Growth Response, Survival and Profitability of Nile Tilapia (Oreochromis niloticus) Fed at Different Feeding Frequencies in Fertilized Earthen Ponds

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Abstract: ***Nile tilapia (Oreochromis niloticus) fingerlings were reared in earthen ponds at three different feeding frequencies; twice daily, twice after 1 day, and twice after 2 days for a period of 7 months. Three hundred and seventy five fish were stocked into each of the nine, 150 m^2 ponds with three replicates for each treatment. The fish were fed with a commercial diet (26% crude protein). Significantly (P < 0.05) best percentage weight gain (3479.59 ± 116.63%) and specific growth rate (SGR) (1.65 ± 0.02%) was observed in groups of fish fed daily compared to fish fed after 1 day and after 2 days which recorded SGR of 1.62 and 1.59% respectively. The lowest feed conversion ratio (1.04 ± 0.01) was observed in fish fed twice after 2 days. The highest survival (83.24%) was recorded in fish fed daily and there were no significant differences among the other feeding groups (P > 0.05). Partial enterprise budget analysis indicated that feeding O. niloticus twice after 2 days in fertilized ponds is significantly profitable (P < 0.05) than feeding twice daily and after 1 day. Thus it is possible to rear O. niloticus in fertilized earthen ponds when fish are fed twice after 2 days.***

Keywords: Growth, *O. niloticus*, feeding frequency

1. Introduction

Feed cost is the largest operating cost of fish farming and often constitutes between 40-60% of the total cost of production in aquaculture [1, 2]. Feed availability and high cost is one of the major challenges facing aquaculture growth in developing countries [3]. Analyses of fish farm budget shows that fish feed constitute 60-70% of total production costs of *O. niloticus* for small-scale, rural farmers [4]. Various fish feed ingredients continuously experience fluctuating prices and competition from other animal feed manufactures. This affects aquaculture feed production and consequently increases the cost of fish feeds in both intensive and semi-intensive systems [5-7]. Several studies have been conducted to reduce cost of feeds in fish production; including replacing fish meal with cheaper plant proteins [5, 8-11], mixed feeding schedules of alternating high and low dietary protein levels in the diet [12-14] and optimizing feeding frequencies [15, 16].

Nile tilapia (*Oreochromis niloticus)* is the most commonly cultured fish after carps and its culture is being practiced in most of the tropical, subtropical and temperate regions throughout the world [17]. In most developing countries the culture of *O. niloticus* is mainly in semi-intensive systems located in remote areas where culture inputs are scarce and expensive [18, 19]. In these systems, production of *O. niloticus* has been done in fertilized ponds without feeding where fish depends largely on natural pond productivity [21, 22]**,** but supplementary feeding in fertilized ponds has been documented to increase fish yields [19, 23-26].

Therefore, a feeding strategy that uses minimal amounts of feed and at the same time increasing economic returns without compromising the protein quality of the feed remains an important aspect in semi-intensive fish production [1, 14] and has the potential to lower production cost by decreasing the quantity of feed used to produce a kilogram of fish [16, 19]. It is therefore important to determine the optimal feeding frequency which will maximize the utilization of feed by *O. niloticus* and reduce feed wastage which can negatively affect water quality and profitability during the course of production. Different species of fish have been shown to have different optimum feeding frequencies; African catfish (*Clarias gariepinus*) twice a day [16], Estuarine grouper (*Epinephelus tauvina*) once after 2 days [27], Common carp (*Cyprinus carpio*) three times daily [28], Olive flounder (*Paralichthys olivaceus*) three times daily [15]. Limited information exists in regards to feeding frequency of *O. niloticus* reared in semi-intensive-pond based systems [19]. This study was designed to evaluate the effects of different feeding frequencies on growth performance of *O. niloticus* and to identify the feeding frequency that gives the best economic returns for *O. niloticus* culture in semi-intensive production systems.

2. Material and Methods

2.1 Experimental design

The study was conducted at the Kenya Marine and Fisheries Research Institute, National Aquaculture Research Development and Training Center (located at 0°39'S, 37°20'E and 1230 m above mean sea level). Nine earthen ponds of 150 m^2 each were used for the study. Hand sexed male *O. niloticus* fingerlings of an average initial weight of 7.09 g were obtained from the hatchery in the farm and were stocked in the experimental ponds at a stocking rate of 3 fish m^{-2}. The ponds were randomly allocated to the three treatments with three replicates per treatment. The treatments used were as follows; fish fed daily (control), fish fed after 1 day and fish fed after 2 days. The fish were fed on 26% crude protein commercial diet (Ugachick Fish Feed Ltd, Uganda) at 3% body weight. Feeding was done at 0900 hours and 1500 hours for each treatment. The experimental ponds were fertilized weekly using urea and diammonium phosphate (DAP) at the rates of 3 gm^{-2} and 2 gm^{-2} respectively to stimulate natural productivity of the pond. Daily feed ration was determined and adjusted every 30 days based on fish body weights.

2.2 Water quality monitoring

Dissolved oxygen (DO) concentrations, temperature and pH were measured weekly using multi-parameter water quality meter, model H19828 (Hanna Instruments Ltd., Chicago, IL., USA). Total Ammonia Nitrogen (TAN), Free Ammonia (NH_3-N), Total nitrogen (TN) and alkanity were measured weekly using standard laboratory water quality analysis methods by Boyd and Tucker [29].

2.3 Fish sampling

Fish were sampled monthly using a seine net. A random sample of 50 fish was collected from each pond for individual weight and length measurements. The fish were weighed by an electronic balance (readability 0.01g) (model KERN 572-33, Germany) and total length (cm) using a measuring board to the nearest 0.1cm. The fish were returned to their respective ponds after measurements. At the end of the experimental period, fish were deprived of feed for 24 hours, all the experimental ponds drained and all the fish were harvested, counted, weighed individually and the total biomass of each pond determined. Fish performances under different feeding frequencies were evaluated in terms of final total length (cm), weight (g), daily weight gain (DWG, g day^{-1}), weight gain (%), specific growth rate (SGR, % day^{-1}), survival (%) and feed conversion ratio (FCR). The following formula was used for the calculation;

SGR (%) = 100 ($\ln W_t - \ln W_0$ / t) where: - (ln = Natural logarithm, W_0 = initial weight (g), W_t = final weight (g) and t = time in days from stocking to harvesting). **(1)**

FCR = feed given (g)/body weight gain (g) . **(2)**

CF (Fultons) = 100W (g)/ L (cm) ^{3}, where W= body weight and L= total length. **(3)**

Weight gain (%) = 100(W_t - W_0)/ W_0. **(4)**

Daily weight gain (g day^{-1}) = 100(W_t - W_0)/ t. **(5)**

Survival = (number of fish harvested/number of fish stocked) ×100. **(6)**

Net fish yield = total weight of fish at harvest – total weight of fish at stocking. **(7)**

2.4 Profitability analysis

A partial enterprise budget was used to evaluate the economic performance of the fish under different feeding frequencies. Fish fed daily was taken as the baseline feeding frequency. The budgets are limited to cost and revenue items influenced by proposed changes in feeding frequency. The enterprise budget analysis was used to determine the potential changes in profit if a given feeding frequency is adopted for *O. niloticus* production.

2.5 Data analysis

All the experimental data including final length, final mean weight, survival, SGR, FCR, DWG, survival, and net returns were analyzed using analysis of variance (one-way ANOVA) to determine the significant difference among the fish fed at different feeding frequencies. Differences between means were further tested for significant differences using Post-Hoc Tukey's HSD tests. Significance level was declared at (P < 0.05). SPSS (version 17.0) for windows was used for all statistical analysis.

3. Results

Growth performance of *O. niloticus* fed at different feeding frequencies is presented in Table 1. After 214 days of feeding trial, the final mean weight of tilapia fingerlings fed daily were significantly (P < 0.05) higher (223.37 ± 2.43 g) compared to the fish fed after 1 day (210.64 ± 0.56 g), and after 2 days (197.04 ± 1.16 g). Daily weight gain was significantly highest (P < 0.05) in fish fed daily followed by fish fed after 1 day. The specific growth rate of fish fed daily (1.65 ± 0.02%) was higher compared to the other feeding frequencies, but no significant difference was observed in the SGR among the feeding frequencies (P > 0.05). The different feeding frequencies had no effect on the daily weight gain (P > 0.05) and fish fed daily recorded the highest daily weight gain (3479.59 ± 116.63%). The lowest food conversion ratio (1.04 ± 0.01) was observed in fish fed after 2 days and a significant difference (P < 0.05) was recorded in FCR in all the feeding frequencies. The condition factor of the fish ranged from 1.69 to 1.70 and was not significantly affected by the feeding frequency (P > 0.05). Fish fed daily had significantly higher (P < 0.05) mean net yield (63.44 ± 0.32 kg) compared to other treatments and there was no significant difference (P > 0.05) between the yields of fish fed after 1 day and fish fed after 2 days. Fish fed daily exhibited significantly (P < 0.05) higher survival (83.24 ± 0.24%) than the other treatments. However, no significant difference (P > 0.05) was realized in survival between the fish fed after 1 day and after 2 days.

Table1: Growth performance of *O. niloticus* fed at different feeding frequencies for a period of 7 months

Variable	*Treatments*		
	Daily	*After 1 day*	*After 2 days*
Initial length (cm fish $^{-1}$)	7.29 ± 0.10^a	7.29 ± 0.30^a	7.29 ± 0.02^a
Initial weight (g fish $^{-1}$)	7.09 ± 0.35^a	7.09 ± 0.90^a	7.09 ± 0.51^a
Final length (cm fish $^{-1}$)	23.72 ± 0.16^a	23.18 ± 0.06^{ab}	22.75 ± 0.10^b
Final weight (g fish $^{-1}$)	223.37 ± 2.43^a	210.64 ± 0.56^b	197.04 ± 1.16^c
SGR (% day $^{-1}$)	1.65 ± 0.02^a	1.62 ± 0.02^a	1.59 ± 0.02^a
Daily weight gain (g day $^{-1}$)	1.01 ± 0.01^a	0.95 ± 0.00^b	0.89 ± 0.01^c
Weight gain (%)	3479.59 ± 116.63^a	3322.64 ± 123.47^a	3092.96 ± 114.97^a
FCR	3.10 ± 0.04^a	1.54 ± 0.01^b	1.04 ± 0.01^c
Condition factor (Fulton's)	1.70 ± 0.03^a	1.70 ± 0.02^a	1.69 ± 0.02^a
Mean gross yield (Kg)	70.09 ± 0.63^a	53.70 ± 0.33^b	52.08 ± 0.09^b
Mean net yield (Kg)	63.44 ± 0.32^a	44.48 ± 0.35^b	43.77 ± 0.69^b
Survival (%)	83.24 ± 0.24^a	67.57 ± 0.23^b	68.33 ± 0.33^b

* Values are expressed as mean ± SE. Values in the same row having different superscript letters are significantly different ($P < 0.05$).

The ranges of values of the physicochemical parameters during the experimental period were as follows: pH 7.65 - 7.75; dissolved oxygen 4.44 - 4.46 mg L^{-1} and temperature 24.60 - 25.08 ºC (Table 2). Mean temperature, pH and dissolved oxygen levels, were not affected ($P > 0.05$) by the feeding frequency during the feeding frequency trial. The recorded mean values of the water quality parameters were within the acceptable ranges for tilapia growth in ponds [29].

Partial enterprise budget analyses of the different feeding frequencies are summarized in Table 3. The cost of feed used in the present study was US $ 0.86 (Ksh 75 kg $^{-1}$) of feed. The net returns decreased with increasing feeding frequency. For all the treatments, net returns above the total cost and net returns above variable cost were significantly higher ($P < 0.05$) in fish fed after 2 days compared to the fish fed daily and the ones fed after 1 day. However, none of the treatments posted negative returns on investment and break even prices above total variable costs were below the market selling price of all the fish at the three feeding frequencies tested.

Table 2: Water quality parameters of *O. niloticus* fed at different feeding frequencies for a period of 7 months

Parameter	*Treatments*		
	Daily	*After 1 day*	*After 2 days*
Dissolved oxygen (mg L $^{-1}$)	4.46 ± 0.04^a	4.45 ± 0.00^a	4.44 ± 0.01^a
Temperature (°C)	25.08 ± 0.08^a	24.60 ± 0.35^a	24.66 ± 0.24^a
pH	7.75 ± 0.07^a	7.66 ± 0.05^a	7.65 ± 0.05^a
TAN (mg L $^{-1}$)	0.16 ± 0.02^a	0.15 ± 0.02^b	0.14 ± 0.02^c
NH_3-N (mg L $^{-1}$)	0.01 ± 0.00^a	0.01 ± 0.00^a	0.00 ± 0.01^b
TN (mg L $^{-1}$)	1.64 ± 0.09^a	1.63 ± 0.07^b	1.59 ± 0.07^c
Nitrites (mg L $^{-1}$)	0.01 ± 0.00^a	0.01 ± 0.00^a	0.00 ± 0.00^b
Alkalinity (mg L $^{-1}$)	38.29 ± 0.28^a	37.04 ± 0.02^{ab}	36.40 ± 0.68^b

* Values are expressed as mean ± SE. Values in the same row having different superscript letters are significantly different ($P < 0.05$). Total Ammonia Nitrogen (TAN), Free Ammonia (NH_3-N), Total nitrogen (TN).

Table 3: Partial enterprise budget analyses of *O. niloticus* fed at different feeding frequencies for a period of 7 months

Parameters	*Unit*	*Treatments*		
		Daily	*After 1 day*	*After 2 days*
Gross revenue	US $	337.52 ± 0.31^a	258.61 ± 0.26^b	251.36 ± 0.36^c
Variable cost	US $	298.31 ± 0.23^a	177.77 ± 0.12^b	138.84 ± 0.58^c
Returns above variable cost	US $	39.14 ± 0.00^a	81.19 ± 0.00^b	112.85 ± 0.04^c
Fixed costs	US $	38.84 ± 0.00^a	38.84 ± 0.00^a	38.84 ± 0.00^a
Total costs	US $	337.54 ± 0.00^a	216.49 ± 0.01^b	177.06 ± 0.00^c
Net return above total cost	US $	0.30 ± 0.00^a	42.35 ± 0.00^b	73.97 ± 0.00^c
Yield (Kg per pond)	Kg	70.09 ± 0.63^a	53.70 ± 0.33^b	52.08 ± 0.09^b
Unit selling price	US $	4.82 ± 0.00^a	4.82 ± 0.00^a	4.82 ± 0.00^a
Breakeven price (total cost)	US $	4.82 ± 0.00^a	4.03 ± 0.00^b	3.40 ± 0.00^c
Breakeven price (variable cost)	US $	4.26 ± 0.00^a	3.31 ± 0.00^b	2.65 ± 0.00^c
Breakeven yield (total cost)	Kg	70.03 ± 0.00^a	44.92 ± 0.00^b	36.74 ± 0.00^c

* Values are expressed as mean ± SE. Values in the same row having different superscript letters are significantly different ($P < 0.05$).

4. Discussion

The present study has indicated that growth performance of *O. niloticus* can be significantly influenced by feeding frequencies that strongly affect feed ingestion and assimilation. The highest growth performance (final mean weight, weight gain and specific growth rate) were recorded in fish fed twice daily followed by fish fed twice after 1 day. It is reported that fish that are fed less frequently can adapt to such conditions by consuming larger amounts of feed during each meal and such a schedule if applied for a longer period, can lead to increased gut capacity and to hyperphagia [30]. The good growth performance reported for fish fed twice daily could be as a result of feeding large amounts of feed which was efficiently converted to flesh indicating that optimum feeding frequency for maximum growth of fish depends upon amount of food provided [31, 32]. Similar growth rate and food efficiency has been reported for African catfish (*C. gariepinus*), fed twice per day [16]. The final weight and weight gain of the fish fed after 1 day and after 2 days was significantly lower that the fish fed daily. This contradicts the findings of Chua and Teng [27], who reported that feeding Estuarine grouper (*Epinephelus tauvina*), after 1 day resulted in optimal growth compared to *E.tauvina* fed every 3, 4, or 5 days which had reduced weight gains.

The results of the present study concurs with those of Davies *et al*. [33] who reported that catfish (*Heterobranchus longifilis*) fed twice per day had higher percentage weight gain, SGR and average final weight compared to fish fed once per day, once on alternate day and twice on alternate day. The increase in growth response for fish fed daily could also be attributed to the fact that frequent feed intake increases amount of nutrients available to the fish as reported by Marimuthu *et al*. [16]. However, Juell *et al*. [34] reported that feeding frequency does not affect the growth of the Atlantic salmon (*Salmo salar*) as long as the fish is fed to satiation and in fact frequent feeding has been reported to reduce growth in rainbow trout fed by an automated feeder since fish exhibit an increase in activity during feeding which is a stress factor that leads to expenditure of energy thus reducing fish growth [35].

Low feed conversion ratio (FCR) values were recorded in *O. niloticus* fed after 2 days followed by fish fed after 1 day and fish fed daily respectively. This shows that the efficiency of feed utilization and feed conversion was influenced by the feeding frequency and indicates that *O. niloticus* fed more frequently utilize the feed less efficiently than fish fed less frequently. It could also be obvious that frequent feeding leads to feed losses compared to less frequent feeding [20]. It has been observed that when fish are temporarily deprived of feed, they grow more rapidly when feeding is resumed and they catch up with fish that were not deprived of feed through compensatory growth, demonstrated by an increase in both growth rate and efficiency of feed utilization when the fish resume feeding [36]. Marimuthu *et al*. [16] also observed no significant differences in FCR of *C. gariepinus* fed once per day, twice per day and twice after 1 day and indicated that food consumption is the main growth limiting factor in fish farming and is in agreement with others studies which indicate that growth of fish is greater when the feed intake is higher [32, 37]. In the present study, feeding frequency affected the survival of *O. niloticus* with fish fed daily exhibiting significantly higher survival than fish fed after 1 day and after 2 days. This observation is similar to the findings of Marimuthu *et al*. [16] who recorded survival of more than 80% on fish fed daily.

The partial enterprise budget analysis in this present study did not take into consideration the cost of pond construction and water use costs as these were considered a constant. Positive net returns were realized for all the feeding frequencies in the study. However feeding fish after 2 days was the most profitable compared with the other feeding frequencies. The lower profits in the fish fed twice daily were as a result of the usage of large quantities of feed without commensurate growth which increased the cost of production.

5. Conclusion

The results of the present study based on the growth performance and feed utilization suggests that *O. niloticus* should be fed daily for maximum growth and better survival. However, feeding *O. niloticus* after 2 days is more profitable and *O. niloticus* farmers can reduce production costs by reducing the quantity of feed and labor costs in feeding *O. niloticus* after 2 days in fertilized earthen ponds.

6. Future Prospects

More studies should be carried out to include other feeding frequencies for supplemental feeding in order to maximize compensatory growth of *O. niloticus* and to lower cost of feeding fish in semi-intensive systems.

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