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Effects of Starvation and Re-Feeding on Growth Performance, Feed Utilization and Body Composition of Tinfoil Barb (*Barbonymus schwanenfeldii*)

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Abstract: The present study was carried out to investigate the effects of short-term starvation and re-feeding on growth performance, feed utilization and body composition of Tinfoil Barb (*Barbonymus schwanenfeldii*). Groups of 20 fish, each in triplicate, were exposed to four different feeding regimes for a period of 64 days; Control (C): fed twice daily; Treatment 1 (T1): two days starvation followed by six days re-feeding; Treatment 2 (T2): four days starvation followed by 12 days re-feeding and Treatment 3 (T3): eight days starvation followed by 24 days re-feeding. Biometric analysis was carried out after every 16 days. At the end of the experiment final weight, SGR (specific growth rate), CF (condition factor) and WG (weight gain) were determined in control and treated groups. The highest final weight (5.30±0.52) and specific growth rate (1.91±0.17 %) were observed in T2. Daily feed intake and total feed intake was significantly different between the deprived and the control fish ($P<0.05$). The lowest values of FCR (2.19±0.40) and the highest values of FCE (48.37±7.52 %) and PER (1.17±0.18 %) were observed in the T2. Total body protein, fat, moisture, ash and energy contents varied between T3 fish and the other treatments ($P<0.05$). This study showed complete compensation in growth and feeding performance of Tinfoil barb suggesting that this feeding schedule involving starvation-re-feeding cycles might be a promising feed management option for the culture of this species.

Key words: Compensatory Growth · Growth Performance · Body Composition · Tinfoil Barb · *Barbonymus schwanenfeldii*

INTRODUCTION

Compensatory or catch-up growth occurs in a wide variety of the animal kingdom such as fish and can be defined as the accelerated growth that usually occurs after some unfavorable environmental condition or due to restricted food availability. After starvation fish are known to show greater growth rates than the constantly fed fish in order to catch-up the lost growth [1-4]. While numerous researches were conducted on the compensatory growth of fishes, it seems that no information is available on the compensatory growth of ornamental fish species.

Ornamental fish industry holds an important place in the global fishery production and trade. The largest market for aquarium fish is led by the countries of the European Union and the United States of America and has become the greatest importer of ornamental fish in the world [5]. The free on-board export value of freshwater and saltwater fish in 2005 was estimated at 264 million US dollars, an increase of 50% with respect to 2001 [6]. The culture of ornamental fish is also an important industry in several Asian countries including Iran.

Cyprinidae is a dominant family in ornamental fish culture industry in Asia. Tinfoil barb (*Barbonymus schwanenfeldii*) is one of important species between

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cyprinids that is widely reared in Asian southeast countries as an ornamental fish; moreover, this species is commercially used in warm water aquaculture industry for rearing with other cyprinids in ponds [7]. Such feeding schedule (continuous feeding and cycles of starvation) in this species culture would lead to increased productivity in fish farms. Enhancing productivity by increased feed efficiency with reduction in feed waste and water pollution could be accompanied. Therefore, this study aimed to investigate the effects of starvation and re-feeding on growth performance and feed utilization. The role of compensatory growth and the effect of feeding regime on body composition of Tinfoil barb were also examined.

MATERIALS AND METHODS

The experiment was carried out on two-month old juvenile Tinfoil barb (*Barbonymus schwanenfeldii*) with initial weight of 1.50±0.82 g for a period of 64 days at the aquaculture facility in an ornamental fish laboratory. The tinfoil barb used in this study was transported from a commercial farm to the laboratory. After adaptation for two weeks with experimental diet and condition, the fish were randomly distributed into 12 rectangular glass aquaria (50×30×35 cm, 52 L) which each aquarium was supported by aeration and filtration. Four treatment groups were established, with three replicates per treatment and each replicate was stocked by 20 fish. The control group (C) was fed to apparent satiation twice a day at 0900 and 1600 h throughout the experiment by a commercial diet (Energy 4EF3001, Thailand; moisture 12%, crude protein 41%, crude fat 6% and fiber 2%). The other three treatments were deprived for two, four and eight days (T1, T2 and T3, respectively) followed by three times re-feeding. The average water temperature, oxygen concentration, hardness and pH were 27±0.8 C, 6.15±0.86 mg/l, 178.4±16.3 mg/l and 7.2±0.3 respectively, are monitored weekly during the experimental period [8]. The photoperiod was 16 h light: 8 h dark using fluorescent lighting.

Fish were weighed (to the nearest 0.01g) and total length was measured (to the nearest 0.1 cm), at the start of the experiment and every 16 days thereafter. Fish were fasted 16 h before handling and anaesthetized by 400 mg/l of clove powder for samples collections and biometrics. All indices were calculated as follows [9]: specific growth rate (SGR% /day) =100[(lnWt-lnW0)/t]; percentage weight gain (%) = 100[(Wt-W0)/ W0], where Wt and W0 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); feed conversion efficiency (%) = wet weight gain (g)/intake (g); protein efficiency ratio (%) = wet weight gain / protein consumed (dry matter); daily feeding intake (g) = g feed/day.

After 64 days rearing, eight fish from each replicate were randomly netted and then sacrificed by a cranial puncture, pooled and dried to constant weight at 105°C for determination of moisture content. The dried samples homogenized for determination of the following: Crude protein (CP) by micro Kjeldahl method (N ×6.25), crude fat (CF) by ether-extraction method using a Soxtec system, ash by combustion in a muffle oven at 550°C for 12 h and energy content by micro bomb calorimetric method [10,11].

All statistical analyses were performed by using SPSS, version 16 for windows. A Kolmogorov-Smirnov test was applied to assess for normality of distributions. Post-hoc comparisons between sample means were tested by Tukey and LSD test and P#0.05 was taken as the level of significance. Data were expressed as mean ± standard error of the mean (SEM).

RESULTS

There were no significant differences in the initial weight or length between the control and the deprived groups. During the 64 day experiment, mortality was low and ranged from zero to one fish per tank. At the end of the experiment, the mean final body weight of the experimental fish did not seem to be affected by short-term starvation periods, but mean body weight in control fish was numerically lower compared with deprived fish. Similar trend was also found for weight gain at the end of the experiment (P>0.05; Fig. 1, Table 1).

Specific growth rate of fish deprived for two, four and eight days was higher than that of the control, though not significant (P>0.05). This parameter seems to have a tendency to decrease with longer starvation periods. There were no significant differences between the treatments in, weight gain or condition factor at the end of the experiment (P>0.05, Table 1).

Feeding performance of the control and deprived fish are presented in Table 2. At the end of the experiment no significant difference were found in feed conversion ratio (FCR), feed conversion efficiency (FCE) and protein efficiency ratio (PER) between the control group and the

Table 1: Growth performance values of barb reared at four feeding regimes (mean ±SEM). C: Control (fed two times daily to apparent satiation); T1: Treatment 1 (two days starvation and six days re-feeding); T2: Treatment 2 (four days starvation and 12 days re-feeding) and T3: Treatment 3 (eight days starvation and 24 days re-feeding). No significant differences observed in four groups

	Treatment			
Parameters	C	T_1	T_2	T_3
Initial weight (g)	1.51±0.02	1.53±0.02	1.54±0.02	1.52±0.01
Final weight (g)	4.38±0.16	5.25±0.41	5.30±0.52	4.95±0.52
SGR (% /day)	1.66±0.07	1.91±0.13	1.91±0.17	1.82±0.15
CF	2.53±0.33	1.90±0.11	2.08±0.18	2.02±0.21
WG (%)	190.07±13.64	242.13±28.27	244.36±36.08	224.77±33.29

SGR (specific growth rate) =100[(lnWt-lnW0)/t]; CF (condition factor) = 100[W/ L^3]; WG (weight gain) = 100[(Wt-W0)/ W0]

Table 2: Feed utilization values of barb reared at four feeding regimes (mean ±SEM). C: Control (fed two times daily to apparent satiation); T1: Treatment 1 (two days starvation and six days re-feeding); T2: Treatment 2 (four days starvation and 12 days re-feeding) and T3: Treatment 3 (eight days starvation and 24 days re-feeding)

	Treatment			
Parameters	C	T_1	T_2	T_3
Daily feed intake (g)	2.40±0.00^a	3.32±0.00^b	3.17±0.03^c	2.85±0.02^d
Total feed intake (g)	154.20±0.48^a	159.66±0.17^b	152.20±1.67^a	136.81±1.45^c
FCR	2.96±0.30	2.66±0.49	2.19±0.40	2.40±0.22
FCE (%)	34.54±3.72	40.37±7.53	48.37±7.52	42.39±4.19
PER (%)	0.84±0.09	0.98±0.18	1.17±0.18	1.03±0.10

-Different superscript letters in the same row denote significant differences between the experimental groups

-DFI (daily feeding intake) = g feed /day; FCR (feed conversion ratio) = intake (g, dry weight) / wet weight gain (g); FCE (feed conversion efficiency) = wet weight gain (g) / intake (g); PER (protein efficiency ratio) = wet weight gain / protein consumed

Table 3: Body composition of barb subjected to four feeding regimes at the end of the experiment (mean±SEM). C: Control (fed two times daily to apparent satiation); T1: Treatment 1 (two days starvation and six days re-feeding); T2: Treatment 2 (four days starvation and 12 days re-feeding) and T3: Treatment 3 (eight days starvation and 24 days re-feeding)

	Parameters (% dry matter)				
Treatment	Protein (%)	Lipid (%)	Moisture (%)	Ash (%)	Energy (kcal/kg)
C	57.82±0.27^a	29.30±0.11^a	66.74±0.49^a	7.65±0.02^a	5999.4±7.55^a
T_1	59.65±0.23^a	27.85±0.14^a	67.91±0.73^{ab}	7.25±0.02^a	5929.7±11.08^a
T_2	58.81±0.14^a	29.50±1.03^a	66.41±0.21^a	7.00±0.05^a	6053.3±5.66^a
T_3	63.09±0.17^b	23.70±0.45^b	69.09±0.50^b	8.35±0.25^b	5662.1±9.02^b

- Different superscript letters in the same column denote significant differences between the experimental groups

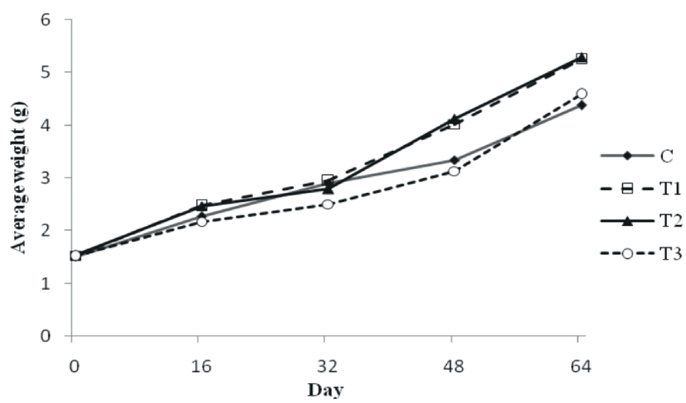

Fig. 1: Mean weight of barb subjected to different cycles of starvation and re-feeding for 64 days. C: Control (fed two times daily to apparent satiation); T1: Treatment 1 (two days starvation and six days re-feeding); T2: Treatment 2 (four days starvation and 12 days re-feeding) and T3: Treatment 3 (eight days starvation and 24 days re-feeding). No significant differences observed in four groups (Error bars have been omitted for clarity)

deprived group (P>0.05). However, the T2 fish had the lowest FCR when compared to the other treatment. At the end of the 64 days experiment in the deprived fish, daily feed intake was significantly higher compared to the control group (P<0.05, Table 2). Total feed intake in over the period of experiment was significantly different between the deprived and the control fish. At the end of the experiment this value was 103.54, 98.70, 88.72 % control fish in T1, T2 and T3 groups, respectively.

In the present study, comparisons between the control and the deprived fish showed that food deprivation had significant effects on protein, lipid, ash, moisture and energy content (P<0.05, Table 3). In all parameters, there were significant differences between T3 fish and the other treatments including control, T1 and T2 (P<0.05).

DISCUSSION

At the end of the experiment, all deprived fish were able to compensate fully for previously lost weight, as they indicated similar values (slightly higher than control fish) of final weight, SGRs than those of the control fish. The results of this study showed that barb is capable to fully compensate as a response to starvation periods and re-feeding. Compensatory growth has been reported in various fish species, especially coldwater fish and warm water fish. However, the starvation and re-feeding cycles that provoke compensatory growth and compensation responses is different between fish species [2, 12-16]. Over-compensation was observed in hybrid sunfish [17]; complete compensation in European minnows [18], rainbow trout [1, 19-22] (fasted for 2 or 4 days)], pikeperch [23] (fasted for 1 day)], Chinese sturgeon [24] and gibel carp [14, 25]. In addition, there are several examples for partial compensation where fish have not fully compensated for the lost growth [26-29]. These results indicate an ability of various fish species to exhibit compensatory growth.

Specific growth rate was higher in fish subjected to starvation-re-feeding cycles than that in fish fed to satiation (though not significant). At the end of the experiment the deprived fish had higher specific growth rate, but not significantly, compared to the control fish, indicating that there was potential of barb to overcompensate if the experiment was continued for more that 64 days, as Hayward *et al.* [17] observed in their experiment on hybrid sunfish. Hayward and Wang [30] explained that overcompensation seem to be species-specific or limited to certain life stages. The increased SGR indicated by the deprived fish may be due to reduced metabolic rate during feed deprivation as a result of decreased activity [31, 32, 33] and increased daily feed intake or a combination of both [34].

Hyperphagia during re-feeding and growth compensation has been reported for many fishes [23, 33-35]. In the present study, daily feed intake significantly decreased as the length of the feed deprivation was prolonged. The daily feed intakes of starved fish were significantly higher than that of the control, but there were no significant difference in feeding performance (as FCR, FCE and PER) when compared to the control fish during the period of re-feeding (Table 2), possibly due to large variation between individuals. Other reason for this might be the fact that short term starvation used in the present study was not long enough to induce FCR and FCE. At the end of the experiment, when total feed intake was measured the deprived fish consumed significantly less food than the control fish except for T1 fish that showed the highest total feed intake. As the length of the starvation increased the total food consumption decreased. Compensatory growth could be achieved by hyperphagia [22, 23, 36, 37, 38] or combination of hyperphagia and FCE [25, 39, 40]. In the present study, the main mechanism involved in compensatory response in the deprived fish was hyperphagia. Also, the authors are assumed that a combination of hyperphagia and improved feed efficiency during the re-feeding period might be a contributing cause for compensatory growth in barb.

The body composition of the fish subjected to starvation at the end of the experiment was similar to that of the control fish except in T3 fish, which was significantly different between the deprived and control fish in protein, lipid, ash, moisture and energy content (Table 3). These results are in accordance with results on rainbow trout [20], barramundi [37, 38], Chinese long snout catfish [41] and great sturgeon [42] in relation to, lipid, energy and moisture content. In contrast, some inconsistent results with our study were observed in rainbow trout protein [20], hybrid tilapia [36] barramundi [37, 38] Chinese long snout catfish [43] and sea bream [44] for ash content. The effect of food deprivation on the use of reserve protein, lipid or glycogen as a metabolic fuel seems to be species-specific [45, 46], which may have caused the difference in the results. As the length of the feed deprivation increased lipid and energy contents decreased in barb of the present experiment. The drop in lipid content increased the moisture content of the fish, indicating the inverse relationship between lipid and moisture content [47]. Two principal groups of fish have been identified on the basis of their metabolic response to starvation: those that use primarily muscle protein as the principal fuel and those that use primarily lipids [48-51]. As evident from the drop in lipid content at the end of our experiment, it could be assumed that lipid reserves were mobilized for supply of energy. The significant difference in protein content could probably be attributed to the small number of fish sampled at the end of the experiment. In the present study, fish were subjected to longer periods of starvation (8 days starvation) seemed to have failed in maintaining body composition (protein, lipid, ash, moisture and energy) similar to that of the control fish.

CONCLUSION

The results of this study showed that short term starvation periods and re-feeding invoke a full compensation in barb. Though fish were subjected to two and eight days starvation induced compensatory growth response, moderate periods of starvation (four days starvation) resulted in the highest final weight, SGR, FCR and PER among the deprived fish. This could perhaps be a suitable feeding strategy for the rearing of this species. The deprived fish were still undergoing compensatory growth at the end of the experiment that was indicative of the potential for overcompensation. However, further research including physiological response is needed to confirm this finding.

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