Evaluation of three diets formulated from local agro-industrial by-products for production of *Oreochromis niloticus* in earthen ponds

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ABSTRACT

Three diets were evaluated for growth, production and economic performance of the Nile tilapia, *Oreochromis niloticus*, after a culture period of 160 days at the Aquaculture Research and Development Centre (ARDEC), Akosombo, Ghana. Locally available agro-industrial by-products were used to compound the diets. Wheat bran and rice bran were used as energy sources while fish meal and groundnut bran were used as protein sources. The crude protein level of the control diet and the test diets were 9 and 15 per cent, respectively. Results from the feeding trials showed that diet F1 performed best in most of the growth and feed utilization parameters tested (mean daily growth rate and mean net weight gain). However, there was no significant difference between the performance of diets F1 and F3 ($P > 0.05$). The control diet F2 was the most economical with respect to profit index and economy of weight gain. It cost ¢1041.00 to produce 1 kg of fish on diet F2, while the same weight of fish costs ¢2013.00 to be produced on diet F3. Considering the overall performance of the three diets in terms of feed utilization and production economics, diet F1 (wheat bran and groundnut bran) was the most cost-effective practical diet. It is recommended to fish farmers for cultivation of *Oreochromis niloticus* fingerlings (90-100 g) to a marketable size of about 220 g in 5 months.

NARS edition; revised 20 July 2006.

Introduction

In all animal farming practices supplementary feeding is a major management procedure used to increase productivity and nutritional value of the animal produced. The situation is also true for fish (Attapatu & MacCormac, 1989). Reference to increasing fish production from fish farming, supplementary/prepared feed are used to maximize growth rates, increase stocking density, enhance reproductive efficiency, increase resistance to diseases and minimize mortality (Cole & Ronnning, 1986). While the above attributes are all desired by farmers, it becomes more profitable when the cost of providing the supplementary feed is kept as low as possible.

The cost of supplementary feeding in most aquaculture systems often exceeds 50 per cent of total production cost, and may be as much as 70 per cent (Shang, 1981). To increase profitability of animal raising, including that of fish, studies continue worldwide to identify less expensive feed ingredients and feed composites that could produce results obtained through use of costly diets. In Ghana, fish culture, as a viable commercial venture, is at its beginning and the use of formulated feeds is limited. The quality of feeds used is higly variable. Most fish culture producers are small scale and practice subsistence extensive farming. At best, they use single items such as wheat bran as feed.

A fair proportion of industries in Ghana are agriculture-based and produced a range of by-products which could be rich ingredients for the formulation of fish feed as they already contribute to livestock and poultry feeds. This study, undertaken in 1998, was part of initial long-term attempts at identifying agro-industrial by-products to develop and formulate commercially viable fish feeds.

The objectives of this study were to assess the effect of three locally formulated diets on the growth performance of the Nile tilapia, *Oreochromis niloticus*, and to evaluate the economic viability of the diets.

Materials and methods

The study was carried out at the Aquaculture Research and Development Centre (ARDEC) of the CSIR-Water Research Institute (WRI), Ghana. Three diets, F1, F2 and F3 (Table 1), were composed from wheat bran, rice bran, groundnut bran and fish meal. All test feeds had two replicates. The study lasted 160 days with all replicates running concurrently. Diet F2 was the control diet. The physico-chemical characteristics of pond water in which the study was conducted were monitored at 21 days' interval between 8 and 10 h throughout the study period. Pond water samples were collected directly into clean 1-litre plastic bottles. Temperature and *p*H were measured *in situ* using mercury-in-glass thermometer and a portable *p*H meter, respectively. Samples for dissolved oxygen determination were collected into 250-ml plain glass bottles. They were fixed using azide modification of Winkler's method for acidification and titration. Hatch powder pillows were used to analyze the following nutrients: nitrite-nitrogen by the diazotization method, nitrate-nitrogen by the cadmium reduction method, ammonia-nitrogen by the Nessler method, and phosphate-phosphorus by the ascorbic acid method. Conductivity was measured with a conductivity meter, while total dissolved solids (TDS) was measured by gravimetric method.

A total of 11534 all-male *Oreochromis niloticus* were used as test fish. The fish were stocked in six of 0.2-ha earthen ponds and fed twice daily at a rate of 5 per cent body weight during the first 3 months, and 4 per cent body weight the last 2 months. The amount of feed was adjusted in relation to change in total biomass after 100 experimental fish from each replicate were sampled every 21 days. The net weight gain per treatment was estimated at the end of the experiment following total harvest. The cost of 1 kg of test diets and the farm gate price of 1 kg of fish at the end of the experiment were estimated using prevailing prices of commodities at Akosombo, Tema, Kumasi and Hohoe markets in July 1998. Proximate analysis of the test diets (Table 2) were carried out using standard methods (AOAC, 1980). Before the beginning of the experiment, four fish per test diet were randomly selected from the ponds for carcass analysis, crude protein, fat and moisture contents. These fish were frozen and stored in polyethylene bags in a freezer. At the end of the experiment, four fish from each of the three test diets were randomly selected and analyzed.

The mean growth rate was calculated using the method of Wayne & Davis (1977) as follows:

$$\frac{W_2 - W_1}{0.5\,(W_1 + W_2)\,t}$$

where W_1 = initial weight
W_2 = final weight
t = experimental period in days
0.5 = a constant

The food conversion ratio (FCR) was estimated using the formula:

$$\frac{\text{Dry weight of feed consumed}}{\text{Wet weight gain}}$$ (Castell & Tiews, 1980)

The relative weight gain (%) was calculated as :

$$\frac{\text{Net production}}{\text{Initial stocking weight}}$$

Economy of weight gain (EWG) was calculated as:

$$\frac{\text{Cost of feed consumed}}{\text{Weight gain (kg)}}$$ (Ita & Okeoyo, 1988)

and Profit Index = Value of fish crop/Total cost of feed.

Results and discussion

Table 1 presents the percentage composition of feed ingredients used in the formulation of the test diets, the cost per kilogram of each diet and feed ingredients, and the calculated crude protein values. The calculated and analyzed crude protein values (Tables 1 and 2) were almost the same. Diet F3, compounded with rice bran, groundnut bran and fish meal, as the main source of protein, was the most costly diet at ¢341.41 per kg. The control diet (F2) was the cheapest at ¢127.24 per kg.

Table 3 shows the means of water temperature and other water quality parameters recorded during the experimental period. The water quality parameters were generally similar for the three treatments, and were within the suitable ranges for tilapia growth (Stickney, 1979). Table 4 summarizes the growth data. Diet F1 showed the highest values for mean final weight, mean net weight gain, and mean daily growth rate; while diet F3 recorded the best FCR. The survival rate was similar for all treatments and ranged between 86.50 and 87.43 per cent, and did not differ significantly between treatments ($P > 0.05$). Mortalities during the experimental period might not be due to differences in treatments because they were mostly experienced a day after sampling. Mortalities might have resulted mostly from handling stress and predation.

Fig. 1 shows the performance of the test fish on the three experimental diets. Growth was good for all the diets containing 15 per cent crude protein (F1 and F3). The control diet (F2), which had 9 per cent crude protein, supported the least weight gain and also the lowest rate of growth. It would seem that the level of protein giving the most optimum growth (F1) would have a better conversion of dietary animal or plant protein into body tissues. However, this was not so in this study. The results did indicate that there was a difference in the conversion rates of fish receiving the different combinations of protein and energy sources. The apparent reason for diet F1 providing the best growth and nearly as much feed conversion efficiency as diet F3 was the high protein and energy contents of the diet (Table 2).

Diet F1 also had the lowest fibre content (13.64 per cent) of the three diets. This could have

TABLE 1

Percentage Composition and Cost of Diets F1 to F3 Used in Feed Trials with Oreochromis niloticus *in 0.2-ha Earthen Ponds*

Feed ingredient	*Percentage content in diet*			*Costs/kg*
	F1	*F2*	*F3*	*(¢)**
Rice bran (RB)	0.0	66.7	51.0	91.40
Wheat bran (WB)	66.7	0.0	0.0	180.00
Groundnut bran (GB)	33.3	33.3	37.0	200.00
Fish meal (FM)	0.0	0.0	12.0	1840.00
Vitamin premix	Trace	Trace	Trace	5000.00
Calculated crude protein (%)	15.0	9.0	15.0	-
Cost of feed/ kg (¢)*	186.60	127.24	341.41	-

Market price during 1998

TABLE 2

Proximate Analysis of Formulated Diets F1 to F3 Used for Feeding Trials with Oreochromis niloticus *for 160 Days*

Parameter	*F1*	*F2*	*F3*
Moisture	5.23	10.05	7.88
Dry matter	94.77	89.95	92.12
Crude protein	15.38	9.07	15.07
Ether extract	9.29	10.05	0.75
Nitrogen-free extract	56.53	38.40	38.33
Crude fibre	13.64	20.23	17.35
Ash	5.65	11.44	10.86
Gross energy (Kj/g)	15.59	11.77	10.02

contributed to easier digestibility of that diet than that of the other diets. The growth performance recorded with diet F1, despite its protein and energy sources, might be because the experimental fish, *Oreochromis niloticus*, is able to use plant protein sources better than carnivorous fishes (Bowen, 1987). Diet F1 also contained relatively very little plant cell material; hence, the energy sources were higly available to the fish to spare the protein. Neil (1961) explained that if there is insufficient energy in the diet, the body will burn protein for energy at the expense of growth and body tissue repair.

Diet F3 recorded the highest relative weight gain (172.55 per cent). The good performance of fish receiving diet F3, which had fish meal as one of its protein sources, might be attributed to enhancement of nutrient utilization due to improvement in the amino acid balance of the protein content of this feed caused by the addition of the fish meal. This might have reduced the quantity of feed required for maximum growth. This might also account for the conversion ratio (3.74) observed. The protein in fish meal is known to have excellent biological value for fish growth (Neuthaus & Halver, 1969). A number of other studies with fish meal-based diets have observed positive correlation between fish meal utilization and growth performance of fish (Ellis & Reigh, 1991; Reigh & Ellis, 1992; Moon & Gatlin, 1994; Gaylord & Gatlin, 1995).

The amount of protein deposited, as shown by carcass analysis (Table 5), supported the conclusion that 15 per cent crude protein level in the diet was the optimum level to feed of the levels tested. However, there was no much diffference

TABLE 3

Mean Values of Physico-chemical Parameters of Pond Water During Experimental Period

Parameter	*Treatment* F1	F2	F3
Temperature (°C)	30.26 ± 0.31*	30.23 ± 0.28	30.24 ± 0.31
*p*H	7.47 ± 0.10	7.38 ± 0.09	7.47 ± 0.13
Dissolved oxygen (mg/l)	4.54 ± 0.48	3.45 ± 0.36	4.50 ± 0.45
Conductivity (µs/cm)	169.92 ± 5.75	152.76 ± 6.76	122.43 ± 4.62
Total dissolved solids (mg/l)	84.80 ± 2.85	76.18 ± 3.42	61.19 ± 2.29
Nitrite (NO_2-N) (mg/l)	0.003 ± 0.002	0.004 ± 0.002	0.015 ± 0.013
Nitrate (NO_3-N) (mg/l)	0.592 ± 0.209	0.604 ± 0.234	0.599 ± 0.252
Ammonia (NH_3-N) (mg/l)	0.510 ± 0.058	0.436 ± 0.029	0.488 ± 0.049
Phosphate (PO_4) (mg/l)	0.321 ± 0.032	0.288 ± 0.023	0.324 ± 0.039
Total alkalinity (as $CaCO_3$) (mg/l)	65.67 ± 2.35	67.44 ± 2.67	49.83 ± 2.07
Total hardness (as $CaCO_3$) (mg/l)	47.56 ± 1.85	51.44 ± 2.12	40.61 ± 2.93

TABLE 4

Summary Results (Means) of Growth Data for Oreochromis niloticus *Fed 160 Days on Diets F1-F3 Formulated Using Local Agro-industrial By-products*

Diet	*Stocking density (m^{-2})*	*Mean initial weight (g)*	*Mean final weight (g)*	*Mean net weight gain (g)*	*Mean daily growth rate (g d^{-1})*	*FCR*	*Relative weight gain (%)*	*Survival (%)*
F1	0.97	91.58	227.95	136.37	0.53	4.20	166.90	87.16
F2	0.95	91.76	188.79	97.03	0.43	4.55	122.40	87.43
F3	0.97	90.70	216.21	125.51	0.51	3.74	172.55	86.50

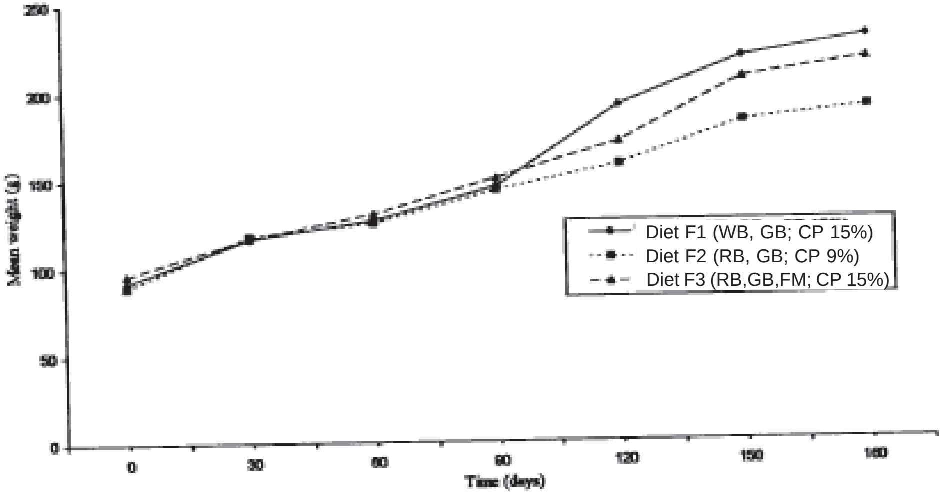

Fig. 1. Performance of *Oreochromis niloticus* fed on three experimental diets after 160 days of treatment.

in the protein levels deposited between diets F1 and F3; both had 15 per cent crude protein levels. The fact that rice bran-based diets (F2 and F3) recorded higher carcass fat deposit after treatment might be due to the high fat contents of the rice bran.

Table 6 shows the economic evaluation of the test diets with reference to profit index and economy of weight gain (Ita & Okeoyo, 1988). Although diet F3, with fish meal as its source of protein, showed the ability to support rapid growth as diet F1, it significantly increased the price of feed required to produce 1 kg of fish to almost twice, and recorded the worst profit index of the three diets tested. Diet F1 gave the highest net profit (¢1.58 million).

Conclusion

Considering the overall performance of the test diets with similar crude protein level of 15 per cent, diet F1 would seem to be the most economical diet which may be recommended for production of tilapia by fish farmers within the country. This study has also shown that the exorbitant price of fish meal (main source of animal protein) has a detrimental effect on the economy of tilapia production. Alternative cheap and cost-effective local sources of protein need to be investigated and incorporated in the formulation of future diets to make tilapia production a profitable venture.

Acknowledgement

The study was financed by the Government of Ghana and the World Bank through the National

TABLE 5

Proximate Analysis of Fresh Samples of Oreochromis niloticus *Before and After Treatment with Three Types of Locally Formulated Diets*

Parameter	*Diet F1*		*F2*		*F3*	
	*BT**	*AT*	*BT*	*AT*	*BT*	*AT*
Moisture (%)	79.80	76.05	81.35	74.92	80.93	74.63
Crude protein (%)	15.04	19.07	14.85	17.87	15.79	18.90
Ether extract (%)	0.68	1.51	1.06	2.91	0.62	3.06
Gross energy (Kj/g)	3.16	4.13	2.26	4.53	3.12	4.73

*BT - Before treatment; AT - After treatment.

TABLE 6

Profit Index and Economy of Weight Gain (EWG) of Three Experimental Diets Used to Feed Fingerlings of Oreochromis niloticus *for 160 Days*

Diet	*Cost of feed consumed (¢)*	*Estimated value of fish crop (¢)**	*Body weight gain (kg)*	*Net profit (¢)*	*Economy of weight gain (EWG)*	*Profit index*
F1	703,108	2,482,600	591.85	1,580,000	1,188	3.53
F2	445,848	2,031,443	428.3	1,390,000	1,041	4.56
F3	1,218,150	2,400,800	605.1	980,000	2,013	1.97

*Total value of big-size tilapia and fingerlings harvested.
Farm gate price of 1 kg of tilapia fingerlings = ¢1000.
Farm gate price of 1 kg of big-size tilapia (approx. 200 g) = ¢3000.

Agricultural Research Programme (NARP). The authors are grateful to Messrs Ken Atsakpo, Justus Teye and Mrs Pat Atsakpo for technical assistance. They would like to thank the fishermen and farm hands at the Aquaculture Research and Development Centre (ARDEC), Akosombo, for their help. Facilities provided by CSIR-ARI are, hereby, acknowledged.

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