The WALTHAM International Nutritional Sciences Symposia

The Influence of Feeding Frequency on Growth and Body Condition of the Common Goldfish (*Carassius auratus*)[1,2]

Steven M. Priestley, Abigail E. Stevenson,[3] and Lucille G. Alexander

WALTHAM Centre for Pet Nutrition, Waltham on the Wolds, Melton Mowbray, Leicestershire, UK

EXPANDED ABSTRACT

KEY WORDS: • *goldfish* • *Carassius auratus* • *feeding frequency* • *growth* • *feed conversion*

The optimal frequency for feeding ornamental fish species has yet to be clearly defined and this has led to uncertainty in the feeding routines used by many aquarists. Both over- and underfeeding can be detrimental to the health of the fish and may cause a marked deterioration in water quality, reduced weight, poor food utilization, and increased susceptibility to infection. Consequently, specific growth rates and the efficiency of feed conversion can be directly related to feed ration and frequency. Therefore, it is important to be able to predict the most favorable feeding frequency relative to the species and size of fish.

Although it is often postulated that feeding ornamental fish little and often throughout the day will result in more efficient feed utilization, research has not yet been conducted to validate this hypothesis. Published literature on frequency of feeding ornamental fish is limited when compared with that available from cultured fish species. Data from aquaculture research is commonly extrapolated and applied to ornamental species, which often proves to be unsatisfactory because of the differences in fish species and variation in diet formulations. In addition, the majority of research has focused on feeding fish to satiation, measuring the food intake, and linking this to growth performance and utilization.

Research conducted with the ornamental Red Swordtail (*Xiphophorus helleri*) indicated that feeding 2 meals/d (where a meal is defined as providing food until fish stop eating [the point of satiation]) resulted in the greatest growth and reproductive success of this species in a cultured system, when compared with 4 alternative feeding regimens (1 meal in 3 d, 1 meal in 2 d, 1 meal/d, and 2 meals/d) (1). Further investigations by the same researchers using the Siamese Fighting Fish (*Betta splendens*. Regan) showed that 2 meals/d fed to satiation elicited maximum growth and reproductive output for this ornamental fish species when compared with 1 meal in 3 d, 1 meal in 2 d, 1 meal/d, and 3 meals/d (2).

Additional research on commercially cultured fish species such as the Black Rockfish (*Sebastes schlegeli*) suggested that feeding to satiation once a day resulted in optimum growth and food utilization when compared with 1 meal every 2 d or 2 meals/d (3). In addition, juvenile Atlantic Halibut (*Hippoglossus hippoglossus*) displayed improved growth rates when fed to satiation 5 times/d, compared with 1/d (4), and African Catfish (*Clarias gariepinus*) exhibited greater growth rates when fed to satiation twice compared with 3 times/d (5). In one study where a set amount of food was offered, Giberson and Litvak (6) established that Shortnose Sturgeon (*Acipenser brevirostrum*) grew significantly better when offered a food ration of 3% of the tank biomass divided into 4 or 8 feedings/d compared to one. However, in the same study, growth and feeding efficiencies of Atlantic Sturgeon (*Acipenser oxyrinchus*) were unaffected by the frequency of feeding.

Currently there appear to be no data available that directly relates feeding frequency to growth and efficiency of food utilization in the Common Goldfish (*Carassius auratus*). However, the closely related subspecies, Gibel Carp (*Carassius auratus gibelio*), exhibited significant increases in growth rate and feed efficiency when feeding frequency increased from 2 to 3, 4, 12, and 24 feedings/d, with the authors recommending an optimal feeding frequency of 24 meals/d for this species (7). However, fish were juvenile and fed to satiation, confirming that feeding frequency in part is a function of fish size, with larval and juvenile fish needing to eat more frequently because of their high energy demands.

This current study aimed to assess the effects of feeding a set amount of food at a variety of meal frequencies on growth parameters of the Common Goldfish (*Carassius auratus*) and to identify the optimum number of feeds/d to maximize utilization of the food ration.

[1] Published in a supplement to *The Journal of Nutrition*. Presented as part of The WALTHAM International Nutritional Sciences Symposium: Innovations in Companion Animal Nutrition, held in Washington, DC, September 15–18, 2005. This conference was supported by The WALTHAM Centre for Pet Nutrition and organized in collaboration with the University of California, Davis, and Cornell University. This publication was supported by The WALTHAM Centre for Pet Nutrition. Guest editors for this symposium were D'Ann Finley, Francis A. Kallfelz, James G. Morris, and Quinton R. Rogers. Guest editor disclosure: expenses for the editors to travel to the symposium and honoraria were paid by The WALTHAM Centre for Pet Nutrition.

[2] Author disclosure: no relationships to disclose.

[3] To whom correspondence should be addressed. E-mail: abigail.stevenson@eu.effem.com.

0022-3166/06 $8.00 © 2006 American Society for Nutrition. J. Nutr. 136: 1979S–1981S, 2006.

TABLE 1

Proximate nutrient analysis for Goldfish flake food[1]

Nutrient	Goldfish flake food, %
Moisture	3.40
Protein	35.60
Fat	11.50
Ash	13.10
Nitrogen-free extract	36.40
Fiber	6.00

[1] Aquarian Goldfish flakes.

MATERIALS AND METHODS

Husbandry

Experimental trials were conducted at the WALTHAM Aquacentre, Birstall, Yorkshire, England. A total of 120 Common Goldfish (*Carassius auratus*) obtained from JMC Aquatics, Derbyshire, England, weighing on average 32.8 ± 7.4 g, were divided equally into twelve 50-L tanks: 10 fish were housed in each tank. All aquarium tanks were in parallel as an integral part of a cold water recirculation system held at a temperature of 18.3 ± 1.3°C. In total there were 4 experimental feeding regimens utilizing 3 tanks/treatment. The fish were randomly allocated a feed frequency of 1, 2, 4, or 6 meals/d (meals times were equally spaced throughout the day from 0900 to 1500). A standard commercially available Goldfish flake food (Aquarian Goldfish flakes) was offered at an allowance of 2% bodyweight (g/g) split equally among the allocated number of meals. The proximate nutrient analysis for this food is provided in **Table 1**. The duration of this study was 8 wk, during which water quality parameters were maintained within safe limits (NH_3 and NO_2 not detectable, NO_3 between 2.64 and 4.84 mg/L, and pH between 7.15 and 7.41).

Weighing and zoometric measures

In order to calculate and monitor various growth parameters and predict a daily feed ration, fish were individually weighed, and zoometric measurements were taken before the start of the trial and then every 2 wk. There were no significant differences in fish body weight, length, or depth between treatment groups at the start of the study. In order to carry out the measurements, fish were removed from the tank using a net and placed into a holding bucket containing tank water. Fish were removed from the bucket individually and placed on laminated graph paper. Length from the mouth to caudal peduncle and depth from the deepest point of the body to the base of the dorsal fin were measured (mm). Fish were then placed in a tared beaker of tank water on a balance for body weight measurements before being returned to their original tank. Total time spent out of the water was <5 s.

Both fish and feed weight data were used in order to calculate the specific growth rate and food conversion ratio using the equations below:

$$\text{Specific growth rate (SGR)} = 100 \times [\ln \text{final wt of fish (g)} - \ln \text{intial wt of fish (g)}]/\text{trial length (days)}$$

where ln is the natural log.

$$\text{Feed conversion ratio (FCR)} = \text{Feed intake (g)}/\text{Body weight gain(g)}.$$

All husbandry and handling procedures were approved by the WALTHAM Ethical Review Committee.

Statistics

Values are expressed as means ± SD. A goodness-of-fit test was applied to check normality of the data. Because data were found to follow a normal distribution, the effect of feed frequency on growth parameters was analyzed using the ANOVA multiple-sample comparison and multiple-range tests (least significant difference) using Statgraphics Plus v. 2.0. The level of significance was set at $P \leq 0.05$.

RESULTS

Growth

Throughout the trial all food was consumed regardless of feed frequency and all fish remained healthy with no mortalities. Growth data are displayed in **Table 2**. Specific growth rates ranged between 0.443 and 0.499%, feed conversion ratios ranged from 2.49 to 2.83, and percentage growth values were between 21.95 and 24.39% over the duration of the study. Growth parameters were influenced by frequency of feeding, with fish fed 4 times/d producing a significantly greater specific growth rate ($P = 0.022$), lower feed conversion ratio ($P = 0.019$), and greater percentage growth per fish ($P = 0.020$) than those fed once. These changes in fish fed 4 feedings/d demonstrated significantly higher growth performance than fish fed once a day. No other significant differences were noted between treatments.

TABLE 2

Specific growth rates (SGR), feed conversion ratio (FCR), and percentage growth for Common Goldfish fed 1, 2, 4, or 6 times daily for 8 wk[1]

	Feeding frequency/d			
Growth parameter	1	2	4	6
SGR, %	0.443 ± 0.009[a]	0.472 ± 0.020[ab]	0.499 ± 0.025[b]	0.453 ± 0.045[ab]
FCR	2.83 ± 0.06[b]	2.65 ± 0.11[ab]	2.49 ± 0.02[a]	2.75 ± 0.29[ab]
Growth per fish, %	21.95 ± 0.38[a]	23.22 ± 0.86[ab]	24.39 ± 1.06[b]	22.41 ± 1.97[ab]
Length gain/fish, *mm*	9.17 ± 0.58[a]	9.75 + 1.58[a]	10.64 + 1.6[a]	9.79 + 1.24[a]
Depth gain/fish, *mm*	5.17 ± 0.49[a]	6.07 ± 0.06[a]	6.53 + 1.16[a]	5.63 + 0.25[a]
Depth:length ratio	0.41 ± 0.02[a]	0.40 ± 0.01[a]	0.41 ± 0.03[a]	0.41 ± 0.02[a]
Increase in depth:length ratio (compared with wk 0)	0.016 ± 0.004[a]	0.014 ± 0.002[a]	0.015 ± 0.005[a]	0.008 ± 0.004[a]

[1] Data are mean ± SD, $n = 3$ for each treatment, 10 fish/replicate. Means in a row without a common letter differ, $P < 0.05$. Data analyzed using ANOVA and multiple range tests (least significant difference). No significant differences in length, depth, or body weight were found between treatment groups at wk 0.

Depth:Length ratio

The depth:length ratio (D:L) was used as a marker of body condition for fish, with values obtained in this study ranging between 0.388 to 0.409. The D:L at the start of the study was 0.39 ± 0.01 (2 feedings/d) to 0.40 ± 0.02 (6 feedings/d) and did not differ between groups ($P = 0.07$). Treatment groups did not differ for the D:L ratios at any time period ($P = 0.54$ at 8 wk), suggesting that all fish grew in a similar manner.

DISCUSSION

Limited data exist for growth parameters of ornamental fish including Goldfish, although some information is available for carp species. Specific growth rates of 0.443 to 0.499 calculated from this investigation were low compared with those published for the closely related Common Carp (*Cyprinus carpio*), which were between 2.81–2.92 (8) and 2.6 for the Indian Major Carp (*Catla catla*) (9). These lower growth rates are probably because the Goldfish in this study were fed rations close to maintenance requirements in order to achieve realistic growth rates for aquarium fish rather than maximal growth. If fish were fed to satiation, a more accurate picture of maximum growth rates for the Goldfish may be achieved. Additionally, a further explanation for the lower SGR values of these fish may be related to the age of the Goldfish, as they were not juveniles but were approximately 4 y old. As typical aquarium fish, these animals were fairly large and therefore not in their rapid growth phase. Furthermore, the need for fast growing ornamental fish species is less imperative than for food fish species, which are typically fed very energy-dense diets to produce fish at a marketable size in the quickest time possible. This is reflected in the formulation of flaked diets available for ornamental fish, which are generally less energy dense, with lower protein and fat compared with commercial production diets used in aquaculture.

Feed conversion ratios from this study (2.49 to 2.83) were directly comparable with those found by Moza et al. (10) for the Goldfish. They are also very similar to values of 2.04–2.79 recently reported for Sutchi Catfish (*Pangasius hypophthalmus*) (11). Relatively high FCRs (of up to 3) have also been reported in Striped Bass (*Morone saxatilis*), which was attributed to body size and nonoptimal thermal conditions (12). These values are high when compared with a range of 1.43–1.5 reported for the Common Carp (8). However, it is likely that water temperature and body size influence the feed conversion ratios, although this has not yet been explored in the Common Goldfish.

The body condition data (D:L) obtained during this trial did not vary between treatments, indicating that all fish grew in similar proportions; however, increased feed frequency has been found to positively affect body condition, particularly for small-sized Channel Catfish (*Ictalurus punctatus*) (13). It is possible that feeding fish to satiation would have had significant effects on the D:L ratio.

Both the highest SGR and best FCR were established for the Goldfish fed 4 times/d, indicating that this frequency of feeding was optimal for the conditions of this trial and suggesting that both growth and feed utilization are more efficient at this frequency of feeding. Increased nutrient digestibility and an increased level of water quality are benefits that can be reached by adopting the most favorable feed frequency. However, other factors such as fish size, age, water temperature, and ration size can influence growth and feed conversion in relation to the frequency of diet presentation and warrant further investigation. It also appeared that feeding the ration in 6 small feedings resulted in a lower food utilization rate than feeding 4 times/d. It is likely that the size of each individual ration became too small for effective utilization at this frequency.

Feeding frequency influenced the growth rate of Common Goldfish (*Carassius auratus*). A feeding frequency of 4 times/d resulted in the most efficient food utilization when compared with 1, 3, and 6 feedings/d under the conditions of this study.

LITERATURE CITED

1. James R, Sampath K. Effect of meal frequency on growth and reproduction in the ornamental red swordtail, *Xiphophorus helleri*. Israeli Journal of Aquaculture – Bamidgeh. 2003;55(3):197–207.
2. James R, Sampath K. Effect of feeding frequency and fecundity in an ornamental fish, *Betta splendens* (Regan). Israeli Journal of Aquaculture – Bamidgeh. 2004;56(2):138–47.
3. Guen-Up K, Jo-Young S, Sang-Min L. Effects of feeding frequency and dietary composition on growth and body composition of juvenile rockfish (*Sebastes schlegeli*). Faculty of Marine Biosience and Technology Kangnung National University Gangneung. 2004;210–702.
4. Schnaittacher G, King W, Berlinsky DL. The effects of feeding frequency on growth of juvenile Atlantic halibut, *Hippoglossus hippoglossus* L. Aquacult Res. 2005;36:370–7.
5. Pantazis PA, Neofitou CN. Feeding frequency and intake in the African catfish *Clarias gariepinus* (Burchell 1822). Israeli Journal of Aquaculture – Bamidgeh. 2003;55(3):160–8.
6. Giberson AV, Litvak MK. Effect of feeding frequency on growth, food conversion efficiency, and meal size of juvenile Atlantic sturgeon and shortnose sturgeon. North American Journal of Aquaculture. 2003;65:99–105.
7. Zhou Z, Cui Y, Xie S, Zhu X, Lei W, Xue M, Yang Y. Effect of feeding frequency on growth, feed utilization, and size variation of juvenile gibel carp (*Carassius auratus gibelio*). J Appl Ichthyology. 2003;19:244–9.
8. Przybyl A, Mazurkiewicz J. Nutritive value of cereals in feeds for common carp (*Cyprinus carpio* L.). Czech Journal of Animal Science. 2004;49:307–14.
9. Murthy HS, Naik ATR. Effects of dietary protein and lipid levels on growth, survival and food conversion of Indian major carp (*Catla catla*). Israeli Journal of Aquaculture – Bamidgeh. 2000;52(3):70–6.
10. Moza U, De Silva SS, Mitchell BM. Effect of sub-lethal concentrations of cadmium on food intake, growth and digestibility in the goldfish, *Carassius auratus* L. J Environ Biol. 1995;16:253–64.
11. Ali MZ, Hossain MA, Mazid MA. Effect of mixed feeding schedules with varying dietary protein levels on the growth of sutchi catfish, *Pangasius hypophthalmus* (Sauvage) with silver carp, *Hypophthalmichthys molitrix* (Valenciennes) in ponds. Aquacult Res. 2005;36:627–34.
12. Duston J, Astatkie T, MacIssac PF. Effect of body size on growth and food conversion of juvenile striped bass reared at 16–28 °C in freshwater and seawater. Aquaculture. 2004;234:589–600.
13. Li MH, Manning BB, Oberle DE, Robinson EH. Effects of maintenance feeding regimens on weight gain, feed efficiency, and body condition of pond-raised channel catfish. North American Journal of Aquaculture. 2005;67:129–32.