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Growth Performance and Cost-Effectiveness of Farm-Made and Commercial Tilapia Starter Diets in Nile Tilapia (*Oreochromis niloticus* L.) Fingerling Production in Ghana

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Abstract

This study investigated the growth performance and cost-effectiveness in producing an average of 2.0 g Nile tilapia (*Oreochromis niloticus*) fingerlings using a farm-made tilapia starter diet (ARDECFEED) and two commonly used commercial ones (MULTIFEED and RAANAN) by tilapia hatchery operators in Ghana. The farm-made diet was formulated and prepared to contain similar crude protein (400 g kg^{-1}) as the commercial ones, using locally available ingredients. The feeding trials were conducted in net hapas of dimensions 3.0 x 1.0 x 1.2 m. Nile tilapia fry with an initial mean weight 0.2 ± 0.01 g were stocked at a density of 33 fish m^{-2} and fed at 10% body weight five times daily. Fry in the various dietary treatments attained mean weight range of 2.8-3.0 g in 4 weeks. No significant differences (ANOVA, P>0.05) were observed in the growth performance indicators among all treatments. The computed profit index values ranged from 6.43 to 9.64 with that of the farm-made feed being significantly higher (Tukey's HSDT, P<0.05). Hence, it was more profitable using the farm-made starter diet than the commercial ones to produce a mean weight of 2.0 g *O. niloticus* fingerlings at a stocking density of 33 fry m^{-2}.

Introduction

Nile tilapia (*Oreochromis niloticus*) is the major tilapia species cultured in Ghana. Most of the fish produced are either consumed directly by fish farmers or sold locally. Currently, there is a ban on tilapia imports in Ghana (FAO, 2006–2015) to encourage increase in local production. However, availability and quality of tilapia fingerlings have been a major bottleneck to many aquaculture operators over the years. The Aquaculture Research and Development Centre (ARDEC) of Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR), Ghana, has to a great extent eliminated this constraint by supplying over 2.5 million fingerlings per year to small-scale fish farmers and ten thousand brood-stock of the improved strain of the Nile tilapia known as the "Akosombo Strain" to medium and large-scale hatcheries (Kassam, 2014; MoFAD, 2014). This effort by ARDEC has increased the production and availability of fingerlings to fish farmers substantially. For instance, the total number of tilapia fingerlings produced in all hatcheries increased from approximately 78, 586, 466 fingerlings in 2012 to about 128, 826, 255 fingerlings in 2013, respectively (Kassam, 2014; MoFAD, 2014).

Another challenge facing the aquaculture industry in Ghana is lack of affordable nutritionally balanced and cost-effective fish diets. This has become a major challenge in the Aquaculture business in Ghana and Africa as a whole. Often feed is the most expensive operating cost item accounting for over 50% of costs in semi-intensive aquaculture (De Silva, 1993) and up to

70% in intensive aquaculture (Thompson, Muzinic, Engler & Webster, 2005). The high and rising costs of commercial tilapia diets are compelling some farmers to opt for alternative feeds including agro and industrial by-products, kitchen leftovers and plant wastes (Olomola, 1990). Some fish farmers rotate commercial fish diets with kitchen and restaurant wastes or chicken by-products. Others replace tilapia diet with cheaper chicken or duck feed. This has affected the development and expansion of aquaculture enterprises in most African countries including Ghana, and this has contributed in no small way, to the low protein intake in many developing African countries (Abu, Sanni, Erondu & Akinrotimi, 2010).

The types of commercial tilapia starter diets used in tilapia fingerling production in Ghana vary in brands, crude protein contents and costs. Almost all brands of fingerling producing diets are in powdered or crumbled forms and these are mostly referred to as starter feeds. Although study has shown that the crude protein requirements of *O. niloticus* fry ranged from 35 to 40% (Shiau, 2002; Fitzsimmons, 2005; El-Sayed, 2006; Lim and Webster, 2006), the crude protein contents of most commercial tilapia diets on the Ghanaian market ranged from 45 to 58% and the price per kilogramme vary from brand to brand with some being over 3.0 USD/kg (Anani, 2015). Due to the rising costs of commercial tilapia starter diets, the costs of tilapia fingerlings are frequently reviewed upwards by commercial tilapia hatchery operators. This is making the costs of tilapia fingerlings highly unaffordable particularly to small-scale tilapia farmers. In an effort to address this challenge in the aquaculture sector and also to support small-scale pond fish farmers to remain in the fish farm business, ARDEC has developed a farm-made tilapia starter diet known as ARDECFEED, using locally available ingredients.

Currently, the average size of tilapia fingerlings mostly produced by commercial tilapia hatchery operators in Ghana is 2.0 g at an average stocking density of 33 fry m^{-2} in earthen ponds, tanks or net hapas. Hence, the objectives of the present study were to investigate the growth performance and cost-effectiveness of producing Nile tilapia fingerlings of average size of 2.0 g using ARDECFEED and two commonly used commercial tilapia starter diets (MULTIFEED and RAANAN) in Ghana.

Materials and Methods

Description of the Study Area

The evaluation of the three tilapia starter diets (ARDECFEED, MULTIFEED and RAANAN) was carried out at ARDEC. The area lies between latitude 6° 13′ North and the longitude 0° 4′ East at Akosombo in the Eastern Region of Ghana.

Selection of Feed Ingredients and Commercial Fish Diets

The ingredients used in the formulation and preparation of the ARDECFEED were selected based on their nutritional value, availability all year round and costs. These were cassava (*Manihot esculenta*) flour, white maize (*Zea mays*), fish meal, soybean (*Glycine* spp.) meal, wheat (*Triticum aestivum*) bran, and palm oil (*Elaeis quineensis*). The ingredients were found to be locally available in all regions of Ghana (Anani, 2015). Broiler vitamin-mineral premix, L-lysine, L-methionine and common salt were included as additives/supplements. The current two most commonly used commercial tilapia starter diets for tilapia fingerling production in Ghana, namely MULTIFEED and RANAAN, each of 40% crude protein were selected for the study. The 2 diet types were procured from commercial fish feed retail outlets near the study area.

Chemical Analyses of Ingredients and Diets

Proximate compositions analyses of the ingredients and diets were carried out in triplicates following standard methods (AOAC, 1995). The protocol was applied in the determination of the percentage (%) dry matter (DM), % crude protein (CP), % ash, % crude lipid (CL) and % crude fibre (CF). Moisture content was estimated by drying samples in a thermostat oven at 105°C for 24 hours. The difference between the initial and final weights after drying gave the moisture content whilst the final weight was that of the DM. The total nitrogen content of each sample was determined by the Kjeldahl method and a factor of 6.25 was used to convert the total nitrogen to CP contents of the ingredient and diet samples. Ash was determined by burning dry samples in a muffle furnace at 550°C for 4-5 hours. The Soxhlet extraction method was used to determine the CL contents of the samples whilst CF was determined by acid/alkaline digestion, then the dry residue was burnt at 550°C in a muffle furnace for 4 hours to determine the % ash. Nitrogen-free extract (% NFE) was computed using the formula: % NFE = % DM - (% CP + % Ash + % CL + % CF). The gross energy contents of the ingredients and fish diets were computed by using the average physiological fuel values of 23.64, 39.54 and 17.15 $MJkg^{-1}$ for protein, fat and carbohydrate respectively (Kim, Lim, Kang, Kim & Son, 2012).

Diet Formulation and Preparation

The ARDECFEED was formulated on as-fed basis to contain 40 g kg^{-1} protein. The fish meal (Tuna fish meal, produced by Pioneer Food Canary, Tema in Ghana) and soybean meal (locally produced) were used as the main dietary protein sources. The Cassava flour, Maize and wheat bran were used as the main dietary carbohydrate sources. The cassava flour also served as a binder. The palm oil was used as the main source of lipid in the diets.

The fishmeal, maize, soybean meal and wheat bran were finely milled separately using a corn milling machine and subsequently sieved through an 800 µm sieve to rid them of relatively larger sized particles. The cassava flour was not milled as it was already in a powdered form before it was procured. However, it was also sieved. The dry powdered ingredients were weighed using top loading electronic balance (KERN EMB Version 3.1 11/2009) into large labelled plastic bowls according to the proportion based on the formulation for the diet. The ingredients were mixed with the hands protected with disposable gloves until uniformly blended and homogenou**s** powdered mixtures were obtained. Common salt and palm oil were added to the mixture at 10 and 50 g kg^{-1} respectively and the mixture was mixed thoroughly. Broiler vitamin-mineral premix was added to the powdered diet at 2 g kg^{-1} whilst L-lysine and L-methionine were added to it at 1 g kg^{-1} each and the contents were thoroughly mixed (Table 1). The final mixture was sieved through the 800 µm sieve again.

The commercial diets, which were originally extruded pellets, were milled separately into powdered forms and sieved through the 800 µm sieve. This was to ensure that all the experimental diets were of the same particle size and form. The various diets were kept in labelled transparent plastic containers. The excess diets were then packaged in labelled polythene bags and stored in a cool, dry and well-ventilated room. Samples of all the diets were analysed for proximate compositions.

Experimental System and Fish

Fish growth study was carried out in nine (9) mosquito netting hapas, each of dimensions 3.0 x 1.0 x 1.2 m (i.e. length, width and height). A monofilament nylon gill net of stretched mesh size 30.0 mm was sewn over each of the hapas as a cover and an opening was left at one end of the 1m side so as to allow input and collection of fish during stocking, measurements and harvest. The cover net was to keep predatory birds from injuring or picking the experimental fish. The hapas were mounted in a 0.2-hectare earthen pond at ARDEC, Akosombo. The pond was supplied with water from the Volta Lake to a mean height of about 1.4 ± 0.2 m. The hapas were suspended with bamboo poles by means of nylon twine and the former were driven into the bed of the pond. Each hapa was separated from others by about 6 m distance to avoid easy drifting of contents of one system into another and to enhance water exchange (Anani, Nunoo, Steiner-Asiedu, Nortey & Agbo, 2017). About two-thirds (0.8 m) of the hapa heights were constantly submerged in the pond water by ensuring periodic topping up of the water when the level fell due mainly to evaporation and seepage.

The ninth generation of mono sex male *O. niloticus* known as the “Akosombo Strain” developed by CSIR-WRI at ARDEC, Akosombo through selective breeding was used in the study. The fry, with an initial mean weight of 0.2±0.01 g, were randomly stocked at a density of 33 fry m^{-2} in each of the 9 hapas.

Feeding Schedule

Each diet was randomly assigned to three hapas (i.e. a treatment with 2 replicates). Feeding of the experimental fish with the various diets commenced the day after fish stocking. All the fish under each treatment were manually fed at 10.0% of their body weight (biomass) three times (between 0800-0830, 1200-1230 and 1600-1630 GMT) daily throughout the culture period.

Water Quality

Water quality parameters [temperature, dissolved oxygen (DO), pH, nitrite, total ammonia and total alkalinity] in the experimental hapas were determined biweekly. Water temperature was measured with a thermometer and DO was measured with oxygen meter (YIS Environmental model no: DO 200), whilst pH with a pH meter (HANNA model no: HI 98128). Nitrite

Table 1. Inclusion levels (%) of ingredients used in preparing ARDECFEED

Ingredients	Inclusion Level (%)
Fish meal	45.0
Soybean meal	25.0
Maize (white)	10.0
Wheat bran	5.0
Cassava flour	5.0
Palm oil	5.0
Broiler vit./min. premix	2.0
Common salt	1.0
L-Lysine	1.0
L-Methionine	1.0

and total ammonia were measured using a spectrophotometer (UV mini-1240). Total alkalinity was measured using a digital titrator (HACH).

Nitrite was determined by measuring 25 ml of the hapa water sample into 30 ml test tube and 25 ml of distilled water into a separate test tube (i.e. the blank). Nitriver 3 nitrite reagent was added to both and they were shook vigorously for one minute. After which they were left undisturbed for five minutes reaction period. The spectrophotometer was set up and programmed to analyse nitrite at 507 nm wavelength. Then it was zeroed with distilled water and the reading for the blank and the sample were determined. The difference between the two values was the actual amount of nitrite in the sample in milligrams per liter (mg L^{-1}).

A sample cell was filled to the 10-mL mark with the water sample and a second cell with deionized water to the 10-mL mark. The contents of one ammonia salicylate powder pillow were added to each cell and shook to dissolve the contents. The spectrophotometer programmed number for ammonia analysis was keyed in and set at 655 nm wavelength. A three-minute reaction period was allowed then the contents of one ammonia cyanurate reagent powder pillow were added to each cell and they were shook to dissolve the contents. The instrument timer was started for a 15-minute reaction period after which the blank was wiped and it was inserted into the cell holder. The instrument was zeroed and the sample was wiped and inserted into the cell holder to read the result in mgL^{-1} NH_3-N.

In measuring total alkalinity, a clean delivery tube was inserted into a 1.600 N sulfuric acid titration cartridge attached to a titrator. The delivery knob was turned to eject air and a few drops of titrant. The counter was reset to zero and the tip was wiped. A sample volume of 100 mL was measured with a graduated cylinder and transferred into a clean 250-mL Erlenmeyer flask. Phenolphthalein and Bromcresol Green-Methyl Red Indicator powder were added in turns and each mixed thoroughly. The titration was continued with sulfuric acid to a light pink colour. The digits displayed on the counter were recorded as alkalinity in mg L^{-1}.

Measurements of Fish During Growth Study

The weights of 20% of surviving fish in each hapa under each treatment were measured fortnightly. The biomass (total weight) of fish in each hapa under each treatment was computed and subsequently the quantity of each diet type for each fish group was adjusted accordingly. The growth study continued till the fish in any dietary treatment and all its replicates attained a mean weight of at least 2.0 g. Then the experiment was terminated and all the fish in each treatment harvested, counted and weighed individually to determine survival and the final growth.

Determination of Biological Parameters

Growth performance was determined in terms of survival rate (SR), weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and feed efficiency (FE) as follows:

SR (%) = number of fish stocked – Mortality/Number of fish stocked × 100%;

WG (%) = final body weight – initial body weight/initial body weight x 100%;

SGR (% day^{-1}) = 100% × [In (final body weight) – In (initial body weight)]/number of days;

FCR = total feed fed/live weight gain;

FE (%) = live weight gain by fish/total feed fed x 100%.

Cost-Effectiveness of the Diets

The cost effectiveness of the farm-made and commercial diets was determined by computing the Incidence Cost (IC) and Profit Index (PI) given as follows:

IC = cost of diet used/weight of fish produced (Abu *et al.,* 2010);

PI = value of fingerlings produced/cost of diet used (Agbo, Madalla & Jauncey, 2011).

The value of fingerlings and cost of diets were calculated based on market prices in Ghana cedis (GHS) and its equivalent amount in US Dollars (US$) per kilogramme. Ten per cent (10%) of the original costs per kilogramme of the farm-made (ARDECFEED) based on the prices of the ingredients used was added to the diet to cover the cost of labour in producing the diet (Anani, 2015). Only the costs of the various diets were considered as other costs were constant.

Data Analysis

All data on fish growth performance were tested for normality using the Kolmogorov-Smirnov test and homogeneity using the Levene's test. All percentages and ratios were arcsine transformed to normalize the data before analyses (Zar, 1984). All results were expressed as mean±standard deviations (S.D). Comparison of means were made by one way-analysis of variance (ANOVA), followed by Tukey's honest significant difference test to identify specific differences between pairs of treatments. Differences were regarded as significant when $P<0.05$.

Results

Water Quality

There were no significant differences (ANOVA, P>0.05) in water quality parameters among the various dietary treatments during the growth study and the recorded values were within the following ranges: Temperature (27.58-29.83°C), dissolved oxygen (4.14-5.02 mg L^{-1}), pH (7.24-7.62), Nitrite (0.013-0.016 mg L^{-1}), total ammonia (0.50-0.62 mg L^{-1}), total alkalinity (125-162 mg L^{-1}).

Proximate Compositions of the Experimental Diets

The proximate compositions and gross energy contents of the ARDECFEED, MULTIFEED and RAANAN diets are shown in Table 2. Proximate analyses of the diets showed that ARDECFEED had the least (39.42%) crude protein content whilst RAANAN had the highest (42.34%). The crude lipid values ranged from 5.50 to 8.37% with that of ARDECFEED being the highest. ARDECFEED had the highest (12.17%) ash content. The gross energy and crude fibre contents of the diets were similar and they ranged from 17.67 to17.91 kJ g^{-1} and 3.25 to 3.84% respectively.

Growth and Production Performance of Cultured Fish

The target mean weight of ≥2.0 g was attained at the end of the fourth week (Figure 1). Both the Farm-made diet and MULTIFEED recorded 2.8 g whilst RAANAN recorded 3.0 g. The growth responses of Nile tilapia fry to the experimental diets are shown in Table 3. There were no significant differences (ANOVA, P>0.05) in final mean weights, weight gains, specific growth rates and net fish productions among the various dietary treatments.

Cost-Effectiveness of the Diets

The costs per kilogramme of the commercial diets were higher compared to the farm-made one and that of MULTIFEED (about US$ 1.45 kg^{-1}) was the most expensive (Table 4). At the time of this study, the cost of 1000 individual tilapia fingerlings of an average weight of 2 g was about US$ 38.66. Although it was profitable producing Nile tilapia fingerlings irrespective of the diet type used, the profit margin was significantly higher (Tukey's HSDT, P<0.05) in the use of the farm-made diet (ARDECFEED) than that of the commercial ones (MULTIFEED and RAANAN). The profit index for the various diet types were 9.64, 6.43 and 7.47 for ARDECFEED, MULTIFEED and RAANAN respectively.

Table 2. Proximate compositions (% as-fed) and gross energy (kJ g^{-1}) of ARDECFEED, MULTIFEED and RAANAN tilapia starter diets fed to Nile tilapia fry in the current study

Diet	DM	CP	CL	CF	Ash	NFE	GE
ARDECFEED	92.82	39.42	8.37	3.47	12.17	29.39	17.67
MULTIFEED	93.65	41.54	5.50	3.84	8.24	34.53	17.91
RAANAN	91.89	42.34	5.86	3.25	8.43	32.01	17.82

DM = dry matter, CP = crude protein, CL = crude lipid, CF = crude fibre, NFE = nitrogen free extract, GE = gross energy

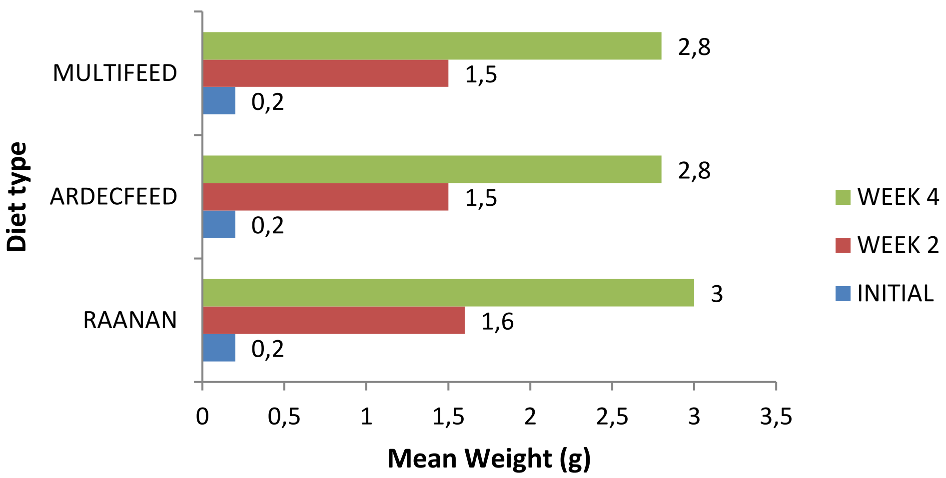

Figure 1. Growth performance of Nile tilapia fry fed with a farm-made diet (ARDECFEED) and two commercial types (RAANAN and MULTIFEED) for 4 weeks.

Table 3. Growth performance and feed utilization of the cultured Nile tilapia fry fed with ARDECFEED (AF), MULTIFEED (MF) and RAANAN (RN) diets at 33 fry m^{-2} for 4 weeks

Parameter	Diets		
	AF	MF	RN
IMW (g)	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
FMW (g)	2.8 ± 0.8	2.8 ± 0.7	3.0 ± 0.8
WG (g)	2.6 ± 0.8	2.6 ± 0.7	2.8 ± 0.8
SGR (% day^{-1})	9.4 ± 0.2	9.4 ± 0.1	9.7 ± 0.4
FI (g $fish^{-1}$)	3.9 ± 0.3	4.2 ± 0.3	4.5 ± 0.4
FCR	1.5 ± 0.2	1.6 ± 0.2	1.6 ± 0.3
FE (%)	66.7 ± 0.1	62.5 ± 0.1	62.5 ± 0.1
SR (%)	85.5 ± 19.7	88.0 ± 10.0	83.5 ± 16.2
NFP (kg m^{-2})	0.44 ± 6.6	0.46 ± 3.3	0.47 ± 5.4

Values are means ± standard deviations of three replicates. There were no significant differences (ANOVA, P>0.05) among mean values.IMW = initial mean weight; FMW = final mean weight; WG = weight gain; SGR = specific growth rate; FI = feed intake; FCR = feed conversion ratio;FE = feed efficiency;SR = survival rate;NFP = net fish production.

Table 4. Cost effectiveness of ARDECFEED, MULTIFEED and RAANAN fed to Nile tilapia fry

Parameter	Diets		
	AF*	MF	RN
Cost of feed (GHS kg^{-1})	4.00	5.60	4.50
Total feed used (kg)	1.00	1.10	1.12
Cost of total feed used (GHS)	4.00	6.16	5.04
Harvested biomass (kg)	0.72	0.74	0.75
Value of fingerlings (GHS)	38.55	39.60	37.65
Incidence Cost (GHS kg^{-1})	5.56	8.34	6.69
Profit Index	9.64	6.43	7.47

*Cost per kg of ARDECFEED included labour, constituting 10% of the cost of ingredients used in producing the diet (Anani *et al.,* 2017). [US$ 1.00 = GHS 3.88 (average) in 2015].

Discussion

The reasonably similarity in growth performance of *O. niloticus* as indicated by the observed final mean weight and weight gain in the various dietary treatments suggests that all the diets were of good quality and they supported good fish growth. The results of this study show that, there were no significant differences (ANOVA, P>0.05) in growth parameters among the various dietary treatments (ARDECFEED, MULTIFEED and RAANAN). The final mean body weight range (2.8–3.0 g) attained at the current stocking density (33 fry m^{-2}) would produce the expected fingerling size of at least 2.0 g within a time period of 4 weeks.

Aside from the good quality of the diets used in this study, the equally good growth recorded could also be attributed to the relatively low stocking density used which reduced social interactions through competition for food and space in all the dietary treatments. Social interactions through competition for food and space negatively affect fish growth (Garr, Lopez, Pierce & Davies, 2011). Higher stocking densities lead to increased stress and consequent increase in energy requirements causing a reduction in growth rates and food utilization. Also, fish density could affect the efficiency of food utilization where the number of fish stocked in a system increases; the amount of feed available to each fish decreases (Chang, 1988). In this study, the survival rates were not affected significantly possibly due to the good water quality recorded. Throughout the experimental period, the water quality in all the treatments remained within the range required for tilapias (Boyd, 1990). Therefore, all the diets used in the present study did not impact water quality negatively.

The estimated total cost of using the various diet types to produce 1000 individual tilapia fingerlings of an average weight of at least 2 g would be approximately US$ 2.86, US$ 4.30 and US$ 3.44 for ARDECFEED, MULTIFEED and RAANAN respectively. Since 1000 individual tilapia fingerlings of an average weight of 2 g is being sold by hatchery operators at about US$ 38.66, then the use of ARDECFEED in tilapia fingerlings will reduce the cost of production and subsequently increase the profit margin of farmers. This suggests that the profitability of using any of the diets depends on the cost of its unit weight (1 kg). Hence, the use of ARDECFEED (US$ 1.03 kg^{-1}) to produce a minimum mean weight of 2.0 g tilapia fingerlings as being produced currently by most hatchery operators in the country will be more profitable than the use of either MULTIFEED (US$ 1.44 kg^{-1}) or RAANAN (US$ 1.16 kg^{-1}).

In the present study, there were no significant differences (ANOVA, P>0.05) among the growth rate and feed efficiency of *O. niloticus* fed with the farm-made and commercial diets at the studied stocking density. Hence, the use of ARDECFEED to raise a tilapia fry to the target fingerling weight of at least 2.0 g may last over the same time period as using either MULTIFEED or RAANAN. This suggests that using ARDECFEED will reduce the production cost of Nile tilapia fingerlings and consequently increase the profit margin of tilapia hatchery operators in the country. Therefore, the use of ARDECFEED will immensely benefit the small-scale pond fish farmers who constitute the majority of fish producers in Ghana.

In conclusion, the study showed that there was no significant difference in growth of fish fed with the farm-made and commercial diets. The study has also established that a mean weight of at least 2.0 g tilapia fingerlings can be produced within four weeks when fry of initial size 0.2 g are stocked at 33 fish m^{-2} and fed with ARDECFEED, MULTIFEED or RAANAN tilapia starter diet. However, it will be more profitable to feed them with ARDECFEED than any of the two commercial diets.

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