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ISSN 0792 - 156X

PUBLISHER:
Israeli Journal of Aquaculture - BAMIGDEH -
Kibbutz Ein Hamifratz, Mobile Post 25210,
ISRAEL
Phone: + 972 52 3965809
http://siamb.org.il

EFFECT OF FEEDING FREQUENCY ON CONSUMPTION, GROWTH, AND EFFICIENCY IN JUVENILE TILAPIA *(OREOCHROMIS NILOTICUS)*

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(Received 15.6.04, Accepted 19.7.04)

Key words: consumption, feed efficiency, feeding frequency, tilapia

Abstract

Triplicate groups of juvenile *Oreochromis niloticus* (34.4 g) were fed a commercial diet once, twice, three, or five times a day for 29 days. Consumption, growth, and feed utilization were evaluated. No significant differences in growth, feed efficiency, or protein utilization were detected among the fish fed two, three, or five times daily, but all were significantly better than in fish fed only once. Fish fed three meals had significantly higher gross energy and lipid and lower crude protein contents than fish in the other treatments ($p<0.05$). Energy retention in fish fed three times daily (84.7%) was significantly higher than in fish fed five times (49.4%). Feeding juvenile tilapia nutrient dense pelleted feeds obviates the need for frequent feedings.

Introduction

Feed and labor are the two highest variable costs in fish culture operations. Both can be reduced through feeding management. The traditional management strategy for maximizing growth is by maximizing feeding. However, wasted feed can account for 5-30% of the feed offered and up to 50% of the total solid waste produced (Warrer-Hansen, 1982; Cho et al., 1991). The result is decreased efficiency, degraded water quality, and increased operating expenses. Good feeding management, including appropriate frequency, can reduce overfeeding and maximize efficiency.

Based on feeding behavior, physiology, and gastrointestinal morphology of wild fish, it has been reported that Nile tilapia *(Oreochromis*

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niloticus) require frequent meals (Moriarty, 1973; Jauncey and Ross, 1982). Relative to farm raised fish, wild tilapia exhibit greater voluntary activity associated with seeking food (Gerking, 1994). It was recently demonstrated that appetite in *O. niloticus* returns four hours after satiation feeding with a pelleted diet (Riche et al., 2004). The higher quality, consistency, and availability of pelleted feeds may reduce the need for frequent feedings.

In intensive systems, frequent feedings may not be economic due to increased labor costs. The objective of this study was to examine the effects of feeding frequency on *O. niloticus* fingerlings fed to satiation by evaluating consumption, growth, and feed efficiency.

Materials and Methods

A mixed sex population of *O. niloticus* was obtained from Illinois State University, Normal, Illinois. Fish were held in a flow-through system with well water heated to 25±1.0°C for four weeks and fed a commercial trout diet (Purina Mills, St. Louis, Missouri) at 2% of their body weight per day, divided into two equal feedings.

During the experiment, four feeding frequencies were evaluated with three replicates per treatment. Five fish were stocked into each of twelve 40-l tanks with flow-through well water heated to 27°C at a nominal flow rate of 2 l/min and a 16:8 light:dark cycle. Five fish were randomly selected at stocking for analysis of proximate composition and gross energy. Analyses were performed in triplicate. Mean fish weight at stocking was 34.4±5.4 g. Prior to the start of the experiment, the fish were allowed a one-week acclimation period during which they were fed 2% of their body weight, divided into two equal meals.

Treatments were once (08:00), twice (08:00, 17:00), three times (08:00, 12:00, 17:00), and five times (08:00, 10:00, 12:00, 15:00, 17:00) per day. The experimental period lasted 29 days. Fish were fed to apparent satiation at each feeding. Satiation was defined as when one pellet remained uneaten for 1 min. The commercial diet contained 46% crude protein and 18.0 kJ/g gross energy by analysis. Total consumption was recorded for each meal, and protein and energy intake were calculated. Fish were fed six days a week and weighed on the seventh. Temperature (26.1-26.8°C) and dissolved oxygen (5.22-11.93 mg/l; mean = 7.94 mg/l) were monitored at each meal. Total ammonia, nitrite, nitrate, and pH were measured three times a week and were within acceptable limits (Chervinski, 1982; Ridha and Cruz, 2001).

At the end of the experiment, fish were starved for 24 hours, weighed collectively, and then euthanized in 500 mg/l tricainemethane sulfonate (MS-222). Whole fish were frozen at -20°C until analyzed for gross energy and proximate composition.

Frozen whole fish were passed through a meat grinder, pulverized with a mortar and pestle, dried at 105°C for 24 h, and ground to pass through an 850 µm screen. A 2.5 g sub-sample was taken from each fish in an experimental tank and pooled. Pooled samples were blended by hand until homogenous, but not less than 1 min. Blended samples were used for proximate analyses which were performed in triplicate. Feed and whole body nitrogen was determined by the Kjeldahl method. Crude protein was calculated as N x 6.25. Gross energy was determined by bomb calorimetry (Parr Instruments, Moline, Illinois). Crude lipid was determined gravimetrically following diethyl ether extraction. Ash was determined by combustion at 550°C. Analyses were performed following standard methods (AOAC, 1990).

Evaluated parameters included feed efficiency, protein efficiency ratio, energy retention, specific growth rate, and apparent net protein utilization, calculated according to Jauncey and Ross (1982).

Data were analyzed as a one-way ANOVA using the general linear method (SAS, 1979). Means were separated using Duncan's multiple range test. Cumulative feed consumed was analyzed by ANOVA using the regression procedure of SAS, and the slopes were tested by *t* tests. Mean daily intake (% body weight/day) was calculated and mean daily consumption partitioned into constituent meals. To account for differential growth, mean daily intake and partitioned daily intake were analyzed by ANCOVA with the weight of the fish as a covariate (Cody and Smith, 1997). Significance was reported at $p<0.05$ unless otherwise indicated.

Results

Mean weight gains were 9±5.4%, 49±1.3%, 60±4.9%, and 36±8.5% for fish fed one, two, three, and five meals daily, respectively. The mean weight increase in fish fed one meal was significantly lower than the others. No mortalities were observed during the study.

The cumulative feed consumed increased linearly in all treatments (Fig. 1). Slope ratio analysis indicated that fish receiving one meal daily consumed significantly less feed than those receiving three or five meals daily. No other differences were detected. Mean daily intake is shown in Fig. 2. According to ANCOVA, differences were independent of differential growth. Fish receiving one meal consumed significantly more feed at 08:00 than fish receiving multiple meals (Fig. 3). Fish receiving two meals consumed significantly more at 08:00 than fish receiving five meals. Fish consumed significantly less feed as the interval between meals decreased. Fish receiving three meals daily consumed significantly more in the third meal than fish receiving five meals daily.

The initial and final proximate compositions of the fish appear in Table 1. Feed efficiency parameters are summarized in Table 2.

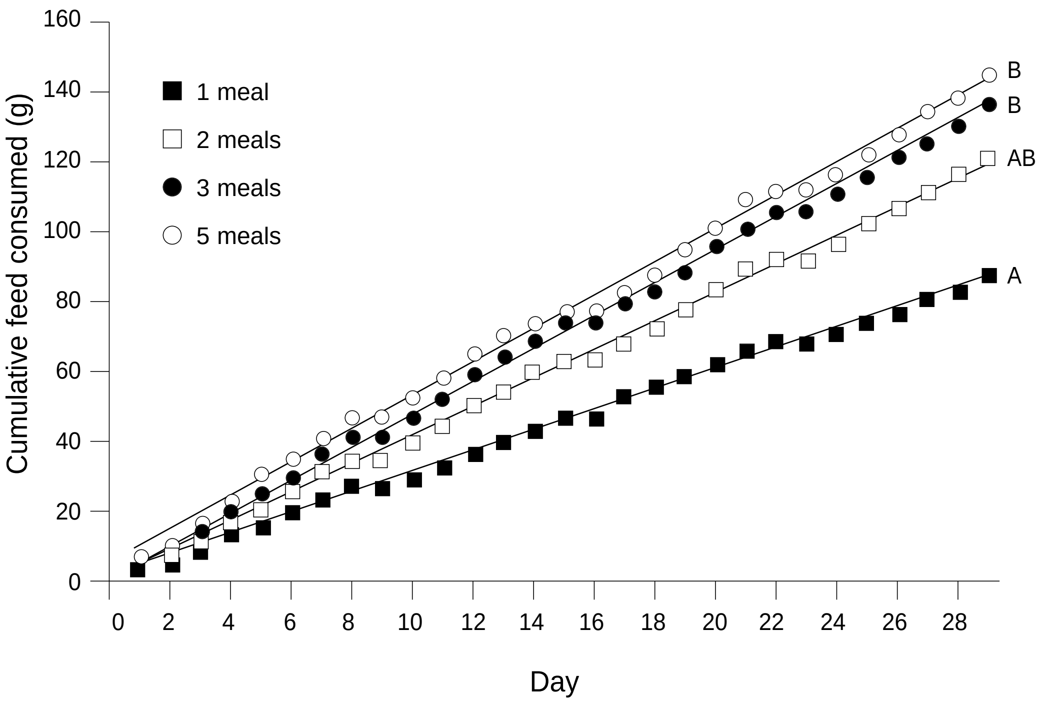

Fig. 1. Cumulative feed consumed by juvenile *Oreochromis niloticus* fed to satiation one, two, three, or five times daily. Means with a common letter do not significantly differ ($p>0.05$).

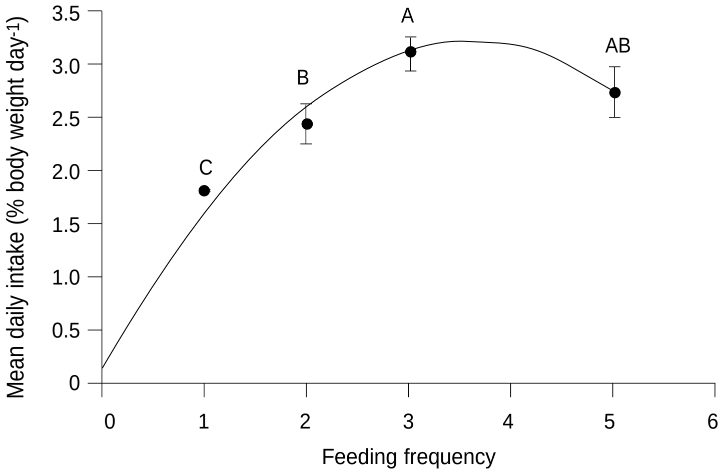

Fig. 2. Mean daily intake of juvenile *Oreochromis niloticus* fed to satiation one, two, three, or five times daily. Means with a common letter do not significantly differ (p>0.05).

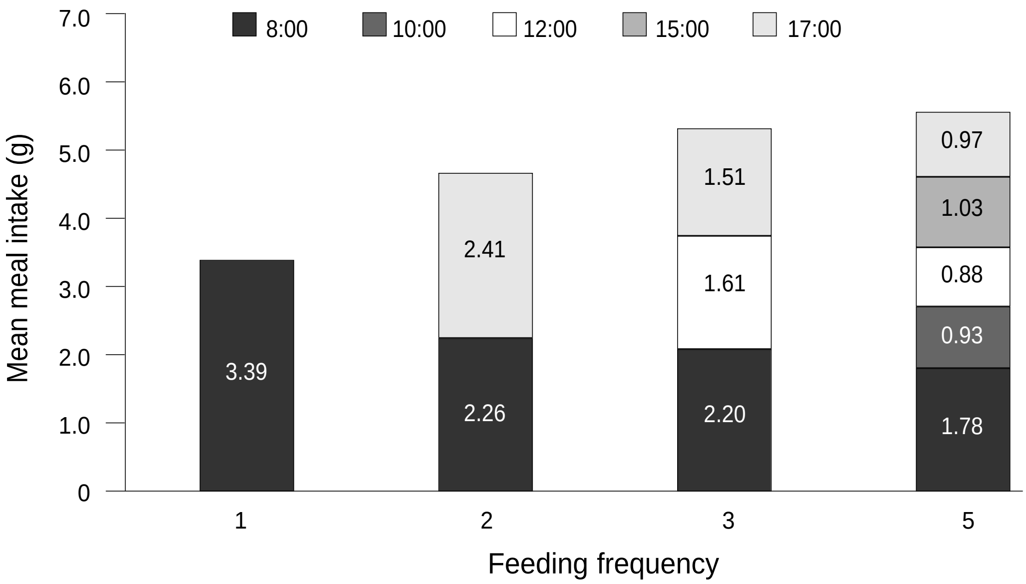

Fig. 3. Mean feed consumed per experimental unit (n = 5 fish) during each meal in juvenile *Oreochromis niloticus* fed one, two, three, or five meals to satiation for 29 days.

Table 1. Initial and final whole body composition (dry matter basis) of *Oreochromis niloticus* juveniles fed a commercial trout diet to satiation one, two, three, or five times daily.

Feeding frequency	*Gross energy (kJ/g)*	*Moisture (%)*	*Crude protein (%)*	*Lipid (%)*	*Ash (%)*
Initial	22.0 (0.09)	73.8 (0.01)	57.8 (0.24)	8.6 (0.09)	18.4 (0.65)
Final					
1	20.4 (0.02)^{c}	72.0 (0.40)^{a}	61.2 (0.66)^{a}	7.3 (0.20)^{c}	18.8 (0.26)^{a}
2	21.5 (0.25)^{ab}	71.8 (0.52)^{a}	60.6 (0.51)^{ab}	8.2 (0.26)^{b}	16.5 (0.61)^{ab}
3	22.3 (0.37)^{a}	70.6 (0.61)^{a}	58.7 (0.56)^{c}	9.1 (0.29)^{a}	15.1 (1.34)^{b}
5	21.3 (0.29)^{b}	71.8 (1.10)^{a}	59.9 (0.97)^{b}	8.1 (0.43)^{b}	16.6 (1.71)^{ab}

Values are means (SEM) of pooled samples (n = 5) from three replicates. Means in a column with a common superscript are not significantly different (p<0.05).

Table 2. Efficiency parameters for *Oreochromis niloticus* fed to satiation one, two, three, or five times daily.

Feeding frequency	*SGR (% body weight/day)*	*FE*	*PER*	*ER (%)*	*ANPU (%)*
1	0.28 (0.11)^{b}	0.16 (0.07)^{b}	0.39 (0.17)^{b}	0.04 (8.95)^{c}	16.1 (1.17)^{b}
2	1.18 (0.22)^{a}	0.52 (0.08)a	1.27 (0.19)^{a}	63.7 (10.57)^{ab}	27.7 (2.12)^{a}
3	1.62 (0.09)^{a}	0.60 (0.02)^{a}	1.23 (0.19)^{a}	84.7 (2.56)^{a}	30.0 (2.04)^{a}
5	1.02 (0.30)^{a}	0.42 (0.11)^{a}	1.01 (0.26)^{ab}	49.4 (12.61)^{b}	22.1 (3.46)^{ab}

Values are means (SEM) of pooled samples (n = 5) from three replicates. Means in a column with a common superscript are not significantly different (p<0.05).
SGR = specific growth rate = [(ln final weight – ln initial weight)/(time 2 – time 1)] x 100
FE = feed efficiency = wet weight gain/total feed intake
PER = protein efficiency ratio = wet weight gain/total protein intake
ER = energy retention = [(final weight x final energy) – (initial weight x initial energy)]/energy intake x 100
ANPU = apparent net protein utilization = [(final weight x final protein) – (initial weight x initial protein)]/protein intake x 100

Discussion

Fish that eat small particles on a continuous basis have small stomachs, as described for wild tilapia (Moriarty, 1973). However, tilapia stomachs can distend to a large size and function as a storage unit, allowing for consumption of large meals when food is available (Fish, 1951).

The mean daily intake of fish fed three and five meals were similar to suggested feeding rates for the temperature and fish size used in this experiment (Jauncey and Ross, 1982) and approached an asymptote at three daily feedings. An asymptotic response has been described for other species (Andrews and Page, 1975; Grayton and Beamish, 1977; Singh and Srivastava, 1984; Seymour, 1989; Tsevis et al., 1992).

Fish fed once a day consumed more feed during the morning feeding than fish fed more often, as observed in other species (Andrews and Page, 1975; Singh and Srivastava, 1984). Increasing the interval between feedings increased the meal intake, as demonstrated in other species (Tyler and Dunn, 1976; Liu and Liao, 1999).

Increased feeding frequencies can reduce aggressive social behavior, resulting in increased growth rate and less size variation (Grayton and Beamish, 1977; Holm et al., 1990). However, there is a limit to the frequency, beyond which increases in growth are negligible (Tsevis et al., 1992; Lee et al., 2000). In the hybrid red tilapia (*O. mossambicus* x *O. niloticus*), growth did not significantly differ with frequency beyond twice a day (Siraj et al., 1988). Growth in the current study did not statistically differ among groups fed more than once daily, similar to results observed in a variety of other species (Tyler and Dunn, 1976; Grayton and Beamish, 1977; Tsevis et al., 1992; Wang et al., 1998).

In 5 g *O. niloticus* fed one, two, four, or eight times daily, differences in growth were observed until the frequency surpassed four times daily (Kubaryk, 1980). Although the diets in Kubaryk's study were similar to those in this study, the nutrient density was diluted by adding 33.6% water before feeding. Kubaryk suggested that bulk limitations may have limited consumption in fish fed at the lower frequencies. It is conceivable that the fish were unable to obtain sufficient protein and energy to maximize growth.

Fish fed three meals daily in the current study contained the most lipid and gross energy. In contrast, no differences were detected in proximate components in rainbow trout fed at different frequencies (Bergot, 1979). However, Bergot's analysis was performed on the carcass instead of the whole body. Bergot found differences in the liver and viscera suggesting that, had the whole body been analyzed, differences may have been found.

Growth and efficiency parameters were similar to values reported for juvenile tilapia by El-Saidy and Gaber (2002) and Cho and Jo (2002) in fish fed more than once a day. The specific growth rate and feed efficiency were significantly lower in fish fed once daily, as observed in red tilapia (Siraj et al., 1988) and eels *Anguilla anguilla* (Seymour, 1989), but not in rainbow trout (Grayton and Beamish, 1977). Unlike tilapia and eels, rainbow trout were able to consume as much in one feeding as in multiple feedings.

Decreased efficiency was described in catfish (Singh and Srivastava, 1984; Pantazis and Neofitou, 2003), rainbow trout (Grayton and Beamish, 1977), and hybrid striped bass (Liu and Liao, 1999) when the optimal feeding frequency was exceeded. A plateau in efficiency was observed in red tilapia (Siraj et al., 1988) and sea bass (Tsevis et al., 1992).

The optimal ration and feeding regimen should reflect the interplay between feed efficiency and specific growth rate (Ofojekwu and Ejike, 1984). Utilizing their model, the optimal frequency in our study is between three and four daily feedings (Fig. 4). This is lower than recommended for tilapia fingerlings by NRC (1993) but higher than the two daily feedings recommended for red tilapia (Siraj et al., 1988), suggesting that there may be differences among tilapia species.

An optimum feeding regimen should be evaluated from two aspects: (a) physiology of the species and (b) production economics (Tsevis et al., 1992). The best production eco-

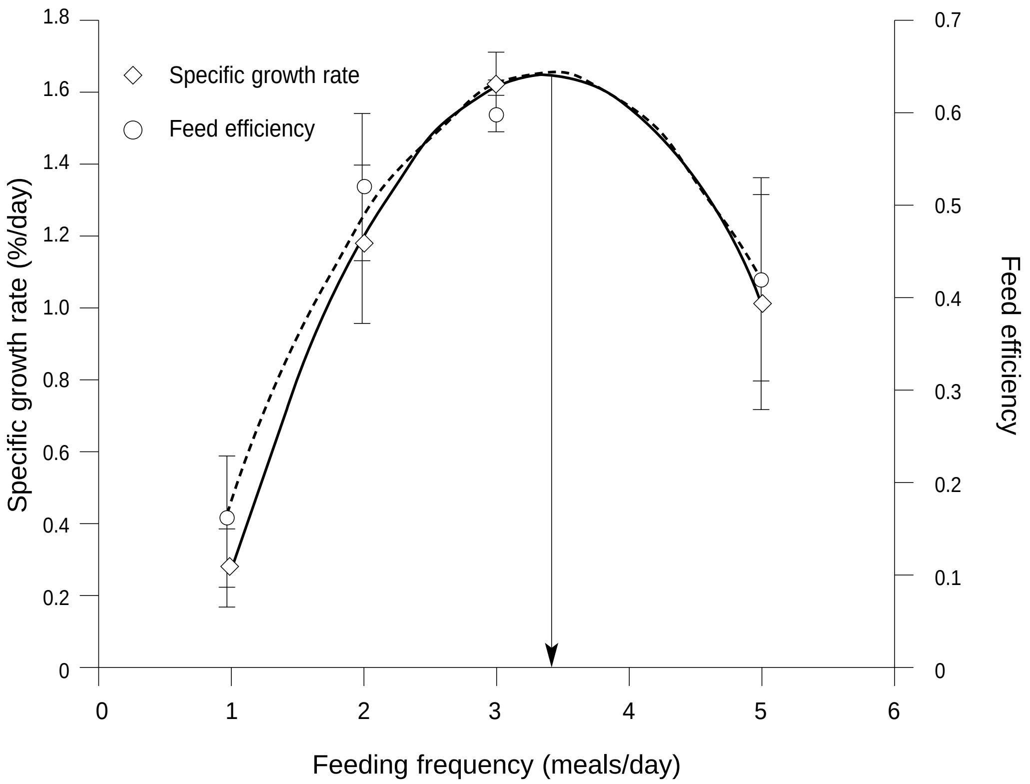

Fig. 4. Specific growth rate and feed efficiency as a function of feeding frequency in *Oreochromis niloticus* fed to satiation one, two, three, or five times daily. Specific growth rate = $-0.241x^2 + 1.63x - 1.15$ ($r^2 = 0.999$; vertex = 3.4); feed efficiency = $-0.083x^2 + 0.56x - 0.30$ ($r^2 = 0.979$; vertex = 3.4).

nomics would suggest two or three daily feedings.

Energy retention was significantly lower when meals were fed at less than 4-5 h intervals during the day. This time period corresponds to the return of appetite in *O. niloticus* (Riche et al., 2004). The interval between feedings may be more important than the total number of daily feedings, as demonstrated in hybrid striped bass (Liu and Liao, 1999). Therefore, we conclude that feeding nutrient dense diets to satiation obviates the need for frequent feedings in juvenile *O. niloticus*.

Acknowledgements

Partial funding for this project was provided by the Michigan Soybean Promotion Committee. Additional support was provided by the North Central Regional Aquaculture Center under grant 96-38500-2631 from the U.S. Department of Agriculture, and by the Michigan State University Agricultural Experiment Station. The U.S. Government and the North Central Regional Aquaculture Center are authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notations appearing hereon.

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