AQUACULTURE CRSP 22ND ANNUAL TECHNICAL REPORT

DEVELOPMENT AND EVALUATION OF THE NUTRITIVE AND ECONOMIC POTENTIAL OF FORMULATED FISH FEEDS AND COMPARISON WITH LOCALLY AVAILABLE FEEDS FOR SEMI-INTENSIVE PRODUCTION OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

Tenth Work Plan, Feeds and Fertilizers Research 4A (10FFR4A)
Final Report

David Liti and Leah Kerogo
Department of Zoology
Moi University
Eldoret, Kenya

Chhorn Lim
Department of Fisheries and Allied Aquacultures
Auburn University
Auburn, Alabama, USA

Jonathan Munguti
Kenya Marine and Fisheries Research Institute
Onditi Kisumu, Kenya

ABSTRACT

An experiment was conducted at Sagana Fish Farm, Kenya, to evaluate the nutritional value and the economic potential of four feeds for semi-intensive production of Nile tilapia (*Oreochromis niloticus*) in 0.08 ha earthen ponds. Two isonitrogenous (24%) diets were formulated from three ingredients at the following inclusion levels: shrimp meal 12%, cottonseed meal 24%, and wheat bran 64%. One of the formulated diets was supplemented with locally available vitamins and mineral premix at 0.5% inclusion level; wheat bran was included at 63.5% to make allowance for the vitamins and minerals premix. Commercial pig pellets and wheat bran were also used in the trials. The four diets were assigned to four replicate ponds, which were stocked with sex-reversed *O. niloticus* (average weight 21 g) and *Clarias gariepinus* fingerlings (average weight 2.4 g) at stocking densities of 20,000 and 1,000 fish ha^{-1}, respectively. *C. gariepinus* was included to control the recruitment of *O. niloticus*. The fish were fed twice a day at 2% body weight for 258 days. The ponds were limed once at a rate of 2.5 ton ha^{-1} and fertilized weekly at rates of 20 kg N ha^{-1} and 8 kg P ha^{-1} with urea and Dap respectively. Samples of fish and water were taken on a monthly basis to monitor fish growth, water quality variables, and adjust the feed ration. Enterprise budgets were used to evaluate the economic performance of the dietary treatments. There were significant ($P < 0.05$) differences in mean fish weight, growth rate, net and gross yields, feed conversion ratio, fingerling recruitment, and percent survival among treatments. However, there were no significant differences ($P > 0.05$) in these variables between the two formulated feeds and also between pig pellets and wheat bran. Performance indicator variables of fish fed on formulated diets were higher than those of fish fed on either wheat bran or commercial pig pellets. However, in terms of economic performance, wheat bran was the best followed by the formulation without vitamins and mineral premix while pig pellets had the least economic performance. Based on the present results, it can be concluded that formulated diets were more effective in the production of *O. niloticus* than pig pellet or wheat bran, but wheat bran was economically the best. Results from the present study also revealed that vitamin and mineral supplementation could be omitted in simple formulations for semi-intensive production of *O. niloticus* in heavily fertilized ponds without significant loss in fish growth. These results suggest that the nutrient deficiency in feed supplements could adequately be met by the natural food items.

INTRODUCTION

There has been an increased demand for animal protein in developing countries as a result of the rapid increase in human population. The African population is estimated to rise to 1.2 billion people by the year 2010 (FAO, 2003), while FAO (1996) reports also indicate that the current protein supply may not be sufficient to meet the increased protein demand in the developing countries. To counter this impending protein shortage,

concerted efforts have been focused on the production of both animal and plant protein.

Fish is one of the potential protein sources in the poor regions of Sub-Saharan Africa, where about 60% of the population is suffering from chronic malnutrition (West, 1996). In 2000, fish protein from capture fisheries and aquaculture contributed only about 15.9% of the world total animal protein supply (FAO, 2003). However, the wild fish stocks are on the decline (Watson and Blake, 1993), while farmed fish supply has continued to remain at its infancy, contributing only about 19% of the 112.3 metric tons of the total fish production in a 1995 estimate (FAO, 1996). Reports from FAO (2003) indicate that developing countries produced only 0.9% of the global farmed finfish protein output in 2000, and tilapia contributed 40% of the total finfish production. *O. niloticus* is the most dominant among the farmed tilapias where it has been farmed either for subsistence or commercial purposes. The suitability of *O. niloticus* species for culture stems from their rapid growth, high plasticity in their food habits, and good productivity per unit volume of water.

Oreochromis niloticus production commonly occurs in semi-intensive ponds where the fish partly depends on natural pond productivity in addition to some supplementation with artificial diets (Diana et al., 1994; Green, 1992; Knud-Hansen, 1992; Schroeder, 1987). However, for intensification in production, qualitative supplemental feeds are required. Feed is among the most costly items in fish production and contributes over 50% of the total operating costs (Shang, 1992). Successful and profitable fish farming will, therefore, require availability of cheap nutritive and cost-effective diets. The present study was aimed at evaluating the performance of two formulated diets as well as comparing them with locally available feeds in the semi-intensive production of *O. niloticus*.

Methods and Materials

Data for the present study was collected at Sagana Fish Farm, which is located in Sagana (0° 39'S, 37° 12'E), approximately 105 km Northeast of Nairobi at an altitude of 1,230 m above mean sea level. Two isonitrogenous (24%) diets were formulated from shrimp meal, cottonseed meal, and wheat bran. The composition of the ingredients and the proximate composition are shown in Table 1. One of the formulated diets was supplemented with a locally available domestic vitamin and mineral premix at 0.5% inclusion level. The composition of the premix is shown in Table 2. Wheat bran in this diet was included at 63.5% to give allowance for the premix. Commercial pig pellets were purchased from a local feed manufacturer, Gold Star, while wheat bran was purchased from a nearby wheat-processing factory, Maisha Flourmills. Twelve earthen 0.08 ha ponds were drained and left to dry two weeks prior to the initiation of the experiment The experimental ponds were limed once at the beginning of the experiment at 2.5 tons ha^{-1} with agricultural lime and the four diets were assigned to the experimental ponds in four replicates.

The ponds were stocked with sex-reversed *O. niloticus* averaging 21 g and *C. gariepinus* fingerlings averaging 2.4 g at stocking densities of 20,000 and 1,000 fish ha^{-1}, respectively. *C. gariepinus* was included to control the recruitment of *O. niloticus* from the unreversed females. The fish were fed twice a day at 2% body weight for 258 days. Each ration was divided into two equal parts. One portion was offered at 10.00 hrs while the other portion was offered at 15.00 hrs.

Fertilization was done weekly using urea and Dap at rates of 20 kg N ha^{-1} and 8 kg P ha^{-1}, respectively. Fish were sampled monthly using a seine net, and each sample contained over 50% of the total pond fish in order to obtain a better estimate of the expected mean weight. All the sampled fish were counted and batch weighed to the nearest 0.1 g using a bench scale (DS10) to determine the mean weight. At harvest, the ponds were drained and all the fish were counted and weighed and the mean weight of fish for each pond determined.

Protein content of the diets was determined by macro-Kjeldhal method, percent fat by ether extraction method, crude fiber by acid-alkali digestion, ash by burning weighed samples at 600 °C in a muffle furnace, and moisture by drying samples to constant weight at 100 °C (AOAC, 1990). Carbohydrate (NFE) was determined by difference.

Samples for water quality variables were taken using a 90 cm water column sampler (Boyd and Tucker, 1992). Pond water was taken from three different pond locations (near inlet and outlet, and close to the shore along the pond length) within each pond and pooled to provide an integrated sample; a sub-sample was drawn from the pooled sample for the analyses of water quality variables.

Water quality analyses included the following variables: ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, orthophospahate-phosphorus, total phosphorus, total nitrogen, alkalinity, hardness, and chlorophyll *a* and were done according to standard methods described in APHA (1989) and Egna et al. (1987). Temperature and dissolved oxygen measurements were obtained by using YSI model 57 meters while pH was measured by glass electrode Hi-9024 microcomputer. A 25 cm diameter white disk was used to measure Secchi disk visibility while weather data was gathered from a meteorological station located at Sagana fish farm. Data was analyzed by use of Statgraphics Plus for Windows 2.1 Program

(1994). Single classification analysis of variance was used to test for significance differences while Duncan's multiple range test was used to discriminate which means were different from each other. Significance was declared at $P = 0.05$

RESULTS

Fish growth data are presented in Table 3. There were significant differences ($P < 0.05$) in fish growth among dietary treatments. Fish that were fed on formulated diets exhibited significantly higher fish mean weight, growth rate, yields, and feed conversion ratio (FCR) than those fed on pig pellets and wheat bran. Fish fed on the two diets formulated with and without vitamins had statistically similar ($P > 0.05$) growth performance but significantly higher ($P < 0.05$) mean weights and yields than those fed pig pellets and wheat bran. The mean weight of fish fed wheat bran and pig pellets were statistically similar ($P > 0.05$). Feed conversion ratio did not differ significantly ($P > 0.05$) among the formulated diets but was better than for fish fed on pig pellets and wheat bran. Pig pellets and wheat bran had statistically similar ($P > 0.05$) FCR. There were no significant differences ($P > 0.05$) in survival among all the dietary treatments. Fingerling production was significantly ($P < 0.05$) lower in formulated diets than in pig pellet and wheat bran, which had similar ($P > 0.05$) recruitment levels.

Figure 1 shows the growth trend curves for *O. niloticus* during the experimental period. Growth trends were exponential for the first 140 days of culture, after which fish growth assumed more or less linear trend. Differential growth among treatments appeared between 100 and 150 days of culture when the two formulated diets separated from wheat bran and pig pellets. Fish did not appear to reduce growth towards the end of the culture period, although there appeared to be a decline towards the harvest period, but this could be attributed to bias caused by using samples instead of total harvest to estimate mean weights. At harvest, the growth curves for pig pellets and wheat bran had not separated from each other and so were those for formulated diets.

Fingerling recruitment occurred in all the treatments. The number of recruits was significantly higher ($P < 0.05$) in WB and PP treatments than in the treatments fed formulated diets. There were no significant differences ($P > 0.05$) in fingerling recruitment between pig pellets and rice bran and also between the two formulated diets.

There were no significant differences ($P > 0.05$) between treatments in most of the water quality variables. Exceptions were total nitrogen ammonia and total nitrgen, which were significantly higher ($P < 0.05$) in the formulation without vitamin and mineral supplements than the other treatments. Dawn DO in all the ponds ranged from 0.6 to 4.5 mg L^{-1} throughout the experimental period and was not significantly different among treatments.

The results of the partial and complete enterprise budgets (Table 5) indicate that wheat bran was the most profitable dietary treatment for *O. niloticus* production in semi-intensive ponds. The formulation without vitamins and minerals premix was second in profitability while pig pellets had the least net returns. Wheat bran treatment had the lowest variable cost, while the diet formulated with vitamins had the highest variable cost.

DISCUSSION

Nile tilapia fed on formulated diets in fertilized ponds had significantly higher mean weight than fish fed with either pig pellets or wheat bran. However, fish fed on formulated diets with or without vitamin and mineral supplementation had similar mean weights. Liti et al. (2001) compared the performance of pig pellets with commercial tilapia diet and rice bran and observed better growth on Nile tilapia with the commercial diets than rice bran. In that study the performances of pig pellets and commercial tilapia diet were similar. The results of this study indicated that pig pellets and wheat bran had similar performance on the growth of *O. niloticus*, suggesting that wheat bran was of equal nutritional value to the locally available commercial tilapia diets. Liti and Mugo (2002) compared the growth performance of *O. niloticus* fed on three feeds—rice bran, maize bran, and wheat bran—and obtained similar growth performance with wheat and maize bran, but with significantly lower growth than rice bran. This observation indicates that maize bran could be used in place of wheat bran if the latter is not available.

The trend curves in the present study demonstrated two growth phases: an exponential growth and a linear growth phase. In the exponential phase, there was no differential growth between treatments, suggesting that the critical standing crop for all the dietary treatments had not been reached. The rate of fish growth during this phase demonstrated steep growth curves, suggesting that fish were adequately catered for by the nutrients from the natural food items. The quality of natural food items ingested by tilapia has been reported to be high (Getachew, 1988; Bowen, 1982). Separation of treatment growth curves became apparent at a mean weight of about 140 g when the formulated diets separated from pig pellets and wheat bran. Fish fed on pig pellets and wheat bran showed reduced growth rates relative to the formulated diets. The overlap between the curves for pig pellets and wheat bran suggested that the critical standing crop for pig pellets and wheat bran were similar and may not below 300 g weight.

Inclusion of vitamins and mineral premix in to the formulated diets did not improve the performance of

O. niloticus, suggesting that vitamins were not limiting in the growth of fish under fertilized semi-intensive culture ponds. Natural foods are rich in minerals and vitamins, and therefore these food items may adequately compensate for the inadequacies of nutrients in feed supplements. This observation has particular relevance to small-scale fish farmers who may formulate simple practical diets without inclusion of vitamins with a remarkable reduction in feed cost.

The growth of Nile tilapia fed on pig pellet, a formulated diet, was similar to those of fish fed on wheat bran, a single ingredient. The protein content of these diets was similar (15–17%) despite the fact that one was a formulation while the other was a single ingredient. Formulations are nutritionally richer than single ingredients, therefore higher fish growth would be expected with formulations than with single ingredients. It appears that under a semi-intensive culture system, the quantity of protein is more important than the sources so long as the protein displays reasonable digestibility. In culture systems where fish partly rely on natural food, protein deficiency has been reported to increase with the difference between the fish biomass and the supply of natural food (De Silva, 1993). Under such conditions, the response of fish to a diet supplement might be expected only when the protein quantity of the supplement surpasses that of natural food supply.

The yields obtained with formulated diets in the present study were comparable to those reported by Liti et al. (2001), where *O. niloticus* was fed on pig pellets and commercial tilapia diet. However, in the present study, fish fed on pig pellets demonstrated lower fish yields for *O. niloticus* than in the previous study. This descrepancy may be explained by the lower survival that was observed in the present study (70%) compared to 90% in the previous study (Liti et al., 2000). The reasons for the lower survival rate in the present study may be attributed to the differences in the initial stocking weights between the two studies. In the previous study, fish were stocked at 90 g while the stocking weight in the present experiment was 21 g. Smaller fish are prone to bird predation in addition to having a longer period of exposure to predation during the culture period. From the results of the present study and those of previous studies (Veverica et al., 1999), it is apparent that the performance of the diets can be ordered as follows: rice bran with the least performance followed by wheat bran and pig pellet with moderate performance and the present formulated diets with the highest performance among all the diets that have been studied at Sagana fish farm.

Net returns were positive for all the diets, but there was a significant variation among treatments. Wheat bran was the most profitable as a supplemental feed compared to the other dietary treatments. Formulation with vitamins and mineral premix had similar yields to that without, but net returns were lower in the former than latter. This difference in economic performance was due to the increased cost from the mineral supplement. The present study demonstrates that wheat bran and the diet formulated without vitamins and mineral premix were more cost-effective in the production of *O. niloticus* than pig pellets and the formulation with vitamins and minerals premix.

Conclusion

The present results demonstrate that all the four feeds could be profitable and that formulated feeds were the best in terms of growth performance but not in economic terms. Wheat bran was the most profitable among the diets studied. The results also revealed that mineral and vitamin supplementation may not be necessary in intensively fertilized ponds. Since the formulated diets gave better growth while wheat bran was economically better, the two could be combined in a feeding strategy that could be cost-effective. One potential strategy would be to practice a staged feeding schedule, starting with wheat bran and changing to the formulated feeds once the fish attain an average weight of 140 g. The strategy could increase profitability by 18%.

Anticipated Benefits

This study was designed to evaluate the potential for cheap and cost-effective diets in *O. niloticus* production in semi-intensive ponds. The present results if implemented can improve profitability in fish farming in Kenya and the East African region as a whole. If simple formulations are used in combination with other locally available single ingredients, more intensification in Nile tilapia production could be attained with remarkable increase in profits.

Acknowledgements

The authors wish to thank the Aquaculture Collaborative Support Research Program (ACRSP) for their financial support. Special appreciation is directed to Hillary Egna and Nancy Gitonga for giving this project an invaluable support, without which we would not have succeeded.

Literature Cited

AOAC (Association of official analytical chemists), 1990. Official methods of analysis of Association of official analytical chemists, 15th edition, AOAC, Inc. Arlington, Virginia, USA.

APHA (American Public Health Association), 1989. Standard methods for the examination of water and wastewater 17th Ed. American Public Health As-

sociation, Washington, D.C.
Bowen, S.H., 1980. Detrital non-protein amino acids are the key to rapid growth of tilapia in Lake Valencia, Venezuela. Science 207:1,216–1,218.
Boyd, C.E. and C.S. Tucker, 1992. Water quality and pond soil analysis for aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama, 183 pp.
Diana, J.S., C.K. Lin, and K. Jalyen, 1994. Supplemental Feeding of Tilapia in Fertilized Ponds. J. World Aquacult. Soc., 5:4 497–506.
De Silva S.S., 1992. Supplementary feeding in semi-intensive aquacultue systems. In: M.B. New, A.G.J. Tacon, and I Csavas (Editors), Farm made aquafeeds. Proceedings of the FAO/AADCP. Regional Expert econsultation on on-farm aquafeeds, 14–18 December 1992, Bangkok, Thailand FAO-RAPA/AADCP, Bangkok, Thailand, 434 pp, pp 24–60.
Egna, H.S. and C.E. Boyd, 1997. Dynamics of pond aquaculture. CRC Press LLC, Florida, USA, 437 pp.
FAO, 1996. Food and Agriculture Organization of the United Nations. Rome, 357 pp.
FAO, 2003. Food and Agriculture Organization of the United Nations. Rome, 357pp.
Getachew, T. and C.H. Fernando, 1989. The food habits of an herbivorous fish (Oreochromis niloticus L.) in Lake Awasa, Ethiopia. Hydrobiologia, 174: 195–200.
Knud-Hansen, C.F. and C.K. Lin, 1992. Strategies for stocking Nile tilapia O. niloticus in fertilized ponds. In: H.S. Egna, M. McNamaya, J. Bowman, and N. Astin (Editors), Tenth Annual Administrative Report, PD/A CRSP. Oregon State University, Corvallis, Oregon, pp. 185.
Liti, D.M. and R. Mugo, 2002. A comparative study on the growth and economic performance of Nile tilapia (Oreochromis niloticus) fed on maize bran, wheat bran, and rice bran in fertilized ponds. World Aquaculture Society, 2002, California, USA.
Liti, D.M., E. MacWere, and K.L. Veverica, 2001. Growth performance and economic benefits of Oreochromis niloticus/Clarias gariepinus polyculture fed on three supplementary feeds in fertilized tropical ponds. World Aquaculture Society 2001, Orlando, Florida, USA.
Shang, Y.C., 1992. The role of aquaculture in the world fisheries. Presented at the World Fisheries Congress at Athens, Greece, 3–8 May, 1992, 30 pp.
Statistical Graphics Corporation, 1997. Statgraphics Plus for Windows 3.0.
Stickney, R., 1979. Principles of warmwater Aquaculture. John Wiley and Sons, N.Y. and Chichester.
Veverica, K., W. Gichuri, and J. Bowman, 1999. Relative contribution of supplemental feed and inorganic fertilizers in semi-intensive tilapia production. In: K. McElwee, D. Burke, M. Niles, and H. Egna (Editors), Sixteenth Annual Technical Report, Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 39–42.
Watson, I. and B.F. Blake, 1993. Aquaculture can answer the fisheries dilemma but how do we feed the fish? World Aquaculture 1993. Editor Algan Cartwright, Stirling Publication group PLC London, pp. 104–105.

Table 1. Proximate composition (on dry weight basis) of the four test diets.

	Diet			
Ingredient analysis	*CV*	*CW*	*WB*	*PP*
			–	–
Shrimp meal	12	12	–	–
Cottonseed meal	24	24	–	–
Wheat bran	63.5	64	–	–
Premix	0.5	0	–	–
Total	100	100	–	–
Dry matter	91.48	91.0	91.2	91.7
Crude protein	24.3	24.1	17.6	15.7
Ether extract	7.6	7.5	9.1	7.6
Crude fibre	13.14	12.2	11.4	9.9
Ash	8.5	7.6	5.0	13.7
N-free extracts	46.5	48.3	60.4	53.6

CV = formulation with vitamins and minerals premix; CW = formulation without vitamins and minerals premix; WB = wheat bran; PP = pig pellets; N-free extracts = nitrogen-free extracts.

Table 2. Vitamin and mineral composition of the domestic premix.

Vitamin Contents		**Mineral Contents**	
Vitamin	*Content*	*Mineral*	*Content*
A	5,000,000 I.U.	Copper Sulphate	1.5mg
D3	1,000,000 I.U	Manganese Sulphate	90mg
E	1,500 I.U	Manganese Iodide	300mg
B1	600mg	Zinc Oxide	70mg
B2	2,500mg	Nicotinic acid	5,500mg
B6	125mg	Calcium Pantothenate	5,000mg
B12	7.5mg		
K	1,250mg		
C			

Table 3. Performance of *O.niloticus* fed on different dietary treatments.

Variable	Dietary Treatments				
	CV	*CW*	*PP*	*WB*	*SE*
Stocking weight (g)	21.0[a]	21.5[a]	21.9[a]	21.5[a]	0.36
Harvest weight (g)	354.1[a]	349.1[a]	303.4[b]	291.3[b]	5.02
Gross yield (kg ha^{-1})	5,867.2[b]	5,742.2[b]	4,864.7[a]	4,908.8[a]	187.8
Net fish yield (Kg ha^{-1})	5,433.1[b]	5,297.5[b]	4,411.4[a]	4,468.9	188.9
Annual net production. (Kg ha yr^{-1})	7,686.3 [b]	7,494.2 [b]	6,240.98[a]	6,322.25[a]	267.2
Growth rate (g/day)	1.5[b]	1.5[b]	1.3[a]	1.3[a]	0.06
FCR	2.55[a]	2.64[ab]	2.9[bc]	3.0 [c]	0.1
Survival (%)	69.7[a]	69.3[a]	68.6[a]	70.1[a]	2.21
Fingerling recruitment (nos)	29,271[a]	28,858[a]	36,856[b]	46,041[b]	730

CV = formulation with vitamins and minerals premix; CW = formulation without vitamins and minerals premix; WB = wheat bran; PP = pig pellets; FCR = feed conversion ratio.

Table 4. Water quality variables under different dietary treatments.

Variable	Dietary Treatments			
	CV	*CW*	*PP*	*WB*
Morning Temperature (°C)	23.97± 0.047[a]	24.1± 0.047[a]	24.1± 0.047[a]	23.98± 0.047[a]
Afternoon Temperature (°C)	26.3± 0.12[a]	26.7 ± 0.12[a]	26.3 ± 0.12[a]	26.6± 0.12[a]
Dawn DO (mg/L)	1.6 ± 0.16[a]	1.4 ± 0.16[a]	1.4 ± 0.16[a]	1.4 ± 0.16[a]
Afternoon DO (mg/L)	7.3 ± 0.5[a]	7.8 ± 0.5[a]	6.8 ± 0.5[a]	7.9 ± 0.5[a]
Total alkalinity (mg/L $CaCO_3$)	87.7± 9.4[a]	85.1± 10.8[a]	87.2± 25.3[a]	86.0± 6.8[a]
Total hardness (mg/L $CaCo_3$)	78.8± 8.5[a]	81.3± 11.8[a]	83.1± 24.4[a]	82.7± 7.5[a]
PH	8.2± 0.2[a]	8.2± 0.04[a]	8.2± 0.06[a]	8.2 ± 0.1[a]
Dissolved P (mg/L)	0.2± 0.2[a]	0.4± 0.09[a]	0.3± 0.2[a]	0.3± 0.2[a]
TAN (mg/L)	1.3± 0.06[a]	1.5± 0.2[b]	1.3±0.1[a]	1.5± 0.1[ab]
NO_2-N (mg/L)	0.05± 0.03[a]	0.08± 0.03[a]	0.06± 0.02[a]	0.03± 0.002[a]
NO_3-N (mg/L)	0.03± 0.02[a]	0.05± 0.02[a]	0.04± 0.02[a]	0.03± 0.01[a]
Total Phosphorus (mg/L)	0.8 ±0.3[a]	1.3± 0.7[a]	1.3± 0.6[a]	0.8± 0.3[a]
Total Nitrogen (mg/L)	3.9± 0.2[ab]	4.4± 0.6[b]	3.6± 0.2[a]	3.7±0.2[a]
TSS (mg/L)	225.5± 21.9[a]	228.8± 25.8[a]	225.5± 18.3[a]	218.0± 14.6[a]
TVS (mg/L)	102.9± 14.1[a]	103.0± 11.8[a]	89.2± 6.1[a]	88.5± 5.5[a]
Chl a (mg/L)	157 .8±29.5[a]	142.0±25[a]	135.4±16.7[a]	118.9±18.3[a]

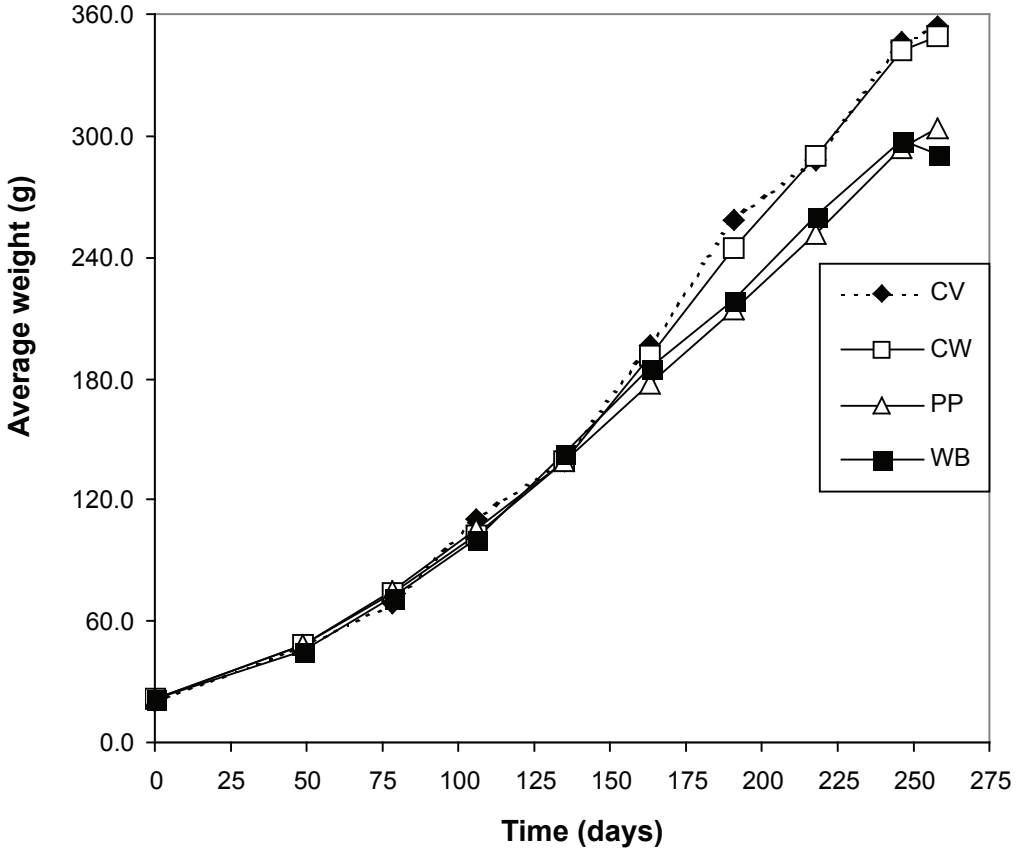
DO = dissolved oxygen; NO_3-N = nitrate nitrogen; NO_2-N = nitrite nitrogen; TSS = total suspended solids; TVS = total volatile solids.

Table 5. Enterprise budget analysis of the dietary treatments.

Item	Unit	Treatment			
		CV	*WV*	*WB*	*PP*
Gross Revenue	US$	7,619.6[a]	7457.4[a]	6,375.1[b]	6,317.8[b]
Variable cost	US$	4,810.4[a]	4,445.5[b]	2,961.7[c]	4,357.2[b]
Income above variable cost	US$	2,809.3[a]	3,011.9[a]	3,413.4[b]	1,980.6[c]
Fixed cost	US$	571.8[a]	571.8[a]	571.8[a]	571.8[a]
Total cost	US$	5,382.2[a]	5,017.3[a]	3,533.4[b]	4,928[a]
Net return	US$	2,237.5[a]	2,440.1[a]	2,841.6[b]	1,388.8[c]
Break-Even Yields (Variable cost)	US$	0.7a	0.6[a]	0.4[b]	0.7[a]
Break-Even Yields (Total cost)	US$	0.9[a]	0.7[a]	0.5[b]	0.9[a]

CV = formulation with vitamins and minerals premix; CW = formulation without vitamins and minerals premix; WB = wheat bran; PP = pig pellets.

Figure 1. Growth trends of *O. niloticus* under different dietary treatments.



CV = formulation with vitamins and minerals premix; CW = formulation without vitamins and minerals premix; WB = wheat bran; PP = pig pellets.

Cite as: [Author(s), 2005. Title.] In: J. Burright, C. Flemming, and H. Egna (Editors), Twenty-Second Annual Technical Report. Aquaculture CRSP, Oregon State University, Corvallis, Oregon, [pp. ___.]