The Influence of Feeding Frequency on Growth and Body Condition of the Common Goldfish (Carassius auratus)\textsuperscript{1,2}

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EXPANDED ABSTRACT

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)\textsuperscript{(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\textsuperscript{(2)}. Additional research on commercially cultured fish species such as the Black Rockfish (Sebastes schlegelii) 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\textsuperscript{(3)}. In addition, juvenile Atlantic Halibut (Hippoglossus hippoglossus) displayed improved growth rates when fed to satiation 5 times/d, compared with 1/d\textsuperscript{(4)}, and African Catfish (Clarias gariepinus) exhibited greater growth rates when fed to satiation twice compared with 3 times/d\textsuperscript{(5)}. In one study where a set amount of food was offered, Giberson and Litvak\textsuperscript{(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 feed 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.\textsuperscript{(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.
TABLE 1

Proximate nutrient analysis for Goldfish flake food

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Goldfish flake food, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>3.40</td>
</tr>
<tr>
<td>Protein</td>
<td>25.60</td>
</tr>
<tr>
<td>Fat</td>
<td>11.50</td>
</tr>
<tr>
<td>Ash</td>
<td>13.10</td>
</tr>
<tr>
<td>Nitrogen-free extract</td>
<td>36.40</td>
</tr>
<tr>
<td>Fiber</td>
<td>6.00</td>
</tr>
</tbody>
</table>

1 Aquarian Goldfish flakes.

MATERIALS AND METHODS

Husbandry

Experimental trials were conducted at the WALTHAM Aquarium Centre, 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 (meal times were equally spaced throughout the day from 0900 to 1500). To maintain water quality parameters within safe limits (NH₃ and NO₂ not detectable, NO₃ 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:

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

where \(\ln\) is the natural log.

\[
\text{Feed conversion ratio (FCR)} = \frac{\text{Feed intake (g)}}{\text{Body weight gain (g)}}
\]

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

<table>
<thead>
<tr>
<th>Feeding frequency/d</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGR, %</td>
<td>0.443 ± 0.009ab</td>
<td>0.472 ± 0.020ab</td>
<td>0.499 ± 0.025ab</td>
<td>0.453 ± 0.045ab</td>
</tr>
<tr>
<td>FCR</td>
<td>2.83 ± 0.066a</td>
<td>2.65 ± 0.115b</td>
<td>2.49 ± 0.022a</td>
<td>2.75 ± 0.29ab</td>
</tr>
<tr>
<td>Growth per fish, %</td>
<td>21.95 ± 0.388a</td>
<td>23.22 ± 0.867ab</td>
<td>24.39 ± 1.066b</td>
<td>22.41 ± 1.97ab</td>
</tr>
<tr>
<td>Length gain/fish, mm</td>
<td>9.17 ± 0.558a</td>
<td>9.75 ± 1.584a</td>
<td>10.64 ± 1.58a</td>
<td>9.79 ± 1.24a</td>
</tr>
<tr>
<td>Depth gain/fish, mm</td>
<td>5.17 ± 0.495a</td>
<td>6.07 ± 0.065a</td>
<td>6.53 ± 1.16a</td>
<td>5.63 ± 0.25a</td>
</tr>
<tr>
<td>Depth:length ratio</td>
<td>0.41 ± 0.023a</td>
<td>0.40 ± 0.011b</td>
<td>0.41 ± 0.033a</td>
<td>0.41 ± 0.02a</td>
</tr>
<tr>
<td>Increase in depth:length ratio (compared with wk 0)</td>
<td>0.016 ± 0.004a</td>
<td>0.014 ± 0.002a</td>
<td>0.015 ± 0.005a</td>
<td>0.008 ± 0.004a</td>
</tr>
</tbody>
</table>

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.
**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 yr 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.

**LITERATURE CITED**