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Compensatory Growth of Juvenile Olive Flounder *Paralichthys olivaceus* during the Summer Season

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This study was performed to determine possibility of compensatory growth of juvenile olive flounder fed a commercial feed during the summer season. Five treatments of fish with triplicates were prepared: C, S1, S2, S3 and S4. Fish in the control group (C) was hand-fed with the commercial feed to apparent satiation twice daily for 6 days a week during 6 weeks. Fish in S1, S2, S3, and S4 experienced 1, 2, 3, and 4 weeks of starvation before fed to satiation twice daily for 5, 4, 3, and 2 weeks, respectively. The feeding trial lasted for 6 weeks. Survival of flounder in C, S1 and S2 was significantly ($P<0.05$) higher than that of fish in S4. Weight gain and specific growth rate (SGR) of flounder in C and S1 were significantly ($P<0.05$) higher than those of fish in S2, S3 or S4. And weight gain and SGR of flounder in S2 and S3 were significantly ($P<0.05$) higher than those of fish in S4. Feed consumption of flounder tended to increase with weeks of feeding. Feed efficiency ratio and protein efficiency ratio for flounder in C, S1, S2 and S3 were significantly ($P<0.05$) higher than those for fish in S4. Moisture content of the whole fish in C was lowest, but highest for fish in S4, respectively. Crude protein content of the whole fish in C was highest, but lowest for fish in S4, respectively. Crude lipid content of the whole fish in C, S1 and S2 was significantly ($P<0.05$) higher than that of fish in S4. In conclusion, full compensatory growth was obtained in juvenile olive flounder fed for 5 weeks after 1-week feed deprivation during the summer season. Compensatory growth of fish was well supported by improvement in feed efficiency ratio and protein efficiency ratio.

Keywords: Compensatory growth, Olive flounder *Paralichthys olivaceus*, Starvation, Satiation

Introduction

Olive flounder *Paralichthys olivaceus* has been regarded as one of the most commercially important fish for aquaculture in Korea due to its high annual production and value (KNSO, 2006). Optimal temperature condition for growth of olive flounder lies between the late spring and early fall in Korea. However, red tide or coldwater mass, which is undesirable condition for growth of fish, frequently occurs during these seasons, especially during the summer season. In the occurrence of red tide or coldwater mass, fish are likely to be starved until it disappears. Because of not only high mortality directly resulted from red tide or coldwater mass, but also reduction in fish growth while starved, fish farmers suffer a great economical loss. Therefore, development of the new feeding strategy or technique to accelerate retarded growth of fish is highly needed.

Application of feeding strategy leading to compensatory growth of fish could elevate fish production and fish farmer's benefit. Compensatory growth commonly occurred in nature due to limited available natural food and has been observed in coldwater fish (Bilton and Robins, 1973; Miglavs and Jobling, 1989; Jobling and Koskela, 1996) as well as warmwater fish (Gaylord and Gatlin, 2000; Wang et al., 2000; Xie et al., 2001; Zhu et al., 2001). Recently, compensatory growth of juvenile olive flounder refed after 2-week feed deprivation was achieved in a 8-week feeding trial during the winter season (Cho, 2005).

Possibility of compensatory growth of fish could largely differ depending on water temperature condition. The objective of this study is to investigate compensatory growth of juvenile olive flounder fed a commercial feed during the summer season.

Materials and Methods

Preparation of fish and feeding conditions

Juvenile olive flounder were purchased from a private hatchery and transferred into a laboratory in Korea Maritime University (Busan, Korea). Fish were acclimated to the experimental conditions for 2 weeks before the initiation of the feeding

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trial. Twenty five juvenile fish (Mean weight±SD:37.9±0.26 g) were stocked into the fifteen of 800 L circular flow-through tanks (water volume: 250 L) each and water source was the filtered natural seawater. During the acclimation period and feeding trial, fish were fed a commercial sinking feed containing 55.6% crude protein and 8.0% crude lipid (Ewha Oil & Fat Industry Co., Ltd, Busan, Korea.) for flounder to satiation twice daily (09:30, 17:00) based on Lee et al. (2000) study. Water flow rate in each tank was 10 L/min and photoperiod was 13 L:11D cycle. Since the feeding trial was performed during the summer season, water temperature ranged from 20.0 to 25.5°C (Mean±SD; 23.0±1.43°C). Uneaten feeds were siphon-removed after every meal from each tank and deducted from total feed consumption. At the end of the feeding trial, fish were collectively harvested and totally weighed. The feeding trial lasted for 6 weeks.

Experimental design

Five treatments with triplicates were prepared for this study: C, S1, S2, S3 and S4. Fish in the control group (C) was fed to apparent satiation twice daily for 6 days a week throughout the 6-week feeding trial. Fish in S1, S2, S3, and S4 experienced 1, 2, 3, and 4 weeks of starvation before fed to satiation twice daily for 5, 4, 3, and 2 weeks, respectively.

Chemical analysis

Ten fish randomly chosen at the beginning and five fish at the termination of the feeding trial were sacrificed for proximate analysis (AOAC, 1990). Protein (Kjeldahl method), lipid (ether-extraction method), ash (muffle furnace, 600°C for 3 h+), and moisture contents (dry oven, 105°C for 24 h) were determined for the sampled fish.

Statistical analysis

One-way ANOVA test was applied to test the significance of treatments. And if the significance was observed, Duncan's multiple range test (Duncan, 1955) was applied to detect the difference among treatments by using SAS program version 6.12 (SAS Institute, Inc., Cary, North Carolina, USA).

Results and Discussion

Survival (%), weight gain (g/fish) and specific growth rate (SGR) of juvenile olive flounder with different feeding strategies are given in Table 1. Survival of flounder in C, S1 and S2 was significantly ($P<0.05$) higher than that of fish in S4, but not significantly ($P>0.05$) different from that of fish in S3. However, unlike this study, survival of fish was not affected by feeding strategies for hybrid tilapia *Oreochromis mossambicus×O. niloticus* (Wang et al., 2000), gibel carp (Xie et al., 2001) and olive flounder (Cho, 2005).

Weight gain and SGR of flounder in C and S1 were significantly ($P<0.05$) higher than those of fish in S2, S3 or S4. And weight gain and SGR of fish in S2 and S3 were significantly ($P<0.05$) higher than those of fish in S4. This indicated that juvenile olive flounder have the limited ability to recover from starvation for 1 week in the 6-week feeding trial during the summer season. Similarly, hybrid tilapia starved for 1 week achieved full compensatory growth, but did not for fish starved for 2 or 4 weeks in the 8-week feeding trial (Wang et al., 2000). However, unlike this study, Cho (2005) reported that when juvenile olive flounder was grown for 8

Table 2. Feed consumption (g/fish), feed efficiency ratio (FER) and protein efficiency ratio (PER) for juvenile olive flounder with different feeding strategies[1]

Treatments	Feed consumption	FER[2]	PER[3]
C	45.2±1.36^a	1.17±0.026^a	2.10±0.047^a
S1	35.7±4.35^b	1.26±0.009^a	2.27±0.016^a
S2	25.6±2.20^c	1.16±0.089^a	2.09±0.160^a
S3	21.3±2.59^c	1.01±0.115^a	1.82±0.206^a
S4	9.6±0.28^d	0.14±0.286^b	0.25±0.515^b

[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.

Table 1. Survival (%), weight gain (g/fish) and specific growth rate (SGR) of juvenile olive flounder with different feeding strategies[1]

Treatments	Initial weight (g/fish)	Final weight (g/fish)	Survival (%)	Weight gain (g/fish)	SGR[2]
C	38.1±0.15	90.7±2.82^a	77.3±5.81^a	52.8±2.78^a	2.7±0.09^a
S1	38.1±0.16	83.1±6.13^a	80.0±0.00^a	45.1±5.80^a	2.4±0.20^a
S2	38.1±0.21	67.9±4.54^b	84.0±9.24^a	30.0±4.60^b	1.8±0.21^b
S3	38.0±0.05	59.0±0.54^b	60.0±18.04^{ab}	20.9±0.44^b	1.4±0.02^b
S4	37.8±0.21	39.2±2.95^c	22.0±6.00^b	1.3±2.71^c	0.1±0.22^c

[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)/days of feeding trial.

Table 3. Chemical composition of the whole body of olive flounder at the end of the feeding trial[1]

Treatments	Moisture	Crude protein	Crude lipid	Ash
C	73.6±0.05^{d}	17.2±0.25^{a}	3.1±0.76^{a}	3.6±0.36
S1	77.2±1.21^{b}	16.6±0.22^{ab}	3.1±0.11^{a}	3.7±0.30
S2	75.0±0.18^{c}	15.8±0.56^{b}	3.1±0.21^{a}	3.9±0.07
S3	75.4±0.14^{c}	16.5±0.24^{ab}	2.2±0.17^{ab}	3.8±0.12
S4	78.9±0.13^{a}	14.6±0.16^{c}	1.3±0.05^{b}	4.3±0.13

Moisture, crude protein, crude lipid and ash content of the initial juvenile flounder were 74.5±0.21%, 18.6±0.34%, 1.5±0.34% and 4.1±0.78%, respectively.
[1]Values (Mean±SE) in the same column sharing a common superscript are not significantly different ($P<0.05$).

weeks under similar feeding strategies like this study except for temperature (15.0~17.5°C, Mean temperature±SD: 15.0±1.57°C) and duration of feeding trial, possible duration of feed deprivation for olive flounder to achieve full compensatory growth was up to 2 weeks. This difference could be primarily resulted from the difference in metabolic rate of fish due to temperature conditions and/or duration of feeding trial in both studies. Also, ability to achieve compensatory growth of fish varied depending on fish size (age), fish species, feed allowance and feed composition (Bilton and Robins, 1973; Jobling and Koskela, 1996; Rueda et al., 1998; Saether and Jobling, 1999; Gaylord and Gatlin, 2000; Zhu et al., 2001).

Feed consumption (g/fish), feed efficiency ratio (FER) and protein efficiency ratio (PER) for juvenile olive flounder with different feeding strategies are presented in Table 2. Feed consumption of flounder tended to increase with weeks of feeding. Similar trend that feed consumption of fish was proportionally affected by duration of feed deprivation was also observed in other fish (Wang et al., 2000; Gaylord and Gatlin, 2001; Xie et al., 2001; Zhu et al., 2001). However, unlike these studies, feed consumption of fish experienced feed deprivation for a certain period was same as that of fish fed throughout the feeding trial due to hyperphagia (Rueda et al., 1998; Gaylord et al., 2001).

FER and PER for olive flounder in C, S1, S2 and S3 were significantly ($P<0.05$) higher than those for fish in S4 in this study. Compensatory growth followed by improved FER was reported in other fish (Jobling et al., 1994; Qian et al., 2000; Gaylord and Gatlin, 2001). Qian et al. (2000) explained that compensatory growth of gibel carp was accompanied by improved FER and protein and energy retention, but such improvements were not resulted from a higher digestibility or reduced swimming activity of fish experienced starvation. However, improvement in FER was not achieved in hybrid tilapia achieving compensatory growth (Wang et al., 2000).

Chemical composition of the whole olive flounder at the end of the feeding trial is shown in Table 3. Moisture content of the whole body of fish in C was lowest, but highest for fish in S4, respectively. And moisture content of the whole flounder in S1 was significantly ($P<0.05$) higher than that of the whole fish in S2 or S3. Crude protein content of the whole flounder in C was highest, but lowest for fish in S4, respectively. Crude lipid content of the whole flounder in C, S1 and S2 was significantly ($P<0.05$) higher than that in S4. Body lipid was primarily utilized for energy source required for fundamental metabolism and maintenance of fish during starvation (Gaylord and Gatlin, 2000; Zhu et al., 2001). Unlike this study, however, chemical composition of fish was not affected by feeding strategy (Quinton and Blake, 1990; Rueda et al., 1998; Cho, 2005). Crude ash content of the whole body of flounder was not significantly ($P>0.05$) affected by feeding strategy in this study.

In conclusion, full compensatory growth was obtained in juvenile olive flounder fed on the commercial sinking feed for 5 weeks after 1-week feed deprivation during the summer season. Compensatory growth of fish was well supported by improvement in FER and PER.

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