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Effect of Dietary Protein and Lipid Levels on Compensatory Growth of Juvenile Olive Flounder (*Paralichthys olivaceus*) Reared in Suboptimal Temperature

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ABSTRACT : Effect of dietary protein and lipid levels on compensatory growth of juvenile olive flounder (*Paralichthys olivaceus*) was determined in suboptimal temperature (13.4±1.42°C). Five hundred forty fish averaging 79.2 g were randomly distributed into 27 of 300 L flow-through tanks (20 fish/tank). Nine treatments were prepared in triplicate: fish were hand-fed with control (C) diet for 10 weeks (10WF-C); four fish groups were starved for 1 week and then fed with C, high protein (HP), high lipid (HL) and combined high protein and high lipid (HPL) diets for 9 weeks, referred to as 9WF-C, 9WF-HP, 9WF-HL, 9WF-HPL, respectively; and other four fish groups were starved for 2 weeks and then fed with C, HP, HL and HPL diets for 8 weeks, referred to as 8WF-C, 8WF-HP, 8WF-HL and 8WF-HPL, respectively. Weight gain and specific growth rate of fish in 9WF-HP, 9WF-HPL, 8WF-HP and 8WF-HPL treatments were higher than those of fish in 9WF-HL and 8WF-HL treatments. Feed efficiency of fish in 8WF-HP treatment was higher than that of fish in 9WF-C, 9WF-HL and 8WF-HL treatments. Protein efficiency ratio of fish in 10WF-C, 8WF-C, 8WF-HP and 8WF-HPL treatments was higher that that of fish in 9WF-HL and 8WF-HL treatments. Juvenile olive flounder subjected to 2-week feed deprivation could achieve full compensatory growth with dietary supplementation of protein or combined high protein and high lipid. (**Key Words :** Olive Flounder (*Paralichthys olivaceus*), Compensatory Growth, Dietary Protein, Dietary Lipid, Suboptimal Temperature)

INTRODUCTION

Full compensatory growth was achieved in juvenile olive flounder (*Paralichthys olivaceus*) subjected to the first 2-week feed deprivation in the 8-week feeding trials in the earlier studies (Cho, 2005; Cho et al., 2006). However, compensatory growth of fish varied depending on fish species, fish size, dietary nutrient content, duration of feeding trial, feeding regime, social factors and physiological/nutritional state of fish (Bilton and Robins, 1973; Jobling et al., 1994; Rueda et al., 1998; Hayward et al., 2000; Gaylord and Gatlin, 2000, 2001; Wang et al., 2000; Ali et al., 2003; Oh et al., 2007; Cho and Cho, 2009; Cho et al., 2010). In addition, growth of fish was critically affected by ambient temperature and usually suppressed at lower temperatures within an acceptable range due to slow metabolism and low feed consumption (Andrews and Stickney, 1972; Kilambi and Robinson, 1979; Iwata et al., 1994; Koskela et al., 1997; Yamamoto et al., 2007).

Optimum temperature for growth of olive flounder was reported to be 20-25°C (Iwata et al., 1994). Growth is relatively slow at low temperature in winter season or suboptimal temperature in early spring. Therefore, in Eastern Asia, fish farmers should manage fish differently from that practiced under optimal temperatures in late spring through early fall. Since, olive flounder must overwinter to attain marketable size, in low or suboptimal temperature conditions, application of compensatory growth can effectively improve production of fish. Juvenile olive flounder were able to achieve full compensatory growth when fish were reared at 22.0°C for the next 30 days after subjected to various temperature as low as 8.5°C (8.5, 13.0, 17.5, 22.0 and 26.5°C) for 10 days (Huang et al., 2008).

Because lipid in fish is primarily utilized as an energy source for the maintenance of basal metabolism and survival (Miglavs and Jobling, 1989; Rueda et al., 1998; Gaylord and Gatlin, 2000), fasting resulted in reduction in body fat. Body weight of olive flounder was linearly reduced in proportion to weeks of feed deprivation (Cho,

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2005; Cho et al., 2006). In addition, increasing dietary protein levels from 32% to 37% seemed to have desirable effect on compensatory growth of channel catfish (*Ictalurus punctatus*) (Gaylord and Gatlin, 2001). Hence, manipulation of dietary nutrient, especially protein and lipid levels could affect performance of fish achieving compensatory growth.

In this study, effect of dietary protein and lipid levels on compensatory growth of juvenile olive flounder was determined in suboptimal temperature.

MATERIALS AND METHODS

Fish and the experimental conditions

Juvenile olive flounder were purchased from a private hatchery and acclimated to the experimental conditions for 3 weeks. During the acclimation period, fish were hand-fed with commercial extruded pellet (52% crude protein and 12% crude lipid) twice a day. Five hundred forty fish (an initial body weight of fish: 79.2±0.29 g) were chosen and randomly distributed into 27 of 300 L flow-through tanks (20 fish/tank). The water source was the sand-filtered natural seawater and aeration supplied to each tank. The flow rate of water into each tank was 8.6 L/min. Water temperature ranged from 10.9°C to 16.2°C (mean±SD: 13.4±1.42°C) and photoperiod followed natural condition.

Preparation of the experimental diets

Ingredient and nutrient composition of the experimental diets are given in Table 1. Four experimental diets were prepared: control (C), high protein (HP), high lipid (HL) and combined high protein and high lipid (HPL) diets. Crude protein and lipid content of C diet were 52.8% and 10.9%, respectively based on Yigit et al. (2004) and Lee and Kim (2005)'s studies proposing that optimum dietary protein levels are over 51-52% for juvenile olive flounder. Crude protein and lipid content in HP and HL diets was increased to 59.9% and 16.7% at the expense of cellulose. Crude protein and lipid content of the HPL diet was increased to 59.2% and 17.6%, respectively. Ingredients of the experimental diets were well mixed with water at the ratio of 7:3 and pelletized by a pellet-extruder. The experimental diets were dried overnight at room temperature and stored at -20°C until use.

Design of the feeding trial

Nine treatments were prepared in triplicate: fish were hand-fed with C diet twice a day, seven days a week, for 10

Table 1. Ingredients and nutrient composition (%, dry matter basis) of the experimental diets

	Experimental diets			
	C	HP	HL	HPL
Ingredient (%)				
Fishmeal[1]	40.00	47.00	40.00	47.00
Dehulled soybean meal[1]	23.00	23.00	23.00	23.00
Corn gluten meal[1]	15.00	15.00	15.00	15.00
Cellulose[2]	12.30	5.90	7.40	1.00
Carboxymethyl cellulose[2]	3.00	3.00	3.00	3.00
Soybean oil	4.60	4.00	9.50	8.90
Vitamin premix[3]	1.00	1.00	1.00	1.00
Mineral premix[4]	1.00	1.00	1.00	1.00
Choline	0.10	0.10	0.10	0.10
Nutrients (DM basis, %)				
Crude protein	52.80	59.90	53.00	59.20
Crude lipid	10.90	9.50	16.70	17.60
Ash	9.50	11.10	10.40	11.00
Fiber	13.60	7.20	8.70	1.30
NFE[5]	13.20	12.30	11.20	10.90
Estimated energy (kJ/g diet)[6]	17.50	16.90	18.50	18.60

[1] Fishmeal, dehulled soybean meal and corn gluten meal were supplied by Jeilfeed Co. Ltd. (Haman, Gyeongsangnam-do, Korea).
[2] Cellulose and Carboxymethyl cellulose were purchased from Sigma Chemical Co. (MO, USA).
[3] Vitamin premix contained the following amount which were diluted in cellulose (g/kg mix): L-ascorbic acid, 121.2; DL-α-tocopheryl acetate, 18.8; thiamin hydrochloride, 2.7; riboflavin, 9.1; pyridoxine hydrochloride, 1.8; niacin, 36.4; Ca-D-pantothenate, 12.7; myo-inositol, 181.8; D-biotin, 0.27; folic acid, 0.68; p-aminobenzoic acid, 18.2; menadione, 1.8; retinyl acetate, 0.73; cholecalciferol, 0.003; cyanocobalamin, 0.003.
[4] Mineral premix contained the following ingredients (g/kg mix): $MgSO_4 \cdot 7H_2O$, 80.0; $NaH_2PO_4 \cdot 2H_2O$, 370.0; KCl, 130.0; Ferric citrate, 40.0; $ZnSO_4 \cdot 7H_2O$, 20.0; Ca-lactate, 356.5; CuCl, 0.2; $AlCl_3 \cdot 6H_2O$, 0.15; KI, 0.15; $Na_2Se_2O_3$, 0.01; $MnSO_4 \cdot H_2O$, 2.0; $CoCl_2 \cdot 6H_2O$, 1.0.
[5] NFE calculated by differences.
[6] Estimated energy calculated based on 16.7 kJ/g for protein and carbohydrate, and 37.7 kJ/g for lipid (Garling and Wilson, 1976).

weeks (10WF-C), in the control group. Four fish groups were starved for 1 week and then fed with C, HP, HL and HPL diets twice a day for 9 weeks, referred to as 9WF-C, 9WF-HP, 9WF-HL and 9WF-HPL, respectively; and other four fish groups were starved for 2 weeks and then fed with C, HP, HL and HPL diets twice a day for 8 weeks, referred to as 8WF-C, 8WF-HP, 8WF-HL and 8WF-HPL, respectively. At 5th week after a commencement and the end of the 10-week trial, fish from each tank were collectively weighed.

Calculation of measurements

Total length and weight of five fish from each tank were individually measured at the end of 10-week trial and fish were dissected to obtain live weight and to determine the biological criteria; condition factor (CF) = body weight (g) ×100/total length (cm)^3 and hepatosomatic index (HSI) = liver weight (g)×100/body weight (g). Other criteria were calculated as follows; specific growth rate (SGR, %/d) = (Ln final weight of fish-Ln initial weight of fish)×100/days of feeding trial, feeding rate (FR) = (100×feed consumption of fish)/((initial weight of fish+final weight of fish)/2) /feeding day, feed efficiency (FE) = weight gain of fish/feed consumed, protein efficiency ratio (PER) = weight gain of fish/protein consumed, and protein retention (PR) = protein gain of fish/protein consumed.

Analysis of chemical composition

Five fish at the initiation and the termination of the 10-week trial were sampled and sacrificed for proximate analysis. Crude protein was determined by the Kjeldahl method (Kjeltec 2100 Distillation Unit, Foss Tecator, Hoganas, Sweden), crude lipid was determined using an ether-extraction method, moisture was determined by oven drying at 105°C for 24 h, fiber was determined using an automatic analyzer (Fibertec, Tecator, Sweden) and ash was determined using a muffle furnace at 550°C for 4 h, all methods were according to standard AOAC (1990).

Statistical analysis

One-way ANOVA and least significant difference (Fisher's LSD) test were used to analyze the significance ($p<0.05$) of the difference among the means of treatments by using SAS Program Version 9.1 (SAS Institute, Cary, NC, USA). All percentage data were arcsine-transformed prior to analysis.

RESULTS

Survival ranging from 90.0% to 98.9% was not significantly ($p>0.05$) different between treatments (Table 2). Weight of olive flounder in 10WF-C was significantly ($p<0.05$) higher than that of fish in all other treatments except for 9WF-HPL treatment at 5th week and 9WF-HP, 9WF-HPL, 8WF-HP and 8WF-HPL treatments at 10th week. In addition, weight of fish in 8WF-HPL and 9WF-HPL treatments was significantly ($p<0.05$) higher than that of fish in 8WF-HL and 8WF-HL treatments, respectively. However, weight gain and specific growth rate (SGR) of fish in 10WF-C treatment were significantly ($p<0.05$) higher than those of fish in 9WF-C, 9WF-HL and 8WF-HL treatments, but not significantly ($p>0.05$) different from those of fish in 9WF-HP, 9WF-HPL, 8WF-C, 8WF-HP and 8WF-HPL treatments.

FR of olive flounder was not significantly ($p>0.05$) different among treatments (Table 3). However, FE of fish in 8WF-HP treatment was significantly ($p<0.05$) higher than that of fish in 9WF-C, 9WF-HL and 8WF-HL treatments, but not significantly ($p>0.05$) different from that of fish in 10WF-C, 9WF-HP, 9WF-HPL, 8WF-C and 8WF-HPL treatments. In addition, FE of fish in 9WF-HP, 9WF-HPL, 8WF-HP and 8WF-HPL treatments were significantly

Table 2. Survival (%), weight gain (g/fish) and specific growth rate (SGR, %/d) of juvenile olive flounder fed the diets containing various nutrient contents with different feeding regime

Treatments	Initial weight (g/fish)	Weight at 5th week (g/fish)	Weight at 10th week (g/fish)	Survival (%)	Weigh gain (g/fish)	SGR[1] (%/d)
10WF-C	79.38±0.06	89.68±1.39^{a}	100.59±2.15^{a}	95.56±1.11^{a}	21.2±2.21^{a}	0.34±0.03^{a}
9WF-C	79.27±0.04	83.81±0.79^{cd}	93.73±1.74^{bcd}	93.33±1.92^{a}	14.5±1.78^{bc}	0.24±0.03^{bc}
9WF-HP	79.31±0.07	84.69±0.89^{cd}	97.62±1.27^{ab}	95.56±1.11^{a}	18.3±1.30^{ab}	0.30±0.02^{ab}
9WF-HL	79.29±0.09	83.49±1.55^{cd}	90.59±0.52^{cd}	90.00±3.33^{a}	11.3±0.56^{c}	0.19±0.01^{c}
9WF-HPL	79.31±0.03	88.22±0.81^{ab}	97.60±2.31^{ab}	94.44±4.01^{a}	18.3±2.29^{ab}	0.30±0.03^{ab}
8WF-C	79.28±0.03	83.41±0.97^{cd}	94.73±2.49^{bcd}	95.56±2.22^{a}	15.4±2.51^{ab}	0.25±0.04^{ab}
8WF-HP	78.47±0.85	82.52±0.51^{cd}	96.26±1.86^{abc}	97.81±1.09^{a}	17.8±2.61^{ab}	0.29±0.04^{ab}
8WF-HL	79.27±0.07	81.72±1.50^{d}	90.13±2.80^{d}	98.89±1.11^{a}	10.9±2.73^{c}	0.18±0.04^{c}
8WF-HPL	79.42±0.03	85.11±0.20^{bc}	98.66±1.00^{ab}	93.33±1.92^{a}	19.2±0.99^{ab}	0.31±0.01^{ab}

Values (mean of triplicate±SE) in the same column sharing a common superscript are not significantly different ($p>0.05$).

[1] Specific growth rate (SGR, %/d) = (Ln final weight of fish-Ln initial weight of fish)×100/days of feeding trial.

Table 3. Feeding rate (FR), feed efficiency (FE), protein efficiency ratio (PER), protein retention (PR), condition factor (CF) and hepatosomatic index (HSI) of juvenile olive flounder fed the diets containing various nutrient contents with different feeding

Treatments	FR[1]	FE[2]	PER[3]	PR[4]	CF[5]	HSI[6]
10WF-C	0.63±0.04[a]	0.53±0.03[ab]	1.01±0.05[a]	13.84±1.63[c]	1.05±0.03[a]	1.77±0.17[a]
9WF-C	0.52±0.03[a]	0.45±0.02[bc]	0.86±0.04[ab]	14.90±1.03[bc]	1.04±0.03[a]	1.88±0.11[a]
9WF-HP	0.54±0.03[a]	0.55±0.01[ab]	0.91±0.02[ab]	16.78±1.18[abc]	1.00±0.04[a]	1.77±0.16[a]
9WF-HL	0.56±0.03[a]	0.34±0.00[d]	0.64±0.01[c]	13.04±1.20[c]	0.99±0.03[a]	1.64±0.19[a]
9WF-HPL	0.56±0.03[a]	0.52±0.05[ab]	0.88±0.08[ab]	15.33±1.31[bc]	1.09±0.05[a]	1.99±0.10[a]
8WF-C	0.51±0.03[a]	0.49±0.05[abc]	0.93±0.09[a]	16.64±2.09[abc]	1.04±0.03[a]	1.74±0.03[a]
8WF-HP	0.50±0.05[a]	0.58±0.07[a]	0.97±0.11[a]	20.51±2.79[a]	1.07±0.01[a]	1.57±0.10[a]
8WF-HL	0.46±0.04[a]	0.38±0.05[cd]	0.72±0.10[bc]	13.46±1.72[c]	0.96±0.06[a]	1.44±0.28[a]
8WF-HPL	0.55±0.01[a]	0.56±0.02[ab]	0.95±0.03[a]	19.08±1.68[ab]	1.04±0.03[a]	1.91±0.21[a]

Values (mean of triplicate±SE) in the same column sharing a common superscript are not significantly different (p>0.05).
[1] Feeding rate (FR) = (100×feed consumption of fish)/((initial weight of fish+final weight of fish)/2)/feeding day.
[2] Feed efficiency (FE) = Wight gain of fish/feed consumed.
[3] Protein efficiency ratio (PER) = Weight gain of fish/protein consumed. [4] Protein retention (PR) = Protein gain of fish/protein consumed.
[5] Condition factor (CF) = Body weight (g)×100/total length (cm)^3. [6] Hepatosomatic index (HSI) = Liver weight (g)×100/body weight (g).

(p<0.05) higher than that of fish in 9WF-HL and 8WF-HL treatments.

PER of fish in 10WF-C, 8WF-C, 8WF-HP and 8WF-HPL treatments was significantly (p<0.05) higher that that of fish in 9WF-HL and 8WF-HL treatments, but not significantly (p>0.05) different from that of fish in 9WF-C, 9WF-HP and 9WF-HPL treatments. In addition, PER of fish in 9WF-HP and 9WF-HPL, and 8WF-HP and 8WF-HPL treatments was significantly (p<0.05) higher than that of fish in 9WF-HL, and 8WF-HL treatments, respectively. However, PR of fish in 8WF-HP treatment was significantly (p<0.05) higher than that of fish in 10WF-C, 9WF-C, 9WF-HL, 9WF-HPL and 8WF-HL treatments, but not significantly (p>0.05) different from that of fish in 9WF-HP, 8WF-C and 8WF-HPL treatments. Neither CF nor HSI of fish was significantly (p>0.05) different among treatments.

Moisture, crude lipid and ash content of the whole body of olive flounder excluding liver or crude protein and lipid content of liver were not significantly (p>0.05) different among treatments (Table 4). However, crude protein content of the whole body of fish excluding liver in 8WF-HP treatment was significantly (p<0.05) higher than that of fish in 10WF-C, 9WF-C, 9WF-HP and 9WF-HPL treatments, but not significantly (p>0.05) different from that of fish in 9WF-HL, 8WF-C, 8WF-HL and 8WF-HPL treatments. Moisture content of liver of fish in 8WF-C treatment was significantly (p<0.05) higher than that of fish in 9WF-C, 9WF-HL, 9WF-HPL, 8WF-HL and 8WF-HPL treatments, but not significantly (p>0.05) different from that of fish in 10WF-C, 9WF-HP and 8WF-HP treatments.

DISCUSSION

SGR (0.34%/d) of juvenile olive flounder in 10WF-C treatment in this study (Table 2) was within value ranges, 0.13%/d at 10°C and 0.91%/d at 15°C of juvenile fish averaging 88 g obtained in Iwata et al. (1994)'s study. In addition, SGR was 0.27%/d for juvenile olive flounder

Table 4. Chemical composition (%, wet weight basis) of the whole body excluding liver and liver of olive flounder at the end of the 10-week trial

Treatments	Whole body excluding liver				Liver		
	Moisture	Crude protein	Crude lipid	Ash	Moisture	Crude protein	Crude lipid
10WF-C	75.28±0.31[a]	16.72±0.14[d]	2.35±0.23[a]	3.54±0.10[a]	72.17±0.97[abcd]	13.40±1.01[a]	9.77±1.03[a]
9WF-C	75.00±0.35[a]	16.97±0.26[cd]	2.67±0.28[a]	3.47±0.15[a]	70.03±0.22[cde]	12.77±0.42[a]	10.60±0.90[a]
9WF-HP	74.27±0.26[a]	17.47±0.09[bc]	3.13±0.13[a]	3.53±0.30[a]	72.83±0.58[abc]	13.70±0.55[a]	9.40±0.20[a]
9WF-HL	74.45±0.43[a]	17.87±0.20[ab]	3.55±0.49[a]	3.46±0.18[a]	69.63±0.88[de]	13.03±0.34[a]	10.57±0.75[a]
9WF-HPL	74.23±0.41[a]	17.48±0.05[bc]	3.32±0.26[a]	3.40±0.16[a]	68.47±1.17[e]	11.97±0.20[a]	11.10±0.78[a]
8WF-C	73.96±0.66[a]	17.58±0.18[abc]	2.87±0.10[a]	3.35±0.08[a]	73.77±1.57[a]	13.03±0.20[a]	9.83±0.47[a]
8WF-HP	73.95±0.08[a]	18.10±0.28[a]	3.75±0.18[a]	3.35±0.10[a]	73.37±0.26[ab]	13.20±0.36[a]	9.67±0.09[a]
8WF-HL	75.39±0.46[a]	17.63±0.01[ab]	3.14±0.62[a]	3.55±0.14[a]	70.63±1.83[bcde]	13.70±0.59[a]	11.33±0.85[a]
8WF-HPL	73.94±0.19[a]	17.99±0.34[ab]	2.48±0.21[a]	3.49±0.13[a]	70.00±0.30[cde]	13.07±0.47[a]	11.63±0.56[a]

Values (mean of triplicate±SE) in the same column sharing a common superscript are not significantly different (p>0.05).

averaging 45 g when fish were fed with the diet containing 52.3% crude protein and 6.6% crude lipid to satiation twice a day at mean temperature of 10.7°C for 60 days (Kim et al., 2005). Therefore, growth of olive flounder in 10WF-C treatment seemed to be relatively well achieved in this study. The 12.3% cellulose content in C diet did not deteriorate growth of olive flounder in this study, agreeing with other studies showing that cellulose content in the diets did not affect performance of European seabass (*Dicentrarchus labrax*) (Dias et al., 1998) and rainbow trout (*Oncorhynchus mykiss*) (Hansen and Storebakken, 2007).

Body weight of olive flounder was linearly reduced in proportion to weeks of feed deprivation (Cho, 2005; Cho et al., 2006) and we assumed that fish also linearly decreased in body weight with 1- and 2-week feed deprivation in this study. However, no difference in weight gain and SGR of olive flounder in between 10WF-C and 8WF-C treatments in this study indicated that olive flounder subjected to 2-week feed deprivation were able to achieve full compensatory growth in 10-week trial at suboptimal temperature. This partially agreed with the earlier studies (Cho, 2005; Cho et al., 2006) showing that juvenile olive flounder experiencing 2-week feed deprivation could fully catch-up to growth of fish fed for 8 weeks when fish were fed daily with either the experimental diet or extruded pellets for 8 weeks or fed for 7, 6, 5 or 4 weeks after 1-, 2-, 3- or 4-week feed deprivation, respectively.

Significant improvement in weight gain and SGR of fish in 9WF-HP and 9WF-HPL, and 8WF-HP and 8WF-HPL treatments compared to those of fish in 9WF-HL, and 8WF-HL treatments with 1-, and 2-week feed deprivation groups in this study probably indicated that dietary supplementation of protein or combined high protein and high lipid was more effective in improving compensatory growth of fish than dietary supplementation of lipid only regardless of 1- or 2-week feed deprivation. Similarly, an increased dietary protein level from 32% to 37% should have a positive effect on cumulative weight gain and feed efficiency of channel catfish, while an increased dietary lipid level would not, although authors concluded that dietary manipulation did not augment growth rate of fish in 6-week trial (Gaylord and Gatlin, 2001). Greater compensatory growth of olive flounder fed on both HP and HPL diets rather than HL diet regardless of a week of feed deprivation in this study could be explained by the high protein diets greatly increasing the T_3 levels of fish (Riley et al., 1993; MacKenzie et al., 1998) as T_3 level of fish played an important role to achieve compensatory growth of fish (Gaylord et al., 2001; Cho and Cho, 2009). However, diets with excessive protein depressed growth of tilapia (*Sarotherodon mossambicus*) under normal culture condition because excess absorbed amino acids may have deaminated and been excreted (Jauncey, 1982).

No difference in weight gain and FR of olive flounder between 10WF-C and 9WF-HP, 9WF-HPL, 8WF-C, 8WF-HP or 8WF-HPL treatments in this study indicated that compensatory growth of fish probably resulted from hyperphagia, agreeing with other studies (Rueda et al., 1998; Wang et al., 2000; Ali et al., 2003; Cho et al., 2006; Oh et al., 2007; Huang et al., 2008). However, no difference in FR, but poorer weight gain of fish in 9WF-HL and 8WF-HL treatments compared to those of fish in 10WF-C treatment in this study indicated that that despite no difference in FR, growth of fish fed the HL diet did not catch up with fish fed C diet containing low lipid.

Although lipid in Arctic charr (*Salvelinus alpinus*), red porgy (*Pagrus pagrus*) and channel catfish was primarily utilized as an energy source for the maintenance of basal metabolism and survival while fasting (Miglavs and Jobling, 1989; Rueda et al., 1998; Gaylord and Gatlin, 2000), high lipid (HL) diet did not effectively improve the weight gain of olive flounder subjected to 1- and 2-week feed deprivation in this study. Juvenile olive flounder averaging 3.1 g responded better on the low lipid (7%) diets than high lipid (16%) diets at 40% and 50% protein levels when fish were fed with the diets containing various protein and energy levels to satiation twice a day at 21.7°C for 5 weeks (Lee et al., 2000). In addition, SGR of juvenile olive flounder averaging 8.9 g fed low lipid (6%) diets was better than the high lipid (13% and 19%) diets at 46% and 51% protein levels (Lee and Kim, 2005). Furthermore, the high protein diets containing over 50% deteriorated weight gain of juvenile olive flounder weighing 22.7 g when fish were fed with the isolipidic (7%) diets containing 40, 45, 50, 55, 60 and 65% protein levels to satiation twice a day at 19.2°C for 9 weeks (Lee et al., 2002).

Higher FE of olive flounder in 9WF-HP, 9WF-HPL, 8WF-HP and 8WF-HPL treatments compared to that of fish in 9WF-HL and 8WF-HL treatments in this study indicated that dietary supplementation of protein or combined high protein and high lipid was more effective than dietary supplementation of lipid in achieving compensatory growth. Similarly, improved FE was observed in fish achieving full compensatory growth (Jobling et al., 1994; Wang et al., 2000; Gaylord and Gatlin, 2001; Cho, 2005; Oh et al., 2007; Huang et al., 2008). Unlike this study, however, FE of olive flounder fed the isolipidic diets with high protein (over 50%) (Lee et al., 2002) or the high lipid diet at 30% and 40% protein levels (Lee et al., 2000) daily throughout the feeding trials tended to deteriorate. In addition, improvement in PER of olive flounder in 9WF-HP and 9WF-HPL, and 8WF-HP and 8WF-HPL treatments compared to that of fish in 9WF-HL, and 8WF-HL treatments, respectively in this study indicated that HP and

HPL diets was effectively utilized by fish achieving full compensatory growth in suboptimal temperature. However, when the diets in excessive protein were fed to fish, protein utilization of fish tended to decrease or did not to improve (Garling and Wilson, 1976; Jauncey, 1982; Lee et al., 2006).

A similar size of juvenile olive flounder averaging 55 g responded differently when the high protein or the lipid diet was fed to fish which underwent the different starving and feeding schedules (Cho et al., 2010). For instance, both HP diets are similar and the HE diet (50% protein and 16% lipid) in Cho et al. (2010)'s study resembles HL diet in the present study, but HL diet reduced growth, FE, PER and PR of fish compared to HP diet in the present study, but did not in Cho et al. (2010)'s study. However, unlike this study showing that both CF and HSI of olive flounder was not different among treatments, HSI was a good index to reflect compensatory growth of olive flounder (Cho, 2005) and channel catfish (Gaylord and Gatlin, 2000).

None of proximate composition of olive flounder was significantly different among treatments except for crude protein content of the whole body excluding liver and moisture content of liver in this study. However, unlike this study, proximate composition of fish was not affected by either feeding regimes (Gaylord and Gatlin, 2000, 2001; Kim et al., 2005; Cho et al., 2006) or dietary nutrient content (Gaylord and Gatlin, 2001; Kim et al., 2005, 2006).

Results of this study demonstrated that juvenile olive flounder subjected to 2-week feed deprivation could achieve full compensatory growth in suboptimal temperature with dietary supplementation of protein or combined high protein and high lipid was more effective to improve compensatory growth of fish than dietary supplementation of lipid only.

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