# Influence of Daily Feed Allowance on Pond Water and Effluent Quality

*Eleventh Work Plan, Water Quality and Availability Research 4 (11WQAR4)*
*Final Report*

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## Abstract

A feeding trial was conducted towards optimization of feeding regimes for semi-intensive culture of Mozambique tilapia in earthen ponds in order to improve pond and effluent water quality, and reduce feeding cost. Fifty Mozambique tilapia fingerlings with an average weight of 17.8 ± 1.6 g were stocked in each of the 40 hapas. The experimental layout consisted of five feeding treatments of 20, 40, 60, 80, and 100% of apparent satiation with 8 replicates each. Fish were fed three times a day for 111 days. Specific growth rate (SGR) and feed conversion ratio (FCR) were used to measure the response to the various feeding regimes. Results were analyzed at three separate periods: at days 27, 55, and 111. At 27 and 55 days no significant improvement in FCR and SGR were observed at feeding levels above levels 60 and 80%, respectively. At 111 days, no significant difference in SGR was observed at feeding levels of 60% and above. This is an indication that 60% is the optimum feeding management regime. Natural food intakes calculated based on SGR and FCR were 0.34, 0.29, and 0.20% of body weight per day at 27, 55, and 111 days, respectively. Results from water quality analyses sampled fortnightly indicated no significant difference between the ponds. Analyses for correlations between production performance parameters and water quality parameters provided a regression equation to predict the natural food intake at specific water quality parameters, viz. Natural food intake (expressed as percentage of bodyweight per day) = 27.2 – 0.0962 morning measured oxygen – 0.0328 conductivity – 0.911 pH + 13.0 ammonia-nitrogen – 2.52 nitrate + 41.2 nitrite – 7.72 phosphate + 0.337 TSS (R2 = 80.9, P = 0.000). These results may provide useful data to quantify the utilization of natural pond productivity in the feeding management of Mozambique tilapia.

## Introduction

Semi-intensive tilapia culture in earthen ponds is widely applied in many countries as tilapia can efficiently utilize the plankton and detritus in pond water (Knud-Hansen, 1998). To maximize fish yield, fertilization of the pond with inorganic or organic fertilizers is necessary to enhance carbon, nitrogen, and phosphorus concentrations. Commercial feed may be used to increase production beyond that possible with natural food (Li and Yakupitiyage, 2003). The inputs of the primary nutrients nitrogen, phosphorus, and carbon should neither be too low to support good phytoplankton growth or too high to cause unnecessary algal blooms (Knud-Hansen et al., 2003). Lack of appropriate feeding regime and management of pond fertilization leads to pond water and effluent deterioration that contributes to the negative impact of aquaculture on the environment. Therefore, optimization of feed management is an important aspect of environmentally-responsible aquaculture and to integrated water use (Cornel et al., 1993). Proper management of the feeding regime, minimizes potential nutrient loading in pond culture by preventing overfeeding, and it also reduces feed costs (Lin et al., 2003; Cunningham et al., 1985).

Previous work by Lin et al. (2003) on the effect of different feeding regimes to Nile tilapia in inorganically fertilized ponds showed that there was no significant difference in fish yield (P > 0.05) between fish receiving the three daily feed rations at 50, 75, and 100% satiation level while the nutrient loading was escalated with the increase in the feeding levels. This finding leads to the conclusion that in inorganically fertilized ponds the supplementation of feed above 50% satiation level will result in a waste of feed, deterioration of pond water quality, and increasing production cost.

The purpose of this study was to determine optimum feeding regimes for Mozambique tilapia in hapas installed in earthen ponds in order to improve pond water and effluent quality as well as to reduce feeding cost.

## METHODS AND MATERIALS

Forty experimental hapas, each with a volume of 1 $m^3$, were installed in four earthen ponds located at the Elsenburg Research Centre, University of Stellenbosch in South Africa. Each pond housed 10 hapas. The earthen ponds were equally fertilized for 4 weeks before stocking fish to ensure adequate natural pond productivity. The fertilization regime was 400 g urea and 200 g superphosphate/pond/week. Fifty Mozambique tilapia fingerlings with average weight of 17.8 ± 1.6 g were stocked in each of 40 hapas. The fish were fed a commercial tilapia starter diet (AquaNutro (Pty) Ltd., Malmesbury) three times a day for the duration of the trial (111 days). The experimental treatments consisted of five different feeding regimes (20, 40, 60, 80, and 100% of the satiation level) with eight replications per treatment. Fish in two hapas in each ponds were randomly assigned to each of the feeding levels. The daily satiation level was calculated from the feeding management software package supplied by the feed company.

Water samples were taken from each pond 2 weeks before stocking tilapia fingerlings and on a fortnightly frequency for the duration of the trial. Water quality variables measured were: temperature, oxygen, turbidity, conductivity, total dissolved solids, salinity, pH, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, phosphate, and total suspended solids. Daily readings of temperature and oxygen were recorded in the morning (0900 h) and in the afternoon (1500 h). Production performance variables considered were: specific growth rate (SGR), feed intake (FI), and feed conversion ratio (FCR) at 27, 55, and 111 days. The values of the production parameters for FCR, SGR, and FI were calculated according to Cunningham et al. (1985), Keshevanath and Rdnuka (1998), and Sanchez et al. (2001), respectively, using the following equations:

FI (% body weight/day) = [total feed fed (g)/day/initial body weight (g)] × 100
FCR = total feed fed (g)/total weight gain of fish (g)
SGR = (lnW2-lnW1)/days × 100, where W2 is the final body weight at the end of each sampling period (days 27, 55 and 111) and W1 is the initial body weight

Data were analyzed using one-way ANOVA, and Tukey's pairwise comparison test was used to determine any significant difference between treatment means for the production parameters and water quality variables at 27, 55, and 111 days. Differences were considered significant at P ≤ 0.05. Analyses for correlations between production performance variables and water quality variables were furthered with multiple regression analyses to predict the natural food intake for specific water quality conditions.

## RESULTS

A large amount of data was collected because the study was separated into three growth periods. Thus, for the sake of brevity, only the average data for the entire 111-day period will be presented in Tables. The analyses of the water quality variables across the four ponds (Tables 1 and 2) indicated no significant differences, except for the D.O. concentrations. This was to be expected given that biomass and organic loading were equally spread across the ponds. Water quality variables remained within acceptable ranges until the end of the study. The correlations among the different water quality variables are provided in a matrix (Table 3) and no explanation is necessary.

At 27 and 55 days, no significant improvement in either final body weight or SGR were observed at feeding levels of 60 and 80% satiation. Feed conversion ratio increased with increasing feeding levels. No significant difference (P > 0.05) was observed among survival of fish receiving various feeding levels at days 27, 55, and 111.

For the first period (27 days), the average final weight was increased steadily from the lowest to the highest feeding levels. Significant differences (P < 0.05) were noted between 20% and at 60% and above as well as between 40% and 80% and above. For the second period, differences were between all levels were significant (P < 0.05) except between the 60 and 80% levels.

At 111 days, no significant difference (P > 0.05) in the final body weight and SGR was observed at feeding levels of 60% and above, indicating that this is the optimum feeding management regime when water temperature falls towards the end of the trial (Table 4). Prediction of daily natural feed intake from linear regression equation of growth and FCR showed 0.34, 0.29, and 0.20% (commercial feed equivalent) of body weight per day for the periods 0-27, 0-55, and 0-111 days, respectively (Table 5).

The linear regression model indicated that the variances caused by the effect of natural feed intake on FCR and growth were 69.7% and 77.4%, respectively, for period 1 (0-27 days); 78.1% and 64.4% for period 2 (0-55 days); and 93.5% and 35.2% for period 3 (0-111 days). Natural food intake (expressed as percentage of body weight per day) = 27.2 – 0.0962 morning measured oxygen – 0.0328 conductivity – 0.911 pH + 13.0 ammonia-nitrogen – 2.52 nitrate + 41.2 nitrite – 7.72 phosphate + 0.337 TSS [$R2$ = 80.9, $P = 0.000$].

## Discussion

On initiation of the trial, the surface area of pond 1 was covered approximately 20% with algal sludge. Pond 4 was completely covered with duckweed. Both duckweed and algal sludge were periodically removed. All four ponds were leaking, with pond 4 being the worst. After four weeks, all four ponds were leaking approximately at the same rate. The dams were topped-up with about 30 cm of water, twice a week for the remainder of the trial.

Except for dissolved oxygen, no differences ($P > 0.05$) in concentrations of water quality variables occurred across the four ponds. This was to be expected given that the biomass and organic loading was equally spread across the ponds. The ammonia-nitrogen concentration showed a trend to increase over time only for pond 1. Dissolved oxygen fluctuated significantly between the four ponds. It was lower and more pronounced for the morning measurement. Given the fact that the organic loading was uniform across the ponds, this fluctuation may be explained by the varying plant and algae cover between ponds, which influenced total pond respiration.

Interpretation of the results in all the three trial periods suggests that the optimum feeding regime for Mozambique tilapia in fertilized earthen ponds is generally below 80% satiation level. During the first period (0-27 days), a significant increase ($P < 0.05$) in SGR was observed as the level of feed intake increased for each level up to the 80% of satiation after which no significant difference ($P > 0.05$) was observed between the 80% and the 100%. Feed conversion ratio (FCR) increased with increasing feeding levels, which was lowest for the 20% ($0.80 \pm 0.26$) and highest ($1.56 \pm 0.45$) at the 100% satiation level. However, differences between the 40% and 60% as well as between the 60% and 80% were not significant, indicating the optimum FCR is between the 60 and 80% satiation level. This feeding level also provided the optimum SGR. The average final weight also was increasing steadily from the lower level to the highest with differences being significant between the 20% and all levels above the 60%, as well as between the 40% and levels above 80%. The optimum average growth rate coincided with the optimum SGR at 80% feeding level. This may lead to the prediction that supplementary feeding at levels above 80% satiation is uneconomical as a result of unused feed and subsequently would lead to the deterioration of pond water quality. Similarly, at the second period (55 days), no significant differences ($P > 0.05$) in either FCR or SGR were observed above the 80% satiation level.

During the third period (day 111), differences in average final weight, FCR and SGR were not significant at and above the 60% satiation level. The optimal values of these production performance parameters at the 60% satiation feeding level indicates that highest yield is favored at daily ration of 60% satiation. In agreement with the current study, Lin & Yi (2003) found that Nile tilapia, *Oreochromis niloticus*, cultured in inorganically fertilized ponds did not show significant difference ($P > 0.05$) in yield when the fish received daily feed rations at 50, 75, and 100% satiation intake. They also observed that the nutrient loading increased with increasing feeding levels. Therefore, the optimal daily supplementary feeding in fertilized ponds requires only 50% satiation level, as Nile tilapia are capable of compensating their diet with abundant plankton and detritus if the ponds are fertilized optimally. These remarks would apply to Mozambique tilapia, as the feeding strategy of both species is basically similar. Tilapia feeding is affected by water temperature (Lovell, 1988). Therefore, changes in temperatures over time should be considered when devising a feeding management program. At 111 days, feeding levels above the 60% satiation do not result in significant difference of the production performance variables which may be attributed to the fall in water temperature towards the end of the trial. Because the appetite of the fish decreases with a fall in temperature, daily feeding levels above the 60% satiation will result in feed wastage and deterioration of pond water and effluent quality.

Natural feed intake (equivalent to commercial feed) for the three periods calculated based on SGR and FCR was found to be 0.340, 0.289, and 0.169% of body weight per day for period 1 (day 0- 27), 2 (day 0-55), and 3 (day 0-111), respectively (Table 5). This decreasing trend may be explained by the increase in fish biomass and decrease in phosphate and nitrite over time, with which natural feed intake show good correlation (Table 6).

Stomach analyses of tilapia grown in intensively fed pond cultures showed that natural food comprised 50% of stomach content, indicating the natural pond productivity contributes substantial amounts of nutrients for the growth of these fish. However, when studying natural food intake, the feeding habit of fish at different developmental stages and the amount of fertilization needed to favor optimum algal growth should be taken into consideration. Tilapia are more pronounced plankton feeders during the early stages of development than during adulthood. Results of other authors corroborate the findings of the present study. Diana et al. (1996) suggested that in semi-intensive culture of Nile tilapia, the most efficient feeding management was to grow to 100-150 g with fertilization alone and thereafter supplementing with commercial feed at 50% satiation level. Investigators in Israel found that natural foods contributed 50 to 70% of the growth of tilapia (Lovell, 1988) polycultured with carp in ponds fertilized with manures and receiving supplemental feeds.

## CONCLUSIONS

The results of the current study indicated that during the first 27 days and first 55 days, the optimum feeding regime was between 60 and 80% satiation level. The optimum feeding level during the entire study period (111 days) did not exceed the 60% satiation. These results suggest that the daily supplementary feeding level for juvenile Mozambique tilapia should not exceed 60% satiation, and especially when water temperature falls below the level optimum for efficient feed intake. The regression equation derived from the regression analysis of daily natural food intake in correlation with the water quality parameters may provide a base for further investigation.

The results should be meaningful for the quantification of natural pond productivity and planning of feeding management for Mozambique tilapia in semi-intensive culture systems. These findings can also contribute to the economical use of manufactured feed and promote environmentally friendly aquaculture by decreasing the organic loading caused by excess feed. Further studies are recommended at various fertilization levels to determine the optimum input of fertilizers that will favor optimum algal growth without affecting the environment.

## ANTICIPATED BENEFITS

The primary target groups to benefit from the results of this research project are the peri-urban and rural communities. These areas are known to have limited or no access to aquaculture inputs. The prominent freshwater aquaculture species in South Africa is rainbow trout (*Oncorhynchus mykiss*). The water quality parameters are more stringent for trout than what are required for tilapia (*Oreochromis mossambicus*) farming. With marginal-quality water resources for trout in these areas, many of the water resources can be successfully used for tilapia farming. Further application will be achieved in the wider commercial aquaculture sector in South Africa.

**Direct Benefits**

- The experiment achieved optimization of feeding management through less feed wastage.

- The importance of natural productivity in ponds to which feeds and fertilizers are applied has been quantified. This information will provide a feeding regime to the farmers. The farmers would be able to reach optimal natural productivity with minimal artificial feed addition and still be able to achieve optimal growth rate and feed conversion ratios.

- Analyses for correlations between production performance and water quality parameters provided a regression equation to predict the natural food intake at specific water quality parameters. This information is beneficial in managing feeding and water quality together as a performance functional unit.

- The results indicated that 60% of apparent satiation level is the optimum feeding regime. This benchmark is important to farmers for efficient feeding management.

**Indirect Benefits**

- Participation in the Aquaculture CRSP program and regular communication has provided us with network and exchange opportunities. An exchange of literature has already taken place.

- The project has highlighted South Africa's aquaculture challenges and will assist in the future strategy and conceptualization of aquaculture development.

- Project collaborators in South Africa have increased their capacity to successfully conduct short-term research projects.

- A platform has been created for follow-up research projects.

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Table 1. Water quality parameter changes during

| Parameter | Period | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Temperature AM | 22.6 ± 2.1[a] | 23.6 ± 1.4[b] | 21.5 ± 2.9[c] |
| Temperature PM | 26.4 ± 1.7[a] | 28.1 ± 1.7[b] | 25.3 ± 3.5[c] |
| Temperature AVG | 24.5 ± 1.9[a] | 26.0 ± 1.3[b] | 23.4 ± 3.0[c] |
| Oxygen AM | 6.4 ± 1.9[a] | 5.3 ± 1.7[b] | 6.1 ± 1.6[c] |
| Oxygen PM | 7.3 ± 1.8[a] | 6.7 ± 1.7[b] | 7.2 ± 1.7[c] |
| Oxygen AVG | 6.8 ± 1.6[a] | 6.0 ± 1.6[b] | 6.6 ± 1.4[c] |

Values with different superscripts in the same row show significant differences ($P < 0.05$).

Table 2. The effect of different *ad libitum* feed intake levels on water quality parameters of Mozambique tilapia after 111 days (period 0-4)[1] across the four ponds.

| Parameter | Ponds | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Conductivity | 772 ± 95 | 866 ± 91 | 784 ± 172 | 793 ± 48 |
| Salinity | 0.3 ± 0.0 | 0.4 ± 0.0 | 0.4 ± 0.0 | 0.4 ± 0.0 |
| TDS | 373 ± 46 | 408 ± 45 | 385 ± 86 | 362 ± 39 |
| pH | 8.28 ± 0.50 | 8.37 ± 0.39 | 8.58 ± 0.33 | 8.15 ± 0.49 |
| Ammonia-Nitrogen | 0.48 ± 0.06 | 0.59 ± 0.03 | 0.49 ± 0.08 | 0.47 ± 0.04 |
| Nitrate | 0.154 ± 0.084 | 0.090 ± 0.051 | 0.066 ± 0.025 | 0.066 ± 0.025 |
| Nitrite-Nitrogen | 0.001 ± 0.001 | 0.001 ± 0.001 | 0.004 ± 0.004 | 0.002 ± 0.001 |
| Phosphate | 0.31 ± 0.15 | 0.27 ± 0.06 | 0.46 ± 0.18 | 0.34 ± 0.14 |
| TSS | 10.2± 2.3 | 11.5 ± 3.0 | 10.2 ± 2.0 | 11.5 ± 4.1 |
| Temperature AM | 21.5 ± 2.9 | 21.4 ± 2.4 | 21.5 ± 3.0 | 21.6 ± 3.2 |
| Temperature PM | 25.3 ± 3.3 | 25.9 ± 3.2 | 25.0 ± 3.5 | 25.1 ± 3.8 |
| Temperature AVG | 23.4 ± 3.0 | 23.6 ± 2.7 | 23.2 ± 3.1 | 23.4 ± 3.3 |
| Oxygen AM | 6.3 ± 1.6[ab] | 6.9 ± 1.5[b] | 5.6 ± 1.6[ac] | 5.6 ± 1.3[c] |
| Oxygen PM | 7.0 ± 1.6 | 7.7 ± 1.7 | 6.9 ± 1.7 | 7.2 ± 1.9 |
| Oxygen AVG | 6.7 ± 1.3[a] | 7.3 ± 1.4[b] | 6.2 ± 1.3[ac] | 6.4 ± 1.3[ac] |

[1]Values with different superscripts in the same row show significant difference ($P < 0.05$).

Table 3. Correlation of water quality parameters after 111 days (period 0-4)[1] across the four ponds[a].

| | $T_{am}$ | $T_{pm}$ | $O_{am}$ | $O_{pm}$ | $O_{avg}$ |
|---|---|---|---|---|---|
| Temperature (am) | 1 | | | | |
| Temperature (pm) | 0.564 | 1 | | | |
| Temperature avg | 0.884 | 0.885 | | | |
| Oxygen (am) | -0.178 | | 1 | | |
| Oxygen (pm) | | 0.228 | 0.527 | 1 | |
| Oxygen avg | -0.141 | 0.142 | 0.884 | 0.863 | 1 |
| Conductivity | | | 0.259 | 0.167 | 0.246 |
| pH | | | 0.403 | 0.282 | 0.395 |
| Ammonia Nitrogen | | | | | |
| Nitrate | | | -0.289 | -0.224 | -0.295 |
| Nitrite | | | | | |
| Phosphate | | | -0.284 | -0.206 | -0.282 |
| Total suspended solids | | | | | |

[a]All correlations are statistically significant at $P < 0.05$.

Table 3. Continued.

| | Cond. | pH | $_{Am}$N | Nitrate | Nitrite | P | TSS |
|---|---|---|---|---|---|---|---|
| Temperature (am) | | | | | | | |
| Temperature (pm) | | | | | | | |
| Temperature avg | | | | | | | |
| Oxygen (am) | | | | | | | |
| Oxygen (pm) | | | | | | | |
| Oxygen avg | | | | | | | |
| Conductivity | 1 | | | | | | |
| pH | 0.729 | 1 | | | | | |
| Ammonia Nitrogen | 0.765 | 0.267 | 1 | | | | |
| Nitrate | -0.411 | -0.463 | -0.122 | 1 | | | |
| Nitrite | -0.349 | -0.482 | | | 1 | | |
| Phosphate | -0.688 | -0.767 | -0.157 | 0.592 | 0.651 | 1 | |
| Total suspended solids | -0.339 | 0.167 | 0.437 | 0.605 | | 0.169 | 1 |

[a]All correlations are statistically significant at P < 0.05.

Table 4. Average values of production parameters of Mozambique tilapia receiving different feeding regimes for 111 days (period 0-3)[1].

| Parameters | Treatments (percentage of satiation level) n=8 | | | | |
|---|---|---|---|---|---|
| | 1 (20%) | 2 (40%) | 3 (60%) | 4 (80%) | 5 100%) |
| Initial body weight (g) | 17.61 ± 1.01 | 18.013 ± 1.73 | 18.063 ± 1.88 | 17.650 ± 1.67 | 17.938 ± 1.89 |
| Final body weight (g) | 52.520 ± 6.60[a] | 66.61 ± 10.75[ab] | 82.71± 11.77b[c] | 88.84 ± 15.07[c] | 88.99 ± 13.70[c] |
| Feed intake (% BW)[3] | 0.775 ± 0.03[a] | 1.369 ± 0.14[b] | 1.949 ± 0.23[c] | 2.468 ± 0.33[d] | 3.123 ± 0.40[e] |
| FCR[4] | 0.950 ± 012[a] | 1.352 ± 0.25[a] | 1.765 ± 0.28[b] | 2.218 ± 0.54[b] | 2.845 ± 0.50[c] |
| SGR[5] | 0.979 ± 1.12[a] | 1.213 ± 0.12[b] | 1.367 ± 0.10[bc] | 1.448 ± 0.16[c] | 1.438 ± 0.10[c] |
| Survival (%) | 91.06 ± 9.33 | 94.78 ± 4.49 | 93.08 ± 4.62 | 90.09 ± 7.01 | 89.68 ± 11.90 |

[1]Values with different superscripts in the same row show significant difference (P < 0.05).

Table 5. Daily natural feed intake (commercial feed equivalent) derived from linear regression model of FCR and SGR at various periods.

| Period | FCR at 0 FI | Growth at 0 FI | Daily Natural Feed Intake | Daily Natural FI (%BW/day) |
|---|---|---|---|---|
| 1 (day 0-27) | 0.55<br>[R-sq (%) = 69.7; P = 0.000] | 4.09<br>[R-sq (%) = 77.4; P = 0.000] | 0.08 | 0.34 |
| 2 (day 0-55) | 0.599293<br>[R-sq (%) = 78.1; P = 0.000] | 8.10422<br>[R-sq (%) = 66.4; P = 0.000] | 0.088 | 0.28 |
| 3 (day 0-111) | 0.256372<br>[R-sq (%) = 93.5; P = 0.000] | 34.6303<br>[R-sq (%) = 35.2; P = 0.000] | 0.079 | 0.16 |

Analyses for correlations between production performance parameters and water quality parameters provided a regression equation to predict the natural food intake at specific water quality parameters.

Table 6. Correlation of water quality parameters and natural food intake after 111 days of culture.

| | $FI_{natural}$ | SGR |
|---|---|---|
| Food intake$_{natural}$ (%BW/day) | 1 | |
| SGR | 0.490 | 1 |
| Conductivity | -0.276 | -0.779 |
| pH | -0.442 | -0.658 |
| Ammonia Nitrogen | 0.133 | -0.411 |
| Nitrate | | 0.507 |
| Nitrite | 0.851 | 0.705 |
| Phosphate | 0.491 | 0.836 |

[a]All correlations are statistically significant at $P < 0.05$

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