Compensatory Growth Of Juvenile Nile Tilapia And Changes In Body Crude Composition During Starvation And After Refeeding

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Abstract

This work was designed to know the effect of starvation and refeeding on compensatory growth and changes in body crude composition in juvenile Nile tilapia (Oreochromis niloticus). There are four feeding regimens, which are C; feeding for 6 weeks (full-fed) for control treatment, S1; 2 weeks of fasting followed by 4 weeks starving, S3; 4 weeks of starving followed by 2 weeks feeding and S3; starving for 6 weeks(fully starved). S1 treatment had higher growth gain, SGR, FER and PER respectively than other treatments. The poorer values for compensatory growth were obtained in tilapia for S3 treatment. The moisture content in fish significantly decreased and the ash content significantly increased with increasing starvation period before re-feeding for third week and six-week experiment. The lipid content is significantly higher in S1 compare to S2 and S3 treatment for third week experiment. However, there is significantly increase in lipid content from third week experiment (3.79%) to sixth week experiment (15.89%). No significance different were found in protein and ash content among control group, S1, S2, S3 treatment for both week of proximate time. The deprived fish showed hyperphagia during the 2 weeks period or starvation and 4 weeks re-feeding. The difference in body crude composition during starvation and re-feeding indicate that there are metabolism changes during lipid and protein utilization. In conclusion, optimum compensatory growth was achieved and there are changes in body crude composition in juvenile tilapia for 2 weeks food deprivation and refeeding for 4 weeks since there is improvement in weight gain, SGR, PER and FER, lipid and protein content in body composition

Keywords: Compensatory growth, body crude composition, juvenile tilapia

1. Introduction

Compensatory or catch up growth is a period of unusually fast growth of fish by following feeding schedule in which period of feed deprivation are followed by period of satiation feeding caused by restricted food availability factors, or by other environmental conditions, such as density alternation, low temperature, hypoxic condition, etc (Ali et al, 2013; Nikki et al., 2004). Cycle starvation or re-feeding regimes for aquaculture have been suggested to increase growth and higher food conversion efficiency (Foss et al., 2009).

There are several hypothesis that attempt to explain the increased growth following a fasting period such as increase of feed intake (hypergia), weight gain and nutrient synthesis (Bower et al., 2009; Hayward et al., 2000). Compensatory growth has been shown in several type of species e.g Atlantic Halibut (A.Heide at al., 2006); Longsnout catfish (X. Zhu et al., 2005) ; Chanel catfish (R.C.Reigh et al., 2006). There are few other reports of compensation growth, some full compensation has been achieved, whereas in others, only partial compensation has been shown (Ali et al., 2013).

Tilapias are omnivorous, euryhaline and warm water fishes that are important in aquaculture (Y.Wang et al., 2000). It is a focus of current aquaculture because it has high demand in Malaysia. Recently, for tilapia, most current research has focus on diet composition on growth (K.T. Tran-Ngoc et al., 2016; A. Al-Souti et al., 2012) and feeding factors (J.-Y. Liang, Y.-H. Chien.,2013). However, there are several studies on compensatory growth for tilapia have been reported (Y.Wang et al., 2000; S.Yamada et al, 1994).

Therefore, the purpose of the present study was to investigate the effect of starvation and after re feeding on compensate growth and changes in body crude composition of juvenile Nile tilapia (*Oreochromis niloticus*).

2. Materials and methods

2.1. Source of animal and acclimation

Juvenile tilapias were obtained from Freshwater Hatchery, Kolej Komuniti Bera. The juveniles were cultured in a fiberglass tank and were acclimated for a week to fully ensure environmental adaptation. The fish were fed twice a day with artificial starter pellets.

2.2. Experimental design

Four treatments were designed in this study i.e., C the control group were fed with feed of 5 % from body weight twice a day at 1000 and 1700 throughout the experiment for 6 weeks; S1, fish were starved for 2 weeks and then hand fed with feed of 5 % from body weight for 4 weeks; S2, fish were starved for 4 weeks and then hand fed with feed of 5 % from body weight for 2 weeks and S4, the starvation group, fish were starved throughout the whole experiment.

2.3. Growth measurement

Ten fish were weighed individually at the start of experiment for each treatment. For each treatment, the fish were weighed approximately every week thought the feeding trial. Specific growth rate (SGR) was calculated according to the formula of Houde and Schekter (1981):
SGR = $(e^{g}-1)/100$ where $g=(\ln(W2) - \ln(W1))\ (t2-t1)^{-1}$ and W2 and W1 are weights on days t2 and t1, respectively. Total feed consumption (CT) was

calculated as total feed supplied to the fish, 5 % from their body weight every day. Feed efficiency ratio (FER) was calculated as consumed fed per biomass gain per gain weight unit. Protein efficiency ratio (PER) was calculated as:
PER = wet weight gain/ protein consumed (dry matter)

2.4. Body crude composition

Twenty juvenile tilapias on the initiation of experiment, 10 juvenile tilapias for first 3 weeks for each treatment , 5 juvenile tilapias from C, S1, S2 and 10 juvenile tilapias from S4 were sampled and proximate analysis based on AAOC's (1990). Moisture was determined by drying the samples in an oven at 105 °C for 24 h to a constant weight; ash was determined by incineration of samples in a muffle furnace at 550 °C for 12 h; crude protein (N×6.25) was measured by an auto Kjeldahl unit (Kjeltex; model 2100), total lipid was measured by extracting the crude fat with petroleum ether with Soxtec model 20143 extractor for 1 hour and drying the sample in 100 ^{0}C. For fiber content, samples were digested with 0.128 M H2SO4 in digestion unit (Hot Extractor, Model-1017) for 30 min. The samples were filtered and washes with boiling water to remove acid. Residue was boiled with 0.223 M KOH for 30 min, then washed in boiling water. The residue was dried in an oven at 130°C for 2 h and ignited in muffle furnace at 500°C for 3 h. The loss of weight represented the crude fiber.

2.6 Statistical analysis

The data were analyzed by the SPSS for Windows (Version 20) statistical package. All parameters between the treatments were compared with one-way ANOVA followed by LSD multiple range tests for post-hoc pairwise comparisons.

3. Analysis and results

During the experiment, 21 fish were found dead in the tanks and total mortality in the different treatment amount to: Control = 4 fish, S1 = 4 fish, S2 = 4 fish and S3 = 8 fish that bring the value of survival rate are presented in Table 1.

Table 1. Survival (%), weight gain (g/fish) and specific growth rate (SGR) in juvenile tilapia reared at four feeding regimes.

Treatments	Initial weight (g/fish)	Final weight (g/fish)	Survival (%)	Weight gain (g/fish)	SGR[a]
C	16	23	84	7	0.86
S1	8.6	19.4	84	10.8	1.9
S2	13.3	8	80	-5.3	-1.2
S3	16	5.8	60	-10.2	-2.4

[a]SGR = (Ln final weight of fish – Ln initial weight) / d of feeding trial

Table 1 showed the survival (%), weight gain (g/fish) and specific growth rate (SGR) of tilapia at the end of feeding trial. Survival rate in control and S1 treatment were the highest as well as the weight gain for fish in S1. Overall, feeding regime had effect on mean individual growth rate as the SI treatment had the highest SGR (1.9 % day^{-1}) followed by control group (1.9 % day-1). The poorer survival, weight gain and SGR were obtained in tilapia in S3.

Table 2. Feed consumption (g/fish), feed efficiency ratio (FER) and protein efficiency ratio (PER) in juvenile tilapia reared at four feeding regimes.

Treatments	Feed consumption	FER[a]	PER[b]
C	116.6	0.06	0.19
S1	54.02	0.19	0.62
S2	13.76	-0.39	-1.19
S3	0	0	0

[a]FER = weight gain of fish / dry feed supply
[b]PER = weight gain of fish / protein fed

FER and PER were highest in S1 compared to other treatments but feed consumption for fish in S1 lower than control treatment (Table 2). Weekly feed consumption (g/tank) of tilapia throughout experiment is given in Figure 1. Feed consumption of tilapia increased shortly after refeeding in S1 and S2.

Feed consumption

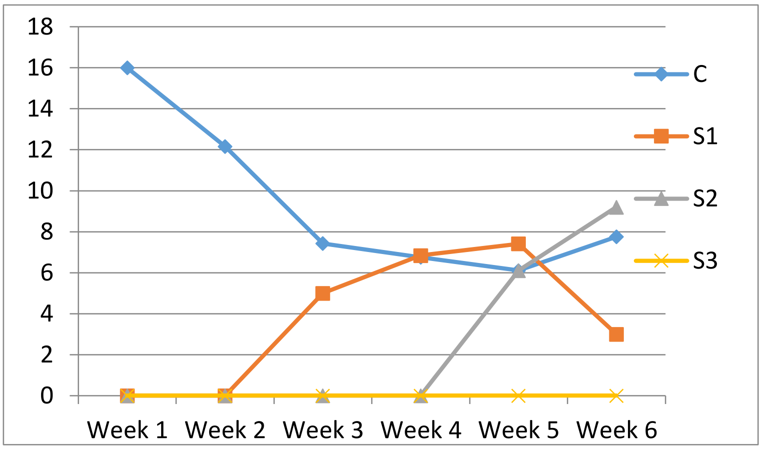

Figure 1: Feed consumption (g/tank) of tilapia during the feeding trial

Table 3. Moisture, lipid, protein, ash and fibre in tilapia at initial, 3 weeks and end of experiment.

Time	Treatment	Moisture (%)	Lipid (%)	Protein (%)	Ash (%)	Fibre (%)
Initial		89.99±2.32	4.75±1.06	51.00±13.92	17.90±0.59	-
3 week	C	73.86±0.64[ca]	13.25±2.01[a]	59.93±0.01[a]	17.75±0.57[c]	2.03±0.49[a]
	S1	80.29±1.62[a]	13.46±2.48[a]	58.98±0.49[a]	23.07±1.12[a]	3.01± 0.93[a]
	S2	82.95±0.42[b]	3.79±0.08[b]	60.64±0.99[a]	30.05±0.23[b]	1.62±0.08[a]
	S3	79.98±0.33[a]	7.99±0.46[ab]	58.65±0.83[ab]	39.79±0.95[d]	2.01±0.71[a]
6 week	C	70.83±0.88[a]	18.22±0.33[ac]	59.65±0.92[a]	16.42±0.04[a]	0.28±0.18[b]
	S1	80.47±1.07[b]	14.71±0.87[a]	61.45±1.27[a]	17.16±0.64[a]	1.99±0.81[a]
	S2	62.89±0.79[c]	15.89±0.61[a]	60.25±1.05[a]	18.31±0.51[a]	1.63±0.05[a]
	S3	50.85±0.86[d]	1.38±0.62[b]	54.04±0.32[b]	36.09±1.1[b]	0.22±0.04[b]

Values (mean±SD) in the same row sharing a common superscript are not significantly different

Due to food deprivation, the moisture content in fish significantly decreased and the ash content significantly increased with increasing starvation period before re-feeding for third week and six-week experiment. The lipid content is significantly higher in S1 compare to S2 and S3 treatment for third week experiment. For sixth week experiment, the lipid content for S1 not significantly different with S2 treatment. However, there is significantly increase in lipid content from third week experiment (3.79%) to sixth week experiment (15.89%). No significance different were found in protein and ash content among control group, S1, S2, S3 treatment for both week of proximate time.

4. Discussion

Throughout the experiment, S3 treatment has the highest mortality rate while Control group and S1 treatment have the highest survival rate. These results of this study are in line with previous experiment, where the same pattern of mortality was found in Atlantic halibut (Heide et al., 20016). A probably reason why is because during deprivation, fish used all the energy for fundamental metabolism and energy reallocation for fish decreased due feed deprivation that lead to mortality (X Tian et al., 2010).

In many species of fish, they have the ability to catch up in weight after a period of restricted feeding (Altlantic Salmon *Salmo salar*, Johansen et al., 2001;barramnundi *Lates calcarifer*, Tian and Qin, 2003; rainbow trout, *Oncorhynchus mykisss*, Nikki et al, 2004). This seemed to the case in our study on S1 treatment, as the weight gain and SGR of fish in S1 treatment have the highest value. Similarly, food restriction for 2 weeks showed great compensation growth for juvenile tilapia in previous research (Wang et al., 2000). This indicates these juvenile tilapias are able to compensate for unusually growth with 2 weeks of feed deprivation. However, for S3 and S4 treatment where the fish are being starved for 4 weeks and more, there is decreseament in weight gain and SGR compare to Control group and S1 group. The compensatory response depends on the length of starvation period where has been described also for another species (Tian and Qin, 2003; OH et al., 2008). Thus, these results suggested that fish need to get used to intermittent feeding before being able to fully compensate for the lost feeding opportunities during long fasting periods, and for full recovery the feeding period must be much longer than the fasting period.

Feed consumption of tilapia increased shortly after refeeding in fish for S1 and S2 treatments that being starved for 2 weeks and 4 weeks. This is in line with available evidence pointing to hyperphagia as the main mechanism involved in the compensatory response due to increasement of feed consumption (Ali et al., 2003). FER and PER were highest in S1 compared to other treatments since previous study have shown improved FER in fish undergoing compensatory growth (Joblinget al., 1994; Van Dijk et al., 2002). This is due to effective utilization of protein by fish in 2 weeks starvation treatment where protein is used to form and the maintance of the muscles, skin and bones.

The different time for food deprivation may affect the moisture and ash contents in the fish tissue because these contents will decrease if there is deduction for starvation time (Jobling, 1980). This is similar to the ash content in this experiment but vice versa for moisture content. The water content in fish during starvation period is important for measuring weight of fish because this will affect the weight gain and SGR. Since the moisture content decrease when food deprivation time is increased in this experiment, this can reveal the true effect of food starvation.

The lipid content significantly lower in S2 for third week experiment compare to Control group and S1 treatment. The decreasement in lipid content due to long food derivation had been shown in previous research (X. Tian et al., 2010; Y. Wang et al., 2000). This result probably indicates that there is reduction in lipase enzyme in a mass specific activities during starvation (L-Q Zeng et al., 2012). However, the value is increasing at sixth week because of refeeding after 4-week deprivation. The protein for fish in S1 and S2 treatments are significantly higher than other treatment at the end of experiment. This is because during periods of starvation, fish only used protein when lipid stores are depleted because generally, fish are consuming stored lipid prior to protein for fundamental metabolism and maintenance of fish (Zhu et al., 2001).

5. Conclusion

In conclusion, the present study confirmed that food starvation and refeeding contribute to compensatory growth in juvenile tilapia, and the compensatory depends on the length of the starvation period. Optimum compensatory growth was achieved and there is changes in body crude composition in juvenile tilapia for 2 weeks food deprivation and refeeding for 4 weeks since there is improvement in weight gain, SGR, PER and FER, lipid and protein content in body composition. However, there is no significance different for moisture, ash and lipid content in body composition. Since compensatory growth can be useful tool in optimizing the meat quality of fish for human consumption because it can affect the body crude composition of tilapia, it is important to determine the limitation starvation period before using growth compensatory in the commercial production of the fish.

References

Ahmed Al-Souti, J. A.-S. (2012). The effects of fish oil-enriched diets on growth, feed conversion and fatty acid content of red hybrid tilapia, Oreochromis sp. *Food Chemistry*, 723-727.

Ali, M., Nicieza, A., Wootton, R.J .(2003). Compensatory growth in fishes: a response to growth depression. *Fish Fish. 4*, 147–190.

AOAC (Association of Official Analytical Chemsist). (1990). Official methods of analysis, 15th edition. Association of Official Analytical Chemists, Arlington, Virginia USA

Atle Foss, A. K. (2009). Compensatory growth in Atlantic halibut: Effect of starvation and subsequent feeding on growth, maturation, feed utilization and flesh quality. *Aquaculture*, 304-310.

Bower, N.I., Taylor, R.G., Johsnton, I.A. (2009) . Phasing of muscle gene expression with fasting-induced recovery growth in Atlantic salmon. *Front. Zool.* 6, 18.

Hayward, R.S., Wang, N., Noltie, D.B.(2000). Group holding impedes compensatory growth of hybrid sunfish. *Aquaculture 183*, 299–305.

Heide, A., Foss, A., Stefansson, S.O., Mayer, I., Norberg, B., Roth, B., Jenssen, M.D., Nortvedt, R., Imsland, A.K. (2006). Compensatory growth and fillet crude composition in juvenile Atlantic halibut: effects of short term starvation periods and subsequent feeding. *Aquaculture 261*, 109–117

Houde, E.D., Schekter, R.C .(1981). Growth rates, rations and cohort consumption of marine fish larvae in relation to prey concentrations. Rapp. P.-V. Reun. - *Cons. Int. Explor. Mer* 178, 441–453.

Johansen, S.J.S., Ekli, M., Stangnes, B., Jobling, M. (2001). Weight gain and lipid deposition in Atlantic salmon, Salmo salar, during compensatory growth: evidence for lipostatic regulation? *Aquac. Res.* 32, 963–974.

Jobling, M., Meløy, O.H., Dos Santos, J., Christiansen, B. (1994). The compensatory growth response of the Atlantic cod: effects of nutritional history. *Aquac. Int. 2*, 75–90.

Jobling, M. (1980). Effects of starvation on proximate chemical-composition and energy-utilization of plaice, Pleuronectes platessa. *J. Fish Biol. 17*, 325–334

Jung-Yuan Liang, Y.-H. C. (2013). Effects of feeding frequency and photoperiod on water quality and crop production in a tilapiaewater spinach raft aquaponics system. *International Biodeterioration & Biodegradation*, 101-108.

Jyrki Nikkia, J. P. (2004). Compensatory growth in juvenile rainbow trout,Oncorhynchus mykiss (Walbaum), held individually. *Aquaculture*, 285-296.

Kim T. Tran-Ngoc, N. T. (2016). Interaction between dissolved oxygen concentration and diet composition on growth, digestibility and intestinal health of Nile tilapia(Oreochromis niloticus). *Aquaculture*, 101-108.

Ling-Qing Zeng, F.-J. L.-M.-D.-J.-G. (2012). The effects of starvation on digestive tract function and structure in juvenile southern catfish (Silurus meridionalis Chen). *Comparative Biochemistry and Physiology*, 200-211.

Nikki, J., Pirhonen, J., Jobling, M., Karjalainen, J. (2004). Compensatory growth in juvenile rainbow trout, Oncorhynchus mykiss (Walbaum), held individually. *Aquaculture* 235, 285–296.

Oh, S.Y., Noh, C.H., Kang, R.S., Kim, C.K., Cho, S.H., Jo, J.Y. (2008). Compensatory growth and body composition of juvenile black rockfish Sebastes schlegeli following feed deprivation. *Fish. Sci.* 74, 846–852.

Robert C. Reigh, M. B. (2006). Influence of repetitive periods of fasting and satiation feeding on growth and production characteristics of channel catfish,Ictalurus punctatus. *Aquaculture*, 506-516.

Shoji Yamada, Y. T. (1994). Effects of starvation and feeding on tissue Na -acetylhistidine levels in Nile tilapia Oreochromis nilo ticus . *Camp. Biochem. Physiol.* , 277-283.

Tian, X., Qin, J.G.. (2003). A single phase of food deprivation provoked compensatory growth in barramundi Lates calcarifer. *Aquaculture 224*, 169–179.

Van Dijk, P.L.M., Staaks, G., Hardewig, I. (2002). The effect of fasting and re-feeding on temperature preference, activity and growth of roach, Rutilus rutilus. *Oecologia 130*, 496–504.

Xiangli Tian, J. F. (2010). Effects of starvation and recovery on the growth, metabolism and energy budget of juvenile tongue sole (Cynoglossus semilaevis). *Aquaculture*, 122-129.

Yan Wang, Y. C. (2000). Compensatory growth in hybrid tilapia,Oreochromis mossambicusxO. niloticus,reared in seawater. *Aquaculture*, 101-108.

Zhu, X., Y. Cui, M. Ali and R. J. Wootton. (2001). Comparision of coensatory growth response of juvenile three spined stickleback and minnow following similar food deprivation protocols. *Journal of Fish Biology 58* : 1149-1165