Compensatory Growth and Feed Utilization of Humpback Grouper, *Cromileptes altivelis* Receiving Preset Period of Unfed-Fed Cycle

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Abstract

The effect of preset periods of unfed-fed cycle on growth, feed efficiency and body condition indices of humpback grouper, Cromileptes altivelis *was studied. The fish receiving non-feeding/feeding cycle of 1/2 day (T1); 1/2 and 3 days alternately (T2); 1/3 day (T3); were compared to that fed daily as a control (C). Each feeding treatment was assigned to five fiberglass tanks according to a completely randomized design. All fish was weighed to obtain final weight gain at the end of the experiment. Feeding rate (FR) was calculated during feeding period throughout the experiment. At the end of the experiment all fish was weighed to obtain final fish weight. Absolute growth rate (AGR); survival; consumption; cumulative feed consumption, and feed conversion efficiency (FCE) were calculated. Data were subjected to analysis of variance and Tukey test (P<0.05). The results showed that humpback grouper Cromileptes altivelis receiving preset unfed-fed cycle elicited compensatory growth and the fish showed hyperphagia and greater feed conversion efficiency.*

***Key words**: humpback grouper, Cromileptes altivelis, unfed-fed cycle, growth, feed efficiency, body condition indices*

Introduction

Grouper is an important fish for tropical aquaculture in Indonesia and other South East Asian countries since it has high economical value in local as well as international market. Among other issues in aquaculture is that feed is the largest part of the production cost. In addition, the use of trash fish practiced in grouper production could threaten the sustainability of marine living resources. Therefore, effort to reduce feed input in aquaculture should be taken into account. Feed deprivation followed by normal feeding could provoke compensatory growth and improve early growth rate of fish so that this feeding regime may be applied in grouper production (Cho *et al*., 2006; Li *et al*., 2006).

Compensatory growth is a period of rapid growth exhibited by fish receiving a period of starvation followed by normal re-feeding. Such fast growth has been successfully elicited in many fishes including rainbow trout, *Oncorhynchus mykiss* (Quinton and Blake, 1990), European minnow, *Phoxinus phoxinus* (Russell and Wootton, 1992), Arctic charr, *Salvelinus alpinus* (Jobling *et al*., 1993), *Ictalurus punctatus* (Kim and Lovel, 1995; Gaylord and Gatlin 2000, 2001), sunfish, F1: female green sunfish *Lepomis cyanellus* X male bluegill *L. macrochirus* (Hayward *et al*., 1997, 2000), turbot *Scophthalmus Maximus* (Saether and Jobling, 1999) gibel carp *Carassius auratus gibelio* (L.) (Qian *et al*., 2000), hybrid tilapia, *Oreochromis mossambicus* x *O. niloticus* (Wang *et al*., 2000), gibel carp, *Carassius auratus gibelio* (Xie *et al*. 2001; Zhu *et al*., 2004) and olive flounder *Paralichthys olivaceus* (Cho, 2005; Cho *et al*., 2006). Such feeding regime resulted in equivalent final body weight with fish fed normally and could be promising means to reduce feed input in fish production.

A single phase of feed deprivation during 1 and 2 weeks followed by 5 weeks satiated feeding elicited complete compensatory growth in gibel carp, *Carassius auratus gibelio* (Xie *et al*. 2001). Tian and Qin (2003) reported that in barramundi *Lates calciferus* deprived from feed for 1 week followed by satiated feeding in 4 weeks elicited complete compensatory growth, but fish deprived from feed for 2 and 3 weeks only showed partial compensatory growth. Juvenile flounder *Paralichthys olivaceus* fed for 6 weeks after 2 weeks starvation showed compensatory growth, but the weight gain of fish starved for 3 and 4 weeks followed by normal feeding for 5 and 4 weeks respectively was significantly lower than fish fed daily (Cho *et al*., 2006). One week feed deprivation followed by satiated feeding also provoked complete compensatory growth in hybrid tilapia *Oreochromis mossambicus* x *O. niloticus*, reared in seawater (Wang *et al*., 2000). Complete compensatory growth did not attained by fish if they were fasted for more than 2 weeks prior to satiated feeding.

Compensatory growth has also been observed in gibel carp, *Carassius auratus gibelio*, and Chinese longsnout catfish, *Leiocassis longirostris*, receiving unfed-fed cycle (Zhu *et al*., 2004). Chatakondi and Yant (2001) obtained compensatory growth in channel catfish *Ictalurus punctatus* by employing preset period (1, 2 and 3 d) of feed deprivation followed by unfixed re-feeding period, i.e. as long as fish exhibiting higher food consumption than normal. A rapid growth observed in the fish receiving repeated cycle of starvation caused by hyperphagia and improved feed efficiency. The amount of feed consumed in fish showed compensatory growth did not significantly different from normal fish. Li *et al*. (2005) reported that partial compensatory growth was elicited in pond cultured channel catfish *Ictalurus punctatus* receiving periodic feed deprivation. They found that fish received unfed/fed cycle of 1/6 day gained similar weight with fish fed daily. Fixed feeding schedule to induce compensatory growth would be more flexible and practical to be applied in feeding management. The present study demonstrated the effect of a preset period of unfed-fed cycle on compensatory growth and feed efficiency of humpback grouper fingerling. The fish receiving unfed/fed cycle of 1/2 day; 1/3 day; 1/2 day and 3 day alternately were compared to that fed daily to satiation.

Material and Method

Humpback grouper *Cromileptes altiveis,* 5.96 ± 0.17 g in average body weight was obtained from Brackish Water Aquaculture Research Center in Situbondo, East Java, Indonesia. As soon as their arrival in the laboratory, 300 fish were acclimated during 2 weeks in 20 rectangular fiberglass tanks 60 x 40 cm; water depth 80 cm; 150 l water volume, with 15 fish per tank. Filtered seawater was distributed to the tanks at 1 l/min/tank . The water in the tank was aerated to keep dissolved oxygen above saturated level. During acclimation and experiment the fish fed with trash fish as much as 10% of body weight per day at 0900 and 1500. Uneaten feed was removed carefully from the aquaria at 20 minutes after presentation by siphoning and placed in filter paper, then dried in oven at 70 ^{0}C to a constant weight. Feed consumption was estimated from the difference between feed delivered into the tank and uneaten feed. Proximate composition of the feed is presented in Table 1.

Feeding treatments applied in these experiment include the following regimes: fish receiving non feeding/feeding cycle of 1/2 day (T1) fish receiving non feeding/feeding cycle of 1/2 day and 3 day alternately, so that the fish was deprived from feed every Monday and Thursday (T2); fish receiving non feeding/feeding cycle of 1/3 day (T3); fish feed daily as control (C). Each feeding treatment was assigned to five fiberglass tanks according to completely randomized design.

All fish were weighed at the beginning of the experiment. The sample of 3 fish was collected randomly from each experimental tank once a week and weighed to calculate weight gain. All fish was weighed to obtain final weight gain at the end of the experiment. Feeding rate (FR) was calculated during feeding period throughout the experiment. At the end of the experiment all fish was weighed to obtain final fish weight. Absolute growth rate (AGR); survival rate; consumption; cumulative feed consumption, and feed conversion efficiency (FCE) were calculated. Data were subjected to analysis of variance and Tukey test.

Water quality parameters including pH, temperature, salinity was measured daily (morning and afternoon) using digital pH meter, thermometer and hand refract meter for salinity, respectively. Samples of 200 ml water were taken from each experimental tank every morning and afternoon to measure dissolved oxygen using digital DO meter.

Result and Discussion

Initial weight, final weight, weight gain and AGR of humpback grouper, *C. altivelis* were presented in Table 2. Initial weight of humpback grouper accounted for 5.6 – 6.0 g, but the mean of fish weight of treatment groups was not significantly different. The fish receiving fixed period of unfed/fed cycle (treatment groups) tend to reach higher final body weight, but there was no significant different between treatment and control. In six weeks of the experiment the fish grew 82.06 %, 97.08 %, 84.05 %, and 94.97 % in T1, T2, T3 and C respectively. At the end of the experiment the weight gain of treatment groups was not significantly different from control (P>0.05). Reducing the period of feed availability did not influence the final fish weight achieved at the end of the experiment. The AGR of the T1, T2 and T3 was significantly greater than control (P<0.05). Survival rates in T1, T3 and C were ranged between 75 % - 100 %, in T2 were ranged between 83.33 % - 100 %. Mean survival rate of humpback grouper receiving fixed period of unfed/fed cycle was not significantly different from control (P>0.05).

Table 1. Proximate composition (mean ± SE) of trash fish used in the experiment

	% dry weight
Protein	56.15 ± 0.15
Lipid	14.75 ± 0.05
Ash	4.05 ± 0.15
Moisture	8.75 ± 0.05

Table 2. Initial weight, final weight, weight gain and AGR (mean ± SE) of humpback grouper, *Cromileptes altivelis*

Parameter	T1	T2	T3	C
Initial weight, g	6.14 ± 0.08[a]	6.01 ± 0.15[a]	5.96 ± 0.08[a]	5.74 ± 0.10[a]
Final weight, g	12.14 ± 0.32[a]	11.62 ± 0.13[a]	11.08 ± 0.16[a]	10.45 ± 0.14[a]
Weight gain, g	6.00 ± 0.41[a]	5.61 ± 0.13[a]	5.22 ± 0.36[a]	4.71 ± 0.27[a]
AGR, g	0.21 ± 0.05[a]	0.18 ± 0.03[a]	0.17 ± 0.03[a]	0.11 ± 0.01[b]
Survival rate, g	86.67 ± 4.25[a]	93.33 ± 3.12[a]	86.67 ± 5.65[a]	85.00 ± 4.08[a]

Weight gain = final weight – initial weight; AGR = weight gain/number feeding day; SR = % number of fish survived in each group at the end of the experiment. Significant differences were found between groups with different superscripts in the same row (P<0.05).

The humpback grouper of T1, T2 and T3 grew in similar pattern and reached similar body weight with control (C) during week 1 to week 3 (Fig. 1). In the forth week the fish of treatment groups began to show higher weight. During week 5 and 6 the fish in treatment groups showed higher body weight but not significantly different from control (P>0.05). The fish in treatment groups seem to grow rapidly as from week 4 to achieve complete compensatory growth.

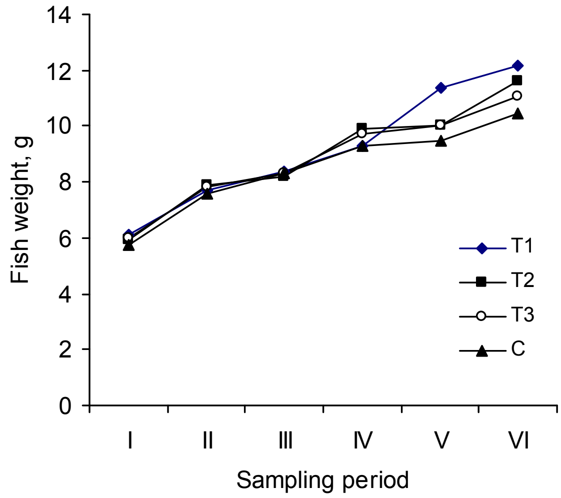

Figure 1. Mean body weight of humpback grouper *Cromileptes altivelis* receiving periodic feed deprivation and control measured weekly in six sampling period during the study

Mean feeding rates during the whole experiment ranged between 4 % – 11.3 %; 2 % – 8.5 %; 2.4% – 10 %; 2 % – 8.7 % in T1, T2, T3 and C respectively. Fish of T1 maintained higher FR throughout the experiment as compared to C, except fish of T2 showed lower FR in day 20, 24, 25 then in day 37, 38 and day 39 and the fish of T3 showed lower FR in day 28 and 42 (Fig.2).

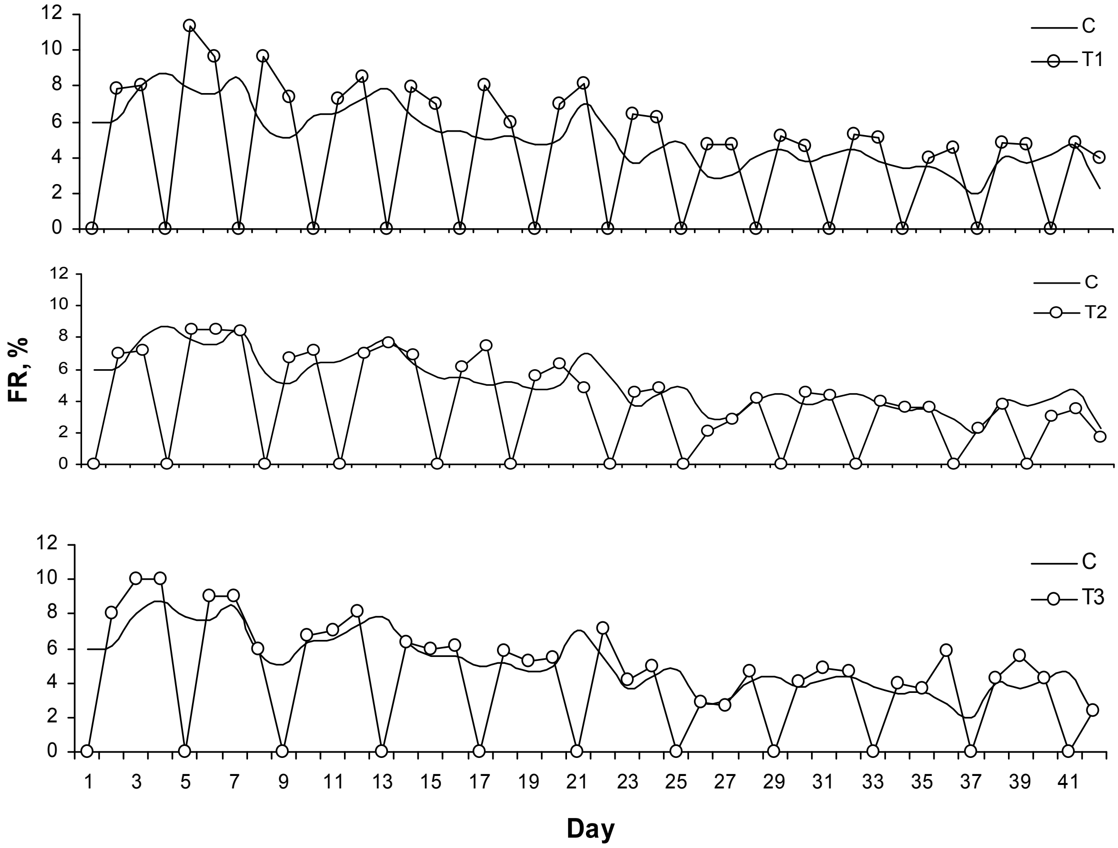

Figure 2. Mean feeding rate of humpback grouper *Cromileptes altivelis* throughout the experiment. FR: % feed consumed/fish/day

Table 3 shows that the fish of T1 was subjected to a greater total unfed-fed cycle followed by T2 and T3. Consumption of T1 was the highest, followed by that of T2 and T3 which were significantly higher (P<0.05) than control. These phenomena indicated that hyperphagia occurred in fish receiving a preset period of unfed/fed cycle. Although the fish of treatment groups consumed a greater amount of feed during feeding period, feed conversion efficiency (FCE) of these fishes was slightly better than control, possibly the fish utilized feed more efficiently.

Table 3. Consumption and feed conversion efficiency (FCE) (mean ± SE) in humpback grouper fed daily and starved periodically for 6 weeks in experimental tanks. Data sharing the same letter was not significantly different (P>0.05)

Parameter	T1	T2	T3	C
Total days of feeding	28	30	32	42
Total fed-unfed cycle	14	12	10	-
Consumption, g	0.55 ± 0.03[a]	0.49 ± 0.03[b]	0.46 ± 0.02[b]	0.41 ± 0.02[c]
FCE	0.39 ± 0.03[a]	0.38 ± 0.01[a]	0.37 ± 0.01[a]	0.27 ± 0.02[b]

Consumption = g feed/fish per day; FCE = gram weight gain/gram feed. Significant differences were found between groups with different superscripts in the same row (P<0.05).

Mean total feed consumed during the experiment accounted for 15.4 g; 13.8 g; 15.7 g and 17.2 g in T1, T2, T3 and C respectively. The cumulative feed consumptions of all treatment was significantly lower (P<05) than control, but there is no significant different between treatments. Although fishes of control consumed greater amount of feed than fish of treatment, this was not the case with the weight gain (Fig.3). The cumulative feed consumptions of T1 and T2 were perfectly in parallel with the weight gain, but the higher cumulative feed consumption in control resulted in lower weight gain.

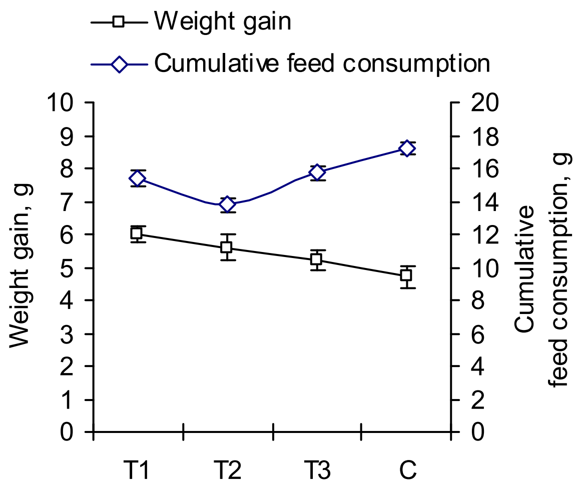

Figure 3. Weight gain and cumulative feeding (mean ± SE) of humpback grouper *Cromileptes altivelis* at the end of the experiment

Compensatory growth has been induced by feed deprivation followed by normal re-feeding in tropical fishes including tilapia (Wang *et al.*, 2000) and barramundi (Tian and Qin, 2003, 2004). Hybrid tilapia, *Oreochromis mossambicus* x *O. niloticus*, reared in seawater showed complete compensatory growth after deprived from feed for 1 week followed by normal feeding for 4 weeks, but such phenomenon did not occur when deprivation were more than 1 week (Wang *et al.*, 2000). Complete compensation has also been reported in barramundi, *Lates calcarifer* starved for 1 week followed by 8 weeks of satiated re-feeding (Tian and Qin, 2003). However, the fish starved for 2 weeks followed by satiated feeding for 5 weeks did not show compensatory growth (Tian and Qin, 2004). Juvenile flounder *Paralichthys olivaceus* starved for 3 and 4 week followed by normal feeding for 5 and 4 weeks respectively achieved significantly lower weight gain than fish fed daily (Cho *et al*., 2006). These suggest that compensatory growth could only occur in fish receiving short term feed deprivation.

Repeated unfed-fed cycle also elicited compensatory growth in hybrid sunfish (Hayward *et al*., 1997, 2000). Channel catfish, *Ictalurus punctatus* receiving a fixed short term feed deprivation and re-feeding showed either complete or partial compensatory growth (Kim and Lovell, 1995; Gaylord *et al*., 2001, Li *et al*., 2005). In fact, overcompensation has been reported to occur in channel catfish deprivation periods of 1, 2 and 3 days followed by re-feeding as long as the hyperphagia persisted (Chatakondi and Yant, 2001). However, gibel carp, *Carassius auratus gibelio* and Chinese longsnout catfish, *Leiocassis longirostris* showed only partial compensation as response to cycles of one week feed deprivation and two weeks of satiation feeding (Zhu *et al*., 2004). The present experiment showed that repeating cycles of preset one day unfed followed by two to three days re-feeding elicited the ability of the humpback grouper, *C. altivelis* to achieve equivalent wet weight with that fed continuously. The short period of food deficiency did not seem to exert negative effect on physiological condition of fish which reduce the growth. In fact, the fish from treatments reached slightly higher final body weight and the AGR of the treatments was significantly higher than control (Table 2). This is in agreement with previous finding that feeding period must be longer than fasting period in order the fish to elicit compensatory growth (Nikki *et al*., 2004).

The present experiment showed that fish experienced repeated fixed period of food availability did not decrease the weight gain in the long term. During the first weeks of the experiment the fish grew similarly with control (Figure 1). The fish apparently required 3 weeks of acclimatization phase and afterward the treatments tended to grow more rapidly than control. Such pattern of acclimatization has also been found in barramundi, *Lates calcarifer* subjected to single phase of feed deprivation followed by normal re-feeding (Tian and Qin, 2003, 2004). Both species, *C. altivelis* and *L. calcarifer* probably require some few days to acclimatize themselves to the feeding regimes they experienced. However, acclimatization most probably occurs in fish encounters a regular disadvantageous condition such as repeated short term food unavailability.

In the present experiment humpback grouper receiving repeating unfed/fed cycles tend to show higher feeding rate (FR) and significantly higher consumption as compared to control (Table 3). Feed consumption higher than normal has also been found in several fish species during compensatory growth as response of a single phase of feed deprivation (Russell and Wootton, 1992; Wang *et al*., 2000). Furthermore, channel catfish, *Ictalurus punctatus* receiving a fixed number of days of starvation (1, 2 and 3 days) followed by unfixed number of days of refeeding also showed hyperphagia which causes compensatory growth (Chatakondi and Yant, 2001). In the present experiment, humpback grouper experiencing unfed-fed cycle showed increased appetite during feeding periods. Hyperphagia as well as improved FCE resulted in compensatory growth in humpback grouper *C. altivelis.* This is not in agreement with other findings which demonstrated that FCE did not contribute to the compensatory growth in rainbow trout *Salmo gairdneri* (Dobson and Holmes, 1984); European minnow, *Phoxinus phoxinus* (Russell and Wootton, 1992); gibel carp, *Carassius auratus gibelio* (Qian *et al*., 2000). Since the number of feeding day of fish receiving unfed-fed cycle was lesser than control the FCE of the fish was better than control (Table 2). Thus, periodic feed deprivation could improve feed efficiency without declining the growth of humpback grouper.

The grouper experiencing unfed-fed cycle grew faster than control probably due to the increase of consumption (Table 3). Similar phenomenon has also been reported to occur in channel catfish *Ictalurus punctatus* receiving unfed-fed cycle, but the fish was fed in variable period as long as hyperphagia persisted following fixed period of feed deprivation (Chatakondi and Yant, 2001). In the present experiment, the humpback grouper was fed in fixed period. Since one week consists of 7 days, 1 day unfed period followed by fixed fed period of 2 and 3 days alternately (T3) should be the most practical for application. Thus the fish is deprived from feed twice a week in two fixed day.

The results showed that despite higher weight gain, cumulative feeding of humpback grouper experiencing unfed-fed cycle was lower than control (Fig. 3). This indicates that the fish deprived from food periodically utilizes the feed more efficiently in term of growth. Reducing feed input by means of periodic food deprivation do not decrease the growth of humpback grouper. However, catfish subjected to repeating cycle of deprivation only achieved 75-80% of fish fed daily (Zhu *et al*., 2004). The length of feed deprivation in the experiment done by Zhu *et al*. (2004) was 1 week, while that in the present experiment was only one day.

Conclusion

To conclude, preset period of unfed-fed cycle do not decrease the fish growth and survival rate, but it improve feed utilization. Application of this feeding regime provides flexibility in feeding management and probably reduces organic discharge into the environment. It would also reduce labor cost and would help the effort toward sustainable and responsible aquaculture.

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