.00	4.60	19.10	18.40	2.10	1.40	5.10	10.20
21	Qinghui Ai	10.1016/j.aquaculture.2006.06.043	17.95	Formulation	Ningbo	0.00	19.30	6.00	0.00	5.20	20.30	19.00	2.20	0.90	4.50	9.60
22	Qinghui Ai	10.1016/j.aquaculture.2006.06.043	18.67	Formulation	Ningbo	0.00	18.10	6.20	0.00	4.10	21.10	21.40	2.30	0.90	4.20	9.90

23	Qinghui Ai	10.1016/j.aquaculture.2006.06.043	16.79	Formulation	Ningbo	0.00	18.30	6.30	0.00	4.60	21.30	17.60	2.20	0.80	4.20	8.60
24	Qinghui Ai	10.1016/j.aquaculture.2006.06.043	13.79	Formulation	Ningbo	0.00	18.50	5.80	0.00	4.30	21.30	19.60	2.90	0.90	4.10	8.20
25	Qinghui Ai	10.1016/j.aquaculture.2006.06.043	13.11	Formulation	Ningbo	0.00	19.60	6.40	0.00	4.80	22.60	21.00	2.60	0.80	4.00	7.00
26	Rantao Zuo	10.1016/j.fsi.2011.11.005	28.22	Formulation	Ningbo	3.35	28.39	6.42	2.51	6.47	20.52	7.49	1.12	3.09	3.01	6.28
27	Rantao Zuo	10.1016/j.fsi.2011.11.005	32.82	Formulation	Ningbo	2.20	36.52	7.19	1.54	5.12	17.18	12.40	1.47	6.58	2.66	6.10
28	Rantao Zuo	10.1016/j.fsi.2011.11.005	36.04	Formulation	Ningbo	2.60	32.03	6.29	1.96	4.36	15.36	12.13	1.36	3.37	3.50	9.06
29	Rantao Zuo	10.1016/j.fsi.2011.11.005	31.18	Formulation	Ningbo	2.73	30.93	5.11	1.82	4.07	14.77	10.52	1.31	3.40	4.47	10.97
30	Rantao Zuo	10.1016/j.fsi.2011.11.005	31.1	Formulation	Ningbo	3.06	29.78	4.93	1.89	3.85	13.65	10.59	1.39	3.57	5.03	11.33
31	Rantao Zuo	10.1016/j.fsi.2011.11.005	31.11	Formulation	Ningbo	3.19	26.72	5.00	1.63	3.42	13.32	10.92	1.33	3.46	5.71	13.60
32	Rantao Zuo	10.1016/j.aquaculture.2011.12.045	31.79	Formulation	Ningbo	2.84	29.60	5.22	2.09	5.14	14.20	9.16	1.19	4.13	5.41	8.58
33	Rantao Zuo	10.1016/j.aquaculture.2011.12.045	33.8	Formulation	Ningbo	2.79	30.89	5.43	2.00	4.90	16.59	9.44	1.20	4.07	4.26	8.92
34	Rantao Zuo	10.1016/j.aquaculture.2011.12.045	36.33	Formulation	Ningbo	2.72	30.14	5.49	1.90	4.55	16.16	10.02	1.19	4.43	3.50	9.82
35	Rantao Zuo	10.1016/j.aquaculture.2011.12.045	35.95	Formulation	Ningbo	2.92	30.77	5.03	1.72	4.48	15.17	11.14	1.31	4.85	3.27	10.66
36	Rantao Zuo	10.1016/j.aquaculture.2011.12.045	35.51	Formulation	Ningbo	3.43	33.41	5.15	1.50	5.09	15.72	10.61	1.24	4.27	2.58	9.64
37	Hong Qiu	10.1371/journal.pone.0169985	39.96	Formulation	Ningbo	3.24	14.91	6.88	1.26	6.49	19.66	10.17	1.89	0.75	4.97	10.62
38	Hong Qiu	10.1371/journal.pone.0169985	40.51	Formulation	Ningbo	2.45	14.08	7.73	1.08	5.90	21.36	16.11	2.93	0.53	3.52	8.36
39	Hong Qiu	10.1371/journal.pone.0169985	38.78	Formulation	Ningbo	2.45	13.26	6.54	1.04	5.13	19.33	12.15	11.00	0.61	3.46	8.78
40	Hong Qiu	10.1371/journal.pone.0169985	38.9	Formulation	Ningbo	2.46	13.53	7.01	1.44	5.48	26.43	12.42	3.30	0.59	3.55	8.49
41	Hong Qiu	10.1371/journal.pone.0169985	40.36	Formulation	Ningbo	2.56	14.03	7.47	1.70	6.07	22.96	13.51	1.72	0.55	3.56	8.51
42	Zhixiang Gu	10.1016/j.cbpb.2018.12.003	61	Formulation	Ningde	3.55	15.88	7.12	0.74	8.56	17.57	12.23	1.64	1.16	6.48	11.93
43	Zhixiang Gu	10.1016/j.cbpb.2018.12.003	61	Formulation	Ningde	2.84	15.40	7.19	0.70	7.65	18.19	20.21	1.09	1.03	5.23	10.28
44	Zhixiang Gu	10.1016/j.cbpb.2018.12.003	61	Formulation	Ningde	2.26	14.90	7.76	0.64	6.57	19.69	26.62	0.72	0.77	3.87	7.37
45	Qi Wang	10.1007/s10695-019-00646-1	62	Formulation	Ningde	2.56	18.20	7.09	0.51	7.24	26.08	16.86	0.57	0.77	4.33	6.73
46	Yuting Wei	10.1016/j.aquaculture.2019.734281	55.36	Formulation	Ningde	3.21	23.29	6.45	2.42	6.89	20.86	15.04	1.78	0.80	3.45	6.56
47	Yuting Wei	10.1016/j.aquaculture.2019.734281	61.68	Formulation	Ningde	3.41	23.34	7.11	1.98	6.27	16.95	14.10	1.85	1.18	3.67	8.44
48	Yuting Wei	10.1016/j.aquaculture.2019.734281	63.9	Formulation	Ningde	3.74	24.57	7.31	2.11	6.74	18.72	15.80	1.81	0.75	3.76	5.70
49	Yuting Wei	10.1016/j.aquaculture.2019.734281	63.5	Formulation	Ningde	3.53	23.60	6.34	1.99	6.58	19.32	16.66	1.98	0.73	4.02	5.82
50	Yuting Wei	10.1016/j.aquaculture.2019.734281	63.07	Formulation	Ningde	4.15	24.91	6.53	1.64	6.99	19.61	14.63	1.74	0.72	4.10	6.27
51	Yuting Wei	10.1016/j.aquaculture.2019.734281	63.76	Formulation	Ningde	4.73	24.59	5.72	1.61	7.19	18.82	15.16	1.76	0.78	4.53	6.14

5. References

1. Duan Q, Mai K, Zhong H, Si L, Wang X. Studies on the nutrition of the large yellow croaker, *Pseudosciaena crocea* R. I: growth response to graded levels of dietary protein and lipid. Aquaculture Research. 2001; 32(1):46-52.
2. Mu H, Shen H, Liu J, Xie F, Zhang W, Mai K. High level of dietary soybean oil depresses the growth and anti-oxidative capacity and induces inflammatory response in large yellow croaker *Larimichthys crocea*. Fish & Shellfish Immunology. 2018; 77:465-473.
3. Ai Q, Mai K, Tan B, Xu W, Duan Q, Ma H *et al.* Replacement of fish meal by meat and bone meal in diets for large yellow croaker, *Pseudosciaena crocea*. Aquaculture. 2006; 260:255-263.
4. Mai K, Wan J, Ai Q, Xu W, Liufu Z, Zhang L *et al.* Dietary methionine requirement of large yellow croaker, *Pseudosciaena crocea* R. Aquaculture. 2006; 253(1-4):564-572.
5. Mai K, Zhang C, Ai Q, Duan Q, Xu W, Zhang L *et al.* Dietary phosphorus requirement of large yellow croaker, *Pseudosciaena crocea* R. Aquaculture. 2006; 251(2-4):346-353.
6. Yi X, Xu W, Zhou H, Zhang Y, Luo Y, Zhang W *et al.* Effects of dietary astaxanthin and xanthophylls on the growth and skin pigmentation of large yellow croaker *Larimichthys croceus*. Aquaculture. 2014; 433:377-383.
7. Duan Q, Mai K, Shentu J, Ai Q, Zhong H, Jiang Y *et al.* Replacement of dietary fish oil with vegetable oils improves the growth and flesh quality of large yellow croaker (*Larmichthys crocea*). Journal of Ocean University of China. 2014; 13(3):445-452.
8. Li J, Zhang L, Mai K, Ai Q, Zhang C, Li H *et al.* Potential of several protein sources as fish meal substitutes in diets for large yellow croaker, *Pseudosciaena crocea* R. Journal of the World Aquaculture Society. 2010; 41:278-283.
9. Wang P, Zhu J, Feng J, He J, Lou Y, Zhou Q. Effects of dietary soy protein concentrate meal on growth, immunity, enzyme activity and protein metabolism in relation to gene expression in large yellow croaker *Larimichthys crocea*. Aquaculture. 2017; 477:15-22.
10. Mo WY, Lau RSS, Kwok ACK, Wong MH. Use of soybean meal and papain to partially replace animal protein for culturing three marine fish species: Fish growth and water quality. Environmental Pollution. 2016; 219:815-820.
11. Rostika R, Rahmanto F, Haetami K, Iskandar, Permana R. The use of various proportions of rough fish and pellets on the growth of giant trevally fish (*Caranx hippos*) in the east coast floating net cages (KJA Pantai timur), pangandaran. International Journal of Fisheries and Aquatic Studies. 2020; 8(1):197-200.
12. Aditi M, Varsha L. Fish processing: Product and by-product, processing and marketing. International Journal of Fisheries and Aquatic Studies. 2020; 8(1):74-77.
13. Wang Q, Mu H, Shen H, Gu Z, Liu D, Yang M *et al.* Comparative analysis of glucose metabolism responses of large yellow croaker *Larimichthys crocea* fed diet with fish oil and palm oil. Fish Physiology and Biochemistry. 2019; 45(5):1603-1614.
14. Chen Y, Huang W, Shan X, Chen J, Weng H, Yang T *et al.* Growth characteristics of cage-cultured large yellow croaker *Larimichthys crocea*. Aquaculture Reports. 2020; 16:100242.
15. Shen X, Yan X, Xu J. Fatty acid profiles in muscle of large yellow croakers (*Larimichthys crocea*) can be used to distinguish between the samples of Dai-qu stock and Min-yuedong stock. Biochemical Systematics and Ecology. 2018; 77:37-43.
16. Jiang L, Chen Y, Zhang J, Zhu A, Wu C, Liu L *et al.* Population structure of large yellow croaker (*Larimichthys crocea*) revealed by single nucleotide polymorphisms. Biochemical Systematics and Ecology. 2015; 63:136-142.
17. Casas SM, Filgueira R, Lavaud R, Comeau LA, La Peyre MK, La Peyre JF. Combined effects of temperature and salinity on the physiology of two geographically-distant

eastern oyster populations. Journal of Experimental Marine Biology and Ecology. 2018; 506:82-90.
18. Danezis GP, Tsagkaris AS, Camin F, Brusic V, Georgiou CA. Food authentication: Techniques, trends & emerging approaches. Trends in Analytical Chemistry. 2016; 85:123-132.
19. Camin F, Perini M, Bontempo L, Galeotti M, Tibaldi E, Piasentier E. Stable isotope ratios of H, C, O, N and S for the geographical traceability of Italian rainbow trout (*Oncorhynchus mykiss*). Food Chemistry. 2018; 267:288-295.
20. El Sheikha AF, Xu J. Traceability as a key of seafood safety: reassessment and possible applications. Reviews in Fisheries Science & Aquaculture. 2017; 25(2):158-170.
21. Shepard RN. Metric structures in ordinal data. Journal of Mathematical Psychology. 1966; 3(2):287-315.
22. Wang X, Li Y, Hou C, Gao Y, Wang Y. Influence of different dietary lipid sources on the growth, tissue fatty acid composition, histological changes and peroxisome proliferator-activated receptor γ gene expression in large yellow croaker (*Pseudosciaena crocea* R.). Aquaculture Research. 2012; 43(2):281-291.
23. Wei Y, Shen H, Xu W, Pan Y, Chen J, Zhang W *et al*. Replacement of dietary fishmeal by Antarctic krill meal on growth performance, intestinal morphology, body composition and organoleptic quality of large yellow croaker *Larimichthys crocea*. Aquaculture. 2019; 512(15):734281.
24. Caballero MJ, Obach A, Rosenlund G, Montero D, Gisvold M, Izquierdo MS. Impact of different dietary lipid sources on growth, lipid digestibility, tissue fatty acid composition and histology of rainbow trout, *Oncorhynchus mykiss*. Aquaculture. 2002; 214(1-4):253-271.
25. Sotoudeh E, Kenari AA, Rezaei MH. Growth response, body composition and fatty acid profile of Caspian brown trout (*Salmo trutta Caspius*) juvenile fed diets containing different levels of soybean phosphatidylcholine. Aquaculture International. 2011; 19(4):611-623.
26. Qiu H, Jin M, Li Y, Lu Y, Hou Y, Zhou Q. Dietary Lipid Sources Influence Fatty Acid Composition in Tissue of Large Yellow Croaker (*Larmichthys crocea*) by Regulating Triacylglycerol Synthesis and Catabolism at the Transcriptional Level. Plos One. 2017; 12(1):e0169985.
27. Tang H, Wu T, Zhao Z, Pan X. Biochemical composition of large yellow croaker (*Pseudosciaena crocea*) cultured in China. Journal of Food Quality. 2008; 31(3):382-393.
28. Li X, Li B, Chen N, Huang X, Hua X, Leng X. A comparison study on flesh quality of large yellow croaker (*Larimichthys croceus*) cultured with three different modes. Journal of Ocean University of China. 2017; 16(6):1187-1194.
29. Ma R, Meng Y, Zhang W, Mai K. Comparative study on the organoleptic quality of wild and farmed large yellow croaker *Larimichthys crocea*. Journal of Oceanology and Limnology. 2020; 38:260-274.
30. Zuo R, Ai Q, Mai K, Xu W, Wang J, Xu H *et al.* Effects of dietary n-3 highly unsaturated fatty acids on growth, nonspecific immunity, expression of some immune related genes and disease resistance of large yellow croaker (*Larmichthys crocea*) following natural infestation of parasites (*Cryptocaryon irritans*). Fish & Shellfish Immunology. 2012; 32(2):249-258.
31. Watanabe T. Lipid nutrition in fish. Comparative Biochemistry and Physiology Part B: Comparative Biochemistry. 1982; 73(1):3-15.
32. Izquierdo MS, Fernandez-Palacios H, Tacon AGJ. Effect of broodstock nutrition on reproductive performance of fish. Aquaculture. 2001; 197(1-4):25-42.
33. Zuo R, Ai Q, Mai K, Xu W, Wang J, Xu H *et al.* Effects of dietary docosahexaenoic to eicosapentaenoic acid ratio (DHA/EPA) on growth, nonspecific immunity, expression of some immune related genes and disease resistance of large yellow croaker (*Larmichthys crocea*) following natural infestation of parasites (*Cryptocaryon irritans*). Aquaculture. 2012; 334:101-109.