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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ABSTRACT

In present experiment one month juveniles (171.60±2.93 mg) of Dawkinsia 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.

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

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 *Dawkinsia tambraparniei*.

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

where \(\Delta T\) was the average weight gain (g) in the treatment group tanks divided by the number of feeding days and \(\Delta C\) 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.

**Results and Discussion**

Initial mean body weight of fishes did not differ significantly (\(P<0.05\)) among the treatment groups (Table 2). On 30\textsuperscript{th} day as well as on 60\textsuperscript{th} 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 90\textsuperscript{th} day) was recorded in T1 and T4 group respectively but there was no significance difference between the final mean body weight (on 90\textsuperscript{th} 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 recorded 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 90\textsuperscript{th} 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±10.18  | 235.56±21.19   | 371.11±27.03   | 440.95±36.79   |
| T1 (D1:R2)    | 171.11±4.44   | 277.78±11.75   | 380.16±33.61   | 479.62±35.02   |
| T2 (D1:R1)    | 173.34±10.18  | 272.01±21.51   | 336.64±29.34   | 416.15±33.65   |
| T3 (D2:R1)    | 173.00±6.67   | 258.84±9.69    | 333.86±9.79    | 350.22±14.64   |
| T4(D3:R1)     | 174.00±3.87   | 215.56±15.55   | 281.87±18.36   | 308.12±24.06   |

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), D1:R2 (feed deprivation for one day and refeeding for two days), and D1:R1 (feed deprivation for one day and refeeding for one day), D2:R1 (feed deprivation for two days and refeeding for one day) and D3:R1 (feed deprivation for three days 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     | Weight gain (%) | Survival (%)  |
|---------------|---------|---------|-----------------|---------------|
| Control       | 7.58c±0.59 | 43.28±3.37 | 166.07bc±25.78 | 97.78±2.22    |
| T1 (D1:R2)    | 4.33a±0.41 | 24.76±2.32 | 181.42±26.00   | 95.56±2.23    |
| T2 (D1:R1)    | 5.35ab±0.62| 30.58±3.54 | 140.5±bc17.89  | 95.56±4.44    |
| T3 (D2:R1)    | 5.09ab±0.31| 29.06±1.77 | 103.11ab±15.15 | 95.56±2.22    |
| T4(D3:R1)     | 6.93b±1.11 | 39.59±6.34 | 77.63±12.23    | 88.89±5.88    |

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), D1:R2 (feed deprivation for one day and refeeding for two days), and D1:R1 (feed deprivation for one day and refeeding for one day), D2:R1 (feed deprivation for two days and refeeding for one day) and D3:R1 (feed deprivation for three days 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-30\(^{th}\) days | 30\(^{th}\) day- 60\(^{th}\) day | 60\(^{th}\) day-90\(^{th}\) day | Total feed Consumed in 90 days | Feed consumed compared to control (%) |
|----------------------|-----------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------------|
| Control              | 0.689\(^{b}\)±0.012         | 0.651\(^{b}\)±0.057             | 0.696\(^{b}\)±0.049             | 2.036\(^{b}\)±0.102             | 100                                    |
| T1 (D1:R2)           | 0.458\(^{b}\)±0.038         | 0.416\(^{a}\)±0.097             | 0.433\(^{b}\)±0.002             | 1.307\(^{b}\)±0.036             | 64.19                                  |
| T2 (D1:R1)           | 0.450\(^{a}\)±0.063         | 0.328\(^{a}\)±0.027             | 0.487\(^{a}\)±0.026             | 1.265\(^{b}\)±0.034             | 62.16                                  |
| T3 (D2:R1)           | 0.253\(^{a}\)±0.027         | 0.365\(^{a}\)±0.067             | 0.271\(^{a}\)±0.019             | 0.889\(^{a}\)±0.053             | 43.66                                  |
| T4 (D3:R1)           | 0.256\(^{a}\)±0.014         | 0.301\(^{a}\)±0.015             | 0.330\(^{a}\)±0.019             | 0.886\(^{a}\)±0.028             | 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), D2R1 (feed deprivation for two days and refeeding for one day) and D3R1 (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

| Days | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Control |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| T1 (D1: R2) |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| T2 (D1: R1) |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| T3 (D2: R1) |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| T4 (D3: R1) |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Note: Control (feed every day), D1: R2 (feed deprivation for one day and refeeding for two days), and D1:R1 (feed deprivation for one day and refeeding for one day), D2:R1 (feed deprivation for two days and refeeding for one day) 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. 2** Specific Growth rate

![Graph showing Specific Growth rate for different treatments.]

**Fig. 3** Compensation coefficient

![Graph showing Compensation coefficient for different treatments.]
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.

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