Thesis for the Degree of Master of Fisheries Science

Effects of Feeding Frequencies on Growth and Body Composition of Juvenile Common Carp (*Cyprinus carpio*) and Their Compensation Growth

by

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먹이 공급 횟수가 잉어치어의 성장 및 체조성 에 미치는 영향 및 보상성장

Advisor: Jae-Yoon Jo

by

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Abstract

Effects of feeding frequencies on growth and body composition of juvenile common carp (Cyprinus carpio) were tested. Two separate experiments were done for this purpose. The first experiment (Exp. 1) was conducted with 1 (1-1), 2(1-2), 3 (1-3), 4 (1-4), 5 (1-5), and 6 times (1-6) of daily feeding frequencies for 40 feeding days and the second experiment (Exp. 2) was done with 1 (2-1), 3 (2-3), 5 (2-5), 6 (2-6), 7 (2-7) and 8 times (2-8) of daily feeding frequencies for 60 feeding days. In the Exp. 1, the fish grew from 2.0 g of initial body weight to 4.4 g (1-1), 6.1 g (1-2), 7.5 g (1-3), 9.1 g (1-4), 9.8 g (1-5), and 10.8 g (1-6) in average weight for 40 days. The 1-6 groups grew highest during this period. The highest crude ash contents (2.4%) were achieved in the group of 1-1 while the highest crude lipid content (7.9~8.0%) was achieved from the groups of 1-5~6 in Exp. 1. The highest crude protein contents (15.0~15.5%) was achieved from the group of 1-3~6 in Exp. 1. In Exp. 2, fish grew from the initial body weight of 2.4 g up to 15.2 g (2-1), 37.5 g (2-3), 50.4 g (2-5), 53.6 g (2-6), 55.4 g (2-7), and 51.1 g (2-8) for 60 days and there were significantly higher in body weight of the groups of 2-6 and 2~7 compared to the groups of 2-3 and 2-1. The moisture and crude ash contents of the group of 2-1 was significantly higher than other groups. The lipid contents of the group of 2-1 was lowest followed by 2-3 and all rest groups, 2-5~8. According to the result of this experiment, 6 times of feeding frequencies are proper for juvenile common carp. Compensation growth of juvenile common carp during feed deprivation for 40 days and after refeeding for 140 days was investigated. Six daily feeding frequencies were prepared (3–1~6). Fish was fed once to six times a day during feed deprivation phase. All groups were fed *ad libitum* six times a day during refeeding phase. Full compensation growth was achieved in 3-(4)-6 and 3-(5)-6 after refeeding for 140 days. Fish in the groups 3-(1)-6~3-(3)-6 achieved partial compensation growth.

Keywords: feeding frequency; compensation growth; growth; body composition; common carp; *Cyprinus carpio*

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1. INTRODUCTION

World aquaculture production has been increased more rapidly than all other animal food producing sectors with an average annual growth rate of 8.7 % (excluding China at 6.5 %) since 1970 (FAO, 2009a). World aquaculture and freshwater finfish production in 2007 were reported as 50.3 and 26.8 million tons, respectively. World common carp production in 2007 was estimated to be 2.8 million tons or 10.4 % of total freshwater finfish production (FAO, 2009b).

Common carp aquaculture is thriving throughout the world, mainly caused by several factors such as their omnivorous feeding habit, high survival rate and growth performance, robust tolerance to lower water quality and disease, resistant to handling, appealing taste, and high reproduction capacity (Kestemont. 1995; Horvath *et al.*, 2002).

Common carp growth in temperate climate is not continuous. Active and passive feeding phases alternated throughout the common carp's life stages. Fish grow rapidly during the active feeding phase, namely during spring, summer and early autumn, where temperatures remain steady above 12 - 14℃. In contrast, there is no growth during the passive feeding phase (no feeding). Due to this discrepancy, carp farming in a temperate climate requires three years to achieve the same body weight (mass) as one year in a tropical climate (Horvath *et al*., 2002).

In addition to traditional pond culture, common carp can be cultured in an intensive recirculating system using pelleted feed. However, due to the need of sophisticated instruments for heating, water filtration, aeration, and pumping, the production cost of intensive farming is much higher than of pond culture (Horvath *et al*., 2002).

Hand feeding was the simplest feeding technique. Experienced hand feeding practitioners are able to detect fish satiation by observing the feeding or swimming activity of fish in surface water before stopping, slowing down or continuing (Alanara *et al*., 2001). Using this technique, practitioners can adjust feeding to daily variations in food intake.

In order to achieve the maximum growth rate, satiation feeding is preferable. Accurate recording of eaten pellets is important in determining the level of satiation. Satiation level is the quantity of food required to satiate a fish in a single feeding (Hepher, 1988). In a condition where food is abundant and fish can freely consume an unlimited amount of food, fish will eventually be full and stop feeding. In this condition, it is said that fish is satiated. During the process of satiation, the feeding rate gradually decreases until feeding stops completely. (Jobling, 2001).

Proper timing and meal size at feedings are known to affect feed intake and growth rate (Sundaraj *et al*., 1982; Noeske *et al*., 1985; Tsevis *et al*., 1992; Jarboe and Grant, 1997; Hossain *et al*., 2001). Different preferences for feeding time have been observed in goldfish (Noeske and Spieler, 1984), and African catfish (Hossain *et al*., 1999; Hossain *et al*., (2001). Tambaqui (Meer *et al*., 1997) and hybrid sunfish (Wang *et al*., 1998) consumed different amount of food at each feeding time. In order to avoid feed wastage, information about feeding time is important so that amount of food can be adjusted at each feeding.

If feed is given *ad libitum*, total daily consumption was larger in fish fed with frequent feeding than with a single feeding. Since the effect of *ad libitum* feeding to feed conversion ratio was small, higher feed intake by frequent feeding will result in better weight gain (Hepher, 1988).

Common carp has no stomach. Therefore food is given more often than the fishes that have stomach, such as catfish and rainbow trout. It has been found that frequent feeding improves feed intake and growth rate of juvenile tambaqui (Meer *et al*., 1997), age-0 hybrid sunfish (Wang *et al*., 1998), juvenile sunshine bass (Thompson *et al*., 2000), ayu post larvae (Cho *et al*., 2003) and juvenile gibel carp (Zhou *et al*., 2003). However, there is currently no information available about the effect of feeding frequency to growth and body composition of juvenile common carp.

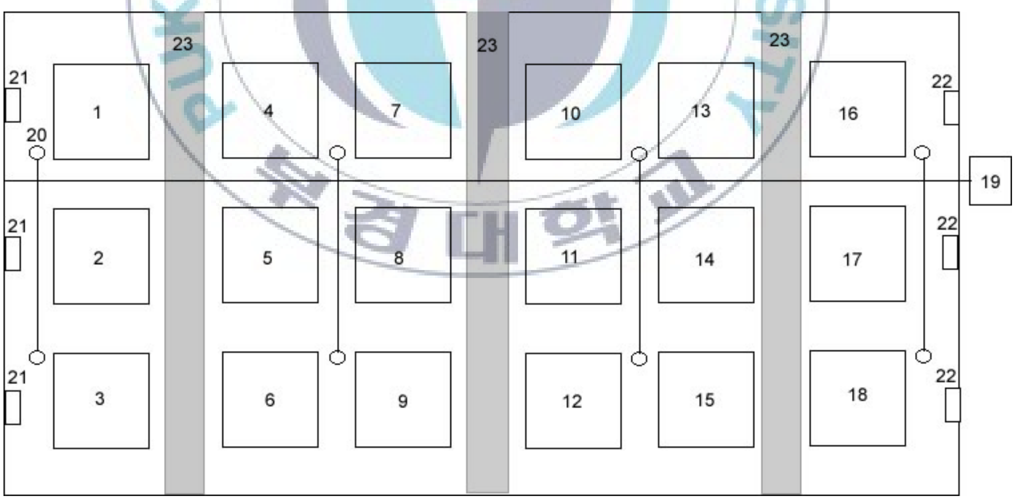
Compensation growth is rapid growth when favorable conditions are restored following growth depression (Ali *et al*., 2003). Fish that experience a period of growth depression may catch up in size with conspecifics of the same age experiencing a more favorable environmental conditions. In this case, fish are able to restore their original growth trajectory from growth depression. The effects of food deprivation (Li *et al*., 2005; Zhu *et a*l., 2005; Cui *et al*., 2006); temperature and season (Dijk *et al*., 2005; Huang *et al*., 2008); oxygen supply (Foss and Imsland, 2002); social behaviour (Hayward *et al*., 2000) and feed quality (Gaylord and Gatlin, 2001) were examined in eliciting compensatory growth in fishes. Currently, there is no information available on the effect of compensation growth to growth and body composition of juvenile common carp.

The objectives of this study are to determine the effect of feeding frequency on growth and body composition in juvenile common carp and their compensation growth.

II. MATERIALS AND METHODS

2.1. Experimental system

The experiment was conducted in a tank inside a Recirculation Aquaculture System (RAS). RAS was located in a greenhouse at Pukyong National University. The experiment was conducted in 18 cages (0.5 x 0.5 x 0.5 m) that set up in a 7.9 m (L) x 2.2 m (W) x 1.4 m (D) tank. Water depth in the tank was maintained at 1.34 m and in the cages were maintained at 0.25 m. Water flow rate in the tank was 420 L/min. Hydraulic loading rate was 9 exchanges / hour. Experimental fish were randomly assigned to the cages. Cages were covered with a net (0.5 x 0.5 m) to prevent fish jumping out from the cages.



1~18	Cages (0.5 x 0.5 x 0.5 m)	21	Inlet pipes
19	Aerator	22	Outlet pipes
20	Aeration stones	23	Bridges

Fig. 1. Schematic drawing of experimental system for feeding frequency and compensation growth experiment for juvenile common carp.

2.2. Experimental fish

2.2.1.First experiment

Juvenile common carp, *Cyprinus carpio*, 2 g in average size were used in the first experiment. Prior to the experiment 360 fish were selected and 20 fish were randomly assigned to each of 18 cages. Treatments were once a day feeding (1 - 1), twice a day feeding (1 - 2), three times (1 - 3), four times (1 - 4), five times (1 - 5), and six times a day (1 - 6) feeding groups.

Experimental fish were given a 3-week of acclimation period. During acclimation, fish were fed formulated feed twice daily. The composition of the feed was: protein 36.8 %, lipid 5.7 %, ash 7.8 %, moisture 8.3 %. After acclimation, fish were fasted for one day and weighed the following day. Average initial weight of experimental fish was 2.0±0.02 g (mean±S.E.). Experiment began on September 24th, 2008 and finished on November 3rd, 2008. Experimental period was 40 days. All treatments were triplicated.

2.2.2. Second Experiment

Juvenile common carp with average size of 2.5 g were used in the second experiment. Prior to the experiment, 360 fish were selected and 20 fish were randomly assigned to each of 18 cages. Treatments in the second experiments were once a day feeding (2 - 1), three times a day feeding (2 - 3), five times a day feeding (2 - 5), six times a day feeding (2 - 6), seven times a day feeding (2 - 7) and eight times a day feeding (2 - 8) groups.

Fish were given a 2-week acclimation period and fed twice a day. Same feed was used as the first experiment. After acclimation, fish were fasted for one day and stocked in the cages after weighing the body weight. The average initial weight was 2.5±0.01g. Experiment began on July 4^{th}, 2009 and finished on September 21^{st}, 2009. Experimental period was 60 days. All treatments were triplicated.

2.2.3. Third Experiment

At the end of the first experiment, the third experiment, compensation growth experiment was started. Initial body weight of each group in the third experiment were 4.4 (3 - (1) - 6); 6.1 (3 - (2) - 6); 7.5 (3 - (3) - 6); 9.1 (3 - (4) - 6); 9.8 (3 - (5) - 6) and 10.8 g (3 - (6) - 6). Density of fish inside of the cage was 18 fish per cage. Same feed were used as the first and second experiment. All treatments of fish were fed 6 times a day. Experiment was conducted at November 5^{th}, and finished at March 30^{th}, 2009. Experimental period was 140 days. All treatments were duplicated

2.3. Experimental design.

2.3.1 First experiment.

Fish were fed from 1 to 6 times a day according to the treatment plan and feeding time is shown in Table 1.

Table 1. Feeding protocols for juvenile common carp under 1 ~ 6 feeding frequencies

Groups*	0900	1100	1200	1300	1500	1600	1800
1 - 1	√						
1 - 2	√						√
1 - 3	√			√			√
1 - 4	√		√		√		√
1 - 5	√	√		√	√		√
1 - 6	√	√		√	√	√	√

* : First number indicates experimental groups while the second number indicates daily feeding frequency.

Feed was given *ad libitum* and introduced gradually until feeding begin to slow. Experimental fish were weighed every 20 days to evaluate growth performance.

Feed consumption rate at each feeding time was measured at the 20th and 40th day to check daily feeding behaviour.

2.3.2. Second experiment

Fish were fed from 1 to 8 times a day according to the treatment plan and feeding time is shown in Table 2. Experimental fish were fed until satiation level.

Table 2. Feeding protocols for juvenile common carp under 1 ~ 8 feeding frequencies

Groups*		1000	1100	1200	1400	1600	1800	1900
2 - 1	√							
2 - 3	√				√			√
2 - 5	√		√		√	√		√
2 - 6	√	√		√	√	√		√
2 - 7	√	√		√	√	√	√	√
2 - 8	√	√	√	√	√	√	√	√

* : First number indicates experiment while second number indicated frequency

Experimental period was 60 days and fish were weighed every 20 days to evaluate growth performance.

2.3.3. Third experiment.

Fish from the Exp. 1 were used for compensation growth test. After all growth measurement of the fish from first Exp. 1, some of the fish in each replicate were randomly taken for proxymate analysis. Left over fish in each treatment were randomly reallocated in two cages for the third experiment, compensatory growth test. Fish in all treatments were fed 6 times a day at *ad libitum* level. This experiment was duplicated.

Table 3. Feeding protocols for compensation growth of juvenile common carp.

Groups*	0900	1100	1300	1500	1600	1800
3 - (1)- 6	√	√	√	√	√	√
3 - (2) - 6	√	√	√	√	√	√
3 - (3) - 6	√	√	√	√	√	√
3 - (4) - 6	√	√	√	√	√	√
3 - (5) - 6	√	√	√	√	√	√
3 - (6) - 6	√	√	√	√	√	√

* : First number indicates experiment number, the second number in parentheses indicates feeding frequencies in the previous experiment, and the third number indicates present feeding frequencies in a day.

All fish were deprived of feed for 1 day prior to weighing. Fish were captured, anesthetized with 60 mg/L MS222 (Tricaine Methanesulfonate), and collectively weighed. The growth performance parameters being evaluated were specific growth rate (SGR), feed conversion ratio (FCR) and daily feed intake (DFI), according to Cui *et al.*, 2006.

Specific growth rate (SGR, % day^{-1}) was calculated by the following equation:

$$\mathrm{SGR} = 100 \times \frac{(\log_e W_t - \log_e W_o)}{t}$$

Feed conversion ratio (FCR) was calculated by the following equation.

$$\mathrm{FCR} = \frac{C}{Weight\ \ gain\ (g)}$$

Daily feed intake (DFI, % day^{-1}) was calculated by the following equation :

$$\mathrm{DFI} = 100 \times \frac{C}{\left[\frac{W_o + W_t}{2}\right] \times t}$$

C amount of feed consumed (g)

W_0 body weight at day 0 (g)

W_t body weight at day t (g)

T duration between two measurements (day)

2.4. Water quality measurements

Dissolved oxygen (DO), temperature (^oC), total ammonia (TAN), nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N) were measured weekly at prior to the first feeding. Dissolved oxygen and temperature were measured by Oxyguard®, TAN by colorimetric Nesslerization method, NO_2-N and NO_3-N by the colorimetric method. Those TAN, NO_2-N, and NO_3-N were all measured by HACH DREL 2000 Spectrophotometer (HACH Company, Colorado, USA).

2.5. Body composition

Proximate analysis of the fish were done at the beginning and at the end of the each experiments. Proximate analysis of experimental diets and fish were performed by the standard methods of AOAC (1995). Samples of diets and fish were dried at 105 °C to determine moisture content. Crude ash was determined by incineration at 550 °C; crude lipid by Soxhlet extraction using Soxtec system 1046 (Foss, Hoganas, Sweden) and crude protein by Kjeldahl method (N × 6.25) after acid digestion.

2.6. Haematological analysis.

Haematological parameters such as erythrocyte counts (RBC), haematocrit (Ht), and haemoglobin level (Hb) were measured at the end of the second experiments. Three fish of each replication were randomly sampled, anaesthetized, and pooled. Blood was taken from the central tail blood vessels for not more than 30 seconds using a 1-ml syringe containing heparin. Blood samples were kept in freezing conditions and analyzed by automatic blood analysis H5-M SEAC cell counter® (Radim Group, Florence, Italy).

2.7. Statistical analysis.

2.7.1. First and second experiment

Statistical analysis was employed using one-way ANOVA performed by SPSS 16 for Windows (SPSS Statistical Software, Chicago, IL, USA). Each cage was considered as an experimental unit. Three replicates in each group were used to test the feeding frequency effect on the growth performance. Two replicates in each group were used to test feeding frequency effect on whole body proximate composition. Significant differences in means were evaluated by Duncan's multiple-range test. All statistical analysis was assessed at a significance level of $P \leq 0.05$.

2.7.2. Third Experiment

Analysis of covariance (ANCOVA) was used to test the effect of treatment on the compensation growth performance parameters. The initial body weight was used as a covariate to test the treatment effect on body weight. Body weight at the start of each term was used as a covariate to test the treatment effect on the growth performance parameters. The Bonferroni test was used to assess differences of mean in ANCOVA. Differences in whole body proximate composition were tested by one way ANOVA. Two replicates in each group were used to test the feeding frequency effect on whole body proximate composition. Significant differences in means were evaluated by Duncan's multiple-range test. All statistical analysis was assessed at a significance level of $P \leq 0.05$.

III. RESULTS AND DISCUSSION

3.1. First Experiment

3.1.1. Water quality.

Average water quality parameters measured in the experimental system were: dissolved oxygen 6.6±0.05 mgL^{-1}; temperature 24.5±0.16 ℃; TAN 0.5±0.04 mgL^{-1}; NO_2-N 0.3±0.03 mgL^{-1}; NO_3-N 21.1±0.31 mgL^{-1}.

3.1.2. Growth performance.

No mortality was observed in any treatment group throughout the experiment. Fish weight at the beginning of the experiment was not significantly different among groups. The effects of feeding frequency on growth and feed intake are shown in Table 4. After 40 days, final weight, and feed intake in every feeding frequency are significantly different ($P \leq 0.05$). Final average weight of fish, maximum and minimum was differed more than two-fold (ranged from 4.4 to 10.8 g), and those of feed intake was differed almost five-fold (ranged from 2.1 to 10.2 g), and specific growth rate (SGR) was differed more than two-fold (ranged from 1.9 to 4.2 %). The 1 - 6 group of fish grew more than five-fold from initial weight while the 1 - 1 group grew 2.2 fold. The 1 - 6 group grew the best among the treatments. The 1 - 6 group had the highest feed intake (10.2 g) while the 1 - 1 group had the lowest feed intake (2.1 g). Frequent feeding significantly increased feed intake of juvenile common carp.

Table 4. Effect of 6 different feeding frequencies on growth performance of juvenile common carp[1].

Groups	Initial weight (gr)	Final weight (gr)	Feed intake (gr)	FCR	SGR (% day^{-1})
1 - 1	2.0 ± 0.03^a	4.4 ± 0.01^a	2.1 ± 0.03^a	0.9 ± 0.01^a	1.9 ± 0.05^a
1 - 2	2.0 ± 0.02^a	6.1 ± 0.14^b	4.7 ± 0.13^b	1.1 ± 0.02^{cd}	2.8 ± 0.03^b
1 - 3	2.0 ± 0.02^a	7.5 ± 0.04^c	5.8 ± 0.06^c	1.0 ± 0.00^b	3.3 ± 0.03^c
1 - 4	2.0 ± 0.02^a	9.1 ± 0.12^d	7.8 ± 0.04^d	1.1 ± 0.03^c	3.8 ± 0.05^d
1 - 5	2.0 ± 0.03^a	9.8 ± 0.03^e	8.8 ± 0.02^e	1.1 ± 0.00^{cd}	3.9 ± 0.03^e
1 - 6	2.0 ± 0.02^a	10.8 ± 0.10^f	10.2 ± 0.04^f	1.2 ± 0.02^d	4.2 ± 0.04^f

[1] Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$).

The final average weights of the fish in all treatments were significantly different. Fish in the group 1 - 6 had the highest final weight (10.8 g) while fish in group 1 - 1 had the lowest final weight (4.4 g). The highest feeding frequency resulted in highest feed supply and highest weight gain. Feed in group 1 - 6 (10.2 g) was the highest among all treatment groups. There was a gradual decline of feed intake and weight gain as feeding frequency decreased. Feeding frequency (Grayton and Beamish, 1977; Thompson *et al*., 2000), time of feeding (Sundararaj *et al*., 1982; Noeske *et al*., 1985; Tsevis *et al*., 1992; Hossain *et al*., 2001), and photoperiod (Biswas *et al*., 2005) all influence food intake of fish. The findings of this study support those of Andrews and Page (1975), Vahl (1979), Thompson *et al*. (2000) and Meer *et al*. (1997) that feed intake can limit growth. Therefore, maximum growth can be achieved by optimum feed intake. Optimum feed intake through more frequent feeding provided some more nutrients, which were needed for a maximum growth rate (Gandra *et al.*, 2007).

Table 5. Daily feed intake (% day^{-1}) for juvenile common carp under 1 ~ 6 feeding frequency

Groups	Period (Day)	
	0 - 20	20 - 40
1 - 1	1.66	1.67
1 - 2	2.87	3.11
1 - 3	3.48	3.05
1 - 4	4.17	3.34
1 - 5	4.70	3.33
1 - 6	5.06	3.58

Daily feed intake of juvenile common carp weight 2.0 ~ 10.8 g fed 6 times a day (Table 5) in Exp. 1 was smaller (5.06 ~ 3.58 %) than daily feed intake recommended by Miyatake (1997) which was 8.80 ~ 7.50 % for size 2.0 ~ 10.0 g.

The 1 - 1 group showed the best feed conversion ratio (FCR) (0.9). No significant difference of FCR was found among the 1 - 2 ~ 6, except in group 1 - 3 that was the best among them.

Feed conversion ratio of the group 1 - 1 was significantly better than all other treatments. In the nature, if food availability is limited, animals are able to synchronize their activities, hormonal level and physiological variables to times of feeding. Thus, when daily amount of food is available for a short period of time, food utilization is maximized (Potter *et al.*, 1968; Fuller, 1971; Suda and Saito, 1979; Sanchez-Vazquez *et al*., 1995). According to the experimental result, FCR increased with increasing feeding frequency. Similar result was also reported by Webster *et al*. (2001) for juvenile sunshine bass and Hossain *et al*. (2001) for African catfish fingerling. Higher FCR might indicate that fish fed more frequently might utilize feed less efficiently than fish fed less frequently (Webster *et al*., 2001). Fish fed at higher frequency consumed large amount of food. If the interval between meals is short, food passed through the digestive tract more quickly, resulted in less efficient digestion (Liu and Liao, 1999)

There was more than two-fold difference of SGR between groups fed most frequently and groups fed least frequently. Group 1 - 1 showed the lowest SGR (1.9 %) while group 1 - 6 had the highest SGR (4.2 %) among all groups. The growth rate of fish increased with increasing feeding frequency. This result was similar to other reports (Grayton and Beamish, 1977; Marian *et al*., 1982; Zhou et al., 2003; Webster *et al*., 2001; Hossain *et al*., 2001).

3.1.3. Body composition

The highest moisture content was shown in the group 1 - 1 (80.8 %) and 1 - 2 (79.9 %). The lowest moisture content (73.8 ~ 74.3 %) was shown in groups 1 - 4 ~ 6. The highest crude protein content (15.0 ~ 15.5 %) was achieved in groups 1 - 3 ~ 6. The 1 - 1 (13.8 %) and 1 - 2 (13.2 %) groups had the lowest crude protein content. The 1 - 5 and 1 - 6 groups of fish had the highest crude lipid content (7.9 ~ 8.0 %). The 1 - 1 group of fish had the lowest crude lipid content

(2.4 %). No significant difference of crude ash content was found among groups 1 - 2 (2.1 %), 1 - 3 (2.0 %) and 1 - 4 (2.1%). The fish in groups 1 - 5 (1.7 %) and 1 - 6 (1.7 %) had the lowest crude ash content while that in the fish of the group 1 - 1 showed the highest (Table 6).

Table 6. Effect of 6 different feeding frequencies on proximate composition (%, wet weight basis; n = 2) of juvenile common carp[1].

Groups	Moisture (%)	Crude Protein (%)	Crude Lipid (%)	Crude Ash (%)
1 - 1	80.8 ± 0.13^{c}	13.8 ± 0.13^{a}	2.4 ± 0.09^{a}	2.4 ± 0.02^{c}
1 - 2	79.9 ± 0.22^{c}	13.2 ± 0.30^{a}	4.4 ± 0.01^{b}	2.1 ± 0.00^{b}
1 - 3	75.7 ± 0.22^{b}	15.3 ± 0.19^{b}	5.9 ± 0.11^{c}	2.0 ± 0.06^{b}
1 - 4	73.8 ± 0.50^{a}	15.5 ± 0.11^{b}	7.7 ± 0.01^{d}	2.1 ± 0.07^{b}
1 - 5	73.9 ± 0.20^{a}	15.3 ± 0.33^{b}	8.0 ± 0.11^{e}	1.7 ± 0.02^{a}
1 - 6	74.3 ± 0.23^{a}	15.0 ± 0.28^{b}	7.9 ± 0.04^{de}	1.7 ± 0.01^{a}
Initial	81.0 ± 0.22	13.30 ± 0.12	2.3 ± 0.01	2.5 ± 0.01

[1] Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$)

The 1 - 1 and 1 - 2 groups of fish had the highest moisture content while the fish in 1 - 4 ~ 6 groups showed the lowest moisture content. There was some trends that as feeding frequency increased, moisture content decreased. This result is similar to that of a study conducted by Grayton and Beamish (1977).

Crude protein content of group 1 - 1, least feeding groups was the lowest among all feeding frequencies. Crude protein content was the highest in the groups 1 - 3 ~ 6. Feeding frequently significantly increase crude protein content.

Groups 1 - 5 ~ 6 had significantly higher crude lipid content in comparison with group 1 - 1, which had the lowest crude lipid content. There were some trends that as feeding frequency increased, crude lipid content increased. This result is similar to that of a study conducted by Grayton and Beamish (1977) and Jeong *et al*. (2003) who found an increase of crude lipid content along with an increase of feeding frequency in rainbow trout and young red-spotted grouper. According to Jobling (1994), enough-fed cod deposited major portion of body energy gain as lipid reserves in the liver.

The 1 - 1 group of fish, least feeding group had the highest ash content. The ash content in the fish in groups 1 - 2, 1 - 3, 1 - 4 were significantly lower than the fish in group 1 - 1 but significantly higher than the fish in group of 1 - 5 and 1 - 6. Therefore it is clear that enough food fed group of fish showed lower ash content in the whole body. This result is similar to that of a study conducted by Zhou *et al*. (2003)

3.1.4. Feeding behaviour

On the 20th day, juvenile common carp in groups 1 - 2 ~ 6 consume more or same amount of feed at late in the afternoon (1800 h) than around noon (Table 7). Early in the morning (0900 h) feed consumption was significantly lower than other feeding time.

On the 40th day, juvenile common carp in the groups 1 - 2 ~ 6, except in the groups 1 - 3, consumed more feed in the late afternoon (1800 h) than early in the morning (0900 h) or around noon (1100 ~ 1300 h). According to the result, at each feeding frequency, juvenile common carp consume different amount of food at each feeding time.

Table 7. Amount of feed consumed by juvenile common carp at each feeding time in a day during 6 different feeding frequency test[1].

20^{th} day							
Groups	0900	1100	1200	1300	1500	1600	1800
1 - 1	0.9 ± 0.03						
1 - 2	1.1 ± 0.16						1.2 ± 0.02
1 - 3	0.9 ± 0.03^{a}			1.1 ± 0.01^{b}			1.2 ± 0.02^{c}
1 - 4	1.0 ± 0.02^{a}		1.1 ± 0.01^{b}		1.1 ± 0.11^{ab}		1.2 ± 0.02^{b}
1 - 5	0.9 ± 0.09^{a}	1.1 ± 0.05^{bc}		1.1 ± 0.01^{b}	1.3 ± 0.08^{c}		1.3 ± 0.04^{bc}
1 - 6	1.0 ± 0.04^{a}	1.1 ± 0.03^{bc}		1.1 ± 0.02^{bc}	1.2 ± 0.03^{c}	1.1 ± 0.01^{b}	1.2 ± 0.03^{bc}
40^{th} day							
Groups	0900	1100	1200	1300	1500	1600	1800
1 - 1	1.6 ± 0.04						
1 - 2	1.5 ± 0.19						1.8 ± 0.05
1 - 3	1.3 ± 0.02^{b}			0.9 ± 0.04^{a}			1.3 ± 0.08^{b}
1 - 4	1.3 ± 0.04^{c}		1.0 ± 0.04^{a}		1.1 ± 0.01^{b}		1.9 ± 0.02^{d}
1 - 5	1.3 ± 0.03^{b}	0.7 ± 0.04^{a}		0.7 ± 0.03^{a}	0.9 ± 0.01^{a}		1.8 ± 0.11^{c}
1 - 6	1.3 ± 0.06^{d}	0.6 ± 0.02^{a}		0.7 ± 0.02^{ab}	0.8 ± 0.04^{bc}	0.8 ± 0.05^{c}	1.6 ± 0.05^{e}

[1] Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$).

Wang *et al*., 1998 concluded that feeding frequency influence daily feeding behaviour of hybrid sunfish change. Hybrid sunfish fed two times a day consume more feed late in the afternoon. Hybrid sunfish fed three times a day consume more feed around noon. However, amount of feed consumption was similar at each feeding time when fish were fed four times a day. Increasing feeding frequency resulted in more uniform feed consumption at each feeding time. However, similar trend was not observed in juvenile common carp in this experiment. Frequent feeding did not resulted in uniform feed consumption at each feeding time.

Juvenile common carp have feeding preference at late in the afternoon. Meer *et al*. (1997) states that *Colossoma macropomum* have maximal feed uptake late in the afternoon. Due to lower feed passage rate in the morning and early afternoon, *C. macropomum* feed consumption increased during the day and peaked at late in the afternoon. According to Getachew (1989), *Oreochromis niloticus* L. stomach fullness increased and stomach pH decreased during the day. *O. niloticus* digestion might be more efficient in the afternoon.

3.2. Second Experiment

3.2.1. Water Quality

Water quality parameters measured in the experimental system were : dissolved oxygen 6.2±0.11 mgL^{-1}; temperature 27.3±0.59 ℃; TAN 0.5±0.12 mgL^{-1}; NO_2-N 0.2±0.05 mgL^{-1}; NO_3-N 22.7±4.01 mgL^{-1}.

3.2.2. Growth performance

No mortality was observed in any group throughout the experiment. Fish weight at the beginning of the experiment was not significantly different between each feeding frequency group (2.4 ~ 2.5 g). After 60 days, final weight, feed intake, feed conversion ratio (FCR), and specific growth rate (SGR) were significantly ($P < 0.05$) different from the treatment groups (Table 8).

Table 8. Effect of 8 different feeding frequencies on growth performance of juvenile common carp[1].

Groups	Initial weight (gr)	Final weight (gr)	Feed intake (gr)	FCR	SGR (% day^{-1})
2 - 1	2.4 ± 0.03	15.2 ± 0.29[a]	12.4 ± 0.27[a]	1.0 ± 0.04[a]	3.1 ± 0.05[a]
2 - 3	2.4 ± 0.04	37.5 ± 0.43[b]	40.4 ± 0.26[b]	1.2 ± 0.01[bc]	4.6 ± 0.02[b]
2 - 5	2.5 ± 0.02	50.4 ± 2.07[c]	53.3 ± 2.26[c]	1.1 ± 0.01[b]	5.0 ± 0.06[c]
2 - 6	2.4 ± 0.04	53.6 ± 0.63[cd]	59.4 ± 0.34[d]	1.2 ± 0.01[bc]	5.1 ± 0.04[c]
2 - 7	2.4 ± 0.06	55.4 ± 0.39[d]	60.2 ± 0.18[d]	1.1 ± 0.01[bc]	5.2 ± 0.02[c]
2 - 8	2.5 ± 0.06	51.1 ± 1.66[c]	57.5 ± 2.08[cd]	1.2 ± 0.00[c]	5.1 ± 0.10[c]

[1] Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$).

Fish grew from the initial body weight of 2.4 ~ 2.5 g up to 15.2 g (2 - 1), 37.5 g (2 - 3), 50.4 g (2 - 5), 53.6 g (2 - 6), 55.4 g (2 - 7), and 51.1 g (2 - 8) for 60 days. Highest final weight was achieved in the group 2 - 7 (55.4 g) but was not significantly different from average final weight in group 2 - 6 (53.6 g). The group with the least frequent feeding schedule (2 - 1) had the lowest final weight (15.2 g). There were three-fold differences between the group with the lowest final weight (2 - 1) and the groups with the highest final weight (2 - 6 and 2 - 7). Fish in groups 2 - 6 and 2 - 7 grew more than 20-fold while group 2 - 1 grew only six-fold from their initial weight.

Highest feed intake was achieved in the groups 2 - 6 (59.4 g) and 2 - 7 (60.2 g) but was not significantly different with average feed intake in the group 2 - 8 (57.5 g). Group 2 - 1 consumed the least feed (12.4 g) followed by the group 2 - 3 (40.4 g) during this period. There were five-fold differences between fish in the groups with lowest feed intake (2-1) and fish in the groups with highest feed intake (2 - 6 and 2 - 7).

Since the fish in the most frequently (6 times a day) fed group had the highest final weight compared to other groups, another experiment with an even higher feeding frequency was conducted (Second Experiment) to measure the maximum feeding frequency for juvenile common carp.

Feed intake was an important factor that limited growth. Optimum feed intake will ultimately result in maximum growth (Vahl, 1979; Thompson *et al.*, 2000; Meer *et al.*, 2007). Frequent feedings increased food intake and growth. However, at a certain limit, more frequent feedings will cease to result in more feed intake. The lowest frequency at which there was no further increase of feed intake may be called "optimum" feeding frequency (Grayton and Beamish, 1977). According to experimental result, there was no further increase of feed intake in groups fed six, seven and eight times a day. Therefore, it is clear that feeding six times a day is the optimum feeding frequency. Optimum frequency was influenced by size, age, temperature and food quality (Grayton and Beamish, 1977; Gandra *et al*., 2007; Booth *et al*., 2008).

Table 9. Daily food intake (% day^{-1}) for juvenile common carp under 1 ~ 8 feeding frequency

Groups	Period (Day)		
	0 - 20	20 - 40	40 - 60
2 - 1	2.84	3.01	2.35
2 - 3	5.84	4.49	2.85
2 - 5	6.67	4.61	2.45
2 - 6	7.12	4.93	2.58
2 - 7	6.87	4.81	2.40
2 - 8	7.25	4.87	2.33

Daily feed intake of juvenile common carp weight 2.4 ~ 53.6 g fed 6 times a day (Table 9) in Exp. 2 was smaller (7.12 ~ 2.58 %) than daily feed intake recommended by Miyatake (1997) which was 8.80 ~ 4.30 % for size 2.0 – 50.0 g.

The best feed conversion ratio (1.0) was achieved in the group of 2 - 1. FCR in the groups of 2 - 3 ~ 8 was higher than 2 - 1, but there was no significant difference between them. According to the experimental result, FCR increased with increasing feeding frequency. Similar result was also achieved in Exp. 1; Webster *et al.* (2001) and Hossain *et al.* (2001). Higher FCR might indicate that fish fed more frequently might utilize feed less efficiently than fish fed less frequently (Webster *et al*., 2001).

The highest SGR (5.0 ~ 5.2 %) was achieved in the groups of 2 - 5 ~ 8. SGR of the fish in the groups of 2 - 3 were (4.6 %) and 2 - 1 (3.1%) per day, respectively. The growth rate of fish increased with increasing feeding frequency. This result was similar to Exp 1. and other reports (Grayton and Beamish, 1977; Marian *et al*., 1982; Zhou et al., 2003; Webster *et al*., 2001; Hossain *et al*., 2001). However, there was no further improvement of SGR for feeding more than five times a day. Andrews and Page (1975) reported that additional physical or endocrine activity caused by excessive feeding frequency may negatively influence growth of channel catfish.

Compared to the second experiment, the first experiment showed no limit to feeding frequency, even in experimental fish being fed 6 times daily. However, in the second experiment, frequent feedings more than 6 times a day, did not result in a significant increase of final weight and feed intake. Therefore, feeding 6 times a day is the maximum feeding frequency for juvenile common carp.

3.2.3. Body composition

The 2 - 1 groups of fish, least fed groups, had the highest moisture content while the fish in 2 - 5 ~ 8 groups showed the lowest moisture content (Table 10). There was some trends that as feeding frequency increased, moisture content decreased. This result is similar to that of a study conducted by Grayton and Beamish (1977) and the result of Exp. 1.

Crude protein content of group 2 - 1 were higher among all feeding frequencies. Feeding frequently significantly reduce crude protein content.

Groups 2 - 6 ~ 8 had significantly higher crude lipid content in comparison with group 2 - 1 and 2 - 3, which had the lower crude lipid content. There were some trends that as feeding frequency increased, crude lipid content increased. This result is similar to the result of Exp. 1 and that of a study conducted by Grayton and Beamish (1977) who found an increase of crude lipid content along with an increase of feeding frequency in rainbow trout. Fish fed more frequently tend to have higher lipid deposits than fish fed less frequent (Grayton and Beamish, 1977; Lee *et al*., 2000; Jeong *et al*., 2003). Accumulation of lipid in fish tissue caused by inadequate feeding practice cannot be utilized as an energy source (Jeong *et al*., 2003). Jobling and Miglavs (1993) suggest that accumulation of body lipid and an abundance of energy reserve were responsible for the decline of a fish's appetite.

The 2 - 1 group of fish, least feeding group had the highest ash content. The ash content in the fish in groups 2 - 3 was significantly lower than the fish in group 2 - 1. The most frequently fed groups 2 - 5 ~ 8 had significantly lower crude ash content. There were some trends that ash content was decreasing if fish were fed more frequent. Therefore it is clear that enough food fed group of fish showed lower ash content in the whole body (Zhou et al., 2003).

Table 10. Effect of 1 ~ 8 feeding frequencies on proximate composition of juvenile common carp[1] (%, wet weight basis; n = 3).

Groups	Moisture (%)	Crude Protein (%)	Crude Lipid (%)	Crude Ash (%)
2 - 1	75.5 ± 0.38^{c}	15.2 ± 0.26^{b}	6.4 ± 0.12^{a}	2.6 ± 0.07^{c}
2 - 3	72.9 ± 0.38^{b}	14.3 ± 0.27^{ab}	10.8 ± 0.12^{b}	2.0 ± 0.05^{b}
2 - 5	70.9 ± 0.78^{a}	14.2 ± 0.42^{a}	12.9 ± 0.66^{c}	1.8 ± 0.05^{a}
2 - 6	70.2 ± 0.65^{a}	14.0 ± 0.11^{a}	13.9 ± 0.55^{cd}	1.9 ± 0.03^{ab}
2 - 7	70.4 ± 0.29^{a}	14.2 ± 0.14^{a}	13.9 ± 0.18^{cd}	1.9 ± 0.06^{ab}
2 - 8	69.5 ± 0.69^{a}	14.1 ± 0.35^{a}	14.2 ± 0.23^{d}	1.9 ± 0.03^{ab}
Initial	83.9 ± 0.02	11.4 ± 0.05	1.07 ± 0.05	2.72 ± 0.02

[1] Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$)

3.2.4. Haematological analysis

The effects of feeding frequencies on haematological parameters in juvenile common carp are shown in Table 11. The RBC of the fish in the group 2 - 6 was lowest (1.9 %) but statistically no different from the groups of 2 - 3, 2 - 5 and 2 - 8. RBC of the fish in the group 2 - 1 was highest (2.5 %) but not significantly different from the groups of 2 - 5, 2 - 7 and 2 - 8.

Feeding frequency contributed no significant effect towards hematocrit in juvenile common carp. Haemoglobin level in group 2 - 1 was significantly lower than the haemoglobin level in group 2 - 7. No significant difference of haemoglobin level was found in groups (2 - 3 ~ 8). There was some trends that as feeding frequency increased, haemoglobin level increased.

Table 11. Effect of 8x feeding frequencies on haematological parameter (n = 3) of juvenile common carp[1].

Groups	RBC (%)	Ht (%)	Hb (%)
2 - 1	2.5 ± 0.02^{c}	52.8 ± 2.20^{a}	20.2 ± 3.75^{a}
2 - 3	2.0 ± 0.10^{ab}	48.8 ± 2.69^{a}	22.3 ± 0.56^{ab}
2 - 5	2.1 ± 0.10^{abc}	49.5 ± 1.18^{a}	21.8 ± 0.67^{ab}
2 - 6	1.9 ± 0.12^{a}	45.43 ± 2.89^{a}	21.1 ± 0.58^{ab}
2 - 7	2.4 ± 0.29^{bc}	51.8 ± 5.39^{a}	25.5 ± 2.25^{b}
2 - 8	2.2 ± 0.07^{abc}	48.7 ± 4.55^{a}	24.3 ± 0.85^{ab}

Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$)

Below normal range of hematocrit (Ht), haemoglobin (Hb), and red blood cell count (RBC) are the sign of anemia resulting from a deficiency of vitamins, mineral or starvation (Mata, 2007). According to the results of the experiments, no significant differences of Ht value and Hb concentrations in all treatments suggested that there were no negative effects on haematological parameters even in the groups of fish fed once a day feeding. This idea might be supported by the growth rates of the fish groups fed once a day that grew 120 % in 40 days and 530 % in 60 days in Exp. 1 and Exp. 2 respectively. Even these fish were fed once a day, they consumed enough nutrition for the growth rates by *ad libitum* feeding.

3.3. Third Experiment

3.3.1. Water Quality

Water quality parameters measured in the experimental system were : dissolved oxygen 7.7±0.13 mgL^{-1}, temperature 19.8±0.62 ℃; TAN 0.4±0.03 mgL^{-1}; NO_2-N 0.2±0.03 mgL^{-1}; NO_3-N 16.0±0.69 mgL^{-1}.

3.3.2. Growth performance.

At the beginning of *ad libitum* feeding, weight of least fed groups (1 - 1) was the lowest compared to all treatment groups. However, after *ad libitum* feeding, weight of 3 - (1) - 6 was similar with the weight of other treatment groups, except 3 - (6) - 6. Feed intake of least fed groups (1 - 1) was the lowest compared to all treatment groups at the beginning of *ad libitum* feeding. After *ad libitum* feeding, feed intake of 3 - (1) - 6 was similar with the feed intake of other treatment groups. FCR of least fed groups (1 - 1) was better compared to all treatment groups at the beginning of *ad libitum* feeding. However, after a*d libitum* feeding, FCR of 3 - (1) - 6 was similar with the FCR of other treatment groups. SGR of least fed groups (1 - 1) was the lowest compared to all treatment groups at the beginning of *ad libitum* feeding. However, after *ad libitum feeding*, SGR of 3 - (1) - 6 was similar with the SGR of other treatment groups

The growth performances of all groups are shown in Table 12 and Fig. 2. Forty days after *ad libitum* feeding, the weight of fish in group 3 - (1) - 6 (6.28 g) was not significantly different from group 3 - (2) - 6 (8.08 g), and those in group 3 - (2) - 6 and 3 - (3) - 6 (9.20 g) were also same. However, the weight of fish in groups 3 - (1) - 6, 3 - (2) - 6 and 3 - (3) - 6 were significantly lower than those in groups of 3 - (4) - 6, 3 - (5) - 6 and 3 - (6) - 6. Weight of fish in groups 3 - (1) - 6, 3 - (2) - 6 and 3 - (3) - 6 were 46.4 %, 59.6 %, and 67.9 % of the weight of fish in group 3 - (6) - 6, respectively.

Table 12. Body weight (g) of juvenile common carp subjected to *ad libitum* feeding

Groups	Time (Day)			
	0	40	80	140
3 - (1) - 6	4.35	6.28	9.39	25.82
3 - (2) - 6	6.05	8.08	10.45	24.00
3 - (3) - 6	7.49	9.20	11.68	25.69
3 - (4) - 6	9.05	11.53	14.28	29.42
3 - (5) - 6	9.78	12.10	14.00	28.07
3 - (6) - 6	10.84	13.54	16.25	30.38

Eighty days after *ad libitum* feeding, weight of fish in groups 3 - (1) - 6, 3 - (2) - 6 and 3 - (3) - 6 were 57.8 %, 64,3 % and 71.9 % of the weight of fish in group 3 - (6) - 6, respectively. Weight of fish in groups 3 - (4) - 6 (14.28 g) and 3 - (5) - 6 (14.00 g) were not significantly (P > 0.05) different from the weight of fish in group 3 - (6) - 6 (16.25 g).

After *ad libitum* feeding for 140 days, weight of fish in the groups from 3 - (1) - 6 to 3 - (5) - 6 were not significantly different (P > 0.05). Weight of fish in 3

- (1) - 6, 3 - (2) - 6 and 3 - (3) - 6 were significantly different from the weight of fish in 3 - (6) - 6 ($P \leq 0.05$).

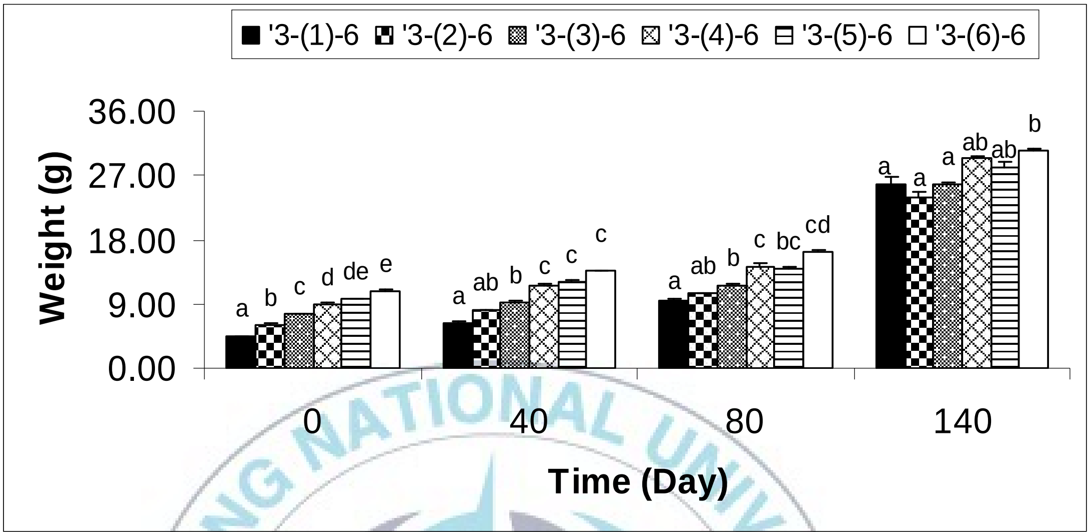


Fig. 2. Body weight (g) of juvenile common carp subjected to *ad libitum* feeding. Values (mean±SE) with different letters on the same day are significantly different ($P < 0.05$).

Complete compensation growth was achieved only in groups 3 - (4) - 6 and 3 - (5) - 6 while the partial compensation growth was achieved in the groups of 3 - (1) - 6, 3 - (2) - 6 and 3 - (3) - 6 after feed deprivation for 40 days.

Xie *et al.*, (2001) reported that the weight of gibel carp after feed deprivation for 1 and 2 weeks were 92 % and 74 % respectively to that of control fish. Both groups were able to show full compensation growth. Wang *et al.*, (2000) reported that the weight of hybrid tilapia after feed deprivation for 1, 2, and 4 weeks were 71 %, 48 % and 26 %, respectively to that of control fish. Full compensation growth was achieved only in fish subjected to 1 week of feed deprivation. Qian *et al*., (2000) reported that the weight of gibel carp after feed deprivation for 1, 2, and 4 weeks were 82 %, 77 % and 58 % respectively to that of control fish. Full compensation growth was achieved only in gibel carp subjected to 1 and 2 weeks of feed deprivation.

In this experiment, the relative body weight of juvenile common carp subjected to feed deprivation for 40 days were 40.2 % (3 - (1) - 6), 55.8 % (3 - (2) - 6), 69.1 % (3 - (3) - 6), 83.5 % (3 - (4) - 6), and 90.2 % (3 - (5) - 6) to that of the body weight of groups fed 6 times a day (10.8 g). According to those results, complete compensatory growth was achieved only in fish that weighed more than 70 % that of the control at the end of a feed deprivation period. Relative body weight to control may be a good indicator for the success or failure of compensation growth.

Amount of feed intake of all treatment groups are shown in Table 13. Feed intake during 0 - 40 days of *ad libitum* feeding was higher than the 40 - 80 days, however, both periods were lower than 80 - 140 days in all treatment.

Table 13. Feed intake (g) of juvenile common carp subjected to *ad libitum* feeding

Groups	Period (Day)		
	0 - 40	40 - 80	80 - 140
3 - (1) - 6	4.52	3.22	17.27
3 - (2) - 6	4.52	3.26	13.81
3 - (3) - 6	4.55	2.95	15.05
3 - (4) - 6	5.01	3.71	16.92
3 - (5) - 6	5.18	3.26	15.73
3 - (6) - 6	5.42	4.12	16.21

No significant difference of feed intake between each treatment groups was found during the Exp. 3 period (compensation growth) of juvenile common carp (Fig. 3).

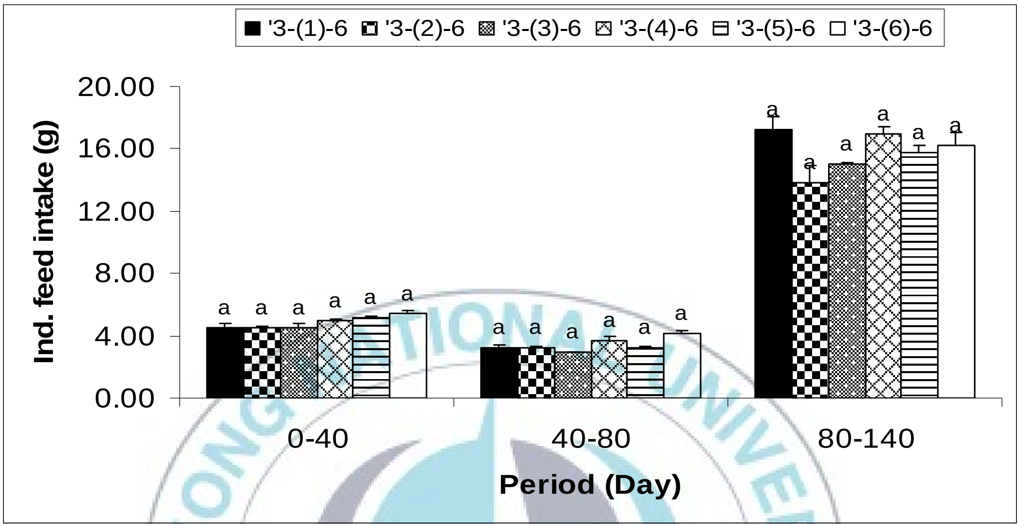


Fig. 3. Individual feed intake (g) of juvenile common carp subjected to *ad libitum* feeding. Values (mean±SE) with different letters on the same day are significantly different (P < 0.05).

Daily feed intake of feed deprived groups (3 - (1) - 6) was higher than all other feeding treatments throughout *ad libitum* feeding period (Table 14). There is also a trend of increased daily feed intake from least deprived groups (3 - (6) - 6) to most deprived groups (3 - (1) - 6) during each *ad libitum* feeding period. Excessive/abnormally high feed intake (hyperphagia) was responsible for compensation growth during *ad libitum* feeding period (Jobling, 1994; Wang *et al*., 2000; Oh *et al*., 2007).

Table 14. Daily feed intake (% day^{-1}) of juvenile common carp subjected to *ad libitum* feeding

Groups	Period (Day)		
	0 - 40	40 - 80	80 - 140
3 - (1) - 6	2.13	1.03	1.63
3 - (2) - 6	1.60	0.88	1.34
3 - (3) - 6	1.36	0.71	1.34
3 - (4) - 6	1.22	0.72	1.29
3 - (5) - 6	1.18	0.62	1.25
3 - (6) - 6	1.11	0.69	1.16

FCR was turned to better throughout the *ad libitum* feeding period. FCR during 0 - 40 days of *ad libitum* feeding was higher than the 40 - 80 or 80 - 140 days. (Table 15). Following restoration to *ad libitum* feeding, rates of synthesis and energy expenditure may increase rapidly, whereas rates of breakdown may take longer to return to levels observed in continuously fed fish. Fish recovering from period of feed deprivation would display rapid growth rate and better feed conversion ratio (Jobling, 1994)

Table 15. Feed conversion ratio of juvenile common carp subjected to *ad libitum* feeding

Groups	Period (Day)		
	0 - 40	40 - 80	80 - 140
3 - (1) - 6	2.36	1.03	1.05
3 - (2) - 6	2.28	1.38	1.02
3 - (3) - 6	2.73	1.20	1.08
3 - (4) - 6	2.03	1.35	1.12
3 - (5) - 6	2.26	1.71	1.12
3 - (6) - 6	2.00	1.52	1.15

No significant difference of the feed conversion ratio (FCR) was found during the Exp. 3 period (compensation growth) of juvenile common carp (Fig. 4). FCR has no effect on *ad libitum* feeding after period of feed deprivation in juvenile common carp. Similar results were also found in the compensatory growth of hybrid tilapia (Wang *et al*., 2000; Wang *et al*., 2005), black rockfish (Oh *et al*., 2008) and channel catfish (Kim and Lovell, 1995).

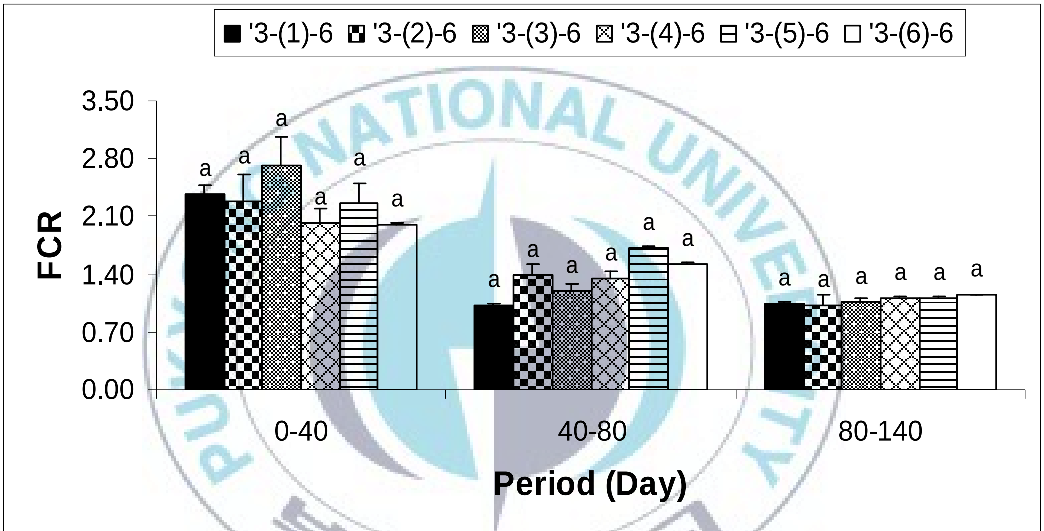


Fig. 4. Feed conversion ratio of juvenile common carp subjected to *ad libitum* feeding. Values (mean±SE) with different letters in the same day are significantly different (P < 0.05).

There was a trend of increasing SGR from control (3 - (6) - 6) to the most deprived groups (3 - (1) - 6) throughout ad libitum feeding period (140 days) (Table 16). Similar result was also achieved by Cui *et al.* (2006) for juvenile gibel carp weighed 2.2 g during 4 weeks of refeeding after 4 weeks of feed deprivation. However, after 4 weeks to 6 weeks of refeeding, inverse trend of better SGR in control than most deprived groups was exhibited by juvenile gibel carp. In this case, common carp may have better ability to maintain better SGR throughout *ad libitum* feeding period compared to gibel carp.

According to Jobling (1994), metabolic rate of fish previously exposed to feed deprivation may not immediately returned to the same level as that of continuously fed fish. There may be some time lag for adaptation of metabolic rate to fully fed condition. Low rates of energy expenditures caused by feed restriction may be maintained for short period of time eventhough the fish are no longer food restricted. Low rates of energy expenditures occuring at the same time with either normal or high food intake result in large amounts of energy available for growth. Thus, weight rapidly increase during short period of time

Table 16. Spesific growth rate (SGR) of juvenile common carp subjected to *ad libitum* feeding

Groups	Period (Day)		
	0 - 40	40 - 80	80 - 140
3 - (1) - 6	0.91	1.01	2.53
3 - (2) - 6	0.72	0.64	2.08
3 - (3) - 6	0.51	0.60	1.97
3 - (4) - 6	0.60	0.54	1.81
3 - (5) - 6	0.53	0.37	1.74
3 - (6) - 6	0.56	0.46	1.57

No significant difference of specific growth rate (SGR) was found during the Exp. 3 period (compensation growth) of juvenile common carp. The spesific growth rates of all groups are shown in Table 16 and Fig. 5.

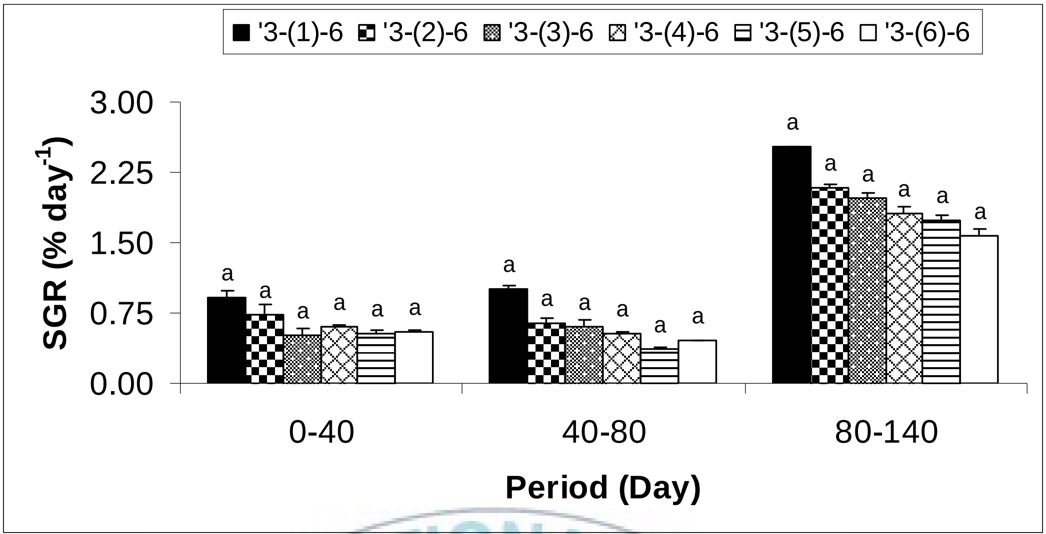


Fig. 5. Spesific growth rate (SGR) of juvenile common carp subjected to *ad libitum* feeding. Values (mean±SE) with different letters in the same day are significantly different ($P < 0.05$).

3.3.3. Body composition

The moisture contents of the fish in group 3 - (1) - 6 (74.0 %) was higher than those in all other groups and the lowest moisture content was achieved in group 3 - (5) - 6 (71.4 %). The highest crude protein content was achieved in groups 3 - (2) - 6 (14.8 %) and 3 -5 (14.9 %). The crude lipid contents of the group of 3 - (1) - 6 (11.4 %) and 3 - (5) - 6 (11.5 %) were the highest of all the groups. Crude lipid contents of the group 3 - (6) - 6 was significantly lower than groups 3 - (1) - 6, 3 - (2) - 6 and 3 - (5) - 6. Lowest crude lipid content was achieved in group of 3 - (3) - 6 (9.3 %). The crude ash content in group 3 - (3) - 6 was significantly higher (2.3 %) than all other groups (1.9 ~ 2.0 %). Crude ash content in groups 3 - (1) - 6 and 3 - (5) - 6 were the lowest among all of the groups (Table 17).

Table 17. Effect of compensation growth on proximate composition of juvenile common carp[1] (%, wet weight basis; n = 3).

Groups	Moisture (%)	Crude Protein (%)	Crude Lipid (%)	Crude Ash (%)
3 - (1) - 6	74.0 ± 0.05[d]	13.9 ± 0.05[b]	11.4 ± 0.06[d]	1.9 ± 0.01[a]
3 - (2) - 6	72.0 ± 0.04[b]	14.8 ± 0.05[d]	9.8 ± 0.01[c]	2.0 ± 0.02[c]
3 - (3) - 6	72.5 ± 0.04[c]	14.6 ± 0.06[c]	9.3 ± 0.01[a]	2.3 ± 0.02[d]
3 - (4) - 6	73.9 ± 0.05[d]	12.9 ± 0.05[a]	9.7 ± 0.00[bc]	2.0 ± 0.05[bc]
3 - (5) - 6	71.4 ± 0.05[a]	14.9 ± 0.05[d]	11.5 ± 0.06[d]	1.9 ± 0.02[ab]
3 - (6) - 6	72.7 ± 0.06[c]	13.8 ± 0.00[b]	9.6 ± 0.04[b]	2.0 ± 0.02[bc]

[1] Values (mean ± SE of triplicates) in the same column not sharing a common superscript are significantly different ($P < 0.05$)

At the end of feed deprivation period, crude body lipid content of feed deprived groups was the lowest among all treatments. However, at the end of *ad libitum* feeding period, there was a trend that most deprived groups (3 - (1) - 6) had the highest percentage of crude lipid increment (384.7 %). On the contrary, control (3 - (6) - 6) and least deprived groups had lower crude lipid increment (Table 18). Jobling and Johansen (1999) suggest that the rate at which animals replenish their lipid reserve during catch-up growth may influence their hyperphagic response and recovery of body weight. Besides restoration in somatic growth, compensatory growth is a response to restore lipid levels in the fish body (Ali *et al*., 2003).

Table 18. Percentage of crude lipid increment of juvenile common carp subjected to *ad libitum* feeding

Groups	Crude lipid content (%)		
	End of feed deprivation period	End of *ad libitum* feeding period	% Crude lipid increment
3 - (1) - 6	2.40	11.40	384.68
3 - (2) - 6	4.40	9.80	125.17
3 - (3) - 6	5.90	9.30	58.31
3 - (4) - 6	7.70	9.70	26.49
3 - (5) - 6	8.00	11.50	43.43
3 - (6) - 6	7.90	9.60	22.49

IV. CONCLUSION

Juvenile common carp 2 ~ 50 g size required 6 times a day feeding frequency for maximum growth performance. Juvenile common carp, 2.0 g in body weight grew 10.8 g (440 % increase) in 40 days when fed 6 times daily while 2.5 g size grew up to 53.6 g (2130 % increase) in 60 days when fed 6 times daily. Frequent feedings resulted in higher specific growth rate (SGR) and better feed conversion ration (FCR). Frequent feeding fish showed lower moisture and ash contents and higher lipid contents in whole body proximate analysis. According to the result of this experiment, feeding frequency of 6 times daily is recommended for juvenile common carp (*Cyprinus carpio*) to achieve maximum growth.

This study suggests that juvenile common carp consume more feed late in the afternoon than other feeding times. Full compensation growth was achieved in 3 - (4) - 6 and 3 - (5) - 6 after refeeding for 140 days. Percentage of crude lipid contents increment after *ad libitum* feeding was highest (380 %) in food-deprived groups.

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