Int.J.Curr.Microbiol.App.Sci (2019) *8*(5): 1817-1827

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 05 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.805.211

Effect of Short-term Cycles of Feed Deprivation and Refeeding to Promote Compensatory Growth of *Dawkinsia tambraparniei*, An Indigenous Ornamental Fish

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Keywords

Feed Restriction, Feed deprivation and refeeding, *Dawkinsia tambraparniei* and Compensatory growth

Article Info

Accepted:
15 April 2019
Available Online:
10 May 2019

A B S T R A C T

In present experiment one month juveniles (171.60±2.93 mg) of *Dowkinsia tambraparniei*, Tambraparni barb; an indigenous ornamental barb fish has been fed with different feeding regimes for 90 days. In control the fish was fed daily up to satiation whereas in T1, one day feed deprivation and 2 day refeeding (1D: 2R), T2, one day feed deprivation and 1 day refeeding (1D: 1R), T3, two day feed deprivation and 1 day refeeding (2D:1R) and T4, three day feed deprivation and 1 day refeeding (3D:1R) for 24 days in every 30 days. The last 6 days of every30 days, fishes from all treatments and control were fed upto satiation for compensatory growth. The mean weight of fishes on 30th day and 60th day in T1 was not significantly different from control and T2 group. The SGR and weight gain (%) in T1 group was not significantly different from control. The feed consumed during the 90 days in T1 group was 36% lesser than the control group. The current study revealed that, approximately 36 % feed can be reduced by depriving *Dawkinsia tambraparniei* to feed for one day and refeeding for two day without affecting growth performance, feed utilization efficiencies and survival rate.

Introduction

The reduction of production cost and negative effect on the environment without affecting production efficiency is ultimate aim of modern aquaculturist. Thus reduction of feed cost (around 60 % of total input cost) is become the constant target through various strategies.

Feeding protocols based on compensatory growth after periods of food deprivation (Jobling, 2010) is one of the best strategy to reduce feeding cost. Feeding strategy i.e. Feed restriction and compensatory growth in fish have been studied very well as a potential way to enhance the growth performance of fish, improving feeding activity after refeeding, and subsequently improving the efficiency of the production system (Chatakondi and Yant, 2001; Hayward *et al.*, 1997; Känkänen and Pirhonen, 2009) besides minimizing water problems (Turano *et al.*, 2008). Compensatory growth is a phase of accelerated growth in which normal conditions are restored after a period of growth restriction by either lack of food availability or unfavorable environmental conditions (Ali *et al.*, 2003). In most studies, compensatory growth has been investigated as a response after a period of total or partial feed deprivation (Skalski *et al.,* 2005).

The growth rate during refeeding is compensated through decrease in metabolic costs, an increase in feed intake or an improvement in feed utilization. With this, reduced basal metabolism (O'Connor *et al.*, 2000), increased feeding conversion efficiency (Jobling, 2010; Skalski *et al.*, 2005; Xiao *et al.*, 2013) and hyperphagia (Gaylord and Gatlin, 2001; Gurney *et al.*, 2003; Hayward *et al.*, 1997; Jobling, 2010; Känkänen and Pirhonen, 2009; Wang *et al.*, 2000; Xiao *et al.*, 2013) following periods of starvation or intermittent feeding was also observed in a number of fish species.

The response of Compensatory growth in fish can be mostly related to the duration and severity of feed restriction imposed prior to re-feeding (Bull and Metcalfe 1997; Hayward *et al.*, 1997).

In present experiment different duration of feed restriction were taken and the restoration phase was kept in fragmented form (6 days normal feeding after every 24 days restricted feeding.) that could lead to better Compensatory growth in terms of growth, feed conversion and survival in Tambraparni barb *Dawkinsiatam braparneie*.

The breeding and culture of Tambraparni barb (indigenous ornamental fish found in Tambraparni River, in the Western Ghats, Tamilnadu) has been standardised at ICAR-CIFA Bhubaneswar. This fish has good market value both in domestic and export market.

Materials and Methods

Animal and experimental design

The experimental animal (Tambraparni barb, *Dawkinsia tambraparniei*) was readily available at ornamental fish farm at ICAR-CIFA. The fishes were acclimatised in concrete tank for 2 week time before starting of experiment. A total of 225 fishes with mean weight of 172±0.003 mg were distributed equally into 15 experimental aquaria (45 litres capacity). The experimental design included one control (C) and four treatments (T1–T4) in triplicate (N = 3), following a completely randomized design (CRD). Water quality parameters like temperature (25^{0}C), dissolved oxygen (5.5–6.0 mg/l), pH (7.3–7.6) and total hardness (140-150 mg/l) were maintained optimum by continuous aeration and alternate day 10% water exchange done while removing the solid metabolic waste.

Feeding

In control fishes were fed daily up to satiation whereas in T1, one day feed deprivation and 2 day refeeding (1D: 2R), T2, one day feed deprivation and 1 day refeeding (1D: 1R), T3, two day feed deprivation and 1 day refeeding (2D:1R) and T4, three day feed deprivation and 1 day refeeding (3D:1R) for 24 days in every 30 days (schedule of feed shown as a chart in figure 1). In last 6 days of every month fishes from all treatments and control were fed upto satiation for compensatory growth. The feeding schedule has been shown in figure 1.

Nutritional composition of feed

In this experiment commercial feed for ornamental fishes (Optimum, Ho-pro feed, manufactured and Distributed by "Perfect Companion Group Co. ltd, Thailand') was used. It was floating feed with 1 mm size granules. The Nutritional composition of feed (as per manufacturer labelled on packet) is given in Table 1.

Fishes in different treatment groups were weighed at monthly intervals to assess the biomass. The growth performances were measured as

Percentage weight gain: [(Final Weight)-(Initial Weight)]x100/Initial Weight]
Specific growth rate (SGR, % day^{-1}) = 100 x (Ln final body weight – Ln initial body weight)/days
Feed conversion ratio (FCR) = total amount of consumed feed (g) / weight gain (g)
Economic Conversion Ratio (ECR)= Feed conversion ratio (FCR)* Price of Diet ($)
Compensation coefficient (CC) = $\Delta T \times \Delta C^{-1}$

where ΔT was the average weight gain (g) in the treatment group tanks divided by the number of feeding days and ΔC was the average weight gain (g) in the control group tanks divided by the number of feeding days; thus, CC>1.0 would indicate compensation)

The mortality of fishes was recorded on daily basis. A pre-weighed feed quantity (50 g) was taken in separate container for each aquaria and remaining feed after 30 days was weighed again to get the feed consumption during 30 days.

Statistical analysis

The data were statistically analyzed by statistical package SPSS version 16 in which data were subjected to one-way analysis of variance (ANOVA) (Snedecor and Cochran 1967 and Sokal and Rohlf 1981). To determine significant differences ($P<0.05$) among the treatments means, Duncan's multiple range test (Duncan 1955) was employed.

Results and Discussion

Initial mean body weight of fishes did not differ significantly ($P<0.05$) among the treatment groups (Table 2). On 30th day as well as on 60th day the mean body weight of control group fishes was not significantly different from T1 and T2 group fishes. The highest and lowest final mean body weight (on 90th day) was recorded in T1 and T4 group respectively but there was no significance difference between the final mean body weight (on 90th day) of control, T1 group and T2 group.

The FCR of different treatment groups along with control showed significant difference (Table 3). Although there was no significant difference in FCR of T1, T2 and T3 group but the lowest FCR was recoded in T1 group whereas highest in Control group.

ECR of different treatment group were significantly different among the control and different treatment groups (Table 3). In this study ECR was recorded lowest for T1 treatment group whereas highest for control group.

Specific growth rate (SGR) on 90th day in control group was not significantly different from T1 & T2 group (Figure 2). The lowest SGR was recorded in T4 group whereas the highest in T1 group. Although the weight gain (%) was also recorded highest in T1 group but it was not significantly different among control and T1 and T2 group (Table 3).

The feed consumption in control and different treatments has been shown in Table 4. The highest feed consumption was recorded in control group whereas lowest in T4 group. The feed consumption in T1 group was not significantly different from T2 group (Table 4). It was calculated that the feed consumption in different treatment group compared to control was lowest in T4 group (43.53% of total feed consumption in control group) where as it was highest in T1 group (64.19% of total feed consumption in control group).

The Compensation Coefficient (CC) of different treatment at the end of experiment is shown in figure 3. The CC for initial to final (0-90) was recorded in highest in T1 group (1.14) whereas lowest in T4 group (0.50). The CC value did not significantly different between T1 and T2 treatment.

During this experiment there was no significance difference ($p>0.05$) of survival (%) among the control and different treatment (Table 3). The highest survival was recoded in control group and lowest in T4 group.

Effect of feed deprivation and refeeding to promote compensatory growth of fish has been reported very well for various species (Ali *et al.,* 2003; Jobling, 2010). The exact mechanisms of compensatory growth are still to be understood. However, it is suggested that during refeeding, growth rate is compensated by either a decrease in metabolic costs, an increase in feed intake or an improvement in feed utilization. In present experiment, different cycle of feed deprivation and refeeding to promote compensatory growth has been done. Our results show that short-term cycles of feed deprivation (one days) followed by refeeding (one day) elicited full compensatory growth in *Dawkinsia tambrapariei* while enabling a reduction of up to 38% in the amount of feed offered to fish. Some similar full compensation results have been obtained in previous studies carried out on different fish species and feeding models (Kim and Lovell, 1995; Gaylord and Gatlin, 2001; Zhu *et al.,* 2001, 2005; Tian and Qin, 2003, 2004; Nikki *et al.,* 2004; Oh *et al.,* 2007). In other study some found partial compensation (Jobling *et al.,* 1993; Hayward *et al.,* 2000; Ali and Jauncey, 2004; Wang *et al.,* 2005, 2009; Eroldoğan *et al.,* 2006a, 2008; Mattila *et al.,* 2009; Liu *et al.,* 2011) and over compensation (Hayward *et al.,* 1997; Turano *et al.,* 2007).

In present study the mean weight of fishes in T1 and T2 group was not significantly different from control. It shows the complete compensatory growth in T1 and T2 treatment. The total feed intake in T1 and T2 treatment was 36% and 38% less compared to control. The feed conversion ratio did not showed any significant difference among the treatment but it was lowest in T1 treatment. Above result expressed the better feed utilization with short feed deprivation (T1 and T2) compared to control. The fishes exposed to longer feed deprivation (T3 and T4) could not get the compensatory growth. Similar results were observed in barramundi (*Lates calcarifer*), as complete compensatory growth occurred in fish that experienced moderate feed restriction (Tian and Qin 2004). Jiang *et al.,* (2002) and Li and Qin (2003) reported that specific growth rate in deprived groups of red drum (*Sciaenopsocellatus*) and barramundi, respectively, was greater to achieve compensatory growth. It was well explained by Ali *et al.,* (2003), that short food deprivation periods where sufficient food is available between the starvation periods, a hyperphagic reaction during refeeding can prevent measurable growth depression, thus the growth patterns of continuously fed and temporarily deprived fish become almost identical. The lowest FCR value in T1 treatment indicates the better feed utilization in this group compared to others. It may be due to increased feed efficiency during growth compensation. In previous studies (Wang *et al.,* 2000; Eroldoğan *et al.,* 2006a and Van Dijk *et al.,* 2002) also improved feed efficiency ratio in fish undergoing compensatory growth were reported.

Table.1 Nutritional Composition as per the manufacturer of commercial feed used during study

S.No.	Nutritional Component	Minimum (Min.) or Maximum (Max.)	In Percentage (%)
1	Crude Protein	Min	38
2	Crude Fat	Min	4
3	Crude Fiber	Max	3
4	Moisture	Max	12
5	Crude Ash	Max	12

Table.2 Mean weight of *Dawkinsia tambrapariei*, *Tambraparni barb* in different treatment group at different time point

Treatment	Initial	30th day	60th day	90th day
Control	$166.67^{a}\pm10.18$	$235.56^{ab}\pm21.19$	$371.11^{b}\pm27.03$	$440.95^{bc}\pm36.79$
T1 (D1:R2)	$171.11^{a}\pm4.44$	$277.78^{b}\pm11.75$	$380.16^{b}\pm33.61$	$479.62^{c}\pm35.02$
T2 (D1:R1)	$173.34^{a}\pm10.18$	$272.01^{b}\pm21.51$	$336.64^{ab}\pm29.34$	$416.15^{bc}\pm33.65$
T3 (D2:R1)	$173.00^{a}\pm6.67$	$258.84^{ab}\pm9.69$	$333.86^{ab}\pm9.79$	$350.22^{ab}\pm14.64$
T4(D3:R1)	$174.00^{a}\pm3.87$	$215.56^{a}\pm15.55$	$281.87^{a}\pm18.36$	$308.12^{a}\pm24.06$

Note: Data are expressed as mean ± SE on wet weight basis. Means with different superscripts in the same column are significantly different (Duncan's multiple range test P\0.05). Control (feed every day), D1R2 (feed deprivation for one day and refeeding for two days), and D1R1 (feed deprivation for one day and refeeding for one day), D2:R1 (feed deprivation for two days and refeeding for one days) and D3:R1 (feed deprivation for three day and refeeding for one day) during 90 days. Here, D: number of feed deprivation days and R: number of refeeding days in feeding-starvation cycle

Table.3 The Feed conversion ratio, economic conversion ratio, percentage weight gain and survival in different treatment group on 90th day of experiment

Treatment	FCR	ECR	Wight gain (%)	Survival (%)
Control	$7.58^{c}\pm0.59$	$43.28^{c}\pm3.37$	$166.07^{bc}\pm25.78$	$97.78^{a}\pm2.22$
T1 (D2:R1)	$4.33^{a}\pm0.41$	$24.76^{a}\pm2.32$	$181.42^{c}\pm26.00$	$95.56^{a}\pm2.23$
T2 (D1:R1)	$5.35^{ab}\pm0.62$	$30.58^{ab}\pm3.54$	$140.51^{bc}\pm17.89$	$95.56^{a}\pm4.44$
T3 (D1:R2)	$5.09^{ab}\pm0.31$	$29.06^{ab}\pm1.77$	$103.11^{ab}\pm15.15$	$95.56^{a}\pm2.22$
T4(D1:R3)	$6.93^{b}\pm1.11$	$39.59^{bc}\pm6.34$	$77.63^{a}\pm12.23$	$88.89^{a}\pm5.88$

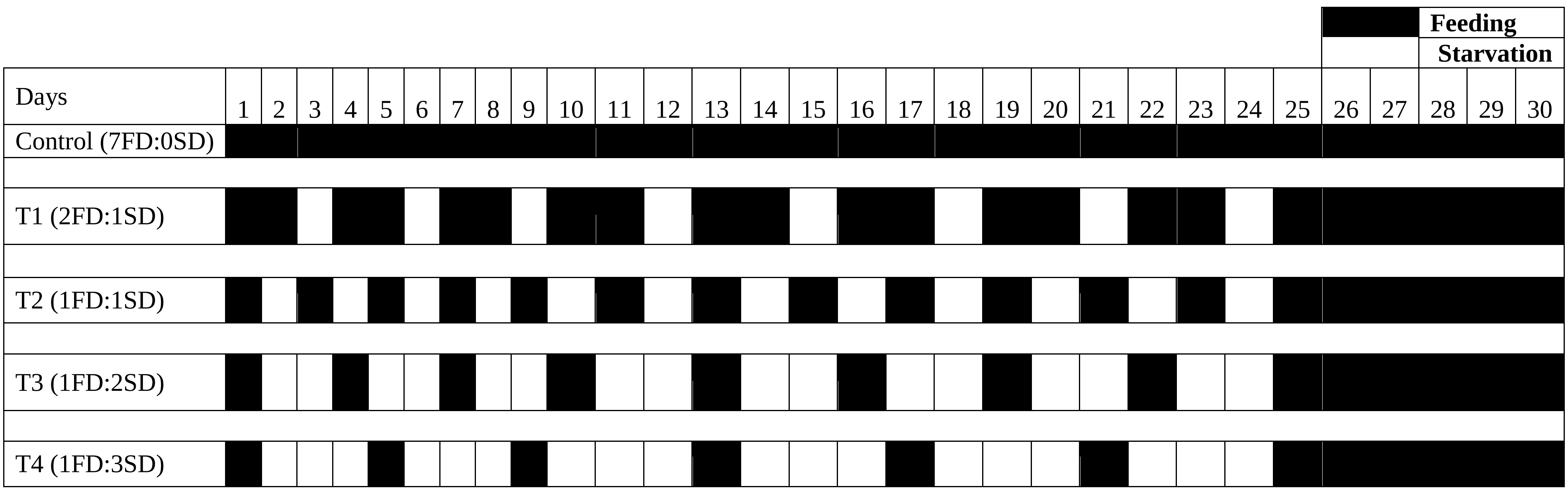
Note: Data are expressed as mean ± SE on wet weight basis. Means with different superscripts in the same column are significantly different (Duncan's multiple range test P\0.05). Control (feed every day), D1R2 (feed deprivation for one day and refeeding for two days), and D1R1 (feed deprivation for one day and refeeding for one day), D2:R1 (feed deprivation for two days and refeeding for one days) and D3:R1 (feed deprivation for three day and refeeding for one day) during 90 days. Here, D: number of feed deprivation days and R: number of refeeding days in feeding-starvation cycle

Table.4 Mean weight (g) of feed consumed in different treatment group during experiment

Treatment	Initial-30th days	30th day- 60th day	60th day-90th day	Total feed Consumed in 90 days	Feed consumed compared to control (%)
Control	$0.689^{c}\pm0.012$	$0.651^{b}\pm0.057$	$0.696^{c}\pm0.049$	$2.036^{c}\pm0.102$	100
T1 (D2:R1)	$0.458^{b}\pm0.038$	$0.416^{a}\pm0.097$	$0.433^{b}\pm0.002$	$1.307^{b}\pm0.036$	64.19
T2 (D1:R1)	$0.450^{b}\pm0.063$	$0.328^{a}\pm0.027$	$0.487^{b}\pm0.026$	$1.265^{b}\pm0.034$	62.16
T3 (D1:R2)	$0.253^{a}\pm0.027$	$0.365^{a}\pm0.067$	$0.271^{a}\pm0.019$	$0.889^{a}\pm0.053$	43.66
T4(D1:R3)	$0.256^{a}\pm0.014$	$0.301^{a}\pm0.015$	$0.330^{a}\pm0.019$	$0.886^{a}\pm0.028$	43.53

Note: Data are expressed as mean ± SE on wet weight basis. Means with different superscripts in the same column are significantly different (Duncan's multiple range test P\0.05). Control (feed every day), D1R2 (feed deprivation for one day and refeeding for two days), and D1R1 (feed deprivation for one day and refeeding for one day), D2:R1 (feed deprivation for two days and refeeding for one days) and D3:R1 (feed deprivation for three day and refeeding for one day) during 90 days. Here, D: number of feed deprivation days and R: number of refeeding days in feeding-starvation cycle

Fig.1 Feeding schedule in different treatment



Note: FD: number of feeding days and SD: number of Starvation days in feeding-starvation cycle

Fig.2 Specific Growth rate

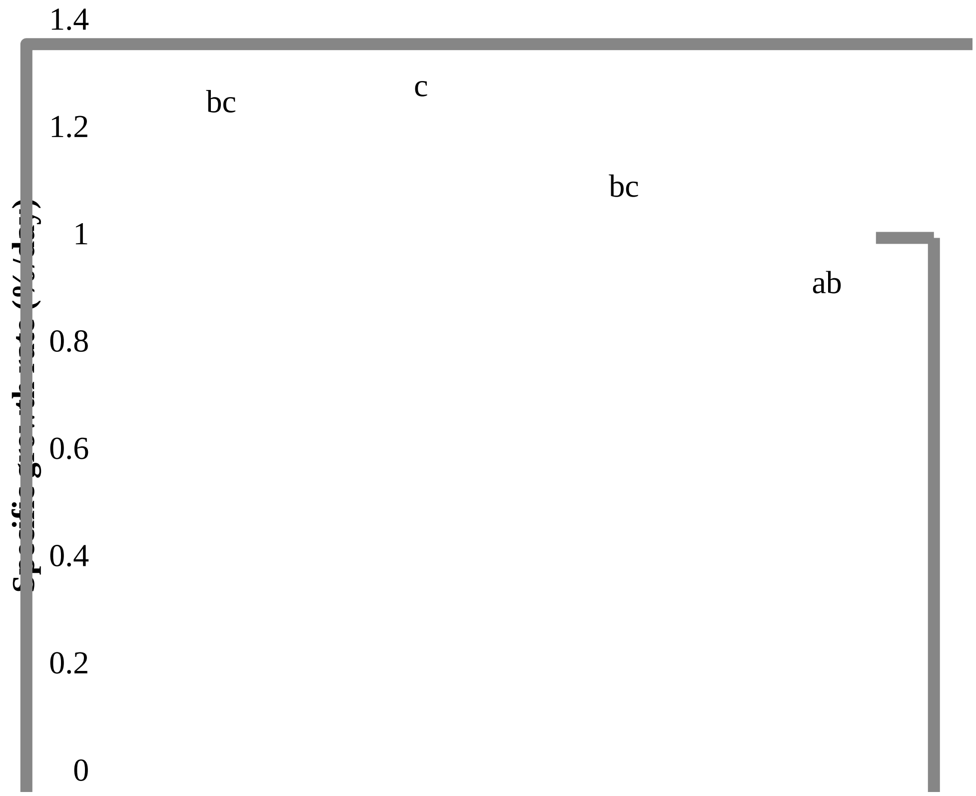
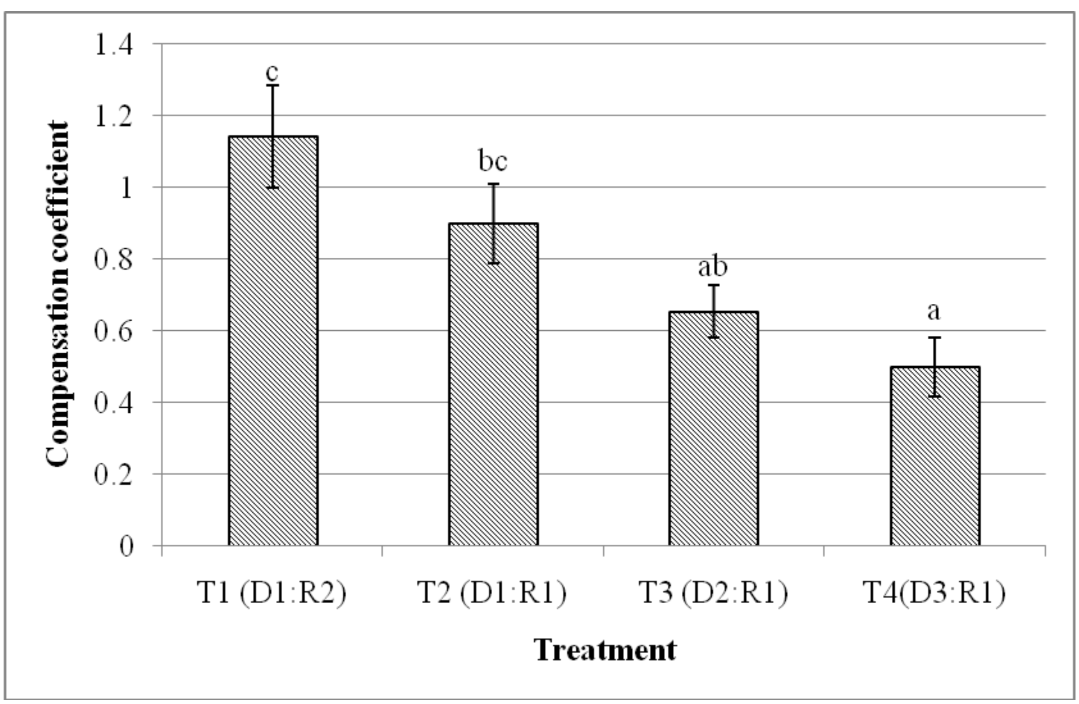


Fig.3 Compensation coefficient



The actual reason for increased growth potential during compensatory growth is poorly understood. Gaylord and Gatlin (2001) reported in channel catfish that the restricted feeding regime had improved cumulative feed efficiency. Improved growth and feed efficiency had also been reported in fishes during compensatory growth (Jobling *et al.*, 1994; Qian *et al.*, 2000).

The ECR value in present experiment was calculated by setting the feed price as 5.71 US$/kg (□ 400/Kg, 1 dollar=70 □).FCR is known to be directly proportional to economic conversion (Adakli and Taşbozan, 2015). Therefore, lowest ECR value of T1 group at the end of the trial shows that this group most utilized the feed effectively following the starvation period. Eroldoğan *et al.*, (2008) and Adakli and Taşbozan (2015) also reported lower ECR in short deprivation and refeeding feeding strategies.

In present study among the feed deprivation treatments, T1 group only showed compensation tendencies during the study with compensation coefficients higher than 1 (CC>1) whereas other group showed very poor (T2) or no compensation tendency (T3 and T4) (CC<1). This type compensation tendency in short feed deprivation and refeeding was reported in whitefish, *Coregonus lavaretus* (L.), (Kankanen and Pirhonen, 2009) and pikeperch fishes (Mattila *et al.*, 2009) (CC>1).

Survival of tambraparnei barb in present experiment was not significantly different among the treatments and control. Wang et al (2000) also reported similar survival percentage among the various treatment of feed restriction in Tilapia. However in present study the specific growth rate was significantly lower in T3 and T4 compared to others. So better compensatory growth in short duration feed deprivation (treatment T1 and T2) proved here. The feed consumed in different treatment was recorded and found that T1 group which showed best compensatory growth used 64.19% less feed of total feed consumption in control group. The use of compensatory growth strategies can reduce the production cost by cutting the feed cost. The better understanding of compensatory growth dynamics may allow the design of feeding schedules that improve growth rates along with minimizing cost in aquaculture (Hayward *et al.*, 1997). This growth spurt mechanism can be exploited in commercial aquaculture as it can result in improved growth and food conversion efficiency (Wang *et al.*, 2000).

In conclusion, best group in terms of full compensatory growth, feed utilisation and economic data growth was T1 group (one day feed deprivation and two day refeeding) during 90 days. The observation that growth in this fish can be fully compensated even with a reduction of nearly 36% of the feed offered, represents a promising alternative to improve the management of this species and the sustainability of its production system. The information may be of interest to fish producers.

Acknowledgement

This research was conducted at ICAR-CIFA. Authors express their obligations to ICAR for providing fund and Director of ICAR-CIFA, for his support during the research work.

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How to cite this article:

Mukesh Kumar Bairwa, Saroj Kumar Swain and Sunil Kumar Ail. 2019. Effect of Short-term Cycles of Feed Deprivation and Refeeding to Promote Compensatory Growth of *Dawkinsia tambraparniei,* An Indigenous Ornamental Fish. *Int.J.Curr.Microbiol.App.Sci.* 8(05): 1817-1827. doi: https://doi.org/10.20546/ijcmas.2019.805.211