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Original Article

Compensatory growth response of sailfin molly, *Poecilia latipinna* (Lesueur, 1821) to starvation and refeeding

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Abstract: Compensatory growth response and body composition of male sailfin molly, *Poecilia latipinna* subjected to short-term starvation and subsequent feeding were studied for 54 days. Four feeding schedules were used in this study: C, Control (were fed to apparent satiation throughout the experiment); T1, Treatment 1 (3 days Starvation and 6 days refeeding); T2, Treatment 2 (6 days Starvation and 12 days refeeding); T3, Treatment 3 (9 days Starvation and 18 days refeeding). At the end of the experiment, the starved fish gained a body weight comparable to that of the control fish. There were no differences in condition factor, specific growth rate and weight gain between the starved and control fish at the end of the experiment. Daily feed intake was significantly higher in T3 than that in the control. Short-term starvation did not influence protein, lipid and ash contents. Moisture content of T2 and T3 fish were significantly higher than those of T1 and control one. The results indicated that complete compensation occurred in the starved fish and that this species can tolerate to short term starvation without any significant effects on growth and feeding performance.

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Introduction

Culture of ornamental fish is an important industry in the world. The volume and value of ornamental fish export in the world are 47,548 tonnes and $703 million US dollars (FAO, 2007). Freshwater teleosts make up to 90-96% of the ornamental fish trade (Livengood and Chapman, 2007). Mollies, the family Poeciliidae, are very popular among the ornamental fish hobbyists worldwide and are cultured usually in outdoor earthen ponds or net cages (Fernando and Phang, 1994). Sailfin molly, *Poecilia latipinna* is a good candidate as an ornamental fish. A high reproductive potential, feeding from different types of feed and tolerance to changes in temperature and dissolved oxygen fluctuations makes sailfin molly a suitable species for aquarium rearing (Jacobs, 1971; Snelson, 1982). As in other aquaculture operations, feed costs can affect the economics of an aquarium business. Thus, a suitable feeding strategy that improves the growth performance may considerably reduce the cost of culture operations. Compensatory (or catch-up) growth in fish is usually defined as a growth acceleration seen following the return of favorable conditions after a period of growth depression (Dobson and Holmes, 1984; Jobling, 1994; Ali et al., 2003). Compensatory growth has a vital role in feed management and optimization in fish culture practices (Lovell, 1980).

There are several studies on the effect of starvation and refeeding in coldwater fishes (Miglavs and Jobling, 1989; Quinton and Blake, 1990; Nicieza and

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Metcalfe, 1997; Nikki et al., 2004) and warm water fishes (Russell and Wootton, 1992; Hayward et al., 1997; Gaylord and Gatlin, 2000, 2001; Wang et al., 2000; Zhu et al., 2001). Sailfin molly, *P. latipinna* is a popular ornamental fish, but compensatory growth has not been examined in this species. Thus, this study was conducted to investigate a compensatory growth response in sailfin molly subjected to short-term starvation and refeeding. This study also aimed to evaluate the effects of feeding regimes on growth, feed utilization, and body composition of sailfin molly.

Materials and methods

The experimental male fish, *P. latipinna*, were transported from a commercial farm (Rahvand Ltd, Kashan, Iran) to the laboratory. Specimens were acclimated in 500 L tank for two weeks before the start of the experiment where they were fed with frozen bloodworms twice a day.

During the experiment, data were collected every 9 days. Fish were randomly selected and weighed to the nearest 0.01 g and measured to the nearest 0.1 mm. After adaptation, 400 fish (1.30±0.82 g) were randomly distributed into 20 rectangular glass aquaria (33.6×25×25 cm, 21 L). Each aquarium was supplied with air stone and aeration. Four treatment groups were established with five replicates. The control group (C) was fed ad libitum twice a day with a commercial formulated feed (manufactured by Tetra, Germany), containing 35% crude protein, 5% crude lipid, 4% crude fiber and 12% moisture, at 09:00 and 16:00 h throughout the experiment. Fish in the other three treatments were starved for 3, 6, or 9 days followed by 6, 12 or 18 refeeding (referred to as T1, T2 and T3, respectively) in repeated cycles during 54 days the experiment. During the refeeding days, the specimens were fed ad libitum twice a day with the same commercial feed as described above. In each tank, the number of uneaten pellets was counted for calculation of daily food consumption. Throughout the experiment, dissolved oxygen, temperature and pH were monitored weekly. Water temperature was maintained at 28±1 °C, dissolved oxygen was > 6 mg L^{-1}, water pH and ammonia were 7-7.6 and 1.01±0.12 mg L^{-1}. A photoperiod of 14L: 10D using fluorescent lights was supplied throughout the experiment.

At the end of the experiment following 16 h of starvation, fish were randomly sampled dried to constant weight at 105°C to measure the moisture content. The dried samples homogenized for determining the following parameters, which crude protein was determined by micro Kjeldahl method (N×6.25) after acid digestion, lipid by ether-extraction method using a Soxtec system, fiber by acid and alkaline digestion then combustion in a muffle oven at 550°C for 5 h and moisture content by drying at an oven with a temperature of 120°C for 5 h (AOAC, 1995).

The following indices were calculated: specific growth rate (SGR % day^{-1}) = $100[(\ln W_t - \ln W_0)/t]$; percentage weight gain (%) = $100[(W_t - W_0)/ W_0]$, where W_t and W_0 are final and initial weight (g) and t is the feeding duration (day); condition factor = $100[W/ L^3]$, where L = length (cm); feed conversion ratio = intake (g, dry weight) / wet weight gain (g); protein efficiency ratio = wet weight gain / protein consumed (dry matter); daily feeding intake (g) = g feed day^{-1}.

Statistical analyses were performed using SPSS, version 15.0 for Windows. The normality of distribution of variables was tested using Kolmogorov–Smirnov test. The homogeneity of variances was tested using the Levene's F test. The possible differences in the variables among the treatments were tested using one-way ANOVA. A significant difference between sample means was tested using the Tukey test. Data were expressed as mean±standard error (SE) and differences were considered statistically significant at $P<0.05$.

Results

Survival of the experimental male fish ranged from 97 to 100% and did not differ among the treatments ($P>0.05$). At the end of the 54 days of experiment, there were no significant differences in mean final

Table 1. Growth performance of sailfin molly reared at four feeding regimes for 54 days (mean ±SE).

Parameters	Treatment			
	C	T_1	T_2	T_3
Initial weight(g)	1.32±0.78	1.41±0.86	1.35±0.90	1.29±0.72
Final weight(g)	2.29±0.17	2.20±0.12	2.30±0.86	2.30±0.94
CF	2.06±0.33	1.93±0.24	1.98±0.24	1.99±0.02
SGR(% day^{-1})	1.00±0.13	0.81±0.09	0.99±0.28	1.07±0.12
WG (%)	73.33±6.28	55.41±1.50	74.49±11.27	79.17±4.12

C, Control (fed twice daily to apparent satiation); T1, Treatment 1 (3 days starvation and 6 days refeeding); T2, Treatment 2 (6 days starvation and 12 days refeeding); T3, Treatment 3 (9 days starvation and 18 days refeeding). Different superscript letters denote significant differences between the experimental groups.

Table 2. Feed utilization of sailfin molly reared in four different feeding regimes for 54 days (mean ±SE).

Parameters	Treatment			
	C	T_1	T_2	T_3
Daily feed intake(g)	0.20±0.01^{a}	0.23±0.01^{ab}	0.21±0.02^{ab}	0.24±0.01^{b}
FCR	4.03±0.98	5.37±0.04	4.04±1.35	3.69±0.19
PER	0.78±0.15	0.53±0.00	0.78±0.24	0.77±0.03

C, Control (fed twice daily to apparent satiation); T1, Treatment 1 (3 days starvation and 6 days refeeding); T2, Treatment 2 (6 days starvation and 12 days refeeding); T3, Treatment 3 (9 days starvation and 18 days refeeding). Different superscript letters denote significant differences between the experimental groups.

body weight between the treatments (P>0.05, Fig. 1, Table 1).

There were no significant differences between the treatments in specific growth rate, weight gain or condition factor at the end of the experiment (P>0.05). However, these parameters increased with increase of starvation periods (Table 1).

At the end of the experiment, daily feed intake was significantly higher in T3 fish than that of the control fish (P<0.05, Table 2). The highest daily feed intake levels were observed in T3, T2 T1and control fish, respectively. Feed conversion ratio (FCR) varied between 3.6 and 5.3 and no significant difference was found between the control group and the starved group. However, FCR tended to decrease with

Table 3. Body composition of sailfin molly subjected to four feeding regimes for 54 days (mean ±SE, n=5, each n consist of measurements of five fish).

Treatment	Parameters			
	Protein (%)	**Lipid (%)**	**Ash (%)**	**Moisture (%)**
Initial	13.87±0.01^{a}	5.79±0.04^{a}	3.08±0.03^{a}	76.19±0.02^{a}
C	13.33±0/47^{a}	5.71±0.08^{a}	2.75±0.16^{a}	76.75±0.74^{a}
T_1	12.14±1.49^{a}	5.12±2.78^{a}	2.76±1.51^{a}	78.76 ±0.28^{ab}
T_2	11.77±0.49^{a}	4.41±2.36^{a}	2.95±1.16^{a}	79.63 ±0.18^{bc}
T_3	11.58±1.38^{a}	4.28±1.56^{a}	2.94±0.39^{a}	79.97±0.34^{c}

C, Control (fed twice daily to apparent satiation); T1, Treatment 1 (3 days starvation and 6 days refeeding); T2, Treatment 2 (6 days starvation and 12 days refeeding); T3, Treatment 3 (9 days starvation and 18 days refeeding). Different superscript letters denote significant differences between the experimental groups.

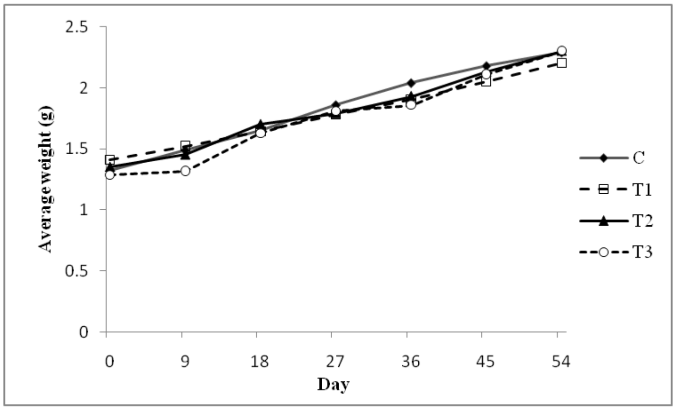

Figure 1. Mean weight of sailfin molly subjected to different cycles of starvation and refeeding for 54 days. C, Control (fed twice daily to apparent satiation); T1, Treatment 1 (3 days starvation and 6 days refeeding); T2, Treatment 2 (6 days starvation and 12 days refeeding); T3, Treatment 3 (9 days starvation and 18 days refeeding). No significant differences observed in four groups (Error bars have been omitted for clarity).

increasing the duration of starvation (*P*>0.05, Table 2). There were no significant differences in protein efficiency ratio (PER) among different treatments (*P*>0.05, Table 2).

Short-term starvation did not affect the whole-body protein, lipid and ash at the end of the experiment (*P*>0.05), and no significant differences was detected between the starved and the control fish (Table 3). However, moisture content was significantly higher in T2 and T3 fish than that of the control fish (*P*<0.05), and the body's water content tended to increase with longer starvation periods (Table 3).

Discussion

This experiment indicated that compensatory growth is occurred following short-term starvation periods in sailfin molly. At the end of the experiment, all starved fish fully compensated the lost weight, which was indicated by the similar final mean weights in the four treatments. The results of this study are in agreement with many other compensatory growth studies (e.g. Gaylord and Gatlin, 2000 (channel catfish, *Ictalurus punctatus*), Xie et al., 2001 (gible carp, *Carassius auratus*), Zhu et al., 2001 (three-spined stickleback, *Gasterosteus aculeatus* and minnow, *Phoxinus phoxinus*), Tian and Qin, 2003 (barramundi, *Lates calcarifer*), Nikki et al., 2004 (rainbow trout, *Oncorhynchus mykiss* fasted for 2 or 4 days), Mattila et al., 2009 (pick perch, *Sander lucioperca* fasted for 1 day)). In contrast, studies on gibel carp and Chinese long snout, *Leiocassis longirostris* (Zhu et al., 2004), gilthead sea bream, *Sparus aurata* (Eroldoĝan et al., 2006), Atlantic halibut, *Hippoglossus hippoglossus* (Heide et al., 2006) and white fish, *Coregonus lavaretus* (Kankanen and Pirhonen, 2009) showed partial compensatory growth. The present differences among these experiment could be due to different experimental protocols or condition, temporal differences, physiological condition and severity of feed deprivation (Jobling, 1987; Jobling and Koskela, 1996).

In the present study, the specific growth rate, although not significantly, tended to increase with increase of the feed deprivation. This may be due to reduced metabolic rate during feed deprivation as a result of decreased activity (Love, 1970; Jobling, 1980; Eroldoĝan et al., 2006) and increased daily food intake or both (Heide et al., 2006). There were no difference in condition factor between the starved and control fish (Table 1) indicating that compensatory mechanisms had occurred (Kankanen and Pirhonen, 2009).

The fish in the T3 treatment had a significantly higher mean daily feed intake than other treatments, but there were no significant differences in feeding performance (as FCR and PER) compared to the control fish during the period of refeeding (Table 2). Compensatory growth can be achieved by hyperphagia (Wang et al., 2000; Tian and Qin, 2003, 2004; Nikki et al., 2004; Mattila et al., 2009) or combination of hyperphagia and improved feed efficiency (Qian et al., 2000; Gaylord and Gatlin, 2001; Li et al., 2005). As there were no differences in feed conversion ratio, it can be assumed that the mechanism to compensate for weight loss in the sailfin molly was probably hyperphagia during the period of refeeding. The present results consistent with the contention (Heide et al., 2006) that for aquaculture purposes, an initial longer period of starvation is preferable to achieve a clear compensatory effect.

The body composition of the fish subjected to a period of starvation was similar at the end of the experiment to that of the control fish. There was an exception in moisture content, which was significantly different between the deprived and control fish. Moisture content was significantly increased in the deprived fish than in the control fish and there was a general tendency for lipid content, although not significantly, to decrease with increasing moisture content (Table 3), indicating that the inverse relationship between lipid and moisture content that was probably caused by replacement of utilized lipid with an equal volume of water (Grigorakis and Alexis, 2005). This is in agreement with the results obtained in previous studies. However, different results have been reported for other fish species. For example, Mattila et al. (2009) reported that moisture content in pikeperch subjected to longer starvation period was much higher than that of the control fish. The results on hybrid tilapia, *Oreochromis mossambicus* × *Oreochromis niloticus* (Wang et al., 2000) and great sturgeon, *Huso huso* (Falahatkar et al., 2009) also indicated that starvation had a significant effect on moisture content. The effect of starvation on utilization of reserve protein and lipid seems to be species-specific (Ince and Thorpe, 1976; Mehner and Wiese, 1994), which may have caused the difference in the results. The present study indicated that sailfin molly adapted to short-term period of starvation and can defend body composition (except moisture) in these periods.

Overall, this study showed that sailfin molly reared under different cycles of starvation and refeeding protocols for 54 days lead to complete compensation. The deprived fish were still undergoing compensatory growth at the end of the experiment. However, further research including physiological response is needed to confirm this finding. The tendency of decreased feed conversion ratio and increased specific growth rate in the deprived fish indicated that the use of starvation-refeeding cycles could decrease costs of labour, food and culture time in the commercial production of sailfin molly. In addition, these regimes could improve water quality in aquarium.

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