Thesis for the Degree of Master of Science

Effect of feeding ratio on growth and body composition of juvenile and sub-adult olive flounder *Paralichthys olivaceus* fed extruded pellets during the summer season

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by

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Abstract

The effect of feeding ratio on growth and body composition of juvenile (feeding trial Ⅰ) and sub-adult (feeding trial Ⅱ) olive flounder (*Paralichthys olivaceus*) fed extruded pellets was determined during the summer season.

In the feeding trial Ⅰ, thirty juvenile olive flounder (initial body weight of 17 g) per tank were distributed into 21, 180 L flow-through tanks. Seven treatments that included triplicate groups of feeding ratio in 5% decrement were prepared for this study: 100% (satiation), 95%, 90%, 85%, 80%, 75% and 70% of satiation.

In the feeding trial Ⅱ, thirteen sub-adult olive flounder (an initial body weight of 319 g) per tank were distributed into 15, 500 L flow-through tanks. Five treatments of feeding ratio in 5% decrement were prepared in triplicate: 100% (satiation), 95%, 90%, 85% and 80% of satiation.

Fish in the control group (100% of satiation) were hand-fed to apparent satiation twice a day for 7 and 10 weeks in the feeding trials Ⅰ and Ⅱ, respectively. Then feed allowance in the rest of six for juvenile and four groups for sub-adult was determined based on average feed consumption of fish in the control group.

In the feeding trial Ⅰ, survival of juvenile olive flounder was over 97% and was not significantly (P>0.05) affected by the feeding ratios. Weight gain and specific growth rate (SGR) of fish fed to 100% of satiation were not significantly different from those fed to 95% of satiation but significantly (P<0.05) higher than those of fish fed to 90%, 85%, 80%, 75% and 70% of satiation. Weight gain, SGR and feed consumption of flounder linearly (P<0.001) decreased with a decrease in feeding ratio. However, feed efficiency ratio (FER), protein efficiency ratio (PER) and protein retention (PR) in fish body were not significantly ($P>0.05$) affected by the feeding ratio. The crude protein levels of the whole body without liver or liver were significantly affected by the feeding ratio. Hepatosomatic index and condition factor of fish were not significantly ($P>0.05$) affected by the feeding ratio.

In the feeding trial Ⅱ, weight gain of sub-adult olive flounder fed to 100% of satiation was significantly ($P<0.05$) higher than that of fish fed to 85% and 80% of satiation, but not significantly ($P>0.05$) different from that of fish fed to 95% and 90% of satiation. However, efficiency (FER, PER, and PR) of diet of flounder was not significantly ($P>0.05$) affected by feeding ratio. Serum total protein, glucose and glutamic pyruvic transaminase were not significantly ($P>0.05$) affected by feeding ratio, but triglyceride and glutamic oxaloacetic transaminase were.

In considering the results from the feeding trials Ⅰ and Ⅱ, it can be concluded that optimum feeding ratio for growth of juvenile and sub-adult olive flounder could be lowered to 95% and 90% of satiation, respectively, without growth suppression when fish were fed the extruded pellets twice a day during the summer season. And optimum feed allowance decreased as fish grew.

General Introduction

Olive flounder (*Paralichthys olivaceus*) belongs to Order Pleuronectiformes and Family Paralichthyidae. It is a carnivorous fish species and distributes into Japan, Sakhalin, Kuril island and Korean Peninsula in Western Pacific, and inhabits the bottom of sea water and depth range of about 20 m (Chyung, 1996).

In the year of 2005, total production of mariculture reached to about 1 million MT in Korea and algae production was 620 thousand MT (60% of total production of mariculture in the same year), and 332 (31%), 81 (8%), 1 (0.1%) and 11 (1%) thousand MT for shellfish, finfish, crustacean and others, respectively (KNSO, 2005). And total value of total production of mariculture in 2005 was estimated to be about 1,348 billion Won. Total value of finfish was 723 billion Won (54% of total value of mariculture in the same year) and 314 (23%), 267 (20%), 23 (2%) and 19 (1%) for shellfish, algae, crustacean and others, respectively, in order. Therefore, aquaculture production of finfish is very important for mariculture in Korea, primarily composed of olive flounder, rockfish (*Sebastes schlegeli*), seabream (*Pagrus major*) and mullet (*Mugil cephalus*). Total production and value of flounder was 40,075 MT (49% of total production of finfish from aquaculture) and 353 billion Won (49% of total value of finfish production form aquaculture), respectively.

Since feed cost makes up 50-60% of total fish production cost, feeding fish an optimum feeding ratio is critical for economically effective fish production. Therefore, many feeding trials on determining dietary nutrient requirements (Lee et al., 2000a; Alam et al., 2002; Furuita et al., 2003; Kim et al., 2002a), availability of dietary nutrients (Estevez et al., 1997; Lee et al., 2000b; Furuita et al., 2002), substitution-effect of other protein sources for fish meal in the diet (Kikuchi et al., 1994a, 1994b, 1997; Sato and Kikuchi, 1997; Kikuchi, 1999, 2002; Cho et al., 2005a, 2005b), optimum feed allowance (Lee et al., 1999, 2000b; Cho et al., 2006a) and feeding strategy (Kim et al., 2002b; Cho, 2006b) have been performed for efficient production of flounder and the diets used in most of the studies mentioned above were in the form of steam dry pellets or moist pellets (MP).

Until now, MP is commonly used in fish farm in Korea and brings about the several problems. Thus, extruded pellets (EP) is highly recommendable for most fish farm in the worldwide because application of EP can achieve improved availability of nutrients in the diet, easy observation on fish feeding activity, reduced water pollution source in effluent discharged from fish farm and spread of disease, easy handling, and long storage time for later use.

The formulation of feeds to satisfy the dietary nutrient requirements for olive flounder has recently been developed. Therefore, determination of optimum feeding ratio is needed for olive flounder when fed EP. Feeding fish to less than satiation without growth retardation is highly preferable for fish production in fish farm due to easy management, high feed utilization and low production of water pollution source. And optimum feed allowance for growth of fish can be largely affected by fish size as well.

In this study, therefore, optimum daily feeding ratio for juvenile and sub-adult olive flounder fed the EP was determined during the summer season.

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Effect of feeding ratio on growth and body composition of juvenile olive flounder *Paralichthys olivaceus* fed extruded pellets during the summer season

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Abstract

The effect of feeding ratio on growth and body composition of juvenile olive flounder fed extruded pellets was determined during the summer season. Thirty juvenile olive flounder (initial body weight of 17 g) per tank were distributed into 21, 180-l flow-through tanks. Seven treatments that included triplicate groups of feeding ratio in 5% decrement were prepared for this study: 100% (satiation), 95%, 90%, 85%, 80%, 75% and 70% of satiation. Fish in the control group were hand-fed to apparent satiation twice a day. Then feed allowance in the rest of the six groups was determined based on average feed consumption in the control group. The feeding trial lasted for 7 weeks. Survival was over 97% and was not significantly ($P>0.05$) affected by the feeding ratios. Weight gain and SGR of fish fed to 100% of satiation were not significantly different from those fed to 95% of satiation but significantly ($P<0.05$) higher than those of fish fed to 90%, 85%, 80%, 75% and 70% of satiation. Weight gain, SGR and feed consumption of flounder linearly ($P<0.001$) decreased with a decrease in feeding ratio. However, feed efficiency ratio, protein efficiency ratio and protein retention in fish body were not significantly ($P>0.05$) affected by the feeding ratio. The crude protein levels of the whole body without liver or liver were significantly affected by the feeding ratio. Hepatosomatic index and condition factor of fish were not significantly ($P>0.05$) affected by the feeding ratio. It can be concluded that optimum feeding ratio for growth of juvenile olive flounder could be lowered to 95% of satiation without growth suppression.

Keywords: Olive flounder *Paralichthys olivaceus*; Feeding ratio; Satiation; Extruded pellet; Summer season

1. Introduction

Olive flounder is one of the most commercially important marine fish species for aquaculture in eastern Asia including Korea, Japan and China.

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Since feed cost makes up 50–60% of total fish production cost, feeding fish an optimum feeding ratio is critical for economically effective fish production. Many feeding trials on determining nutrient requirements or availability in the diets (Estevez et al., 1997; Lee et al., 2000a,b; Alam et al., 2002; Furuita et al., 2002, 2003; Kim et al., 2002a), substitution effect of other protein sources for fish meal in the diet (Kikuchi et al., 1994a,b, 1997; Sato and Kikuchi, 1997; Kikuchi, 1999, 2002; Cho et al., 2005), feeding frequency (Lee et al., 1999, 2000b) and feeding strategy (Kim et al., 2002b; Cho, in press) have been performed for efficient production of olive flounder and the diets used in most of the studies mentioned above were in the form of steam dry pellets or moist pellets.

Extruded pellets (EP) are highly recommended for most fish because use of EP can minimize water pollution and spread of disease and improve the digestibility of carbohydrate, feed efficiency and storage time of feed for later use. EPs are generally well accepted by olive flounder. The formulation of feeds to satisfy the dietary nutrient requirements for olive flounder has recently been developed. Therefore, determination of optimum feeding ratio is needed for olive flounder when fed EP. Improvement in feed efficiency ratio for fish is generally achieved at slightly below satiation (Meyer-Burgdorff et al., 1989; Shimeno et al., 1997; Van Ham et al., 2003; Eroldogan et al., 2004). Feeding fish to less than satiation without growth suppression is highly preferable for fish production in fish farm due to easy management, high feed utilization and low production of water pollution source.

In this study, therefore, the effect of feeding ratio on growth and body composition of juvenile olive flounder fed EPs was determined during the summer season.

2. Materials and methods

2.1. Fish and the experimental conditions

Juvenile olive flounder (*Paralichthys olivaceus*) were purchased from a private hatchery (Tonggyoung City, Kyoungsangnamdo, Korea). Before the initiation of the feeding trial, fish were acclimated to experimental conditions for 2 weeks. Thirty fish (an average body weight of fish: 17.0 ± 0.02 g) per tank were randomly stocked into 21, 180-l flow-through tanks (water volume, 150 l). During the acclimation period, fish were fed commercial extruded pellets (Ewha Oil and Fat Industry Co. Ltd., Korea) containing 50.0% crude protein and 7.0% crude lipid twice a day. The flow rate of water into each tank was 6.5 l/min/tank. The water source was sand-filtered natural seawater and aeration was supplied to each tank. Water temperature ranged from 16.0 to 25.5 °C (Mean ± S.D.: 23.6 ± 0.26 °C) since the feeding trial was performed during the summer season. Natural photoperiod was used and fish were fed 6 days a week throughout the feeding trial.

2.2. Design of the feeding trial

Seven treatments of feeding ratio in 5% decrement with triplicates were used: 100% (satiation), 95%, 90%, 85%, 80%, 75% and 70% of satiation. Fish in the control group were hand-fed to apparent satiation, 100% of satiation, twice a day at 09:00 and 17:00 hours. Uneaten feed was removed 30 min after feeding and deducted from feed consumption calculations. Feed allowance of fish in the six experimental groups was determined based on the average feed consumption of fish in the control group. The feeding trial lasted for 7 weeks.

2.3. Preparation of the experimental diet

Ingredients, chemical composition and essential amino acid composition of the experimental diet are given in Table 1. Mackerel meal, dehulled soybean meal and corn gluten meal were used as the protein sources. Wheat flour, α-potato starch and wheat gluten, and fish oil were used as the carbohydrate and lipid sources, respectively. The ingredients of the experimental diet were well mixed and extruded by a pellet extruder (EX 920, Matador, Denmark) in Sinchon Feed Co. Ltd., (Incheon, Korea). The experimental diet contained 51.9% crude protein and 8.1% crude lipid with a gross energy level of 23.8 J/g diet, which should meet the nutrient requirements for growth of juvenile flounder (Lee et al., 2000a, 2002; Kim et al., 2002a).

Table 1
Ingredient and nutrient composition of the experimental diet

Ingredient	Composition (%)
Mackerel meal	55.5
Corn gluten	3
Dehulled soybean meal	2
Wheat flour	15
α-potato starch	2
Wheat gluten	4
Fish oil	5.5
Vitamin premix[a]	1
Mineral premix[a]	1.7
Others	10.3
Nutrients (%,DM)	
Crude protein	51.9
Crude lipid	8.10
Ash	11.6
Gross energy (J/g)	23.8
Essential amino acids (% protein)	
Arg	7.1
His	2.8
Ile	4.0
Leu	8.5
Lys	7.9
Met+Cys	0.8
Phe+Tyr	8.0
Thr	5.2
Val	5.8

[a] Vitamin and mineral premix provided by Suhyup Feed Co. Ltd. (South Korea).

2.4. Analytical procedures of fish

Fifteen fish at the initiation and five fish from each tank at the termination of the feeding trial were sampled and sacrificed for proximate analysis. Crude protein was determined by the Kjeldahl method (Auto Kjeldahl System, Buchi B-324/435/412, Switzerland), 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). Amino acid composition of the experimental diet was analyzed using an automatic analyzer (Pharmacia Biochrom 20, Li+ type high performance ultra pack, UK).

Blood samples were obtained from the caudal vein of randomly chosen 5 fish from each tank by using a heparinized syringe after they were starved for 24 h and anesthetized with MS-222 at a concentration of 100 mg/l at the end of the feeding trial. Plasma was collected after centrifugation (3000 rpm for 10 min), stored in freezer at −70 °C as separate aliquots for analysis of total protein, glucose, glutamic pyruvic transaminase (GPT) and triglyceride (TG), and analyzed by using automatic chemistry system (Vitros DT60 II, Vitros DTE II, DTSC II Chemistry System, Johnson and Johnson Clinical Diagnostics Inc., New York, USA).

2.5. Statistical analysis

One-way ANOVA and Duncan's multiple range test (Duncan, 1955) were used to analyze the significance of the difference among the means of treatments. Besides, regression analysis for weight gain, specific growth rate and feed consumption of fish against feeding ratio were conducted by using regression analysis through SAS version 9.1 (SAS Institute, Cary, NC, USA).

3. Results

Survival (%), weight gain (g/fish), and specific growth rate (SGR) of juvenile olive flounder fed the EP with various feeding ratios for 7 weeks are given in Table 2. Survival was over 97% and not significantly ($P>0.05$) affected by the feeding ratio.

However, weight gain and SGR of fish fed to 100% of satiation were not significantly different from those of fish fed to 95% of satiation, but significantly ($P<0.05$) higher than those of fish fed to 90%, 85%, 80%, 75% and 70% of satiation, and weight gain and SGR of fish fed to 90% of satiation were significantly ($P<0.05$) higher than those of fish fed to 80%, 75% and 70% of satiation. Weight gain and SGR of flounder linearly ($P<0.001$) decreased with a decrease in feeding ratio: Y (weight gain)$=0.7584\times$(feeding ratio)-0.5826 ($r^2=0.8376$) and Y (SGR)$=0.0247\times$(feeding ratio)$+1.9831$ ($r^2=0.8747$) (Fig. 1), respectively.

Feed consumption (g/fish), feed efficiency ratio (FER), protein efficiency ratio (PER) and protein retention (PR) of olive flounder fed the extruded pellet with various feeding ratios for 7 weeks are

Table 2
Survival (%), weight gain (g/fish) and specific growth rate (SGR) of juvenile olive flounder fed the extruded pellets with various feeding ratios[1]

Feeding ratio (%)	Initial weight (g/fish)	Final weight (g/fish)	Survival (%)	Weight gain (g/fish)	SGR[2]
100	16.9 ± 0.06	93.1 ± 5.35	100 ± 0.0	76.1 ± 5.39[a]	4.5 ± 0.14[a]
95	17.1 ± 0.03	87.2 ± 1.52	98 ± 1.1	70.1 ± 1.53[a,b]	4.3 ± 0.05[a,b]
90	17.1 ± 0.05	84.6 ± 1.59	98 ± 1.1	67.6 ± 1.64[b]	4.2 ± 0.06[b]
85	17.0 ± 0.02	81.9 ± 0.51	98 ± 1.1	64.9 ± 0.52[b,c]	4.1 ± 0.02[b,c]
80	17.1 ± 0.18	76.5 ± 1.45	100 ± 0.0	59.4 ± 1.32[c,d]	3.9 ± 0.03[c,d]
75	17.1 ± 0.03	74.0 ± 0.73	99 ± 1.1	57.0 ± 0.73[d]	3.9 ± 0.03[d]
70	17.0 ± 0.05	69.2 ± 0.27	100 ± 0.0	52.1 ± 0.22[d]	3.7 ± 0.00[d]

[1] Values (mean of triplicates ± SE) in the same column sharing a common superscript are not significantly different ($P<0.05$).
[2] SGR = (ln final weight of fish − ln initial weight of fish) × 100/ days of feeding trial.

presented in Table 3. Although feed consumption of flounder fed to 80% of satiation was not significantly different from that of fish fed to 75% of satiation, it linearly ($P<0.001$) decreased with the decrease in feeding ratio (Fig. 1). However, FER, PER and PR of flounder were not significantly ($P>0.05$) affected by the feeding ratio.

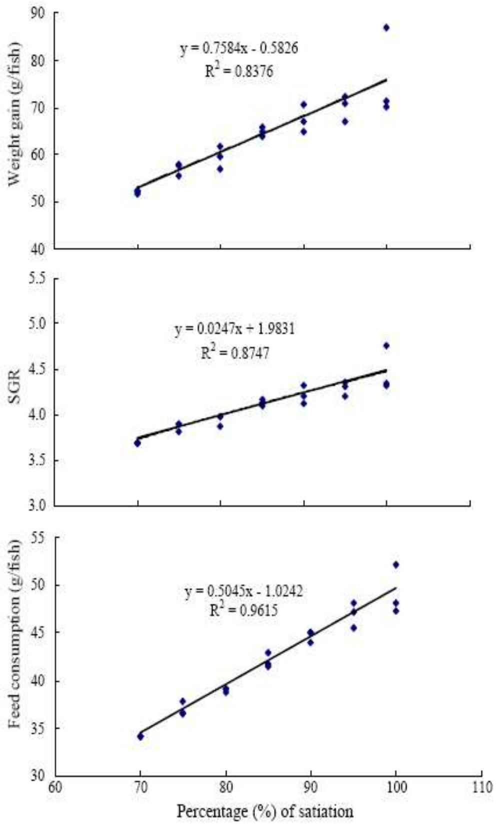

Fig. 1. Changes in weight gain (g/fish), specific growth rate (SGR) and feed consumption (g/fish) of olive flounder (g/fish) fed the extruded pellets with various feeding ratios for 7 weeks ($n=3$).

Proximate composition of olive flounder fed the extruded pellets for 7 weeks is shown in Table 4. Moisture, crude lipid and ash content of the whole body of flounder without liver was not significantly ($P>0.05$) affected by the feeding ratio. However, crude protein content of flounder fed to 80% of satiation was not significantly ($P>0.05$) different from that of fish fed to 95%, 90% and 85% of satiation, but significantly ($P<0.05$) higher than that of fish fed to 100%, 75% and 70% of satiation. The lowest crude protein content was observed in fish fed to 70% of satiation. Liver moisture, crude protein and crude lipid content were not significantly affected by the feeding ratio. Body condition indices of flounder such as HSI, ranged from 2.17 to 2.57, and CF, ranged from 0.96 to 1.05, were not significantly ($P>0.05$) affected by the feeding ratio.

Blood analysis of olive flounder fed the extruded pellets for 7 weeks is given in Table 5. Hematocrit of flounder fed to 100% and 85% of satiation was significantly ($P<0.05$) higher than that of fish fed to 75% and 70% of satiation. Serum glucose ranged from 208.1 to 265.8 mg/dl and 2.8 to 3.3 g/dl, 576.0 to 670.8 mg/dl and 14.6 to 21.4 IU/ml for total protein, TG and GPT, respectively; however, none of them was significantly affected by the feeding ratio.

4. Discussion

Relatively high (>97%) survival of olive flounder was obtained at the end of the feeding trial. With the

Table 3
Feed consumption (g/fish), feed efficiency ratio (FER), protein efficiency ratio (PER) and protein retention (PR) of juvenile olive flounder fed the extruded pellets with various feeding ratios[1]

Feeding ratio (%)	Feed consumption	FER[2]	PER[3]	PR[4]
100	49.2 ± 1.53[a]	1.54 ± 0.060	2.83 ± 0.110	54.4 ± 1.47
95	46.9 ± 0.73[b]	1.49 ± 0.009	2.74 ± 0.018	53.7 ± 0.42
90	44.7 ± 0.37[c]	1.54 ± 0.021	2.77 ± 0.068	54.5 ± 1.12
85	42.1 ± 0.42[d]	1.54 ± 0.012	2.83 ± 0.021	55.9 ± 0.88
80	39.0 ± 0.10[e]	1.51 ± 0.017	2.79 ± 0.056	57.3 ± 0.99
75	37.0 ± 0.43[e]	1.54 ± 0.016	2.82 ± 0.030	54.6 ± 1.10
70	34.2 ± 0.02[f]	1.53 ± 0.006	2.80 ± 0.011	52.4 ± 1.24

[1] Values (mean of triplicates ± SE) in the same column sharing a common superscript are not significantly different ($P<0.05$).
[2] Feed efficiency ratio (FER) = weight 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.

decrement in the feeding ratio, weight gain and SGR of olive flounder linearly decreased although weight gain and SGR of flounder fed to 100% of satiation were not different from those of fish fed to 95% of satiation (Fig. 1). Shimeno et al. (1997) reported that feeding ratio could be lowered to 80% of satiation without reduction in weight gain of common carp (initial weight of 46 g) when fish were fed a commercial diet 5–6 times a day at various feeding ratios (100–30% of satiation) for 30 days. They demonstrated that feed restriction stimulated fatty acid and glycogen mobilization, maintained gluconeogenesis and amino acid degradation, and depressed glycolysis and lipogenesis in the hepatopancreas in order to supply energy and blood glucose for maintenance of overall metabolism.

Table 4
Proximate composition (percentage of wet weight) of olive flounder fed the extruded pellets with various feeding ratios[1]

Feeding ratio (%)	Whole body of fish without liver			
	Moisture	Crude protein	Crude lipid	Ash
100	72.4 ± 0.26	18.9 ± 0.20[b,c]	4.6 ± 0.29	3.3 ± 0.02
95	73.1 ± 0.33	19.2 ± 0.20[a,b]	4.2 ± 0.21	3.6 ± 0.10
90	72.9 ± 0.27	19.3 ± 0.04[a,b]	4.4 ± 0.49	3.7 ± 0.43
85	73.3 ± 0.22	19.3 ± 0.18[a,b]	3.6 ± 0.16	3.4 ± 0.12
80	72.7 ± 0.12	19.9 ± 0.02[a]	4.4 ± 0.23	3.6 ± 0.11
75	72.9 ± 0.32	18.9 ± 0.19[b,c]	4.2 ± 0.36	3.1 ± 0.18
70	73.4 ± 0.22	18.4 ± 0.30[c]	3.7 ± 0.24	3.9 ± 0.10

Feeding ratio (%)	Liver		
100	61.8 ± 0.89	9.4 ± 0.13	18.6 ± 1.30
95	61.8 ± 0.78	9.8 ± 0.48	19.6 ± 0.51
90	62.8 ± 1.05	9.1 ± 0.11	18.6 ± 1.37
85	61.8 ± 0.53	9.6 ± 0.14	18.3 ± 0.84
80	63.2 ± 0.93	9.5 ± 0.14	18.4 ± 1.60
75	62.1 ± 1.21	9.7 ± 0.14	18.9 ± 2.42
70	63.9 ± 0.31	9.6 ± 0.20	16.5 ± 2.10

[1] Values (mean of triplicates ± SE) in the same column sharing a common superscript are not significantly different ($P<0.05$).

When the feeding ratio was lower than that for optimal growth, higher weight gain of fish was achieved at a higher feeding ratio (Arzel et al., 1998; Ballestrazzi et al., 1998; Van Ham et al., 2003; Eroldogan et al., 2004). Van Ham et al. (2003) reported that weight gain and SGR of juvenile turbot with the same feeding ratio were not different regardless of water temperature but linearly decreased with a decrease in feeding ratio when fish were fed to 100%, 65% and 35% of satiation twice daily at either 16 or 22 °C. The highest weight gain and SGR of European sea bass with an initial weight of 2.6 g was obtained at 100% of satiation in both fresh- and seawater when fish were fed a commercial diet at 36%, 45%, 54%, 63%, 71% and 100% of satiation daily (Eroldogan et al., 2004). However, they recommended an optimum daily feeding ratio of 54–63% of satiation for the European sea bass because of deterioration of feed efficiency ratio at higher feeding ratios.

Although feed consumption of olive flounder linearly decreased with the decrease in feeding ratio, FER, PER and PR were not significantly affected by the feeding ratio in this study. This was probably because weight gain of fish was proportionally lowered with the reduction in feed consumption of fish. Similar trends have been observed in other feeding

Table 5
Blood analysis of olive flounder fed the extruded pellet with various feeding ratios for 7 weeks[1]

Feeding ratio (%)	Hematocrit (%)	Glucose (mg/dl)	Total protein (g/dl)	TG (mg/dl)	GPT (IU/ml)
100	43.1 ± 2.57^{a}	265.8 ± 12.36	3.3 ± 0.08	648.8 ± 41.71	18.2 ± 1.99
95	$42.1 \pm 2.10^{a,b}$	243.4 ± 13.33	3.3 ± 0.34	598.5 ± 47.66	21.4 ± 1.85
90	$42.4 \pm 2.13^{a,b}$	243.2 ± 31.33	3.0 ± 0.01	633.1 ± 42.30	20.2 ± 1.54
85	43.7 ± 0.36^{a}	253.3 ± 14.33	3.4 ± 0.12	603.7 ± 17.04	18.6 ± 2.43
80	$40.8 \pm 1.81^{a,b,c}$	227.7 ± 10.08	2.9 ± 0.10	670.8 ± 34.16	20.4 ± 1.76
75	34.9 ± 2.93^{c}	208.1 ± 7.96	2.8 ± 0.18	602.4 ± 21.02	19.7 ± 1.69
70	$35.7 \pm 1.31^{b,c}$	234.4 ± 28.19	2.9 ± 0.17	576.0 ± 40.85	14.6 ± 1.52

[1] Values (mean of triplicates ± SE, each replicate consists of measurements of 5 fish) in the same column sharing a common superscript are not significantly different ($P < 0.05$).

trials (Shimeno et al., 1997; Ballestrazzi et al., 1998; Eroldogan et al., 2004). Shimeno et al. (1997) showed that feeding common carp with slightly less than satiation feeding, such as 90% and 80% of satiation, as compared to satiation feeding achieved somewhat higher feed efficiency ratio and lower body lipid content although it did slightly lower weight gain. They emphasized a benefit of slightly restricted feeding than satiation, in which slight feed restriction improved feed efficiency without a reduction in growth of fish and fish quality by decreasing body fat content. Improvement in FER, PR and energy retention was obtained in turbot fed 65% of satiation compared to those of fish fed to satiation (Van Ham et al., 2003).

Crude protein levels of the whole body without liver was significantly affected by the feeding ratio in this study. Lipid levels of fish normally increase with increased feeding ratio while moisture and/or ash levels decrease (Shimeno et al., 1997; Abdelghany and Ahmad, 2002; Mihelakakis et al., 2002; Van Ham et al., 2003; Eroldogan et al., 2004).

Body condition indices such as HSI and CF were not affected by the feeding ratio in this study. CF of European sea bass was not affected by the feeding ratio, but HSI was (Eroldogan et al., 2004). Blood analysis of flounder except for hematocrit was not affected by the feeding ratio in this study, probably due to high variation in replication within the same treatment. However, Shimeno et al. (1997) reported that serum triglycerides, cholesterol, total protein and ammonia increased as feeding rate increased while serum glucose scarcely changed. Although water quality was not monitored during the feeding trial in this study, deterioration of water quality in fish farm could be related to feed nutrients and/or feed allowance and eventually affect fish performance. Also feeding fish to satiation every meal on a commercial scale of a fish farm is very difficult to be achieved. Therefore, optimum feeding ratio for fish should be carefully determined based on the primary concern of criteria one is interested in.

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Feeding trial Ⅱ. Effect of daily feeding ratio on growth and body composition of sub-adult olive flounder, *Paralichthys olivaceus*, fed extruded pellet during the summer season

Abstract

A 10-week feeding trial to determine effect of daily feeding ratio on growth and body composition of sub-adult olive flounder (*Paralichthys olivaceus*) fed the extruded pellet was determined during the summer season. Thirteen flounder (an initial body weight of 319 g) per tank were distributed into 15, 500 L flow-through tanks. Five treatments of feeding ratio in 5% decrement were prepared in triplicate: 100% (satiation), 95%, 90%, 85% and 80% of satiation. Fish in the control group (100% of satiation) were hand-fed to apparent satiation twice a day. Then feed allowance in the rest of four groups was determined based on average feed consumption of fish in the control group. Weight gain of fish fed to 100% of satiation was significantly (P<0.05) higher than that of fish fed to 85% and 80% of satiation, but not significantly (P>0.05) different from that of fish fed to 95% and 90% of satiation. Serum total protein, glucose and GPT were not significantly (P>0.05) affected by feeding ratio, but triglyceride and glutamic oxaloacetic transaminase were. In considering these results, it can be concluded that optimum daily feeding ratio for growth of sub-adult olive flounder seemed to be 90% of satiation when fish were fed the extruded pellet twice a day during the summer season.

1. Introduction

Since olive flounder, *Paralichthys olivaceus*, is one of the most commercially important marine fish species for aquaculture in Eastern Asia, such as Korea and Japan, many studies to determine dietary nutrient requirements (Lee et al., 2000a; Alam et al., 2002; Furuita et al., 2003; Kim et al., 2002a), alternative protein sources for fish meal (Kikuchi et al., 1994a, 1994b; Sato and Kikuchi, 1997; Kikuchi 1999; Cho et al., 2005a, 2005b) in the diet, optimum feed allowance (Lee et al., 1999, 2000b; Cho et al., 2006a), and feeding strategy (Kim et al., 2002b; Cho, 2005; Cho et al., 2006b) have been performed for effective fish production.

Use of extruded pellets (EP) is highly desirable for most of fish farm in terms of improved availability of nutrients in the diet, easy observation on fish feeding activity, reduced water pollution source in effluent discharged from fish farm and spread of disease, easy handling, and long storage time for later use. The formulation of EP to satisfy dietary nutrient requirements for olive flounder has been developed and commercially available EP is being adapted to many olive flounder farm in Korea. Excessive amount of feed supply commonly result to lower feed availability of fish, deteriorate of water quality in fish farm, and eventually increase fish production cost.

In the previous study, optimum daily feeding ratio for growth of juvenile olive flounder grown from 17 to 90 g has been reported to be 95% of satiation when fish were fed by the EP with various feeding ratio (100%, 95%, 90%, 85%, 80%, 75% and 70% of satiation) during summer season (Cho et al., 2006a). However, optimum feed allowance for growth of fish could be largely affected by fish size as well. In this study, therefore, optimum daily feeding ratio for sub-adult olive flounder fed the EP was determined during the summer season.

2. Materials and Methods

2. 1. Fish and the Experimental Conditions

Similar size of sub-adult olive flounder were purchased from a private hatchery and transferred into the Lab (Finfish Research Center, Uljin, Kyoungsangbukdo, Korea). Before the initiation of the feeding trial, fish were acclimated to experimental conditions for 3 weeks. Thirteen fish (an average body weight of 319 g) per tank were randomly chosen and distributed into 15, 500 L flow-through tanks (water volume: 300 L). During the acclimation period, fish were fed a commercial EP for flounder twice a day. The flow rate of water into each tank was 16 L/min/tank. The water source was sand-filtered natural seawater and aeration was supplied to each tank. Water temperature ranged from 17.5 to 23.0℃ (Mean ± S.D.: 21.1 ± 1.3℃) since the feeding trial was performed during the summer season. Natural photoperiod was used and fish were fed for 7 days a week throughout the 10 weeks feeding trial.

2. 2. Design of the Feeding Trial

Five treatments of feeding ratio in 5% decrement with triplicates were prepared for this study: 100% (satiation), 95%, 90%, 85% and 80% of satiation. Fish in the control group were hand-fed to apparent satiation, 100% of satiation, twice a day at 09:00 and 17:00. Uneaten diet was removed 30 min after feeding and deducted from diet consumption calculations. Diet allowance of fish in the rest of four experimental groups was determined based on the average diet consumption of fish in the control group.

2. 3. Preparation of the Experimental Diet

Ingredients and chemical composition of the experimental diet are given in Table 1. Mackerel meal, dehulled soybean meal, and corn gluten meal were used as the protein sources. Wheat flour and gluten, and fish oil were used as the carbohydrate and lipid sources, respectively. The ingredients of the experimental diet were well mixed and extruded by a pellet-extruder in Suhyup Feed Co. Ltd. (Uiryeong, Gyeongsangnamdo, Korea). The experimental diet (diameter: 9.0-9.4 mm) contained 49.5% crude protein and 9.2% crude lipid with a gross energy level of 6.0 kcal/g diet, based on the previous studies (Lee et al., 2000a, 2002; Kim et al., 2002a; Cho et al., 2006a).

2. 4. Analytical Procedures of Fish

Five fish at the initiation and termination of the feeding trial were sampled and sacrificed for proximate analysis. Crude protein was determined by the Kjeldahl method (Auto Kjeldahl System, Buchi B-324/435/412, Switzerland), crude lipid by using an ether-extraction method, moisture by oven drying at 105℃ for 24 hr, fiber by using an automatic analyzer (Fibertec, Tecator, Sweden), and ash by using a muffle furnace at 550℃ for 4 hr, according to standard AOAC (1990).

2. 5. Blood Analysis of Fish

Blood samples were obtained from the caudal vein of randomly chosen 5 fish from each tank by using a heparinized syringe after they were starved for 24 hr and

Table 1. Ingredient and nutrient composition of the experimental diet

Ingredient	composition (%)
Mackerel meal	57.0
Soybean meal	4.0
Corn gluten meal	3.0
Wheat flour	14.0
Wheat gluten	4.0
Krill meal	2.5
Fish oil	5.0
Vitamin premix[1]	1.0
Mineral premix[1]	1.7
Nutrients (%, DM)	
Crude protein	49.5
Crude lipid	9.2
Ash	11.2
Gross energy (kcal/g diet)	6.0
n-3 HUFA[2]	2.8

[1]Vitamim and mineral premix provided by Suhyup Feed Co. Ltd. (Korea).

[2]Highly unsaturated fatty acid ($C \geq 20$).

anesthetized with MS-222 at the concentration of 100 mg/L at the end of the feeding trial. Plasma was collected after centrifugation (3,000 rpm for 10 min), stored freezer at -70℃ as separate aliquots for analysis of total protein, glucose, cholesterol, triglyceride (GT), glutamic pyruvic transaminase (GPT), and glutamic oxaloacetic transaminase (GOT), and analyzed by using automatic chemistry system (HITACHI 7180 and 7600-210, Hitachi, Japan).

2. 6. Statistical Analysis

One-way ANOVA and Duncan`s multiple range test (Duncan, 1955) were used to analyze the significance of the difference among the means of treatments through SAS version 9.1 (SAS Institute, Cary, NC, USA).

3. Results and Discussion

Survival (%), weight gain (g/fish), and specific growth rate (SGR) of olive flounder fed the EP with various feeding ratio for 10 weeks are given in Table 2. Survival was not significantly ($P>0.05$) affected by feeding ratio. However, weight gain of flounder fed to 100% of satiation was significantly ($P<0.05$) higher than that of fish fed to 85% and 80% of satiation, but not significantly ($P>0.05$) different from that of fish fed to 95% and 90% of satiation. Weight gain of flounder fed to 95% of satiation was significantly ($P<0.05$) higher than that of fish fed to 80% of satiation. Weight gain of flounder tended to decrease with a decrease in feeding ratio in this study. SGR of fish fed to 100% and 95% of satiation was significantly ($P<0.05$) higher than that of fish fed to 80% of satiation, but not significantly ($P>0.05$) different from that of fish fed to 90% and 85% of satiation. When feeding

Table 2. Survival (%), weight gain (g/fish) and specific growth rate (SGR) of sub-adult olive flounder fed the extruded pellet for 10 weeks with various feeding ratio[1]

Feeding ratio (%)	Initial weight (g/fish)	Final weight (g/fish)	Survival (%)	Weight gain (g/fish)	SGR[2]
100	318.6 ± 0.1[a]	487.5 ± 24.8[a]	100 ± 0[a]	168.8 ± 24.9[a]	0.73 ± 0.09[a]
95	319.3 ± 0.4[a]	479.1 ± 0.7[a]	100 ± 0[a]	159.8 ± 0.3[ab]	0.70 ± 0.00[a]
90	319.5 ± 1.0[a]	461.7 ± 5.4[a]	100 ± 0[a]	142.2 ± 6.0[abc]	0.63 ± 0.03[ab]
85	319.0 ± 0.1[a]	459.0 ± 0.2[a]	100 ± 0[a]	139.9 ± 0.2[bc]	0.63 ± 0.00[ab]
80	318.8 ± 0.1[a]	448.8 ± 7.0[a]	100 ± 0[a]	130.0 ± 7.0[c]	0.59 ± 0.03[b]

[1]Values (mean ± SE) in the same column sharing a common superscript are not significantly different (P>0.05).

[2]SGR = (Ln final weight of fish-Ln initial weight of fish) 100/days of feeding trial.

ratio was lower than optimal level, higher weight gain of fish was achieved at a higher feeding ratio (Arzel et al., 1998; Ballestrazzi et al., 1998; Van Ham et al., 2003; Eroldogan et al., 2004).

Feeding fish to less than satiation without growth retardation is highly recommendable for fish production in fish farm because of less cost in diet and production of water pollution source, easier management, and higher diet utilization of fish. No significant difference in weight gain among fish fed to 100%, 95% and 90% of satiation in this study indicated that daily feeding ratio could be lowered to 90% of satiation for sub-adult olive flounder without growth retardation during summer season. However, optimum daily feeding ratio for growth of juvenile olive flounder grown from 17 to 90 g was reported to be 95% of satiation during summer season when fish were fed to satiation twice a day for 7 weeks (Cho et al., 2006a). According to the pervious and this study, optimum daily feeding ratio for growth of olive flounder seemed to lower from 95% to 90% satiation as fish grew from juvenile to sub-adult. Similar findings that optimum diet allowance and/or dietary nutrient requirements decreased as fish grew was reported in other fish (Page and Andrews, 1973; Skalli et al., 2004; Hatlen et al., 2005; Sweilum et al., 2005).

Diet consumption (g/fish), feed efficiency ratio (FER), protein efficiency ratio (PER), protein retention (PR), hepatosomatic index (HSI), and condition factor (CF) of sub-adult olive flounder fed the EP with various feeding ratio for 10 weeks are presented in Table 3. Since diet allowance of flounder was determined based on diet consumption of fish in the control group, consumption linearly decreased with the decease in feeding ratio. However, efficiency of diet (FER, PER, and PR) of

Table 3. Feed consumption (g/fish), feed efficiency ratio (FER), protein efficiency ratio (PER) and protein retention (PR) of sub-adult oliver flounder fed the extruded pellet for 10 weeks with various feeding ratio[1]

Feeding ratio (%)	Feed consumption	FER[2]	PER[3]	PR[4]	HSI[5]	CF[6]
100	170.8 ± 25.4[a]	0.99 ± 0.00[a]	2.00 ± 0.00[a]	45.3 ± 8.7[a]	1.5 ± 0.2[a]	0.99 ± 0.01[a]
95	160.2 ± 0.0[ab]	1.00 ± 0.00[a]	2.02 ± 0.00[a]	45.2 ± 2.4[a]	1.7 ± 0.1[a]	1.06 ± 0.03[a]
90	151.7 ± 0.1[abc]	0.94 ± 0.04[a]	1.89 ± 0.08[a]	41.3 ± 3.0[a]	1.7 ± 0.1[a]	1.08 ± 0.02[a]
85	143.2 ± 0.0[bc]	0.98 ± 0.00[a]	1.97 ± 0.00[a]	45.3 ± 4.8[a]	1.8 ± 0.1[a]	1.07 ± 0.02[a]
80	134.9 ± 0.2[c]	0.96 ± 0.05[a]	1.95 ± 0.10[a]	42.6 ± 3.6[a]	1.7 ± 0.3[a]	1.08 ± 0.01[a]

[1]Values (mean ± SE) in the same column sharing a common superscript are not significantly different (P>0.05).

[2]Feed efficiency ratio (FER) = Weight 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]Hepatosomatic index (HSI) = Liver weight100/fish weight.

[6]Condition factor (CF) = Fish weight100/total length^3.

flounder was not significantly (P>0.05) affected by feeding ratio in this study. This is probably because weight gain of fish decreased proportion to the reduction in feeding ratio. A similar trend that no difference in feed efficiency of fish was obtained at various diet allowance was observed in other studies (Shimeno et al., 1997; Ballestrazzi et al., 1998; Eroldogan et al., 2004; Cho et al., 2006a). Wide variation in diet consumption of sub-adult flounder at satiation feeding in the control group due to easy disturbance of feeding activity of fish during the feeding trial resulted to wide variation in weight gain of fish in the control group in this study. However, fish were more likely to consume all diets in other groups (95%, 90%, 85% and 80% of satiation) and achieved less variation in weight gain. Body condition indices (HSI and CF) of flounder was not significantly (P>0.05) affected by feeding ratio in this study. The similar result was obtained in the previous study (Cho et al., 2006a). However, Eroldogan et al. (2004) showed that feeding ratio significantly affected CF of European sea bass, *Dicentrarchus labrax*, but did not HSI.

Proximate composition of olive flounder fed the EP for 10 weeks is presented in Table 4. Chemical composition (moisture, crude protein and lipid, and ash content) of the whole-body of fish without liver or liver was not significantly (P>0.05) affected by feeding ratio. Similarly, proximate composition of flounder, except for crude protein, was not affected by feeding ratio (Cho et al., 2006a), but conflicted with other studies showing that body lipid content of fish increased with the increase in diet allowance or feeding frequency (Grayton and Beamish, 1977; Kayano et al., 1993; Shimeno et al., 1997; Lee et al., 2000b; Mihelakakis et al., 2002; Van Ham et al., 2003; Eroldogan et al., 2004).

Table 4. Proximate composition (% of wet weight) of sub-adult olive flounder fed the extruded pellet for 10 weeks with various feeding ratio[1]

	Whole-body of fish without liver			
Feeding ratio (%)	Moisture	Crude protein	Crude lipid	Ash
100	71.5 ± 1.1.	20.7 ± 1.6	2.5 ± 0.8	3.9 ± 0.3
95	71.8 ± 0.9	20.4 ± 0.4	4.5 ± 0.4	3.7 ± 0.2
90	71.9 ± 0.9	20.2 ± 0.7	3.5 ± 1.0	3.3 ± 0.2
85	72.7 ± 0.6	20.5 ± 0.7	3.7 ± 0.3	3.4 ± 0.2
80	72.7 ± 0.7	20.2 ± 0.4	3.1 ± 0.7	3.6 ± 0.3

	Liver		
Feeding ratio (%)	Moisture	Crude protein	Crude lipid
100	66.8 ± 1.6	12.5 ± 0.2	14.0 ± 1.3
95	63.4 ± 2.0	11.3 ± 0.5	17.6 ± 2.0
90	63.9 ± 2.7	11.6 ± 0.4	15.8 ± 3.8
85	62.6 ± 2.5	11.3 ± 0.5	20.0 ± 4.1
80	63.7 ± 2.1	11.3 ± 0.5	19.2 ± 3.4

[1]Values (mean ± SE) for either whole-body or liver are not significantly different for any treatment (*P*>0.05).

Blood analysis of olive flounder fed the EP with various feeding ratio for 10 weeks is shown in Table 5. Serum total protein, glucose, and glutamic pyruvic transaminase (GPT) of flounder was not significantly (P>0.05) affected by feeding ratio. However, serum triglyceride (TG) of flounder fed to 95%, 90% and 85% of satiation was significantly (P<0.05) higher than that of fish fed to 100% or 80% of satiation, although a wide variation was observed within the same treatment. Serum glutamic oxaloacetic transaminase (GOT) of flounder fed to 95% of satiation was significantly (P<0.05) higher than that of fish fed at other feeding ratio. GOT values of fish were ranked 100%, 85%, 80% and 90% of satiation in order. Similarly, serum glucose, total protein, TG, and GPT was not affected by feeding ratio (Cho et al., 2006a). These results probably indicate that blood analysis of fish was not likely affected by the feeding regimes used in the present study. However, Shimeno et al. (1997) showed that serum total protein, TG, cholesterol, and ammonia in common carp, *Cyprinus carpio*, increased as feeding rate increased, while serum glucose scarcely changed when fish were fed by the commercial diet at various feeding rates (100%, 90%, 80%, 70%, 50%, 30% and 0% of satiation) for 30 days.

Diet allowance largely affects not only availability of nutrients in diet, cost of fish production, and fish performance, but also effluent discharged from fish farm. Also, other factors, such as fish species, fish size, dietary nutrient composition, water temperature, rearing conditions, etc. could affect optimum diet allowance for fish in the feeding trial. Therefore, the least amount of diet without growth reduction could be regarded as the optimum level for fish and it must be carefully determined.

Table 5. Blood analysis of sub-adult olive flounder fed the extruded pellet with various feeding ratio for 10 weeks[1]

Feeding ratio (%)	Total protein (g/dL)	Glucose (mg/dL)	TG (mg/dL)	GOT (IU/L)	GPT (IU/L)
100	3.5 ± 0.0[a]	15.0 ± 1.2[a]	113.5 ± 2.5[ab]	13.7 ± 0.9[b]	2.0 ± 0.6[a]
95	3.8 ± 0.1[a]	18.0 ± 1.2[a]	146.7 ± 17.0[a]	25.5 ± 2.5[a]	3.3 ± 1.9[a]
90	3.6 ± 0.2[a]	16.0 ± 1.0[a]	166.5 ± 9.5[a]	7.0 ± 1.0[c]	0.3 ± 0.3[a]
85	3.6 ± 0.1[a]	16.7 ± 0.9[a]	158.5 ± 20.5[a]	10.3 ± 2.2[bc]	2.7 ± 0.9[a]
80	3.6 ± 0.3[a]	16.7 ± 1.3[a]	90.0 ± 10.0[b]	10.0 ± 2.5[bc]	0.3 ± 0.3[a]

[1]Values (mean ± SE, each replicate consist of measurements of 5 fish) in the same column sharing a common superscript are not significantly different (P>0.05).

In considering these results, it can be concluded that optimum daily feeding ratio for growth of sub-adult olive flounder seemed to be 90% of satiation when fish were fed the EP to satiation twice a day during the summer season.

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Conclusion

The effect of feeding ratio on growth and body composition of juvenile (initial body weight of 17 g) and sub-adult (initial body weight of 319 g) olive flounder, *Paralichthys olivaceus* when fed extruded pellets was determined during the summer season in the feeding trials Ⅰ and Ⅱ, respectively. It can be concluded that optimum feeding ratio for growth of juvenile and sub-adult olive flounder could be lowered to 95 and 90% of satiation, respectively, without growth suppression when fish were fed the extruded pellet twice a day during the summer season. And optimum feed allowance decreased as fish grew.

국문요약

여름철 동안 부상용 배합사료(Extruded pellet)의 다양한 사료 공급율에 따른 넙치(*Paralichthys olivaceus*) 유어기(실험 Ⅰ) 및 미성어기(실험 Ⅱ)의 성장과 체조성에 미치는 영향을 조사하였다. 실험 Ⅰ에는 21개의 180 L 유수식 탱크에 30마리의 유어(시작 시 무게 17 g)를 수용하였다. 실험에 이용된 사료 공급율은 5% 간격으로 설정하였고, 총 실험구는 7구간(100% 만복, 만복의 95%, 90%, 85%, 80%, 75% 및 70%)을 두었으며, 각 실험구는 3 반복구로 7주 동안 사육실험을 실시하였다. 실험 Ⅱ에는 15개의 500 L 유수식 탱크에 13마리의 미성어(시작 시 무게 319 g)를 수용하였다. 실험에 이용된 사료 공급율은 5% 간격으로 설정하였고, 총 실험구는 5구간(100% 만복, 95%, 90%, 85% 및 80%)을 두었으며, 각 실험구는 3반복구로 10주 동안 사육실험을 실시하였다. 실험 Ⅰ과 Ⅱ에서의 사료 공급양은 대조구(100% 만복)에서는 1일 2회 매일 손으로 만복시 까지 사료를 공급하였다. 나머지 6구간(실험 Ⅰ) 및 4구간(실험 Ⅱ)은 대조구의 일일 사료 섭취량에 따라서 매일 조절하여 공급하였다.

실험 Ⅰ에서 유어 넙치의 생존율은 사료 공급율에 따른 유의적인 차이를 보이지 않았다($P>0.05$). 사료를 만복시 까지 공급한 대조구의 어체중 증가 및 일일성장률(SGR)은 만복의 95%를 공급한 실험구와 유의적인 차이를 보이지 않았지만, 만복의 90%, 85%, 80%, 75% 및 70%를 공급한 실험구보다 어체중 증가 및 일일성장률은 유의적으로 높게 나타났다($P<0.05$). 유어 넙치의 어체중 증가, 일일성장률 및 사료 섭취량은 사료 공급율의 감소에 따라 직선적으로 감소하는 것으로 나타났다($P<0.001$). 그러나 사료효율(FER), 단백질전환효율(PER) 및 단백질축적율(PR)은 사료 공급율에 따라 유의적인 차이를 보이지 않았다($P>0.05$). 어체와 간의 조단백질 함량은 유의적인 차이를 보였지만 ($P<0.05$), 지질과 수분 함량은 사료 공급율에 따른 유의적인 차이를 보이지 않

았다(P>0.05). 간체장지수(HSI)와 비만도(CF)는 사료 공급율에 따른 유의적 차이를 보이지 않았다(P>0.05).

실험 Ⅱ에서 사료를 만복시 까지 공급한 미성어 넙치의 어체중 증가는 만복의 85%와 80%를 공급한 실험구와 유의적인 차이를 보였지만(P<0.05), 만복의 95%와 90%를 공급한 실험구와는 유의적인 차이를 보이지 않았다(P>0.05). 사료효율(FER), 단백질전환효율(PER) 및 단백질축적율(PR)은 사료 공급율에 따른 유의적인 차이를 보이지 않았다(P>0.05). 사료 공급율에 따른 혈청의 total protein, glucose 및 glutamic pyruvic transaminase는 유의적인 차이를 보이지 않았지만, triglyceride와 glutamic oxaloacetic transaminase는 유의적인 차이를 보였다(P<0.05).

이상의 결과를 고려할 때, 여름철 유어기 넙치의 적정 사료 공급율은 만복의 95%이고, 미성어기는 90%로 판단되며, 넙치가 성장함에 따라서 적정 사료 공급율은 감소하였다.

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