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Response of Rainbow Trout, (*Oncorhynchus mykiss*, Walbaum 1792) to Short Term Starvation Periods and Re-Feeding

[1]M. Azodi, [2]E. Ebrahimi, [2]O. Farhadian and [2]N. Mahboobi-Soofiani

[1]Division of Fisheries, Department of Natural Resources, Isfahan University of Technology, Iran and Persian Gulf Research and Study Centre, Persian Gulf University, Bushehr, Iran
[2]Division of Fisheries, Department of Natural Resources, Isfahan University of Technology, Iran

Abstract: In present study the effects of short-term starvation and refeeding on growth, feeding performances and body composition of rainbow trout (*Oncorhynchus mykiss*) with an average initial weight of 17.50±0.5 g were studied. After 2 weeks adaptation to experimental condition, 270 fish in four treatments were randomly distributed in twelve 100L cylindrical fiberglass tanks with a flow-through system. The fish were exposed to 4 different feeding regimes; control: fed two times daily to apparent satiation; T1: 1 day starvation and 2 days refeeding; T2: 1 day starvation and 4 days refeeding; T3: 3 days starvation and 12 days refeeding. Short terms starvation and refeeding was continued for 30days. At the end of the experiment, growth performance did not vary significantly ($P<0.05$) between the control and treatments. Although daily food consumption was significantly ($P<0.05$) higher in T1, but there weren't any significant differences in feeding performance including: FCR, FER and PER. Total body moisture, ash, protein and lipid contents did not fluctuate between the control and treatments. At the end of the experiment all experimental treatments showed complete compensation suggesting that this feeding schedules are useful for distancing inappropriate environmental conditions and economical exploitation in rainbow trout farms as a management instrument.

Key words: *Oncorhynchus mykiss* % Compensatory growth % Growth performance % Feeding performance % Body composition

INTRODUCTION

Success in fish culture depends on decline in production process costs. An important method to reduce food costs in commercial aquaculture is to develop appropriate management feeding and culture strategies [1]. Formulated food cost is the most important effective parameter in production of carnivore fish [1-4]. Currently the major ratio of culture costs (50 to 60 percent) is spent on food supply that it causes increase in fish price [5]. Food efficiency is not only dependent on quality, but also is dependent on feeding management. Good quality and to be appropriate of food in nutrients can be useful when using an appropriate method of feeding (feeding rate, frequency and daily schedule, method of feeding) [6, 7]. An inappropriate feeing status in aquaculture may lead to overfeeding that waste the food in ponds and subsequently higher production costs and contaminant in water environment; feeding less that is necessary lead to poor growth and high mortality in fish that can produce high damage in aquatic environment [8].

One of the appropriate methods of feeding is to use periods of starvation and refeeding that is described as a compensatory growth. Compensatory growth is a part of fast growth that occur after refeeding follow a period of food restriction or abnormal condition like low temperature [9]. The degree of compensation that occurs after feed deprivation is highly variable depending on species and feeding protocol including length and severity of deprivation [10].

There are a lot of results about compensatory growth with using a period of restriction [11, 12] or periods of restriction and refeeding alternatively [13-15] for induce compensatory growth as a types of partial, complete or overcompensation [10].

Corresponding Author: M. Azodi, Division of Fisheries, Department of Natural Resources, Isfahan University of Technology, Iran and Persian Gulf Research and Study Centre, Persian Gulf University, Bushehr, Iran
Tel: +98 311 3912841-3565; Fax: +98 311 3912840.

Wieser *et al.* [16] suggested a lag in compensatory growth response in chub, *Leuciscus cephalus*, but not in Danube bleak, *Chalcalburnus chalcoides mento*, or rudd, *Scardinius erythrophthalmus*. Heide *et al.* [17] expressed the reasons of partial compensation are increased food consumption and improved food efficiency. This study was conducted to study compensatory growth response in rainbow trout subjected to short-term starvation and re-feeding periods.

MATERIALS AND METHODS

This experiment was done in the facilities of the Division of Fisheries, Department of Natural Resources and Isfahan University of Technology that lasted for thirty days. Juvenile trout (*Oncorhynchus mykiss*) were obtained from a commercial local farm from Shahrekord province, Iran. A semi circulated system was used for maintaining fish, 270 experimental fish with average initial weight of 17.50±0.5 g (Mean±SE) was kept 2 weeks for acclimation to experiment conditions prior to start of the experiment.

During the experiment, fish were fed *ad libitum* rations twice daily using a formulated feed (manufactured pellet for trout by Esfahan Mokammel Co., Isfahan, Iran). Feed contained 43% crude protein, 15% crude lipid, 14% moisture, 11% ash.

The average water temperature, oxygen concentration, ammonia and pH were 14.9±0.9 °C, 7.4±0.55 mg/l, 0.007±0.002 mg/l and 7.4±0.15 respectively, these parameters were measured weekly during the experimental period [18]. The photoperiod was 12 h light: 12 h dark.

Four treatment groups were established with three replicates for each. Control group (C) fed twice a day, T1 deprived for 1 day and refed for 2 days, T2 deprived for 1 day and refed for 4 days, T3 deprived for 3 days and refed for 12 days.

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 10 days thereafter. All indices were calculated as follows [19]: specific growth rate (SGR % /day) =100[(lnWt-lnW0)/t]; weight gain (WG) = 100[(Wt-W0) / W0], where Wt and W0 are final and initial weight (g) and t is the feeding duration (day); Condition factor (CF) = 100[W/ L^3], where L = length (cm); feed conversion ratio (FCR)= intake (g, dry weight) / wet weight gain (g); feed efficiency ratio (FER) =100 [wet weight gain (g) / intake (g)]; protein efficiency ratio (PER) = wet weight gain / protein consumed (dry matter); daily feeding intake (DFI) = g feed/day.

After 30 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 ºC for determination of moisture content [20].

Before the beginning of the experiment, 10 fish were randomly sampled to determine the initial body composition. At the end of the experiment, after the final measurement, 5 fish from each tank were randomly sampled, viscera remove and the carcass was frozen (-20ºC). Proximate analysis of fish body composition was carried out after drying and homogenization of samples. Duplicate homogenized samples were used. The samples were dried to constant weight at 105 ºC. The dried samples homogenized for determination of the following: ash by combustion in a muffle oven at 550 °C for 12 h, Crude protein (CP) by micro Kjeldahl method (N×6.25), crude fat (CF) by ether-extraction method using a Soxtec system [21].

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. *Post hoc* comparisons between sample means were tested by Tukey test. Data were expressed as mean ± standard error (SE) and differences were considered statistically significant at $P<0.05$ level.

RESULTS

Results attributed growth performance is shown in table 1. Final weight, weight gain, specific growth rate and condition factor didn't show any significant difference ($P<0.05$) at the end of experiment, the maximum final weight, weight gain, specific growth rate and condition factor were in control group but these value were similar in control and other treatments.

Results of feeding indices are presented in table 2. At the end of experiment food conversion ratio, feed efficiency, protein efficiency and food consumption in this period didn't show any significant difference ($P<0.05$), but daily food intake showed significant difference between T1 and the other treatments ($P<0.05$). There weren't any significant differences ($P<0.05$) between control and other deprived treatments in body moisture, ash, protein and lipid (Table 3).

Table 1: Growth performance values of *O. mykiss* at four feeding regimes (mean±SEM)

	Treatments			
parameters	C	T1	T2	T3
Initial weight(g)	17.76±0.14	17.55±0.12	17.40±0.13	17.51±0.15
Final weight(g)	38.85±0.92	36.01±1.66	37.49±1.31	35.47±1.14
WG (%)	118.71±3.68	105.02±8.31	115.28±5.98	102.39±4.78
SGR(%day)	2.60±0.05	2.38±0.13	2.55±0.09	2.34±0.07
CF	0.87±0.39	1.17±0.01	1.11±0.01	1.13±0.01

C, Control (fed two times daily to apparent satiation); T1, Treatment 1 (one days starvation and two days re-feeding); T2, Treatment 2 (one day starvation and 4 days re-feeding); T3, Treatment 3 (three days starvation and twelve days re-feeding). No significant differences were observed among the four studied groups.

Table 2: Feed utilization values of *O. mykiss* at four feeding regimes (mean±SEM)

	Treatments			
Parameters	C	T1	T2	T3
FCR	0.84±0.01	0.85±0.02	0.82±0.00	0.85±0.01
Feed efficiency	118.52±2.37	117.21±3.05	120.74±1.33	116.95±1.73
Protein Efficiency	2.96±0.05	2.93±0.07	3.01±0.03	2.92±0.04
DFI	14.28±0.26[a]	18.10±0.99[b]	14.46±0.77[a]	14.64±0.61[a]
Food consumption	385±7.27	344±18.84	361±19.33	336±14.23

C, Control (fed two times daily to apparent satiation); T1, Treatment 1 (one days starvation and two days re-feeding); T2, Treatment 2 (one day starvation and 4 days re-feeding); T3, Treatment 3 (three days starvation and twelve days re-feeding). Different superscript letters denote significant differences among the experimental groups.

Table 3: Body composition of *O. mykiss* at four feeding regimes at the end of the experiment (mean ±SEM) in dry weight

	Treatments				
Parameters	Initial	C	T1	T2	T3
Moisture	75.24±0.01	73.78±0.16	73.70±0.39	74.25±0.30	74.41±0.17
Ash	2.17±0.29	2.48±0.15	3.59±4.99	2.38±0.59	2.45±0.13
Lipid	6.39±0.09	6.77±0.41	6.86±1.32	6.29±0.87	6.33±0.73
Protein	15.63±1.18	15.45±1.85	15.06±3.05	16.27±1.75	15.13±1.87

C, Control (fed two times daily to apparent satiation); T1, Treatment 1 (one days starvation and two days re-feeding); T2, Treatment 2 (one day starvation and 4 days re-feeding); T3, Treatment 3 (three days starvation and twelve days re-feeding). No significant differences were observed among the four studied groups.

DISCUSSION

The most important factor in fish culture is the growth control. One of the most reliable methods for growth control is using of compensatory growth phenomenon. It has been reported that compensatory growth have a vital role in optimization and management of feed in fish culture practices [22, 23, 24] including efficient feed utilization, increasing in growth rate, minimizing food waste and more flexible feeding regimes [25], but results have been inconsistent in different species.

Responses of fish to compensatory growth are different between various species, In other words, there are different ways that fish species respond to starvation and re-feeding periods [16, 26-30]. Over-compensation was observed in hybrid sunfish by Hayward *et al.* [13]. Complete compensation were reported in European minnows by Russel and Wootton [31]; in rainbow trout with different periods of starvation and refeeding by Weatherly and Gill [32], Dobson and Holmes [9], Quinton and Blake [32], Nikki *et al.* [14]; in Atlantic cod by Jobling *et al.* [2]; in pikeperch by Mattila *et al.* [33]; Chinese sturgeon by Liu *et al.* [34] and Xie *et al.* [28].

Partial compensation were reported in Atlantic charr by Jobling *et al.* [35], in gilthead sea bream by Eroldogan *et al*. [8], Atlantic halibut by Heide *et al.* [17] and in Whitefish by Kankanen and Pirhonen [36]. Furthermore, no compensation are also reported in common carp by Schwarz *et al*. [37] and great sturgeon by Falahatkar *et al*. [38] after realimentation following food restriction. At the end of this experiment, all deprived fish had fully compensated for previously lost weight as indicated by the similar final mean weights in the four treatments. The results of this study are in agreement with studies that have been reported fully compensatory growth. These differences among these illustrated results could be due to different experimental procedures or condition, physiological condition, temporal differences and time of feed deprivation [39, 40].

It can be suggested from the obtained results that rainbow trout are capable to fully compensate short terms deprivation following refeeding, however the growth rate was lower in deprived treatments but were not significantly different compared to control. The results of Xie *et al.* [28] on gibel carp and Eroldogan *et al.* [41] on *carassius auratus* are in agreement with ours, they didn't observe any significant difference in SGR between different treatments, so deprived fish achieved 92%, 96% and 91% of control final weight, respectively, that indicating a high ability of the Rainbow trout to grow sufficiently to fully compensate for weight loss during starvation. This may be due to reduced metabolic rate during feed deprivation as a result of decreased activity [1, 8, 42] and increased daily feed intake or a combination of both [17]. No significant difference in condition factor confirms this phenomenon, too.

In some studies hyperphagia during re-feeding has been reported for many fish [2, 8, 17, 33]. It has been reported that hyperphagia in the first day of refeeding period is in maximum value, especially after some cycles of deprivation and refeeding [13, 27, 30, 43]. In the present study, it is possible that hyperphagia be as a main mechanism of compensatory growth. There was significant difference in daily feed intake between T1 and other treatments but there weren't any significant difference in FCR and other feeding performances. Our results are in agreement with Tian and Qin [12] and Kankanen and Pirhonen [36], but in conflict with Jiwyam *et al*. [44] and Foss [45]. Studies are shown restriction or food deprivation might be a reason to increase enzymatic activity in digestion system [46, 47] and this may lead to improvement in FCR.

In this study feed deprivation did not seem to have significant effect on the total body moisture and ash of the deprived fish. This is in accordance with the results on rainbow trout [23], barramundi [12, 25] and gilthead sea bream [41]. Wang *et al.* [48], Xie *et al.* [28], Iqbal *et al.* [49] and Abdel-Hakim *et al.* [50] didn't observe any significant difference on ash, too. On the contrary wang *et al.* [48] and Matilla *et al.* [33] observed significant difference on moisture, the reason of these differences can be due to the inverse lipid-moisture relationship that it occurs due to the replacement of utilized lipid with an equal volume of water [51]. Furthermore, Maintenance of weight after these periods perhaps is due to the replacement of utilized lipid with water [1, 51]. There weren't any significant difference in lipid and protein too. Zhu *et al.* [29], Tian and Qin [12, 25], Zhu *et al.* [24], Heide *et al.* [17] and Falahatkar *et al.* [38] Eslamloo *et al.* [52] presented significant difference in lipid content. Protein of whole body similar to Tian and Qin [25] on barramundi didn't show significant difference, but the results of Quinton and Blake [23], Xie *et al.* [28], Tian and Qin [12], Iqbal *et al.* [49], Matilla *et al.* [33] are in contrary with ours. The effect of periods of starvation and refeeding on utilization of reserve protein and lipid seems to be species-specific [53, 54], which may have caused the difference in the results and maybe the period of experiment was not long enough to create difference in our treatments, so it can be another reason to create difference in the results. The present study indicated that rainbow trout adapted to short term starvation and can defend body composition in these periods.

CONCLUSION

Overall, it can be suggested that rainbow trout can tolerate short terms starvation and refeeding periods alternatively by compensatory growth, it means through physiological and biological means fish tries to buffer the effect of starvation on its body composition [55], however, further research including physiological response is needed to confirm this finding.

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