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Growth performance, carcass composition and profitability of Nile tilapia (*Oreochromis niloticus* L.) fed commercial and on-farm made fish feed in earthen ponds

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ABSTRACT
Fish feed is the most expensive of all the operational costs in semi-intensive culture of Nile tilapia (*Oreochromis niloticus)* in Kenya. An experiment was conducted to compare growth and economic returns of *O. niloticus* reared on feeds from commercial companies and on farm made fish feeds in Kenya. Two commercial feeds, Uga feed (diet 1), Crop king feed (diet 2) and one on-farm made feed, Bidii feed (diet 3) were tested for six months. Proximate analyses for the crude protein level of the diets were 32.7, 16.0 and 28.0% for diets 1, 2, and 3 respectively. There were significant differences (P<0.05) in mean weights, specific growth rates and feed conversion ratios between diet 1, diet 2 and diet 3. Fish fed on diet 1 grew significantly larger than those fed on diet 2 and diet 3 (P<0.05) with mean weight of 122.47 g. However, fish fed on diet 3 gave the highest (P<0.05) net returns while those on diet 2 had the least net returns. Cost benefit analysis results showed that the on-farm formulated feed, diet 3 was economically viable for semi-intensive system rearing of *O. niloticus.*

Keywords: Diet, growth, protein, net returns

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is the most widely cultured fish among the tilapias [1]. It has an efficient feed conversion ratio, demonstrates fast growth rates and has high tolerance to low water quality, ease of spawning and resistance to disease [1]. Traditionally, *O. niloticus* was cultured in freshwater ponds with low stocking densities and supplemental feeding mainly cereal brans, however; recent intensification of culture practices necessitates the use of well-formulated feeds [2]. Fish feed is widely recognized as the most expensive component among all the operational cost in fish farming [3, 4, 5]. Farm budget analyses show that fish feed constitutes 60-70% of total production costs of *O. niloticus* for small-scale, rural farmers [6]. Much of the costs of fish feed production are due to the extensive use of fish meal in the feed [7, 8, 9].

The growth of the fish farming in Kenya has undergone significant changes since 2009, due to government policies initiated to support the development of aquaculture operations, in order to increase supply of fish for domestic market and to create employment in rural areas [10]. The government invested over 5 billion Kenya Shillings between 2009-2012 towards supporting fish farming under a program called "Fish Farming Enterprise Productivity Program" (FFEPP) [11]. Consequently, the annual production moved from 4,000 MT in 2009 to 22,154 MT in 2012 [1, 12]. The sustained fast growth of the industry resulted in an increased demand for processed fish feeds. Since only one commercial fish feed company existed at the inception of the government funded program [12, 13], the high demand resulted in high cost of commercial feeds for semi intensive farming of *O. niloticus*. To ensure that the fish farming sector continues to grow sustainably, the government through the Ministry of Agriculture, Livestock and Fisheries introduced the cottage feed industry among clusters of farmers to produce on-farm made feeds.

In many countries, where fish farming is conducted at semi- intensive culture level, more than 90% of farmers use on-farm made feeds in order to reduce production cost [14]. The use of nutritionally balanced feeds constitute an unwise use of resources and economically unsound practices in semi-intensive aquaculture where external feed input is expected to supplement natural food production [15, 16]. Therefore, development and management of fish feed play a vital role in aquaculture growth and expansion. In fact, it is a major factor that determines the profitability of aquaculture ventures [17]. The current study was designed to evaluate the effects of commercial diets and cottage, on-farm made diets on growth performance, carcass composition and economic returns of *O. niloticus* cultured under semi-intensive system in earthen ponds.

2. Materials and Methods

2.1 Experimental set-up and dietary treatments

The experiment was conducted at the National Aquaculture Research Development & Training Centre, Sagana (altitude 1230 m above sea level, latitude 0°39´S and longitude 37°12´E). Three dietary treatments were used. These included two commercial feeds: Uga fish feeds (Diet 1), Crop King fish feed (Diet 2) and, on-farm made feed (Bidii fish feeds) (Diet 3). The feeds, Uga, Crop king and Bidii were purchased from the companies' outlets in Nairobi, Nakuru and Luanda towns respectively. Each pond was randomly allocated a particular dietary treatment and each treatment was in triplicate. Each of the feeds was marked 26% crude protein tilapia feed at purchase. Proximate analysis of the feeds was conducted according to the standard methods by Association of Official Analytical Chemists [18]. The composition of experimental diets and their biochemical proximate composition are shown in table 1.

Table 1: Proximate composition of commercial and on-farm made diets

Parameter (% of dry matter)	Diet 1	Diet 2	Diet 3
Dry Matter	88.5	89.2	88.2
Crude protein	32.7	16	28
Crude fat	2.5	6.5	4.1
Total Ash	8.9	11.9	8.1
Fibre	9.5	17.6	8.5
Nitrogen free extracts	34.9	37.2	39.5

The diets were randomly allocated to groups of mixed sex *O. niloticus* fingerlings stocked at rate of 3 fish m^{-2} in nine earthen ponds measuring 150 m^2 each. The average stocking weight in the ponds was 15.25±0.72 g. The experimental fish were acclimatized for two weeks prior to the feeding experiment. They were fed by hand, two times a day at 1000 hrs and 1600 hrs at 3% of body weight. A group of 30 fish was sampled from each pond monthly to monitor growth and adjust feed rations. The experiment was carried out for a period of six months.

2.2 Pond and water quality management

Before stocking of the fish, ponds were limed at the rate of 2500 kg ha^{-1} with $CaCO_3$ and fertilized at a rate of 20 kg N and 8 kg P ha^{-1} with Urea and diammonium phosphate (DAP), respectively. Water quality was assessed weekly by measuring temperature, pH, dissolved oxygen (DO), Total Ammonia Nitrogen (TAN), Total nitrogen (TN), Total phosphorus (TP), Nitrates (NO_2), and Nitrites (NO_3) at 9.30 am. Dissolved oxygen, pH, and temperature were measured using multi-parameter water quality meter, model H19828 (Hanna Instruments Ltd., Chicago, IL., USA), while NH_4-N, TN, TP, NO_3, and NO_2, were determined using standard laboratory water quality analysis methods [19].

2.3 Carcass composition analysis

Samples of eight fish were taken at the times of stocking and harvest for the initial and final proximate carcass analyses respectively. The proximate analysis was carried out according to the standard methods [18]. The following nutrients were analysed: crude protein (CP), ether extract (EE), ash, nitrogen free extracts (NfE), and crude fibre (CF). Crude protein was estimated from Kjeldahl nitrogen, while crude lipid was quantified through the loss in weight after extraction of the sample with petroleum ether (40-60 °C). Ash was determined by burning dry samples in a muffle furnace at 550 °C for 4 hours. Crude fibre was determined by alkaline/acid digestion, followed by ashing of the dry residue at 550 °C in a muffle furnace for 4 hours. NfE was determined by the difference method (DM-CP-EE-CF-Ash).

2.4 Evaluation of dietary performance

At the end of the study, all fish from the ponds were harvested, measured for total length, counted and weighed. Growth performance of the experimental diets was evaluated by measuring final harvest mean weight, weight gain, specific growth rate (SGR) and feed conversion ratio (FCR). The following formulae were used for the calculation according to Ricker [20].

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

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

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

Net fish yield = total weight of fish at harvest– total weight of fish at stocking..4

2.5 Economic analysis

Partial enterprises budgets were used to evaluate the economic performance of each dietary treatment. Variable costs included the cost of labour, fertilizers, feeds and fingerlings. The prices of the feeds were based on the retail prices of the feeds at the feed companies. Labour costs were based on the prevailing rates at Sagana town and its environs. The US dollar exchange rate against Kenya shillings was pegged at Ksh 83.00. The following information was used for the partial enterprise budget analysis of each dietary treatment.

2.5.1 Input expenditure

- *Oreochromis niloticus* fingerlings @ Kshs 7 × 450 per pond = Ksh 3150 per pond.
- Cost of Feed (Uga feed-Diet 1) @ Kshs 75×80 Kg^{-1} = Ksh 6000 per respective pond.
- Cost of Feed (Crop king feed-Diet 2) @ Kshs 75×66.67. Kg^{-1} = Ksh 5000 per respective pond.
- Cost of Feed (Bidii feed-Diet 3) @ Kshs 70×70 Kg^{-1} = Ksh 4900 per respective pond.
- Cost of fertilizer @Kshs 65×1 Kg^{-1} = Ksh 65 per pond.
- Cost of lime @ Kshs 5×60 Kg^{-1} = Ksh 300 per pond.
- Cost of feeding fish and pond management @ Ksh 2800 per month per pond.
- Cost of packaging fish @ Ksh 25 Kg^{-1} of fish harvested.
- Cost of transporting fish @ Ksh 25 Kg^{-1} of fish harvested.

2.5.2 Income from the fish yield at harvest

Fish harvested from each pond were summed up for each of the dietary treatments and were sold at US$ 4.22 Kg^{-1} which was the prevailing market price for 1 Kg of body weight of fresh gutted tilapia.

2.6 Statistical analysis

Results were expressed as means ± SE. Data were subjected to a one-way analysis of variance (ANOVA) and subsequent comparison of means was performed using Tukey's multiple range tests. All the statistical analyses were done using SPSS statistical software (Version 17.0 for Windows). Differences were considered statistically significant at $P<0.05$ [21].

3. Results

3.1 Growth performance

The overall values of growth performance (in terms of final mean weight, weight gain and SGR) are shown in table 2. Among the three treatments, fish fed diet 1 showed the highest growth performance followed by fish fed diet 3. In nutrient utilization, there was a significant difference ($P<0.05$) in the FCR of the different diets, which were between 1.66 and 2.15. Growth performance was significantly affected by the type of diet fed ($P<0.05$). Highest final mean weight, weight gain and SGR were obtained in fish fed diet 1. Trend curves for growth of *O. niloticus* under different diet treatments for the entire growth period are shown in figure 1. The growth of fish fed diet 1 was higher than fish fed on diet 2 and diet 3.

Table 2: Growth performance of *O. niloticus* fed on commercially and on-farm made diets.

Variable	Treatments		
	Diet 1	**Diet 2**	**Diet 3**
Initial length (cm $fish^{-1}$)	$9.13±0.14^{a}$	$9.13±0.14^{a}$	$9.13±0.14^{a}$
Initial weight (g $fish^{-1}$)	$15.25±0.72^{a}$	$15.25±0.72^{a}$	$15.25±0.72^{a}$
Final length (cm $fish^{-1}$)	$18.72±0.24^{a}$	$16.66±0.24^{b}$	$17.95±0.23^{b}$
Final weight (g $fish^{-1}$)	$122.47±2.54^{a}$	$84.09±2.09^{b}$	$104.95±2.20^{c}$
Mean gross yield (Kg)	$45.84±5.52^{a}$	$35.57±0.75^{b}$	$45.37±2.63^{c}$
Mean net fish yield (Kg)	$38.98±0.01^{a}$	$28.71±0.03^{b}$	$38.51±0.03^{a}$
SGR (% day^{-1})	$1.25±0.02^{a}$	$1.01±0.02^{b}$	$1.16±0.01^{c}$
Weight gain	$107.22±0.02^{a}$	$68.84±0.02^{b}$	$89.70±0.02^{c}$
FCR	$1.66±0.02^{a}$	$2.15±0.00^{b}$	$1.73±0.02^{a}$
Condition factor	$1.81±0.02^{a}$	$1.72±0.02^{b}$	$1.76±0.02^{b}$
Proportion of males (%)	$42±0.00^{a}$	$56±0.00^{b}$	$68±0.00^{c}$

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

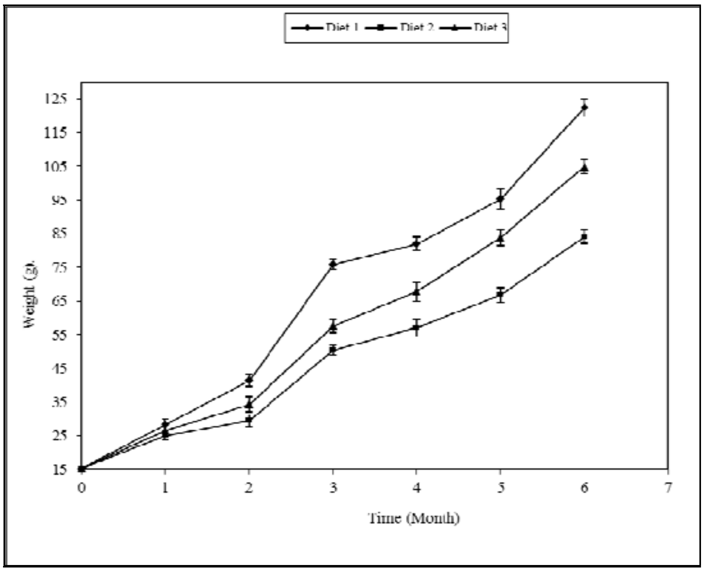

Fig 1: Growth in weight (±SE) of *O. niloticus* fed on commercially and on-farm formulated diet.

3.2 Water quality
The means and standard errors of different water quality parameters in each of the experimental diets are shown in table 3. There were no significant differences among treatments in all the water quality parameters measured (P>0.05). All the water quality parameters were within the acceptable ranges for tilapia growth in ponds [19].

Table 3: Water quality parameters measured in ponds of *O. niloticus* fed on commercial and on farm made diets

Parameter	Treatments		
	Diet 1	Diet 2	Diet 3
Dissolve oxygen (mg L $^{-1}$)	4.47±0.24^{a}	4.45±0.23^{a}	4.41±0.22^{a}
Temperature (°C)	25.18±0.38^{b}	24.60±0.25^{b}	24.66±0.34^{b}
pH	7.75±0.07^{c}	7.66±0.08^{c}	7.63±0.60^{c}
TAN (mg L $^{-1}$)	0.16±0.02^{d}	0.14±0.02^{d}	0.15±0.02^{d}
TN (mg L $^{-1}$)	1.64±0.19^{e}	1.63±0.17^{e}	1.59±0.17^{e}
TP (mg L $^{-1}$)	0.39±0.01^{f}	0.37±0.11^{f}	0.36±0.11^{f}
Nitrates (mg L $^{-1}$)	0.03±0.00^{g}	0.02±0.00^{g}	0.01±0.00^{g}
Nitrites (mg L $^{-1}$)	0.01±0.00^{h}	0.00±0.00^{h}	0.01±0.00^{h}
Alkalinity (mg L $^{-1}$)	37.04±1.27^{i}	35.04±1.07^{i}	39.04±1.62^{i}

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

3.3 Whole body carcass composition
The initial and final mean body compositions of Nile tilapia fed on various diets (diet 1, 2 and 3) are presented in table 4. Crude fat content was highest in fish fed diet 2 (8.1±0.40) and lowest in fish fed diet 1 (7.4±0.24). There was a significant difference (P<0.05) in crude fat content between fish fed diet 1 and those fed diet 2 and diet 3. In general, the final fibre contents in the harvested fish were markedly lower than the initial fibre content of the fish. On the other hand, final ash contents of fish for all the feeds were lower than the initial content and was not affected (P>0.05) by the diet fed.

Table 4: Carcass proximate composition of *O. niloticus* fed on commercially and on-farm made diets.

Chemical analysis (% of dry matter)	Initial value	Value after feeding different diets		
		Diet 1	Diet 2	Diet 3
Moisture	50.4±0.14	45.1±0.20^{a}	45.2±0.12^{a}	53.8±0.19^{b}
Crude protein	30.5±0.10	39.6±0.14^{a}	30.1±0.50^{b}	38.1±0.14^{c}
Crude fat	5.8±0.24	7.4±0.24^{a}	8.1±0.40^{b}	8.0±0.18^{b}
Fibre	9.3±0.15	6.7±0.22^{a}	6.1±0.24^{b}	6.3±0.21^{c}
Total ash	4.0±0.18	3.6±0.01^{a}	3.7±0.04^{a}	3.7±0.05^{a}

* Values are expressed as mean± SE. Values in the same row having different superscript letters are significantly different (P<0.05). Comparisons were made between dietary treatments and excluded the initial values.

3.4 Economic analysis
Fish yield under different diets and the partial enterprise budget for different treatments is provided in table 5. Highest fish yield was obtained when feeding diet 1 followed by diet 3 (P<0.05). The lowest total fish yields occurred in treatments with diet 2.

Table 5: Partial enterprise budget analysis per pond of commercial and on-farm made diets for production of *O. niloticus* based on selling price of US $4.22

Parameters	Unit	Diet 1	Diet 2	Diet 3
Gross revenue	US $)	193.30±0.24^{a}	149.99±0.33^{b}	191.32±0.27^{c}
Variable cost	US $)	107.83±0.31^{a}	93.98±0.17^{b}	93.98±0.18^{b}
Returns above variable cost	US $)	85.47±0.28^{a}	56.02±0.24^{b}	97.34±0.26^{c}
Fixed costs	US $)	1.81±0.03^{a}	1.81±0.03^{a}	1.81±0.03^{a}
Total costs	US $)	109.64±0.28^{a}	95.79±0.30^{b}	95.78±0.31^{b}
Net return above total cost	US $)	83.66±0.22^{a}	54.21±0.27^{b}	95.54±0.28^{c}
Yield (Kg)	Kg	45.84±0.34^{a}	35.57±0.38^{b}	45.37±0.32^{c}
Unit selling price	US $)	4.22±0.00^{a}	4.22±0.00^{a}	4.22±0.00^{a}
Breakeven price (total cost)	US $)	4.09±0.00^{a}	4.84±0.00^{b}	3.55±0.00^{c}

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

The total investment and operational costs were significantly (P<0.05) higher in diet 1 compared to diet 2 and 3 (table 5). There was a positive net return for all the treatments. Net returns above both the total and variable cost were significantly (P<0.05) better in fish fed diet 3. The break-even price in diets 1 and 3 were below the selling price of fish locally (US $ 4.22) with diet 3 registering the lowest break-even price. However, for diet 2, the breakeven price was higher than the prevailing market price.

4. Discussion

Results from proximate analysis and feeding trials in the present study demonstrate that the test-diets (1, 2 and 3) differed both in nutritional quality and efficiency in promoting the growth of *O. niloticus.* Although at purchase all the feeds were marked to contain 26% crude protein, proximate analysis indicated that diets 1, 2 and 3 had crude protein levels of 32.7%, 16% and 28% respectively. The difference between the analyzed value and the indicated value of crude protein in the diets could be an indication of lack of proper proximate analysis of ingredients before feed formulation and production. Variations in feed ingredients might occur due to regionalism and seasonality in availability of the ingredients [13]. Feed producers should therefore carry out routine proximate analyses when a new batch of fish feed ingredients is procured. The high protein in diet 1 and diet 3 resulted in fast growth and higher net fish yields from fish fed on diet 1 and diet 3 and are in agreement with other studies which recommend a protein level of 25-35% protein level for fast growth and profit of Nile tilapia production [22, 23]. It has also been reported that the growth of fish containing mixed rations, depends on the nutrient composition of the individual feed components and the ability of the animal to digest and absorb the combined nutrients [24].

Feed conversion ratio (FCR) is an important indicator of the quality of fish feed, a lower FCR indicate better utilization of the fish feed [25]. The low FCR of 1.66 exhibited in fish fed diet 1 is an indicator that the fish utilized the feed well. The current FCR values coincided with ranges reported for *O. niloticus* ranging from 1.43 to 2.30 [26, 27, 28] but were lower than the FCR of 2.6 to 3.0 in tilapia fed on on-farm formulated diets in fertilized ponds [29]. It is reported that high fibre and ash content reduces the digestibility of other ingredients in the diet leading to low feed palatability and poor fish growth [30, 31]. In the present study, proximate analysis of the diets indicated that the diet 2 had highest ash and fibre content and could have been the cause of the low growth recorded in fish fed diet 2.

Whole body composition of the fish at harvest indicated that the crude fat contents of the harvested Nile tilapia fed diet 2 were higher than those fed diet 1 and 3. This is consistent with higher lipid level reported in fish fed low protein diets [32] and could be attributed to the utilization capability of high dietary carbohydrate by Nile tilapia. A higher lipid composition was reported in the body of Nile tilapia fed on a higher dietary carbohydrate regime [33]. The ash content was not affected by the diets which contained different protein levels. Similar observations have been reported for Nile tilapia cultured in ponds in Abbassa, Egypt [27].

The economic analysis in the present study indicates positive net returns for all the diets. Although net returns were positive for all the diets, there were significant differences in economic returns among the diets with diet 3 being most profitable. This is in agreement with other studies which indicated that on-farm made diets were cost-effective in the production of *O. niloticus* in semi-intensive fertilized ponds [17, 29]. Despite the similarity in fish yields in diet 1 and diet 3, the net economic returns were significantly higher in diet 3 resulting in higher profits margins. The lower profit in diet 1 is likely to be due to higher cost of the feed without commensurate increase in yields when compared to diet 3.

5. Conclusion

The results of the present study have shown that on-farm made diet is cost effective and can boost growth of aquaculture in rural areas which form over 80% of semi-intensive aquaculture in Kenya. It also agrees with other studies, which indicate that local production of fish feed is very crucial to the development and sustainability of aquaculture in sub-Saharan Africa. In conclusion, the results of the present study revealed that cottage; on-farm made feeds are economically sustainable and suitable for production of *O. niloticus* in a semi intensive system.

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