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Growth parameters and economics of tilapia cage culture using two commercial fish diets

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Abstract

Two commercial aquaculture feed diets available on the Ghanaian market was subjected to daily feeding of Oreochromis niloticus and growth parameters and economic profitability evaluated in a 66.67 m^3 cages. The 12 week trial performed using 16,000 fish with mean weight 102.17 ± 3.1 g was sampled, counted and divided equally to four cages. The two test diets (Diet I: Nicoluzzi and Diet II: Rannan) were in duplicate. Mean live weights of fish in trial groups reached 420.23 ± 20.44 g and 408.62 ± 54.31 g for test Diets I and II respectively. Growth data indicated that, the final live weight, average daily weight gain, condition factor showed no significant difference among test diets ($p > 0.05$). The best FCR of 1.47 was obtained from test Diet I. Specific growth rate also showed similar values. High gross and net yield was recorded for fishes fed with Diet I and could be due to their relatively good growth performance, good feed conversion rate, relatively high survival rate which, in turn, gave high profit index of 1.87. The total feed fed to fish allotted Diet II was high which reflected in the total cost of feed, coupled with the high price of feed per kilo. This increased the cost of production (in Diet II cages) affected the profit index (1.76) generated from the sale of fish although not significant from fish fed Diet I. The results suggest that, both test diets with almost similar crude protein level, is economical and may be recommended for production. However, alternative source of cheap and cost effective feeds needs to be investigated and encourage our local industry in the production of relatively cheaper aquaculture feeds.

Keywords: Akosombo strain, Treatment diets, Proximate composition, Profit index

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1. Introduction

The aquaculture industry continues to grow more rapidly than all other animal food-producing sectors in many countries of the world, with the world average annual growth rate for the world of 8.8% per year since 1970, compared with only 1.2% for capture fisheries and 2.8% for terrestrial farmed animal production systems (FAO, 2006).

The Nile tilapia, *Oreochromis niloticus* is one of the most important freshwater fish in world aquaculture. It is widely cultured in many tropical and subtropical countries of the world. Rapid growth rates, high tolerance to adverse environmental conditions, efficient feed conversion, ease of spawning, resistance disease and good consumer acceptance make it a suitable fish for culture. Shelton (2002) describe the fish as currently being ranked second only to carps in global production, hence gaining popularity among the fish farmers as a readily available source of animal protein in the diets of rural and urban dwellers especially those belonging to the lower socio-economic strata.

The culture practices of tilapia can be extensive, semi-intensive and intensive. There has been a gradual shift in tilapia culture from traditional semi-intensive to non-traditional intensive farm systems. But, deciding the optimal culture method for tilapia farming can be quite complex. Cage culturing makes it possible to grow tilapia in water bodies where draining and seining would be difficult or impossible. Cages are for instance utilized in lakes, large reservoirs and rivers.

Tilapia culture in cages for the past decade is gaining prominence in Ghana (FAO, 2005); however it is being faced with a number of challenges which includes, land, water, feed, capital. Feed which accounts for about 30-60% of production cost has often left production at a standstill (De Silva and Anderson, 1995). Since feed is vital in operating intensive culture systems (Anderson et al., 1997), the economic viability of the culture operation depends on the feed and feeding frequency.

Obtaining high quality locally manufactured feed is the most serious constraint to commercial cage farming especially in Ghana. Local extruded feeds are not readily available. Most farmers (pond based) make their own moist sinking feed on site (Blow and Leonard, 2007). Cage farmers often rely on imports of high-quality extruded feed from Europe and Asia which often increase the cost of production.

There are a few numbers of imported feeds with different crude protein levels on the Ghanaian market these days which comes with its associated cost. Currently (as at August, 2011), there are two major feeds available for use by farmers, namely: Nicoluzzi (from Brazil) and Rannan (from Isreal). The choice of feed is a determining factor for successful cage farming. This study aims at generating information on production parameters and profitability in using commercial feeds in cage culture.

2. Methodology

2.1. Study area

The study was conducted at the Aquaculture Research and Development Centre (ARDEC) at Akosombo, Ghana, between August and October, 2011. Fingerlings of improved "Generation 6" *'Akosombo strain'*

Oreochromis niloticus were used for the feed trial. The fingerlings were originally stocked in 0.2 hectre ponds from post-hormonal treatment stage (0.5 g) at a rate of 4 fish per metre square and fed on an 'on-station' feed for four months.

2.2. Culture system and fish stocking

Four cages of size 66.67 m^3 each used were constructed using galvanized pipes welded into a cage frame and floated on the river using rubber drums. The inner netting (1 inch) and outer netting (2.0 inches) were securely fixed in and out of the cages respectively on the Volta Lake. The cages were anchored to prevent it from drifting by the current from its original position.

Fish were acclimatized to the conditions prevalent in the river prior to stocking in the trial cages. Nile tilapia of average size 102.17 ± 3.1 g harvested from the ponds were stocked in the cages (4,000 fish per cage) with each commercial diet being duplicated. Fish ranged in size from 93.8 g to 110.4 g at stocking. The used stocking density was 60 fish per cubic metre. The initial standard and total lengths of the fishes were measured to the nearest ± 0.1 cm using a fish measuring board. Their various weights were also taken to the nearest ±1.0 g using a weighing balance for each treatment before stocking.

2.3. Feeding regime and fish sampling

Two different treatment diets with the brand name: Nicoluzzi (Diet I) and Raanan (Diet II) with similar crude protein level 32% and 33% respectively, purchased from the local industrial market were fed to the fish. Cages were selected randomly for the two feed types.

The fish were fed trice (8.30 am, 12.00 pm and 4.00 pm) a day at an initial rate of 4% of body weight with the respective floating pelletized feed types and adjusted to 3% and 2.5% towards the end of the culture period. The amounts of feed in respective feed types were determined through the sampling that was carried out biweekly throughout the culture period to monitor growth performance. At least 50 fish in each cage were randomly sampled on a biweekly basis by partially lifting the cage netting and removing fish with a dip net. The cage nets were cleaned twice a week.

2.4. Proximate analysis of feed

Proximate compositions of the commercial feeds as carried out by TICOMFFE Project, (2011) using AOAC (1990) standard methods for various nutritional components, which included: moisture, crude protein, crude lipid, crude fibre, and ash were compared with what was provided by the manufacturers.

2.5. Determination of water quality

The water quality measurements and sample collection were made between 8.00 am and 9.00 am on each sampling day. Water samples picked at three locations (before, in and out of cage) of the cage were pooled before analysis. Water quality parameters like temperature (Celsius thermometer), Dissolved oxygen (WTM

Inolab Oxi Level 2 Oxygen metre), pH (Suntex Model SP-701 pH metre), conductivity, total alkalinity and hardness (Secchi Disc) were monitored on weekly basis. Nutrients such as ammonia, nitrite, nitrate and phosphate were analyzed at 21 days intervals at the laboratory using the visible spectrophotometre.

2.6. Fish harvest

At the end of the study, all experimental cages were emptied and fish in each cage graded, counted and weighed to determine average fish weight and survival. Production input costs were recorded throughout the trial and net income and return on investment calculated at the end of the trial.

2.7. Growth and yield analysis

Specific Growth Rate, SGR

The specific growth rate for each treatment group was calculated as:

$SGR = (\ln W_f - \ln W_i \times 100) / t$,

where, $\ln W_f$ = the natural logarithm of the mean final weight (g), $\ln W_i$ = the natural logarithm of the mean initial weight (g), t = time (days) between $\ln W_f$ and $\ln W_i$ (Ricker, 1975).

Condition Factor, K

The condition factor was calculated as:

$K = BW / SL^3$, (Tesch, 1971; Weatherley, 1972), where K = condition factor, BW = body weight of fish (g), SL = standard length of fish (cm).

Food Conversion Ratio, FCR

The food conversion ratio was then calculated as: FCR = dry weight of feed consumed (g) / wet weight gain (g), (Castell and Tiews, 1980).

Mean Daily Weight Gain

This was calculated as $Wf - Wi / t$, where Wf is the final weight at harvest, Wi is the initial weight at stocking and t, the duration of culture.

Relative Weight Gain, (RWG %)

This was calculated as, $(Wf - Wi) * 100 / Wf$

Gross and Net Yield

The gross yield was calculated as the product of the average final weight and the total number of survivors. The net yield was estimated as the biomass harvested minus the biomass stocked. It is expressed in kilograms (Mohammed et al., 2006).

2.8. Profitability analysis

A simple economic analysis was developed to estimate the profitability in each treatment. The cost of feed, fingerlings and total revenue generated from harvest were estimated

Economy of Weight Gain (EWG)

It was calculated as cost of feed consumed / weight gain (Ita and Okeoye, 1988).

Profit Index = value of fish crop / total cost of feed (Ita and Okeoye, 1988).

2.9. Data analyses

Data gathered on both fish morphometry and water quality were assembled and fed into a computer from which statistical analyses were performed using Graphpad Instat software programme (Graphpad Software, 1993) and Microsoft excel programme when appropriate. Statistical analyses done through analysis of variance with Tukey-Kramer multiple range tests, for samples of 50 observations. The standard deviation in each growth parameter and treatment was calculated and expressed as mean ± SD.

The differences between the observed and expected crude protein levels of the test diets were subjected to significance testing using the Chi-Square test. This was to determine whether the observed differences were significantly different from the expected.

3. Results

3.1. Treatment diet

Table 1 shows the proximate composition and analyses carried on the experimental diets. The values represent the percentage contributions obtained as indicated in the commercial diets.

The calculated protein levels in Diet I and II were 33.68% and 32.79% respectively, which was higher in Diet I and lower in Diet II as analyzed by the manufacturer. Although the two diets have different protein levels as provided by the manufacturer, its difference is not significant at $p > 0.05$. The moisture content analyzed was almost similar, however, the fibre content analyzed was high in Diet II (5.1%) than in Diet I (2.3%).

The chi-square formula used for the analysis (Montgomery, 1984)

$$X^2 = \frac{\sum (O - E)^2}{E}$$

where o and e represent the observed and expected values respectively.

$X^2_{tab} = \alpha\ 0.05, 1\ (df) = 3.841$ (critical value for accepting ho)

Table 2 above shows a chi-square test analysis for the crude protein levels for the test diets. By comparing the calculated chi-square value (x^2_{cal}) of 0.091 to the critical value (x^2_{tab} α 0.05, 1) of 3.841 the differences between the observed and expected crude protein levels of the prepared diets were not significant.

Table 1. Proximate composition of experimental diets analyses

PARAMETER	DIET I		DIET II	
	Manufacturer	Analyzed	Manufacturer	Analyzed
Moisture (%)	12.5	9	9.5	8.6
Crude protein (%)	32	33.68	33	32.79
Ash (%)	13	10.62	7.7	8.16
Crude fibre (%)	4.5	2.3	5	5.1
Fat (%)	6.5	-	6	-

Table 2. Chi-square test analysis for crude protein levels in test diets

TEST DIET	(O)	(E)	(O-E)	$(O-E)^2$	X^2
Diet I	33.68	32	1.68	2.82	0.09
Diet II	32.79	33	-0.21	0.044	0.001
Total	**66.47**	**65**	**1.47**	**2.864**	**0.091**

3.2. Fish growth parameters

Table 3 shows the growth evaluation of the fish fed under the two treatment diets. The mean final weight of the fish increased to about 420.23 ± 20.44 g and 408.62 ± 54.31 g in treatment diets I and II respectively from the initial value of about 102.17 ± 3.1 g. Although no significant differences were observed (at $p > 0.05$) in the growth parameters evaluated, the highest growth rate was observed in the fish fed with treatment Diet I (420.23 ± 20.44 g), with a mean relative weight gain of 59.11 ± 1.00%. The mean relative weight gains as well as the average daily weight gain for fish in the two dietary treatments were similar. Condition factor, which shows the physiological well-being of the fish although not significantly different from each other, was high in fish fed with treatment Diet II (4.04 ± 0.08) than in Diet I.

The FCR recorded was relatively high in fish fed with treatment Diet II with an average of 1.61 ± 0.03. Specific growth rates (SGR) exhibited some similarities with overall mean values of 1.137 and 1.116 in Diets I and II respectively (Table 3). The growth data clearly indicated that the final live weight and SGR values of fish fed with Diets I and II were not significantly different from each other ($p < 0.05$).

Table 3. Comparative account of growth parameters under the two treatment diets

GROWTH PARAMETER	DIET I	DIET II
Initial Mean Weight (G)	*103.72 ± 4.13	100.62 ± 6.02
Final Mean Weight (G)	420.23 ± 20.44[A]	408.62 ± 54.31[A]
Initial Av. Condition Factor, K	3.61 ± 0.14[A]	3.34 ± 0.13[A]
Final Av. Condition Factor, K	3.79 ± 0.03[A]	4.04 ± 0.08[A]
Mean Relative Weight Gain (%)	59.11 ± 1.00[A]	59.04 ± 0.92[A]
Average Daily Weight Gain (G)	2.41 ± 0.16[A]	2.34 ± 0.27[A]
Specific Growth Rate, SGR	1.137± 0.004[A]	1.116 ± 0.028[A]
Feed Conversion Ratio, FCR	1.47 ± 0.01[A]	1.61 ± 0.03[A]

*mean ± standard deviation, [a] = no significant difference

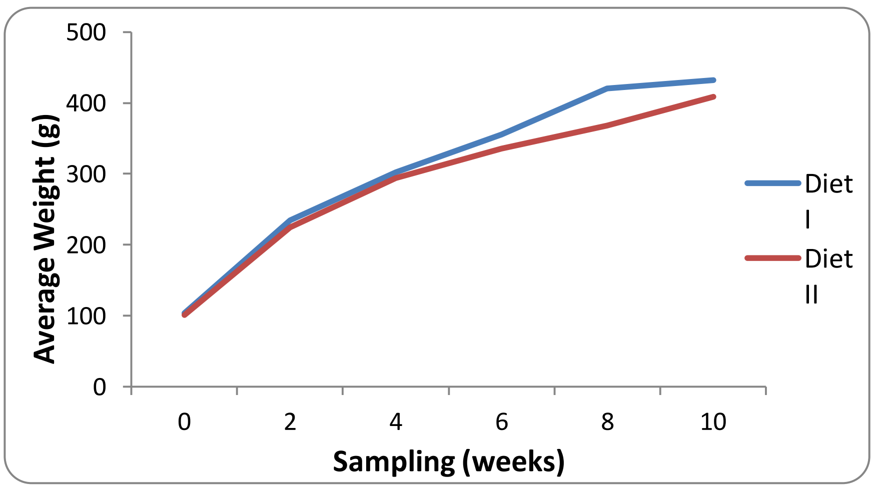

Figure 1. Graph of average weight of *o. Niloticus* fed with test diets i and ii

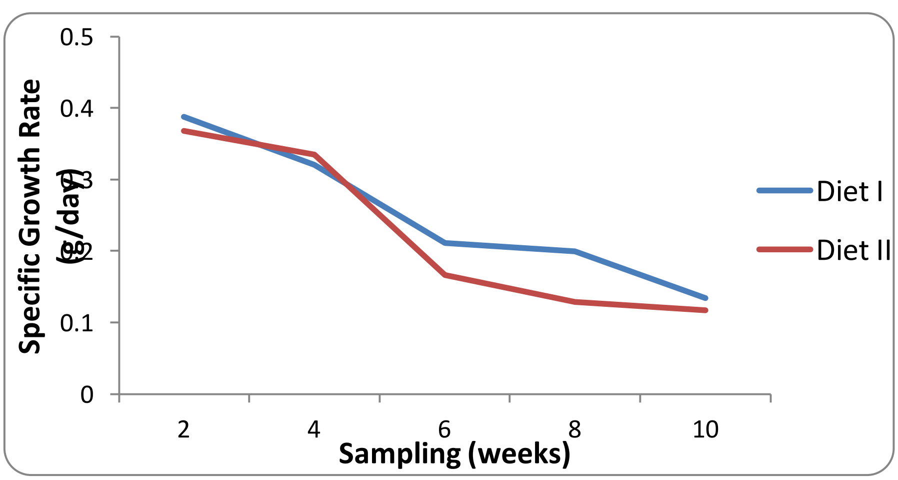

Figure 2. graph of specific growth rate of *o. Niloticus* fed with test diets i and ii

The figures above, 1 and 2 shows a graphical representation of the average weight and specific growth rates of fish fed with the test diets. The graph of average weight of fish showed similar trend with slight variation in the specific growth rate although not significant from each other.

3.3. Water quality parameters

The water quality parameters reflected the environmental conditions under which the fish were cultured during the study. A summary of mean values of water quality parameters measured in the treatment cages during the experimental period are presented in Table 4.

All parameters measured did not differ significantly (at $p > 0.05$) from each treatment and were all within the optimal rage for tilapia growth (Boyd, 1982).

Table 4. Mean values of physico-chemical parameters of experimental cages during the culture period

WATER PARAMETER	DIET I	DIET II
Temperature (°C)	*27.8 ± 0.08^{A}	27.9 ± 0.14^{A}
pH (pH unit)	7.2 ± 0.18^{A}	7.1 ± 0.12^{A}
Dissolved Oxygen (mg/l)	4.37 ± 0.54^{A}	4.63 ± 0.17^{A}
Total Dissolved Solids (mg/l)	30.8 ± 0.16^{A}	30.9 ± 0.21^{A}
Conductivity (µS/cm)	61.5 ± 0.27^{A}	61.7 ± 0.41^{A}
Nitrite (NO_2-N) (mg/l)	0.002 ± 0.0002	0.002 ± 0.0002
Nitrate (NO_3-N) (mg/l)	0.16 ± 0.006^{A}	0.19 ± 0.007^{A}
Ammonia (NH_4-N) (mg/l)	0.02 ± 0.005	0.02 ± 0.003
Phosphate (PO_4-P) (mg/l)	0.01 ± 0.002	0.01 ± 0.001
Total Alkalinity (as $CaCO_3$) (mg/l)	28.1 ± 0.24^{A}	27.7 ± 0.14^{A}
Total Hardness (as $CaCO_3$) (mg/l)	26.7 ± 0.76^{A}	25.7 ± 0.44^{A}

*mean ± standard error, a = no significant difference

3.4. Yield Characteristics

Table 5 shows the yield obtained from the cages under the two treatment diets. Biomass harvested from fish fed with Diet I was higher (1306.8 ± 22.63 kg) than fish fed with Diet II (1271.41 ± 91.97 kg) hence a high net yield of 891.92 ± 6.11 kg.

Total recovery of fish from cages fed with Diet I was high (3491 ± 43.24) with a survival rate of 87.28 ± 6.08% whiles recovery from Diet II was low at 3175 ± 32.53 with a survival rate of 79.38 ± 0.81% without any significant difference. No significant difference also exited in the yield characteristics in fish among the two treatment diets, although by direct observation, yield was high in fish fed with Diet I.

Table 5. Results of yield characteristics of the two treatment diets

YIELD CHARACTERISTICS	DIET I	DIET II
Stocking Density	4000	4000
Stocking Rate (fish/m³)	60	60
Biomass Stocked (kg)	414.88 ± 16.52^{A}	402.48 ± 104.09^{A}
Biomass Harvested (kg)	1306.8 ± 22.63^{A}	1271.41 ± 91.97^{A}
Gross Yield (kg)	1464.54 ± 30.88^{A}	1306.77 ± 73.67^{A}
Net Yield (kg)	891.92 ± 6.11^{A}	868.93 ± 12.11^{A}
Total Recovery	3491 ± 43.24^{A}	3175 ± 32.53^{A}
Survival (%)	87.28 ± 6.08^{A}	79.38 ± 0.81^{A}
Mortality Rate (%)	12.73 ± 6.08	20.63 ± 0.81

*mean ± standard deviation, ^{a} = no significant difference

A graphical presentation of the biomass harvested, average weight and feed used in the two test diets is shown in Fig. 3. The relation between these parameters is similar and not significant from each other.

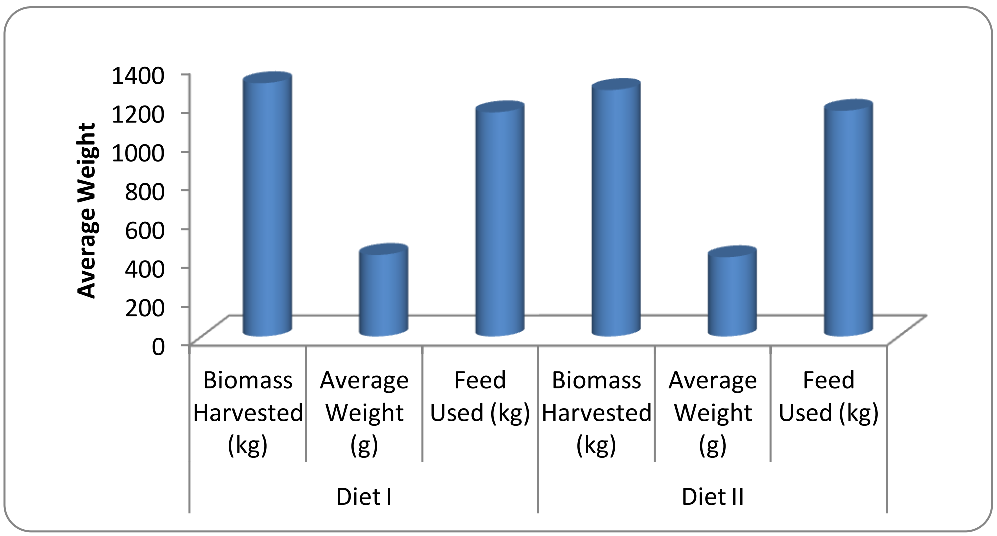

Figure 3. Bar chart showing the biomass harvested, average weight and total feed applied to fish under the two test diets

3.5. Economic profitability

Table 6. Comparison of the cost-benefit analysis of the two commercial diets

ECONOMIC PARAMETERS	DIET I	DIET II
Prize of Fingerling (GH¢)	0.5	0.5
Cost of Fingerlings (GH¢)	2000	2000
Prize of Feed/Kg (GH¢)	1.88	1.90
Total Feed Fed (KG)	1920.99 ± 20.72	2046.97 ± 49.43
Total Cost of Feed (GH¢)	3611.46 ± 38.95	3889.24 ± 93.91
Value of Fish Crop (GH¢)	6852.36 ± 710.88	6749.97 ± 102.23
Profit (GH¢)	1138.51 ± 63.29	963.12 ± 616.96
Profit Index	1.87 ± 0.01	1.76 ± 0.19
Economy of Weight Gain (KG)	2.76 ± 0.01	3.06 ± 0.06

*mean ± standard deviation

Table 6 shows the economic profitability in using the two commercial fish diet for the cage culture of the Nile tilapia. The price per kilogram of Diet I and II was GH¢ 1.88 and GH¢ 1.90 respectively. Total feed applied in both treatments was high in fish fed with Diet II (2046.97 kg), hence the high cost of feed (GH¢ 3889.24).

The revenue realized from the sales of fish was low in fish fed with Diet II with an amount of GH¢ 6749.97 and a high economy of weight gain of 3.06 which suggest that a greater percentage of the fish fell below 350 g. This affected the profit index (1.76).

4. Discussion

Tilapia has good potential for the enhancement of production in the fishery sector in Ghana but considerable research is required to adopt different techniques of tilapia culture especially with feeds that are practiced in other countries. In many African countries, feed quality, availability and cost constitute a constraint to the development of the practice (FAO, 2006b).

In the study, feeds applied were physically stable in the water. The protein requirement and feed size used just match the fish size suitably and may be considered quantitatively complete to meet the requirements of fish in culture. Many studies have indicated that protein requirement for maximum performance of tilapia during larval stages is relatively high (35 - >50%), and decreases with increasing fish size (Jauncey and Ross, 1982; Siddiqui et al., 1988; El-Sayed and Teshima, 1992). For tilapia juveniles, the protein requirement ranges from 30-40%, while adult tilapias require 20-30% dietary protein for optimum performance (Al Hafedh, 1999; De Silva and Radampola, 1990).

Experimental fish grew differently from each other, although not significant on the fed treatment diets, which could be attributed to a number of reasons. The observed differences in growth could be due to a combination of factors involving diet, water quality and density of fish at the end of experimentation.

The observed crude protein levels (analyzed) were approximately 34% and 33% in Diets I and II respectively. These were found to be higher in Diet I and approximate in Diet II as stated by the manufacturer. The differences between the observed and expected crude protein levels were not significant (at $p > 0.05$). A possible explanation of the observed differences could be that, the crude protein levels of feedstuffs were approximations and not true values as also reported by Chow et al., (1980) and may also be due to errors encountered during the proximate analysis determination.

All the water quality parameters were within the acceptable ranges as recommended for tropical aquaculture (Boyd, 1982; Beveridge, 1996).

Fish fed with Diet I attained the highest growth of 420.23 g and this can be attributed to the relatively high protein found in feed when analyzed and effective feed utilization. This also reflected in the average daily weight gain and feed conversion ration of 1.47. Diet I also had the lowest fibre content when analyzed (2.3%). This could have contributed to easier digestibility of the diet by fish than the other. Diet II fish recorded a high condition factor of 4.04 compared to Diet I, although not significant.

Feeding rates, growth and food conversion are the major variables for the commercial aquaculture enterprises. An understanding of the relationships between these is fundamental in optimizing feeding the fish (Nadir et al., 2007).High intake of feed by fish was recorded in fish fed with Diet II, which reflected in the high FCR. According to De Silva and Anderson (1995), when fish are fed to satiation, they do not tend to eat again until the stomach is almost completely evacuated, hence poor feed utilization. Mortalities experienced during the experimental period may not be due to differences in treatments since they were mostly experienced a day after sampling and might have resulted mostly from handling stress.

Production estimates that were based on gross and net yield for growth gain were also the basis for estimating the economic revenue from the fish culture operation. The biomass harvested (1271.41 kg) from cage fed with Diet II was lower than fish fed with Diet I and this may probably be due to the low survival rate (79.38%).The high gross and net yield (Table 5) recorded for fishes fed with Diet I could be attributed to good growth performance, relatively high survival rate which, in turn, gave high profit index of 1.87 (Table 6).

The total feed fed to cage with Diet II was high which reflected in the total cost of feed fed, coupled with the high price of feed per kilo (Table 6). This increased the cost of production and affected the profit index from the revenue generated from the sale of fish.

5. Conclusion

Considering the performance of the test diets with almost similar crude protein levels of feed, the two diets would be economical for production of tilapia by fish farmers since parameters evaluated were not significant. However, the escalating price of feed in the country has a detrimental effect on the economy of tilapia production, hence alternative source of cheap and cost effective feeds needs to be investigated and encourage our local industry in the production of feeds to make tilapia production more profitable.

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