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Effect of Lipid Levels on the Growth Performance and Hepatic Lipid Deposition in the Post-Larval Coho Salmon (*Oncorhynchus kisutch*)

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Abstract: In this study, the effect of different lipid levels (6.6, 10.56, 15.43, 18.91, 22.52 and 26.91%) on the body composition, growth performance and lipid deposition was investigated in the post-larval coho salmon (*Oncorhynchus kisutch*). The results showed that the optimum lipid level for post-larval coho salmon was 15.8% based on the Specific Growth Ratio (SGR). Moreover, 15.43, 18.91, 22.52 and 26.91% lipid levels significantly elevated the content of crude lipid in fish. However, the moisture, ash and crude protein was not significantly influenced by various lipid levels. The lipid levels of 18.91, 22.52 and 26.91% significantly elevated the content of TC, TG and NEFA, whereas significantly decreased the activity of FAS, ACC and ACL in the liver of coho salmon. In addition, the higher lipid levels significantly increased the activity of HL and LPL in liver. The total content of Saturated Fatty Acids (SFA) was increased but that of Polyunsaturated Fatty Acids (PUFA) was decreased by 18.91, 22.52 and 26.91% lipid levels. In all, the appropriate lipid levels had positive effects on the growth performance and hepatic lipid deposition of the post-larval coho salmon. Our results will be beneficial for optimizing the use of lipid in the diets of Coho salmon.

Keywords: Lipid Levels, Fatty Acid Composition, Growth, Lipid Deposition, Coho Salmon

Introduction

As one of main components of fish diets, lipid is a key energy substance for the growth of fish species. Moreover, lipid not only provides the essential fatty acids, phospholipids and steroids, but also promotes the absorption and transportation of fat-soluble vitamins (Panserat *et al.*, 2019; Paulino *et al.*, 2020). Previously, the effects of lipid levels on fish growth have been studied in *Rachycentron canadum*, *Oncorhynchus mykiss* and *Sillago sihama* (Liu *et al.*, 2021; Song *et al.*, 2018; Wang *et al.*, 2005). It is found that the appropriate lipid levels in diets are beneficial for fish growth. However, the insufficient supply of dietary lipids will lead to the deficiency of the essential fatty acids and affect fish growth.

Recently, with the increasing usage of high-fat diets in the fish aquaculture, the negative effects of excessive dietary lipids has been observed in some fish species (Gou *et al.*, 2019; Hua *et al.*, 2019; López *et al.*, 2006). The high dietary lipid levels not only affect the absorption and utilization of nutrients, but also lead to the abnormal hepatic or visceral lipid deposition in fish species (Cai *et al.*, 2017; Paulino *et al.*, 2020). In addition, the abnormal lipid deposition further affects the lipid metabolism and immunity of fish (Mir *et al.*, 2020). Thus, the studies on dietary lipid levels will make a better use of lipid in fish aquaculture. Moreover, the digestive ability is different for the different growth stages of fish species. The significant differences on the nutrients demand have been observed in the different growth stages of fish species

(Alam *et al.*, 2020; Busti *et al.*, 2020; Canosa and Bertucci, 2020; Lopes *et al.*, 2021; Pereira *et al.*, 2019).

In addition, it is known that fat has the protein saving effect in animals (Silva-Brito *et al.*, 2019; Tian *et al.*, 2015; Xie *et al.*, 2021). The protein sparing effect by fat has been observed in various studies and the protein utilization could be promoted by adding suitable lipid levels in fish diets (Jiang *et al.*, 2015; Wang *et al.*, 2005; 2019). Furthermore, the protein sparing effect could decrease the discharge of nitrogen-containing waste into the water environment (Watanabe, 2002). Recently, the study on optimizing dietary lipid levels has been given more attention (Nayak *et al.*, 2018). Therefore, in the current study, the effect of lipid levels on the growth performance, body composition, fat acid composition and hepatic lipid deposition was to be investigated in the post-larval coho salmon (*Oncorhynchus kisutch*).

Materials and Methods

Experimental Diets

Six diets were formulated by adding 6 levels of lipid into diets (Table 1). The diets were made by using a double-screw extruder and dried in a ventilated oven for 12 h at 40°C. The final concentration of lipid in diets was 6.6, 10.56, 15.43, 18.91, 22.52 and 26.91% after detected with Folch method (Folch *et al*., 1957). Then the following experiments were performed as the process map (Fig. 1).

Animals and Procedures

The coho salmon (0.39±0.03 g) were put into 18 tanks (100 fish in each tank) with continuous aeration and freshwater in a re-circulating aquaculture system (Linyi, China). After 2-weeks' acclimatization, each lipid level diet was assigned to three tanks, respectively. Then fish were fed to satiation four times daily (7:00, 10:30, 14:00 and 17:30) at about 5% of whole body weight for 12 weeks. All animal procedures were approved by Weifang University of China's Institutional Animal Care Committee.

Sample Collection

12 weeks later, the total number of fish in each tank were counted and fish were deprived of feed for 24 h before sampling. Then fish were anaesthetized with 0.1 g/L MS 222 and weighed to determine the growth performance. 12 fish were randomly sampled from each tank for analyzing crude protein, crude lipid, Dry Matter (DM) and ash in whole fish body, respectively. Moreover, the livers were sampled from 10 fish in each tank for detecting the activities of enzymes related to lipid metabolism.

Proximate Composition Analysis

Crude protein levels in the diets and whole body were detected from the determination of total nitrogen by Kjeldahl digestion (Kjeltec 8400, Foss Tecator, Sweden). The crude lipid content in samples was detected with Folch method (Folch *et al.*, 1957). The water content was assayed by drying at 105°C and the ash content was estimated through combustion using a muffle furnace at 550°C for 4 h.

Growth Performance and Feed Utilization Analysis

The calculation formulae for the growth performance and feed utilization are as follows:

- Survival (%) = 100 × (final amount of fish)/(initial amount of fish)
- Specific Growth Ratio (SGR) = 100 × [ln (final body weight) -ln (initial body weight)]/days
- Hepatosomatic Index (HSI) = [100 × (liver weight/body weight)]
- Viscerosomatic Index (VSI) = [100 × (viscera weight/body weight)]
- Condition Factor (CF) = (body weight/body length^3) × 100
- Feed Conversion Rate (FCR) = feed intake/(final body weight-initial body weight)

Assay the Activities of Lipid Metabolism Enzymes

Liver samples were homogenized in 0.1 M pH 7.4 Tris-HCl buffer at 4°C and the supernatants were collected for enzyme analysis. The activities of Hepaticlipase (HL) and Lipoprteinlipase (LPL) as well as the levels of Nonesterified Fatty Acids (NEFA), Total Cholesterol (TC) and Triglyceride (TG) were assayed with the commercial kits (Nanjing Jiancheng Bioengineering Institute, China). The activities of Acetyl-CoA Carboxylase (ACC), ATP-Citrate lyaSE (ACL) and Fatty Acid Synthetase (FAS) were assayed with the commercial kits purchased from Zhuocai biology Co., Ltd. (Shanghai, China).

Fatty Acid Analysis

The liver samples were freeze-dried for 48 h and the fatty acid contents were detected with a GC-MS chromatograph (Agilent Technologies 7890-5977A, USA) according to a previous method (Xu *et al.*, 2010).

Statistical Analysis

Data were presented as mean values ± standard error of mean (s.e.m). SPSS 16.0 (SPSS Inc., 2005, USA) was used to perform the statistical analyses. Regression analysis was used for analyzing the optimum lipid level. In addition, the normality and homogeneity of variances among groups were tested and results were subjected to one-way Analysis of Variance (ANOVA) followed by Tukey's test. Differences were considered significant at $P<0.05$.

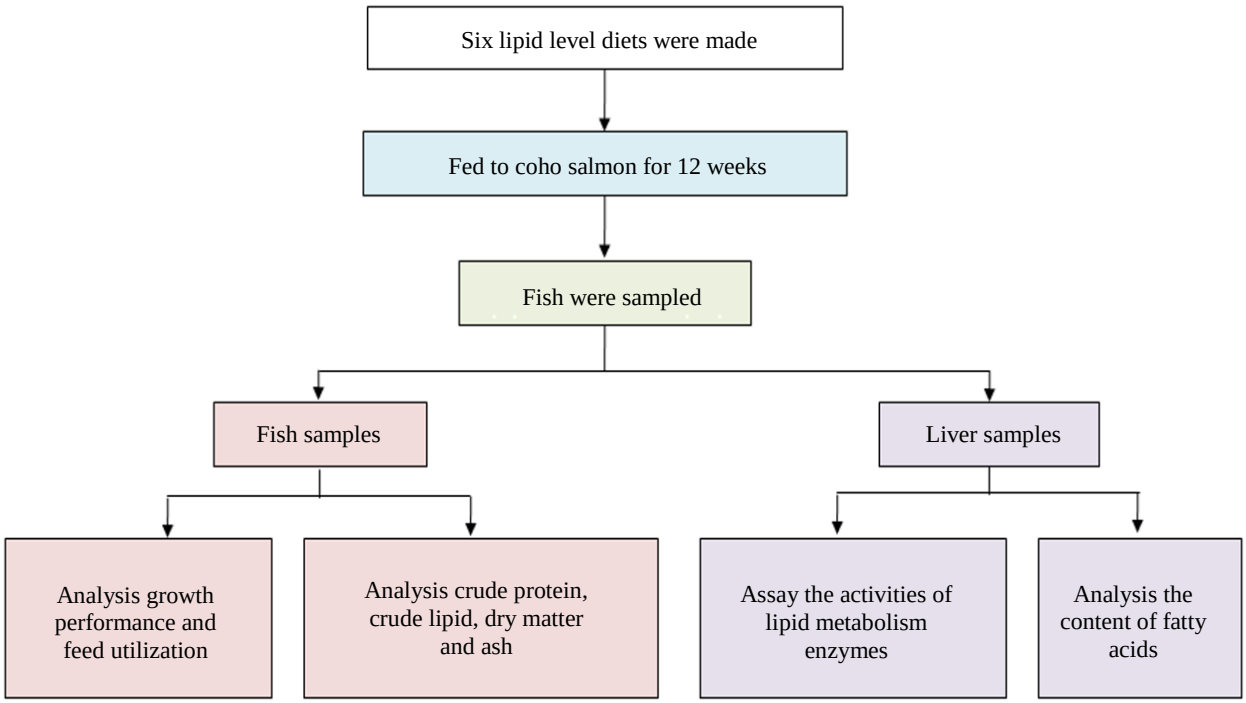


Fig. 1: The process map of the experiment. Six lipid level diets were made and fed to Coho salmon for 12 weeks. Then fish were sampled for various analysis

Table 1: Formulation and proximate composition of the experimental diets (% in dry matter)

	Dietary lipid levels (%)					
Ingredients	6.6	10.56	15.43	18.91	22.52	26.91
Fish meal[1]	40.00	40.00	40.00	40.00	40.00	40.00
Hydrolyzed fish meat protein[1]	5.00	5.00	5.00	5.00	5.00	5.00
Soybean meal[1]	20.00	20.00	20.00	20.00	20.00	20.00
Peanut meal[1]	9.80	9.80	9.80	9.80	9.80	9.80
α-Starch[1]	20.00	16.00	12.00	8.00	4.00	0.00
Sodium alginate[1]	2.00	2.00	2.00	2.00	2.00	2.00
Soybean lecithin[1]	1.80	1.80	1.80	1.80	1.80	1.80
Fish oil[1]	0.00	2.00	4.00	6.00	8.00	10.00
Soybean oil[1]	0.00	2.00	4.00	6.00	8.00	10.00
Mineral premix[2]	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix[3]	0.50	0.50	0.50	0.50	0.50	0.50
Ascorbic acid phosphate	0.10	0.10	0.10	0.10	0.10	0.10
Choline chloride	0.25	0.25	0.25	0.25	0.25	0.25
Ethoxyquin	0.05	0.05	0.05	0.05	0.05	0.05
Proximate composition						
Moisture (%)	7.31	7.26	7.27	7.11	7.18	7.20
Crude protein (%)	45.73	45.90	45.90	45.73	46.00	46.01
Crude lipid (%)	6.60	10.56	15.43	18.91	22.52	26.91
Ash (%)	11.06	10.96	10.83	10.82	10.52	10.79

[1]Provided by Shandong Conqueren Marine Technology Co., Ltd., Weifang, China

[2]Composition (mg kg^{-1} mineral premix): $AlK(SO_4)_2 \cdot 12H_2O$, 123.7; $CaCl_2$, 17879.8; $CuSO_4 \cdot 5H_2O$, 31.7; $CoCl_2 \cdot 6H_2O$, 48.9; $FeSO_4 \cdot 7H_2O$, 707.4; $MgSO_4 \cdot 7H_2O$, 4316.8; $MnSO_4 \cdot 4H_2O$, 31.1; $ZnSO_4 \cdot 7H_2O$, 176.7, KCl, 1191.9; KI, 5.3; NaCl, 4934.5; $Na_2SeO_3 \cdot H_2O$, 3.4; Ca $(H_2PO_4)_2 \cdot H_2O$, 12457.0; KH_2PO_4, 9930.2

[3]Composition (IU or g kg^{-1} vitamin premix): Retinal palmitate, 10,000 IU; cholecalciferol, 4,000 IU; *α*-tocopherol, 75.0 IU; menadione, 22.0 g; thiamine-HCl, 40.0 g; riboflavin, 30.0 g; D-calcium pantothenate, 150.0 g; pyridoxine-HCl, 20.0 g; meso-inositol, 500.0 g; D-biotin, 1.0 g; folic acid, 15.0 g; ascorbic acid, 200.0 g; niacin, 300.0 g; cyanocobalamin, 0.3 g

Results

Effect of Different Lipid Levels on the Growth Performance and Feed Utilization of Coho Salmon

Compared to the control, the lipid levels of 10.56, 15.43, 18.91, 22.52 and 26.91% had no significant difference on the survival rate (Table 2). The final body weight was significantly increased by 10.65, 15.43, 18.91 and 22.52% lipid levels (Table 2). In addition, the lipid levels of 15.43 and 18.91% significantly increased SGR, but the lipid level of 26.91% significantly increased FCR (Table 2). The results showed that the optimum lipid level was 15.8% based on SGR analysis (Fig. 2). However, no significant difference was observed on CF, HSI and VSI among various lipid levels treatments (Table 2).

Effect of Different Lipid Levels on the Proximate Composition of Coho Salmon

Compared to the control, 15.43, 18.91, 22.52 and 26.91% lipid levels significantly increased the content of crude lipid in the whole body of Coho salmon (Table 3). However, there was no significant difference between 6.60 and 10.56% lipid level treatments (Table 3). In addition, no significant difference was observed on moisture, ash and crude protein in the whole body among various lipid level treatments (Table 3).

Effect of Different Lipid Levels on the Activity of Lipid Metabolism Enzymes in the Liver of Coho Salmon

The treatments of 10.56, 15.43, 18.91, 22.52 and 26.91% lipid levels significantly enhanced the activity of HL in liver (Table 4). Moreover, the activity of LPL was significantly elevated by 15.43, 18.91 and 22.52% lipid levels (Table 4). The lipid levels of 18.91, 22.52 and 26.91% significantly decreased the activity of FAS in liver (Fig. 3A). Furthermore, the activities of ACC and ACL were significantly decreased by the lipid levels of 18.91, 22.52 and 26.91% (Fig. 3B and 3C). No significant difference was found on the activity of FAS, ACC and ACL between the lipid levels of 6.60, 10.56 and 15.43% (Fig. 3A and 3C).

Effect of Different Lipid Levels on the Lipid Deposition Indexes in the Liver of Coho Salmon

Compared to the control, the lipid levels of 18.91, 22.52 and 26.91% significantly increased the content of TG and TC in liver (Fig. 4A and 4B). Moreover, the content of NEFA was significantly increased by the lipid levels of 18.91, 22.52 and 26.91% (Fig. 4C). No significant difference was found on the content of TG, TC and NEFA between 6.60, 10.56 and 15.43% lipid level treatments (Fig. 4A and 4C).

Effect of Lipid Levels on the Fatty Acid Profiles in the Liver of Coho Salmon

The content of C16:0, C14:0 and C18:0 fatty acids was significantly increased, but that of C18:1n-9 and C22:1n-9 was significantly decreased by the lipid levels of 18.91, 22.52 and 26.91% (Table 5). The content of C20:5n-3, C18:2n-6 and C22:6n-3 was significantly decreased by the lipid levels of 18.91, 22.5 and 26.91% (Table 5) and the content of C18:3n-3 was significantly decreased by the lipid levels of 22.52 and 26.91% (Table 5). Moreover, the total content of Saturated Fatty Acid (SFA) was significantly increased but that of Polyunsaturated Fatty Acid (PUFA) was significantly decreased by 18.91, 22.52 and 26.91% lipid level treatments (Table 5).

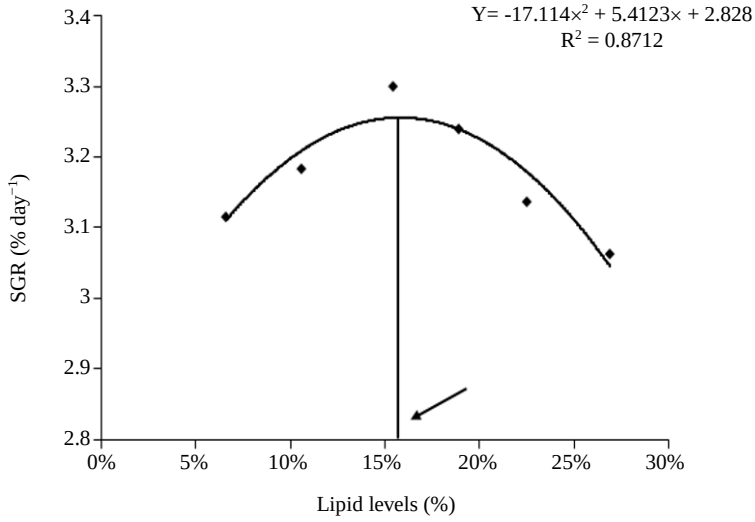
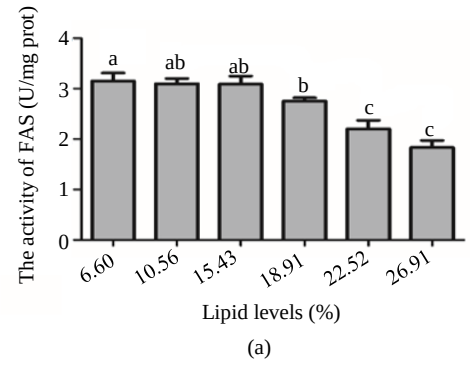
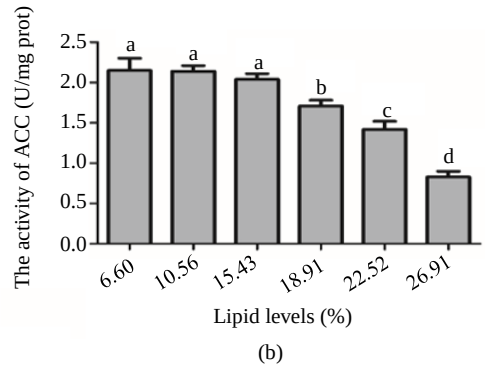


Fig. 2: The optimum dietary lipid level for post-larval Coho salmon. The optimum lipid level was 15.8% based on SGR for Coho salmon



(a)



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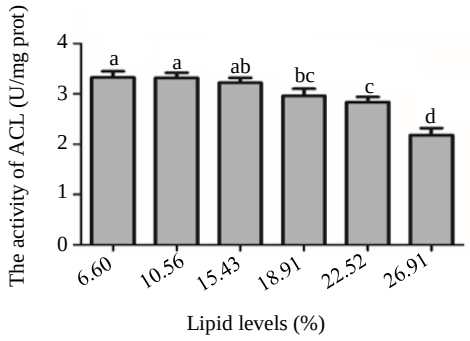
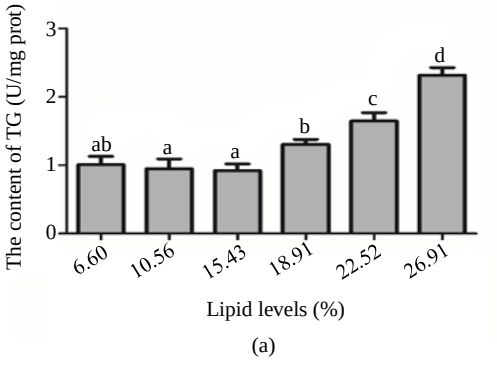
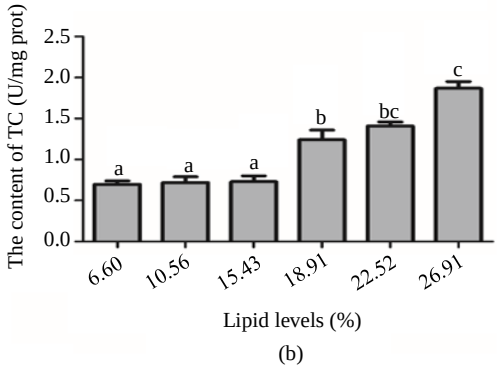


(c)

Fig. 3: Effect of different lipid levels on the activity of FAS, ACC and ACL in liver. (A) Effect of different lipid levels on the activity of FAS. (B) Effect of different lipid levels on the activity of ACC. (C) Effect of different lipid levels on the activity of ACL



(a)



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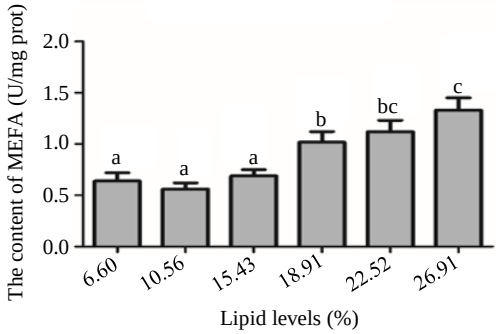

(c)

Fig. 4: Effect of different lipid levels on the content of TG, TC and NEFA in liver. (A) Effect of different lipid levels on the content of TG. (B) Effect of different lipid levels on the content of TC. (C) Effect of different lipid levels on the content of NEFA

Table 2: Effect of lipid levels on the growth performance and feed utilization

lipid levels	6.60%	10.56%	15.43%	18.91%	22.52%	26.91%
Survival rate (%)	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}
Initial body weight (g)	0.38±0.02^{a}	0.39±0.01^{a}	0.38±0.02^{a}	0.38±0.03^{a}	0.39±0.01^{a}	0.39±0.02^{a}
Final body weight (g)	5.24±0.07^{ab}	5.65±0.09^{c}	6.13±0.10^{d}	5.77±0.07^{c}	5.43±0.06^{b}	5.06±0.05^{a}
SGR (% day^{-1})	3.11±0.04^{ab}	3.18±0.04^{abc}	3.30±0.06^{c}	3.24±0.09^{bc}	3.14±0.02^{ab}	3.06±0.07^{a}
CF	1.23±0.15^{a}	1.27±0.02^{a}	0.99±0.07^{a}	1.08±0.20^{a}	1.19±0.03^{a}	1.31±0.12^{a}
FCR	0.90±0.02^{ab}	0.89±0.02^{ab}	0.87±0.03^{a}	0.89±0.04^{a}	0.91±0.04^{ab}	0.98±0.03^{b}
HSI	1.15±0.02^{a}	1.28±0.20^{a}	1.26±0.06^{a}	1.13±0.06^{a}	1.04±0.01^{a}	1.26±0.15^{a}
VSI	1.03±0.04^{a}	1.04±0.18^{a}	1.43±0.18^{a}	1.22±0.07^{a}	1.45±0.21^{a}	1.30±0.05^{a}

Values are expressed as means ± s.e.m. (n = 3). Statistically significant differences are denoted by different letters (P<0.05)

Table 3: Effect of lipid levels on the whole-body composition of coho salmon

lipid levels	6.60%	10.56%	15.43%	18.91%	22.52%	26.91%
Moisture (%)	76.98±0.69^{a}	77.45±0.02^{a}	76.91±0.26^{a}	77.85±0.14^{a}	77.98±0.58^{a}	78.27±0.67^{a}
Crude protein (%)	12.26±0.49^{a}	12.42±0.26^{a}	12.37±0.04^{a}	13.58±0.83^{a}	13.02±0.19^{a}	12.68±0.01^{a}
Crude lipid (%)	3.79±0.62^{a}	4.70±0.15^{ab}	5.63±0.36^{bc}	6.23±0.07^{c}	6.40±0.24^{c}	6.22±0.66^{c}
Ash (%)	3.29±0.10^{a}	3.29±0.01^{a}	3.20±0.02^{a}	3.24±0.02^{a}	3.24±0.01^{a}	3.21±0.01^{a}

Values are expressed as means ± s.e.m. (n = 3). Statistically significant differences are denoted by different letters (P<0.05)

Table 4: Effect of lipid levels on the activity of HL and LPL in the liver of coho salmon

lipid levels	6.60%	10.56%	15.43%	18.91%	22.52%	26.91%
HL (U/g prot.)	0.52±0.03^{a}	0.65±0.01^{b}	0.68±0.03^{b}	0.69±0.01^{b}	0.76±0.01^{c}	0.70±0.01^{bc}
LPL (U/g prot.)	0.48±0.01^{a}	0.49±0.02^{a}	0.57±0.02^{bc}	0.58±0.01^{c}	0.58±0.03^{c}	0.52±0.01^{ab}

Values are expressed as means ± s.e.m. (n = 3). Statistically significant differences are denoted by different letters (P<0.05)

Table 5: Effect of lipid levels on the fatty acid composition in the liver (% total fatty acids)

	lipid levels					
Fatty acid (%)	6.60%	10.56%	15.43%	18.91%	22.52%	26.91%
C14:0	1.61±0.07^{a}	1.64±0.03^{a}	1.66±0.05^{a}	2.21±0.11^{b}	3.32±0.10^{c}	3.20±0.12^{c}
C16:0	22.25±0.22^{a}	22.35±0.12^{a}	22.18±0.20^{a}	23.83±0.41^{b}	24.76±0.21^{b}	24.67±0.48^{b}
C18:0	9.29±0.16^{a}	9.21±0.13^{a}	9.33±0.11^{a}	12.01±0.13^{b}	13.83±0.28^{c}	13.63±0.38^{c}
∑SFA	33.14±0.45^{a}	33.20±0.28^{a}	33.17±0.36^{a}	38.05±0.64^{b}	41.82±0.59^{c}	41.50±0.97^{c}
C16:1n-7	3.14±0.08^{a}	3.19±0.03^{a}	3.07±0.04^{a}	3.21±0.16^{a}	3.46±0.08^{a}	3.26±0.13^{a}
C18:1n-9	16.29±0.15^{a}	16.33±0.11^{a}	16.38±0.17^{a}	14.95±0.14^{b}	13.41±0.11^{c}	13.11±0.10^{c}
C20:1n-9	2.29±0.08^{a}	2.22±0.03^{a}	2.27±0.05^{a}	2.39±0.06^{a}	2.48±0.12^{a}	2.43±0.10^{a}
C22:1n-9	3.25±0.15^{a}	3.36±0.12^{a}	3.21±0.09^{a}	2.21±0.17^{b}	2.23±0.11^{b}	2.19±0.13^{b}
∑MUFA	24.97±0.45^{a}	25.10±0.29^{a}	24.93±0.35^{a}	22.76±0.54^{b}	21.58±0.34^{c}	20.99±0.46^{c}
C18:2n-6	5.52±0.09^{a}	5.42±0.11^{a}	5.56±0.08^{a}	5.25±0.05^{b}	5.23±0.09^{b}	5.18±0.14^{b}
C18:3n-3	1.94±0.07^{a}	1.91±0.04^{a}	1.84±0.08^{a}	1.21±0.07^{a}	1.57±0.06^{b}	1.46±0.12^{b}
C20:5n-3	6.77±0.06^{a}	6.72±0.05^{a}	6.83±0.07^{a}	5.19±0.14^{b}	4.34±0.12^{c}	4.24±0.20^{c}
C20:4n-6	5.35±0.14^{a}	5.31±0.09^{a}	5.45±0.16^{a}	5.36±0.06^{a}	5.51±0.19^{a}	5.39±0.14^{a}
C22:6n-3	23.29±0.15^{a}	23.19±0.19^{a}	23.25±0.11^{a}	22.43±0.39^{b}	21.54±0.08^{c}	21.40±0.19^{c}
∑PUFA	42.87±0.51^{a}	42.55±0.48^{a}	42.93±0.50^{a}	39.45±0.71^{b}	38.19±0.54^{c}	37.87±0.79^{c}

Values are expressed as means ± s.e.m. (n = 3). Statistically significant differences are denoted by different letters (P<0.05)

Discussion

The essential fatty acids derived from lipids play a key role for the developmental, physiological and reproductive functions of fish species (Kandathil Radhakrishnan *et al.*, 2020; Kumar *et al.*, 2018; Pamungkas *et al.*, 2020). Nevertheless, the excessive or insufficient dietary lipid levels may have negative effects on muscle quality, growth and disease resistance of fish species (Liu *et al.*, 2021; Xu *et al.*, 2020). Previously, it is observed that the appropriate content of lipid levels in diets improves the growth performance of *Micropterus salmoides*, *Oncorhynchus mykiss* and *Scylla paramamosain* (Guo *et al.*, 2019; Meng *et al.*, 2019; Xu *et al.*, 2020). In this study, the final body weight was significantly increased by 10.65, 15.43, 18.91 and 22.52% lipid levels in the post-larval Coho salmon, which was consistent with these previous studies. Moreover, it has been found that the growth performance of large yellow croaker was not affected by moderate (12% lipid level) and high (18% lipid level) dietary lipid levels (Yan *et al.*, 2015). For grass carp, the lipid level of 40 g/kg has better effect on feed utilization and growth performance (Yuan *et al.*, 2016). Our results showed that the optimum lipid level was 15.8% based on SGR and the appropriate lipid level had positive effect on the growth performance of Coho salmon. Thus, the different of lipid levels may be required for different fish species. In addition, our results will be beneficial for optimizing the use of lipid in the diets of Coho salmon.

In a previous study, the level of NEFA and TG was elevated in large yellow croaker fed with a higher lipid level diet (18% lipid level) (Yan *et al.*, 2015). However, 6% lipid level diet decreased the hepatic lipid content in the large yellow croaker (Yan *et al.*, 2015). In our study, the lipid levels of 15.43, 18.91, 22.52 and 26.91 significantly increased the content of crude lipid. However, no significant difference was observed on moisture, ash and crude protein in six lipid level treatments. In addition, the higher lipid levels 18.91, 22.52 and 26.91% significantly increased the level of TC, TG and NEFA in the liver of Coho salmon, which was consistent with the previous study.

In the liver of grass carp, the biosynthesis of fatty acids was inhibited following the increase of lipid uptake (Yuan *et al.*, 2016). In the present study, the lipid levels of 18.91, 22.52 and 26.91% decreased the activity of ACC, FAS and ACL in liver, but the lower lipid levels had no significant difference on these enzymes. In addition, the higher lipid levels enhanced the activity of HL and LPL in the liver of Coho salmon. It demonstrated that the different lipid levels affected the activities of FAS, ACC, ACL, HL and LPL, which may result in the difference on the hepatic lipid deposition.

In a previous study, the higher SGR and whole-body lipid content as well as the lower FCR were observed at a higher fish oil level (120 g/kg diet) in silver barb (Nayak *et al.*, 2018). The level of SFA was increased, whereas MUFA level was decreased by higher fish oil levels in the muscle of silver barb (Nayak *et al*., 2018). In our study, the total content of SFA was increased but that of PUFA was decreased by 18.91, 22.52 and 26.91% lipid levels. It showed that the lipid levels affected the levels of SFA and PUFA. Previously, the content of n-3 LC-PUFA and n-3 PUFA was increased with the increase of fish oil levels in the liver and muscle of silver barb (Nayak *et al*., 2018). The difference maybe that the content of SFA and PUFA was related to the different fish species and growth stages of fish.

Conclusion

In summary, the effect of different lipid levels on the body composition, growth and lipid deposition was investigated in the post-larval Coho salmon. The results showed that the appropriate lipid levels had positive effect on growth performance. The higher levels of lipid treatments decreased the activity of enzymes related to lipid deposition, while increased the level of TC, TG and NEFA in liver. The total content of SFA was increased but PUFA was decreased by the higher levels of lipid treatments. In all, the appropriate lipid levels had positive effects on the growth performance and hepatic lipid deposition in the post-larval Coho salmon. The results will be beneficial for optimizing the use of lipid in the diets of Coho salmon.

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Author's Contributions

Hairui Yu and Jinqing Wang: Participated in all experiments and coordinated the data-analysis of the manuscript.

Dongwu Liu: Designed the research plan and organized the study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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