# GROWTH PERFORMANCE AND ECONOMIC BENEFITS OF *OREOCHROMIS NILOTICUS*/*CLARIAS GARIEPINUS* POLYCULTURE FED ON THREE SUPPLEMENTARY FEEDS IN FERTILIZED TROPICAL PONDS

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## ABSTRACT

An experiment was conducted for 180 days at Sagana Fish Farm, Kenya, to evaluate the performance of two formulated pellet feeds and a locally available rice bran. A polyculture of *Oreochromis niloticus* and *Clarias gariepinus* in fertilized tropical ponds was used. Twelve 800-$m^2$ ponds were used, and each pond was limed at a rate of 20,000 kg $ha^{-1}$ and stocked at a rate of 19,375 $ha^{-1}$ with sex-reversed male *O. niloticus* and 625 $ha^{-1}$ with *C. gariepinus*. The fish were fed daily at a rate of 2% body weight. Two formulated diets were compared with rice bran in three treatments that were replicated four times. The composition of the diets was as follows: Pig finisher pellet (PFP): crude protein 12.5%, lipids 10.9%, crude fiber 15.1%; Rice bran (RB): crude protein 6.5%, lipid 10%, crude fiber 37.9%; Test diet pellet (TDP): crude protein 12.5%, lipid 13.1%, crude fiber 14.1%. Diammonium phosphate (DAP) and urea were used at rates of 8 kg P $ha^{-1}$ $wk^{-1}$ and 20 kg N $ha^{-1}$ $wk^{-1}$, respectively. After one month urea input was reduced from 2.7 to 2.2 kg $pond^{-1}$ to allow for the nitrogen contributions from the feed and to maintain the inputs at 35 kg N $ha^{-1}$ $wk^{-1}$ in the ponds. Water quality analyses showed no significant differences ($P > 0.05$) among treatments in the parameters measured. Exceptions were alkalinity, pH, and dissolved oxygen (DO), which were significantly ($P < 0.05$) different among treatments. The lowest dawn DO level (0.9 mg $l^{-1}$) was recorded in the PFP treatment, while the highest afternoon value (9.9 mg $l^{-1}$) was recorded in the RB treatment. The lowest pH value of 7.9 was recorded in PFP, while the highest value (8.3) was recorded in the RB treatment. The overall range of monthly mean total alkalinity was 98.0 to 118.8 mg $CaCO_3$ $l^{-1}$, and the lowest value was observed in the RB treatment. The phytoplankton community was dominated by green algae in the beginning of the culture period but later by the blue-greens towards the end of the experiment. The overall mean diversity index of phytoplankton was 0.7, and values were not significantly different ($P > 0.05$) among treatments. Gross primary production ranged from 0.1 to 11.5 g C $m^{-2}$ $d^{-1}$. However, the values were also not significantly different ($P > 0.05$) among treatments. The RB treatment gave significantly ($P < 0.05$) lower values in fish growth rate and annualized net fish yield (0.69 g $d^{-1}$ and 5,000 kg $ha^{-1}$, respectively) than both PFP (1.17 g $d^{-1}$ and 9,298 kg $ha^{-1}$, respectively) and TDP (1.15 g $d^{-1}$ and 8,828 kg $ha^{-1}$, respectively). The feed conversion ratio was highest in the RB treatment. There were no significant differences ($P > 0.05$) in survival rates and relative condition factors among the treatments. Profitability analysis by using partial and enterprise budgets revealed that locally available pig finisher pellets were the most profitable followed by rice bran at the local market price of US\$1.17 $kg^{-1}$ fish. At a higher price of US\$1.56, PFP would still be the best choice, followed by TDP, while RB would be the least profitable. The net returns were positive for all the treatments. However, RB had the lowest break-even price and the least investment cost.

## INTRODUCTION

Tilapia farming in tropical and subtropical developing countries is practiced at either extensive or semi-intensive levels. The extensive culture of fish is undertaken mostly by cash-poor farmers, while semi-intensive culture is practiced on a more commercial scale. The suitability of tilapia for culture revolves around its ability to tolerate a wide range of environmental conditions as well as utilize food from the lowest trophic level and the detrital food chain (Moriarty and Moriarty, 1973; Bowen, 1979, 1982). The fish also displays high plasticity in its food habits, thus accepting a wide range of materials that are available as food (Maitipe and De Silva, 1985).

The semi-intensive culture of tilapias is particularly ideal in developing countries because it provides a wide variety of options in management and capital investments. Management strategies in the lower levels of intensification involve the use of fertilizer to encourage natural productivity and to improve the levels of dissolved oxygen (DO). Fish yields from such techniques have been found to be higher than those from natural unfertilized systems (Hickling, 1962; Hepher, 1963; Green, 1992; and Diana et al., 1994a). Moreover, increases in fish yields above those attained by fertilization only require the use of feed-fertilizer combinations, which result in higher critical standing crop (CSC). This increment occurs either by allowing for an increase in fish size or a higher stocking rate (Hepher, 1978). The fertilizer-feed management technique boosts fish yields but also offers the possibility of reducing feed inputs (Teichert-Coddington and Rodriguez, 1995). Diana et al. (1994a) demonstrated that when fish were fed on half ration and full ration in fertilized ponds, the yields were similar in both treatments, indicating that the feed inputs could be reduced by as much as one-half.

A wide range of materials have been utilized as feed supplements in Nile tilapia farming, including single ingredients (Binh et al., 1996). The role of a single ingredient as a feed supplement in fish production is determined by the quality, quantity, and availability of its nutrients to fish. Cottonseed meal, for example, has a higher protein content and is a more efficient fish producer than rice bran. To achieve a higher production than that achieved with single ingredients, formulated feeds have been utilized in semi-intensive culture of *Oreochromis niloticus* (Diana et al., 1994b). Formulated diets produce significantly higher fish yields than single ingredients (Binh et al., 1996). Besides the improved quality, complete feeds provide some micronutrients that enhance fish production (Binh et al., 1996). However, formulated diets for fish in Kenya have not been adequately developed. Moreover, the few that are available are of questionable quality in addition to their high cost. Diets formulated for other domestic animals, however, are cheaper and readily available. Therefore, there is a need to evaluate the performance of these feeds as possible alternatives.

The performance of a diet in fish culture depends on the quantity and quality of the feed as well as its effects on water quality. Water quality is inversely related to the amount of feed inputs (Boyd, 1990). Un-ionized ammonia and dissolved oxygen (DO) are the two most critical water quality parameters that may depress fish growth, even though the supplemental feed may be of high nutritional quality. Ammonia toxicity is dependent on the pH of the water (Trussel, 1972). Therefore, diurnal pH variation may affect fish yields significantly. A complete evaluation of the performance of a supplemental feed should therefore include evaluation of the concomitant responses of the water quality variables.

This study was conducted to evaluate the performance of two formulated diets in fertilized ponds for polyculture of *O. niloticus* and *Clarias gariepinus*. Locally available pig finisher pellets (PFP) and specially prepared formulated test diet pellets (TDP) were compared with the widely used rice bran (RB). PFP were selected because they are less expensive than poultry pellets, and previous trials indicated that they were just as effective as poultry pellets. TDP were formulated to contain about 20% crude protein. The effects of these supplemental diets on water quality variables were also monitored.

## METHODS AND MATERIALS

Twelve 800-$m^2$ ponds were stocked with male sex-reversed *O. niloticus* at a rate of 19,375 fish $ha^{-1}$ and an average weight of 89.3 g. *C. gariepinus* was introduced at a stocking rate of 625 fish $ha^{-1}$ and an average weight of 331.7 g as a predator in tilapia culture to control any breeding. The ponds were divided into three treatments with four replicates each. Ponds were randomly assigned the following diets: locally available PFP containing 14% protein, TDP formulated by using cottonseed cake and maize as the major components and containing 20% crude protein, and locally available RB with 6.5% protein.

The fish were fed at a rate of 2% body weight per day (BWD), equally divided between morning and afternoon feedings. Sampling was done fortnightly by seining to determine the average weight of the fish and adjust the feed accordingly. The experiment was run for 180 days. The TDP and PFP were manufactured by the same company. The ponds were fertilized with urea and diammonium phosphate at weekly doses of 20 kg $ha^{-1}$ $wk^{-1}$ nitrogen and 8 kg $ha^{-1}$ $wk^{-1}$ phosphorus.

Samples for pond water quality parameters were taken from three points in each pond by using a column sampler (Boyd and Tucker, 1992). The three samples were pooled into one. Water quality parameters analyzed include total nitrogen (TN), total ammonia nitrogen (TAN), total phosphorus (TP), total alkalinity (TA), dissolved reactive phosphorus (DRP), nitrate-nitrogen, nitrite-nitrogen, and total hardness (TH). All the parameters were analyzed as described in *Standard Methods for the Examination of Water and Wastewater* (APHA, 1980). Temperature and DO measurements were taken at 25-, 50-, and 75-cm depths, and the values were used in the calculations of phytoplankton primary productivity.

Partial and enterprise budgets were used to compare the relative profitability of the diets and their combinations. All costs were converted to monetary values, and the net returns to investments were determined. The analysis was based on the local market prices and expressed in US$ (US$1 = KSh 77).

Data from the experiment were subjected to single classification analysis of variance (ANOVA) using the Statgraphics program. Significant differences were judged at an alpha of 0.05.

## RESULTS

The growth curves for *O. niloticus* for the entire culture period are illustrated in Figure 1. Separation of treatments became apparent during the first 20 days of culture. After 170 days of culture the curves for all the treatments had leveled off, indicating that the carrying capacity had been reached. The growth of fish fed PFP leveled off at an average weight of 364.5 g, while those fed TDP and RB leveled off at lower average weights of 335.2 g and 231.9 g, respectively.

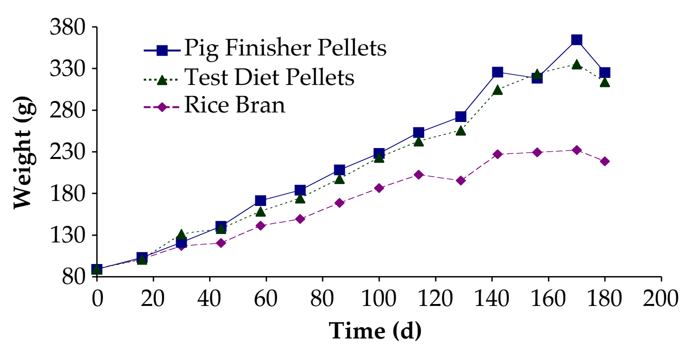


Figure 1. Growth of *O. niloticus* fed three supplemental diets during a 180-d experiment in earthen ponds at Sagana Fish Farm, Sagana, Kenya.

All three diets contained lower protein levels than expected. RB, which previously tested at 11% crude protein (CP) (Veverica et al., 1999), was analyzed and found to contain only 6.5% CP. The PFP was advertised as containing 14% CP but tested at only 12.5% CP. The TDP contained three types of oilseed meal, making up over 30% of the ingredients, but still tested at 12.5% CP.

The results of tilapia performance in various supplemental diets are summarized in Table 1. There were significant differences ($P < 0.05$) in growth rate of *O. niloticus* among treatments, with fish in PFP and TDP treatments having similar but higher growth rates (1.17 and 1.15 g $d^{-1}$, respectively) than those in the RB treatment (0.69 g $d^{-1}$). Survival rates varied among ponds but were not significantly ($P > 0.05$) different among treatments. The net yields and average weights showed trends similar to those for growth rates, with PFP and TDP having similar yields of 9,298 and 8,825 kg $ha^{-1}$ $yr^{-1}$, respectively, and RB with a significantly ($P < 0.05$) lower value of 5,000 kg $ha^{-1}$ $yr^{-1}$. Fish in PFP and TDP had statistically similar ($P > 0.05$) final average weights (325.1 and 313.9 g, respectively).

Although the harvest weight, growth rate, and annualized net fish yields were similar in the PFP and TDP treatments for *O. niloticus*, these variables differed significantly ($P < 0.05$) among the three treatments for *C. gariepinus* (Table 2). The PFP treatment was the best, while RB recorded the worst performance in these variables for the latter species. The mean individual growth rate of *C. gariepinus* was faster than that of *O. niloticus* in all the treatments. Overall production figures (for all fish—*O. niloticus* and *C. gariepinus*) are shown in Table 3.

Water quality parameters varied among and within treatments, but most of the parameters were not significantly different except for TA, DO, and pH. The TDP treatment had significantly ($P < 0.05$) higher TA values than PFP and RB, while the latter two had statistically similar values. Mean water temperature and pH ranged from 24.3 to 28.9°C and from 7.9 to 8.3, respectively. The pH values were significantly different ($P < 0.05$) among treatments. The dawn DO was lower than the afternoon value in all the treatments and differed significantly ($P < 0.05$) among treatments (Table 4). The highest pH values were recorded in the RB treatment, while the lowest values were recorded in the PFP treatment. Total hardness was slightly lower than total alkalinity in all treatments.

Minimum DO levels were significantly ($P < 0.05$) different among treatments, with the highest value (1.70 mg $O_2$ $l^{-1}$) recorded in the RB treatment. PFP had significantly ($P < 0.05$) the lowest value (0.92 mg $O_2$ $l^{-1}$), while the TDP value (1.26 mg $O_2$ $l^{-1}$) was intermediate. The value for TP was also high (1.21 mg $l^{-1}$) in the RB treatment but not significantly ($P > 0.05$) different from the other treatments.

Table 1. Stocking, harvest size, condition factor, fish growth, survival, gross fish yield, net fish yield, and net annualized production of *O. niloticus* with different feed treatments (mean ± standard error).

| **Parameter** | **Treatment** | | |
|---|---|---|---|
| | *Rice Bran* | *Pig Finisher Pellets* | *Test Diet Pellets* |
| Stocking Size (g) | 89.5 ± 1.87 $^{a}$ | 88.9 ± 2.53 $^{a}$ | 89.6 ± 0.37 $^{a}$ |
| Harvest Size (g) | 218.5 ± 8.27 $^{a}$ | 325 ± 10.19 $^{b}$ | 314 ± 16.5 $^{b}$ |
| Relative Condition Factor | 0.9 ± 0.19 $^{a}$ | 1.0 ± 0.15 $^{b}$ | 0.9 ± 0.16 $^{a}$ |
| Growth Rate (g $d^{-1}$) | 0.9 ± 0.06 $^{a}$ | 1.2 ± 0.13 $^{b}$ | 1.2 ± 0.10 $^{b}$ |
| Survival (%) | 90.8 ± 1.48 $^{a}$ | 88.1 ± 2.94 $^{a}$ | 90.1 ± 2.30 $^{a}$ |
| Gross Yield (kg $ha^{-1}$) | 4,100 ± 173 $^{a}$ | 5,823 ± 350 $^{b}$ | 5,746 ± 224 $^{b}$ |
| Net Yield (kg $ha^{-1}$) | 2,366 ± 148 $^{a}$ | 4,101 ± 323 $^{b}$ | 4,010 ± 225 $^{b}$ |
| Net Annualized Production (kg $ha^{-1}$ $yr^{-1}$) | 4,731 ± 297 $^{a}$ | 8,202 ± 647 $^{b}$ | 8,020 ± 451 $^{b}$ |

Note: Values followed by the same superscript in a row are not significantly different.

Table 2. Stocking, harvest size, condition factor, fish growth, survival, gross fish yield, net fish yield, and net annualized production of *C. gariepinus* in different feed supplements (mean ± standard error).

| **Parameter** | **Treatment** | | |
|---|---|---|---|
| | *Rice Bran* | *Pig Finisher Pellets* | *Test Diet Pellets* |
| Stocking Size (g) | 333 ± 19.1 $^{a}$ | 326 ± 19.9 $^{a}$ | 336 ± 12.5 $^{a}$ |
| Harvest Size (g) | 602 ± 47.1 $^{a}$ | 1,148 ± 55 $^{b}$ | 1,031 ± 75.0 $^{c}$ |
| Growth Rate (g $d^{-1}$) | 1.5 ± 0.27 $^{a}$ | 4.6 ± 0.41 $^{b}$ | 3.9 ± 0.42 $^{c}$ |
| Survival (%) | 92.5 ± 3.6 $^{a}$ | 104 ± 6.7 $^{a}$ | 95.0 ± 9.85 $^{a}$ |
| Gross Fish Yield (kg $ha^{-1}$) | 349 ± 32.9 $^{a}$ | 752 ± 93.0 $^{b}$ | 612 ± 78.5 $^{c}$ |
| Net Fish Yield (kg $ha^{-1}$) | 138 ± 29.1 $^{a}$ | 548 ± 104.8 $^{b}$ | 402 ± 81.0 $^{c}$ |
| Net Annualized Production (kg $ha^{-1}$ $yr^{-1}$) | 275 ± 58.0 $^{a}$ | 1,097 ± 210 $^{b}$ | 805 ± 162.0 $^{c}$ |

Note: Values followed by the same letter in a row are not significantly different.

TN ranged among treatments between 4.9 and 5.6 mg $l^{-1}$, but the values were not significantly different. Mean gross primary productivity was also not significantly different ($P > 0.05$) among treatments and varied between 4.8 and 5.7 g C $m^{-2}$ $d^{-1}$. However, the range between individual ponds was high, with minimum and maximum values of 0.1 and 11.6 g C $m^{-2}$ $d^{-1}$ recorded during the study. Similarly, chlorophyll *a* did not show significant differences among treatments, and the mean range was 133.6 to 176.8 mg $m^{-3}$ (Table 4).

The results of partial and complete enterprise budgets shown in Table 5 indicate that PFP and fertilizer was the most profitable treatment for *O. niloticus* and *C. gariepinus* polyculture. It was followed by RB at a price of US$1.17 for fish under 300 g. However, when fish above 300 g were valued at US$1.56, RB was the least profitable. PFP gave significantly higher returns than RB and TDP but had a break-even price similar to that of RB. TDP had the highest break-even value among all the treatments. Feed and fertilizer together cost US$0.42, 0.23, and 0.51 $kg^{-1}$ of fish produced for PFP, RB, and TDP, respectively.

## DISCUSSION

The results of this study demonstrate that the use of formulated supplemental feeds is more efficient than single ingredient supplements, further illustrating the potential for expansion of semi-intensive management practice.

The CSC was reached in less than 20 days after commencement of the present experiment, when differences in growth rates of fish between the formulated diets and rice bran were observed. *O. niloticus* has been shown to reach the CSC during the first month of culture and at a size of 30 g (Diana et al., 1991). Diana et al. (1994b) observed differences in growth rates during the first month of culture of *O. niloticus* that was stocked at a size of 10.1 g. During an experiment that utilized staged feeding (Diana et al., 1996), fish growth differentiated soon after the first feeding was initiated. This differential growth rate occurred at a size of 50 g, indicating that the CSC had already been reached at that level of fertilization. In the present experiment, fish were stocked at average weights of 89.3 g, and separation occurred in fewer than 15 days of culture, suggesting that the CSC may have been exceeded at the time of stocking. This observation supports the evidence suggesting early achievement of CSC for *O. niloticus* (Diana et al., 1994a).

Supplemental feeding with formulated feeds resulted in much more rapid growth of *O. niloticus* than did supplemental feeding with a single ingredient. The two formulated feeds gave similar growth rates and yields that significantly differed from that of rice bran. Fish in the RB treatment recorded a

Table 3. Overall gross fish yield, net fish yield, net annualized production, and apparent feed conversion ratios for the *O. niloticus*/*C. gariepinus* polyculture with different feed treatments (mean ± standard error).

| Parameter | Treatment | | |
|---|---|---|---|
| | *Rice Bran* | *Pig Finisher Pellets* | *Test Diet Pellets* |
| Gross Fish Yield (kg $ha^{-1}$) | 4,448 ± 163.0 [a] | 6,575 ± 325.0 [b] | 6,359 ± 215.0 [b] |
| Net Fish Yield (kg $ha^{-1}$) | 2,503 ± 148.0 [a] | 4,649 ± 309.0 [b] | 4,412 ± 221.0 [b] |
| Net Annualized Production (kg $ha^{-1}$ $yr^{-1}$) | 5,006 ± 295.0 [a] | 9,298 ± 617.0 [b] | 8,825 ± 443.0 [b] |
| Apparent Feed Conversion Ratio | 5.1 ± 0.31 [a] | 3.4 ± 0.24 [b] | 3.5 ± 0.18 [b] |

Note: Values followed by the same superscript in a row are not significantly different.

Table 4. Water quality parameters (mean ± standard error).

| Water Quality Parameter | Treatment | | |
|---|---|---|---|
| | *Pig Finisher Pellets* | *Rice Bran* | *Test Diet Pellets* |
| Dissolved Oxygen, dawn (mg $l^{-1}$) | 0.9 ± 0.05 [b] | 1.7 ± 0.05 [a] | 1.3 ± 0.05 [c] |
| Dissolved Oxygen, afternoon (mg $l^{-1}$) | 8.4 ± 0.17 [b] | 9.9 ± 0.18 [a] | 9.1 ± 0.18 [c] |
| Temperature (°C), dawn | 24.6 ± 0.05 [a] | 24.3 ± 0.05 [a] | 24.4 ± 0.05 [a] |
| Temperature (°C), afternoon | 28.1 ± 0.43 [a] | 28.9 ± 0.44 [a] | 28.2 ± 0.45 [a] |
| Alkalinity (mg $CaCO_3$ $l^{-1}$) | 108.5 ± 3.84 [b] | 98.0 ± 3.84 [a] | 118.8 ± 3.84 [b] |
| Total Hardness (mg $CaCO_3$ $l^{-1}$) | 88.7 ± 5.98 [a] | 95.1 ± 7.72 [a] | 107.8 ± 6.68 [a] |
| Primary Production (g C $m^{-2}$) | 4.82 ± 1.50 [a] | 5.5 ± 1.95 [a] | 5.7 ± 2.71 [a] |
| Total Ammonia Nitrogen (mg $l^{-1}$) | 0.9 ± 0.08 [a] | 1.0 ± 0.10 [a] | 0.9 ± 0.09 [a] |
| Total Phosphorus (mg $l^{-1}$) | 1.0 ± 0.10 [a] | 1.2 ± 0.13 [a] | 0.9 ± 0.12 [a] |
| Total Nitrogen (mg $l^{-1}$) | 5.6 ± 0.44 [a] | 4.9 ± 0.57 [a] | 5.2 ± 0.49 [a] |
| Total Suspended Solids (mg $l^{-1}$) | 255.9 ± 110.14 [a] | 255 ± 85.57 [a] | 278.1 ± 103.50 [a] |
| Chlorophyll *a* (mg $m^{-3}$) | 176.81 ± 6.81 [a] | 133.60 ± 16.81 [a] | 163.1 ± 16.81 [a] |
| pH | 7.9 ± 0.06 [a] | 8.3 ± 0.06 [b] | 8.0 ± 0.06 [a] |

Note: Values followed by the same letter in a row are not significantly different.

Table 5. Economic comparison among three experimental diets with interest rates at 24% per annum (US$1 = KSh 77).

| Item | Unit | Treatment | | |
|---|---|---|---|---|
| | | *Pig Finisher Pellets (PFP)* | *Rice Bran (RB)* | *Test Diet Pellets (TDP)* |
| Gross Revenue | US$ | 7,685 [b] | 5,199 [a] | 7,433 [b] |
| Variable Cost | US$ | 5,761 [b] | 3,880 [a] | 6,293 [b] |
| Income above Variable Cost | US$ | 1,924 [b] | 1,319 [a] | 1,140 [a] |
| Fixed Cost | US$ | 431.6 [a] | 431.6 [a] | 431.6 [a] |
| Total Cost | US$ | 6,192.6 [b] | 4,311.6 [a] | 6,724.6 [b] |
| Net Return | US$ | 1,492.9 [b] | 874.1 [a] | 708.4 [a] |
| Break-Even Yields | kg | 5,821 [b] | 4,182 [a] | 6,791 [b] |
| Break-Even Price (Variable Cost) | US$ | 0.88 [a] | 0.87 [a] | 0.99 [b] |
| Break-Even Price (Total Cost) | US$ | 0.94 [a] | 0.97 [a] | 1.06 [b] |

Note: Values followed by the same letter in a row are not significantly different.

growth rate of 0.68 g $d^{-1}$, while fish in the PFP and TDP treatments recorded growth rates of 1.17 and 1.15 g $d^{-1}$, respectively. The values obtained in the present study for PFP and TDP are similar to the 1.17 g $d^{-1}$ growth rate obtained with the same species based on fertilization alone, but are lower than the value of 3.10 g $d^{-1}$ observed with feed and fertilizer in Thailand (Diana et al., 1996). Green (1992) obtained a value of 2.03 g $d^{-1}$ in Honduras using feed and fertilizer. The differences in the growth rates between these studies may be attributable to temperature differences between regions and the use of manure (Green, 1992), which has been shown to produce higher fish yields than chemical fertilizers.

Rice bran (6.5% CP) in the present experiment recorded a net annualized fish yield of 5,000 kg, which is slightly lower than the 5,319 kg recorded for the same bran (11% CP) by Veverica et al. (1999). The way rice bran is processed greatly affects its quality. During periods of scarcity of rice bran, some traders mix rice bran with rice hulls, thus lowering its quality. It is therefore possible that the variability of the quality of rice bran contributed to the slightly lower yields observed in the present experiment.

While working on defatted loose and pelleted rice bran in Arkansas, Perschbacher and Lochmann (1995) recorded yields of 6,128 and 6,316 kg $ha^{-1}$, respectively, in fertilized ponds. Despite differences in the CP content of the two materials (13 and 18%, respectively), these yields were not significantly different. Although the protein contents of brans differed markedly within a country, fish yields showed only a slight difference. The more than one tonne increase in fish yields between Kenya and Arkansas could be attributed to the temperature differences under which these experiments were conducted and possible strain growth rate differences.

Diana and Lin (1998) obtained values close to 6,600 kg $ha^{-1}$ $yr^{-1}$ with chemical fertilization alone in Thailand, which are slightly higher than values reported for the rice bran and fertilizer combination in this study. These observations suggest that rice bran, which has a very high level of crude fiber, may be acting merely as a fertilizer rather than as a feed.

Single ingredients are of relatively inferior quality compared to formulated diets. The net annualized fish yields of 9,300 and 8,800 kg $ha^{-1}$ for PFP and TDP, respectively, in the present experiment were much higher than that recorded for the RB treatment (5,000 kg $ha^{-1}$). The present values for the formulated diets fall within the range obtained in other studies. Diana et al. (1994b) obtained values between 8,400 and 11,600 kg $ha^{-1}$ $yr^{-1}$ in a fertilizer and supplemental feeding combination fed at 50% *ad libitum*. The values in the present experiment can be considered to be similar to the range above if the variability normally observed within treatments is taken into account.

Pond water in the RB treatment had lower alkalinity than in the formulated diet treatments. Long-term increases in alkalinity in ponds treated with organic matter has been associated with the release of carbon dioxide from the decomposing organic material (Knud-Hansen, 1998). The rice bran used in the present study had very high levels of crude fiber (37.9%) and therefore would be decomposed at a much slower rate than formulated feeds with low levels of crude fiber (14 to 15%). Rice bran residues were observed on the bottom mud after harvest and draining of the ponds. The rice bran residues contained some carbon, which would have been converted into carbon dioxide to boost the alkalinity through the carbonate equilibrium (Boyd, 1990). Furthermore, since the fish in the RB treatment grew at a slower rate than those fed the formulated diets, the input of organic matter was less in the RB treatment than in the formulated diets. This provides a plausible explanation for why pond water in the RB treatment had lower alkalinity than in the other treatments.

Primary production and other water quality parameters that affect fish performance were not significantly different among treatments in the present experiment. However, dawn DO levels were lowest in the PFP treatment. Despite these low levels, the treatment was the best performer, indicating that the low oxygen levels did not significantly affect fish growth. Therefore, the differences in fish growth can mainly be attributed to the quality of the diets offered. This observation also provides further evidence on the ability of *O. niloticus* to tolerate low DO levels. Formulated diets contribute more to the growth of fish than do single ingredients (Cao et al., 1998).

The PFP diet was formulated to contain 14% CP, while the TDP were formulated to contain 20% CP. Actual laboratory analysis indicated CP levels of 10 and 11% for PFP and TDP, respectively. The yields from these diets were similar despite their differences in cost.

Net returns were positive for all diets but varied among treatments. Pig finisher pellets were more profitable as a supplemental feed than rice bran and test diet pellets. Rice bran and pig finisher pellets had lower break-even prices than test diet pellets, while rice bran required the least operational cost. Although the test diet pellet resulted in similar yields to the pig finisher pellet, the break-even price for the former was higher. This difference occurred as a result of the high cost of fish diets compared to domestic animal diets. This study revealed that formulated diets produce higher fish yields than single ingredients and that locally available pig finisher is more cost-effective than specially prepared diets for *O. niloticus* and *C. gariepinus* polyculture.

## ANTICIPATED BENEFITS

The development of cost-effective feeding and fertilizing strategies and the identification of economical feeds for use in aquaculture in Africa should increase the profitability of fish farming in the region and stimulate commercial aquacultural enterprises. Testing of pond management strategies that are locally and regionally practicable is required to identify those that are most cost-effective; such testing may require a number of sequential experiments using different feeds and fertilizers. This experiment and the previous Feeds and Fertilizers studies conducted at Sagana Fish Farm (8KR3 and 8KR3A) constitute two steps in such a testing program, and both have produced valuable results in the effort to develop cost-effective management strategies for Kenya and East Africa. Collaboration with local feed manufacturers and testing of already available feeds such as the pig finisher pellet can lead to viable partnerships with private enterprises and the development of cost-effective feeds for tilapia. The production of natural food organisms in feed-fertilizer management practices is often highly variable among sites. The need to evaluate this more intensive fish production practice and the results of experiments like this one under different environmental conditions may stimulate future intraregional collaboration.

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