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# Evaluation of Farm-made and Commercial Tilapia Diets for Small-scale Hapa Production of Nile Tilapia (*Oreochromis niloticus* L.) in Ghana

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author FAA carried out the research work, supervised by authors FKEN and MSA. Authors TNNN and NWA provided technical guidance in diet formulation and chemical analyses. Authors FAA and NWA performed statistical analysis. Revision of manuscript was read by authors TNNN and NWA and corrections were made by author FAA. Authors FKEN and MSA read and approved the manuscript for submission.*

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## ABSTRACT

**Aims:** To evaluate a farm-made and commercial tilapia diets for small-scale production of Nile tilapia (*Oreochromis niloticus*), the most cultured fish in Ghana.
**Study Design:** Completely randomized design.
**Place and Duration of Study:** The Aquaculture Research and Development Centre (ARDEC), Akosombo, of Water Research Institute (WRI) of Council for Scientific and Industrial Research (CSIR), Ghana, from February to July, 2014.

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**Methodology:** A 30% crude protein (CP) farm-made diet, ARDECFEED was formulated and prepared using locally available ingredients. The two most commonly used commercial fish diets (RAANAN, 30% CP and COPPENS, 34% CP) by small-scale fish farmers were also selected for the study. The feeding trial was conducted in net hapas of dimension 5.0 × 2.0 × 1.2 m installed in a 0.2 hectare earthen pond. *O. niloticus* with an initial mean weight of 22.8 ± 2.1 g were stocked at a density of 2 fish $m^{-2}$ and fed at 4 to 3% body weight three times a day including weekends for 140 days. At the end of the period, growth performance, feed utilization and cost-effectiveness of each dietary treatment were determined.

**Results:** The final mean weights of *O. niloticus* for the various dietary treatments were 140.3 ± 23.4, 187.6 ± 42.1 and 148.3 ± 25.4 g for ARDECFEED, RAANAN and COPPENS respectively. That of RAANAN was significantly higher ($P$ = .03) than those fed with the other diets. There was no significant difference ($P$ = .67) in specific growth rate among dietary treatments. The highest survival (100.0%) was observed in fish fed with RAANAN whilst the least (86.67%) occurred in those fed with COPPENS. However, there were no significant differences among dietary treatments. In terms of cost effectiveness, the farm-made diet was more profitable than the commercial ones, with COPPENS being the least profitable.

**Conclusion:** The farm-made diet, ARDECFEED has the best prospects based on growth performance, nutrient utilization and economic returns.

*Keywords: Farm-made and commercial tilapia diets; hapa; Oreochromis niloticus; small-scale.*

## 1. INTRODUCTION

In Ghana, most fish farmers are using commercial fish diets, particularly those involved in intensive cage culture. Most of these diets are imported into the country and their prices are mostly affected by the exchange rate of the local currency (Ghana cedis, GHS) to the US dollar. Although there is a major local producing company of commercial fish diets by brand name Raanan, its products are not easily affordable to farmers, particularly small-scale fish producers. The price of fish diet ranges from 50 to 60% of the total operational cost of aquaculture production [1,2]. The responsible factor for the increment of fish diet production and its price is the rapid growth rate of the aquaculture industry [3]. The expansion of the aquaculture industry in Ghana has been mainly hampered by the high costs of commercial fish diets.

Most small-scale fish farmers in Ghana use earthen ponds and tilapia constituted about 80 % of all cultured fish [4]. Majority of these farmers have folded up and those who still remain in the fish farm business have resorted to alternative sources of feed including agro-industrial by-products as well as kitchen and agricultural wastes to feed cultured fish [5]. Investigations at field level, revealed that only 3 (Raanan, Coppens and Biomar) out of about 16 commercial fish diets currently available in the country were being used by farmers in the major pond fish farming regions of the country [6]. Raanan was most used and it constituted about 86.2% of the used commercial diets.

Of the 138 farmers using different types of fish diets in all the five (5) major pond fish farming regions surveyed, 37.7% used commercial diets only, 26.8% used farm-made diets only whilst 35.5% used both [6]. Some of the farmers who used both types either fed them to the fish alternatively or fed them at different stages of the culture period. These farmers used the expensive commercial ones as starter feed (i.e. feeding them to the fish at the fingerling stage) and used the farm-made ones as the grower feed (i.e. from the juvenile till the fish are harvested), whilst others used the farm-made diets throughout the culture period. In an effort to reduce cost of fish production by small-scale pond fish farmers in the country, the Aquaculture Research and Development Centre (ARDEC) of the Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR) has developed a farm-made grower tilapia diet known as ARDECFEED, using locally available ingredients. Hence, this study was carried out to evaluate the ARDECFEED and that of 2 commonly used commercial tilapia diets for small-scale production of Nile tilapia (*Oreochromis niloticus*), the most cultured fish in Ghana [4].

## 2. MATERIALS AND METHODS

### 2.1 Selection of Feed Ingredients and Commercial Fish Diets

The ingredients used in the formulation and preparations of the farm-made diet

(ARDECFEED, 30% crude protein) were selected based on the findings of regional surveys conducted in 5 main pond fish farming regions in Ghana [6]. Six commonly used ingredients by small-scale pond fish farmers in the preparation of farm-made diets were selected based on their nutritional value, availability throughout the year and costs. These were cassava (*Manihot esculenta*) flour, white maize (*Zea mays*), fish meal (produced from tuna fillet remains), soybean (*Glycine* spp) meal, wheat (*Triticum aestivum*) bran, and palm oil (*Elaeis quineensis*). Broiler vitamin-mineral premix, L-lysine, L-methionine and common salt were included as additives/supplements. The two most commonly used commercial fish diets (RAANAN, 30% crude protein and COPPENS, 34% crude protein) by the farmers were also selected.

### 2.2 Determination of the Proximate Compositions of Ingredients and Diets

Proximate analyses of the selected commercial fish diets and feed ingredients for the study were done in triplicates following standard methods [7]. The protocol was applied in the determination of the percentage (%) dry matter (DM), % crude protein (CP), % ash, % crude lipid (CL) also known as ether extracts (EE) and % crude fibre (CF). Gross energy was computed by using the physiological fuel values of 23.64, 39.54 and 17.15 MJ $kg^{-1}$ for protein, fat and carbohydrate respectively [8].

### 2.3 Diet Formulation and Preparation

The formulation, preparation and evaluation of the diets were carried out at ARDEC, Akosombo, which lies between latitude 60 13' North and the longitude 00 4' East in the Eastern Region of Ghana.

ARDECFEED was formulated and prepared to contain 300 g $kg^{-1}$ protein, 100 g $kg^{-1}$ lipid and 18 kJ $g^{-1}$ to meet the nutrient requirements of Nile tilapia [9] using the selected ingredients. Broiler vitamin-mineral premix (Kardelen 2 400 VM) and essential amino acids (L-Lysine and L-Methionine) were added to the diet at 5 g $kg^{-1}$ each. Common salt was added at 2 g $kg^{-1}$ (Table 1).

The fishmeal, maize, soybean meal and wheat bran were finely milled separately using a corn milling machine and subsequently sieved through a 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 a large plastic bowl based on the formulation for the diet. The ingredients were mixed with the hands protected with disposable gloves until uniformly blended and homogenous powdered mixture was obtained. The measured quantity of broiler vitamin-mineral premix, L-lysine, L-methionine, common salt and palm oil were added to it and the mixture was mixed thoroughly. About 40% of water was added slowly to the mixture with continuous stirring until dough was formed. A 32# Hand-Operated Meat Mincer was used to pellet the diet using a die size of 2 mm into strands.

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

| Ingredients | Inclusion levels (%) |
|---|---|
| Fish meal | 25.0 |
| Soybean meal | 26.8 |
| Maize (white) | 27.0 |
| Wheat bran | 5.0 |
| Cassava flour | 10.0 |
| Palm oil | 4.5 |
| Vitamin/Mineral premix | 0.5 |
| Common salt | 0.2 |
| Lysine (optional) | 0.5 |
| Methionine (optional) | 0.5 |

The two commercial diets (RAANAN and COPPENS) which were originally extruded were milled into powdered forms and then pelleted as for the ARDECFEED so as to ensure consistency in the forms and sizes of all the diets. The pellets were sun-dried for 8 to 10 hours to reduce the moisture content so as to prevent the growth of mould and consequently the strands were broken into smaller sizes (between 2-3 mm) that the experimental fish could pick. The diets to be used immediately were put into labelled transparent plastic containers of each having a capacity of about 10 litres. The excess diets were then packaged in labelled polythene bags and stored in a well-ventilated room. Samples of the prepared diets were analysed for proximate compositions. The values obtained were used to compute the energy contents of the various diets. Ten (10) kg of each diet type was prepared at a given time as and when the old stock was getting depleted.

## 2.4 Evaluation of Diets

### 2.4.1 Experimental system

Fish growth study was carried out in a 5.0 x 2.0 x 1.2 m (i.e. length, width and height) mosquito netting hapas mounted in a 0.2 hectare earthen pond at ARDEC, Akosombo. The hapas were suspended to bamboo poles by means of nylon twine and the former were inserted in the bed of the pond. A monofilament nylon gill net of stretched mesh size 30.0 mm was sewn over the hapas as a cover and an opening was left at one end of the 2 m side so as to allow input and collection of fish during stocking, measurements and harvest [10]. The cover net was to keep predatory birds from injuring or picking the experimental fish as well as to prevent the fish from jumping out as they grow bigger. The pond was supplied with water from the Volta Lake to a mean height of about 1.4 ± 0.2 m.

Each hapa was separated from others by about 6 m distance to avoid easy drifting of contents of one system into another [11]. 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.

### 2.4.2 Conditioning and stocking of experimental fish

A total number of one hundred and eighty (180) of the ninth generation of monosex male *O. niloticus* known as the "Akosombo Strain" developed by CSIR-WRI at ARDEC, Akosombo through selective breeding was used in the growth study. The initial Standard Length (SL), Total Length (TL) and wet weight of the individual fish to be stocked were measured (to the nearest 0.1 cm and 0.1 g respectively) using a fish measuring board and a top loading electronic balance. The fish were randomly divided into three groups of 20 fish (3 treatments in triplicate) and stocked in nine hapas, each of operational water volume of about 8.0 $m^3$.

### 2.4.3 Feeding and measurements of fish during growth study

Feeding of fish with the experimental diets commenced the day following stocking. All the fish under each treatment were manually fed at 4.0% of their body weight (biomass) three times daily (between 0800-0830, 1200-1230 and 1600-1630 GMT) throughout the week including weekends. During the first week of stocking, all dead fish (mortality) in each hapa under each treatment were replaced with live ones of similar weights. The 4.0% rate of feeding was maintained until the fish in any hapa attained a mean body weight greater than 100.0 g. Then the feeding rate was reduced to 3.0%, but feeding frequency of 3 times per day was maintained throughout the growth study.

The SL, TL and weights of all the fish in each hapa under each treatment were measured fortnightly. A bamboo pole was used at the opposite sides of the longer side of each hapa, starting from the bottom of the sewn end of the cover; the pole was drawn to confine the fish at the open end of the cover. All the fish were then netted and put into a large bowl containing pond water. The hapas were cleaned with pond water to ensure water circulation. The total number of fish was recorded. Each fish was gently blotted on a soft towel so as to remove excess water from the body. Then the SL and TL were measured followed by the weight. Each fish was then returned into a bowl containing fresh pond water. After measuring the lengths and weights of all the fish in each hapa, they were put back into their respective hapas.

The biomass (total weight) of fish in each hapa under each dietary treatment was computed and subsequently the quantity of each diet type for each fish group was adjusted accordingly. The measurements were done between 0630 and 0930 GMT. The fish were not fed on the day they were handled, feeding commenced at 0800 GMT of the following day. The growth study was carried out for 20 weeks (140 days). The day after the 140 days, all the fish from each treatment were harvested, counted and measured individually to determine the final growth and survival.

## 2.5 Determination of Biological Parameters

Growth performance and feed utilization were determined in terms of weight gain (WG), specific growth rate (SGR), feed intake (FI), feed conversion ratio (FCR), protein efficiency ratio (PER), protein productive value (PPV) and energy retention (ER) as follows: WG (%) = final body weight−initial body weight/initial body weight × 100%, SGR (% $day^{-1}$) = 100% × [In(final body weight)−In(initial body weight)]/no. of days, FI (g) = Total feed given per fish/no. of days, FCR = feed given/live weight gain, PER = live weight gain/crude protein fed, PPV (%) = protein retained in tissue/dietary protein fed × 100%, ER (%) = 100% × (final fish body energy−initial fish body energy)/gross energy fed.

### 2.6 Cost-effectiveness of the Diets

Cost-effectiveness of the diets was determined using Incidence Cost (IC) and Profit Index (PI) [12,13] as follows: IC = Cost of feed used (GHS)/weight of fish produced (kg), PI = value of fish produced (GHS)/Cost of feed used (GHS). The cost of the ARDECFEED was calculated using market prices of the ingredients used whilst for RAANAN and COPPENS, the price per kilogramme (kg) as existing in the study area was used. Only the cost of the diets was used in the calculations with the assumption that all other operating costs (e.g. transport, hapa, fingerlings and labour) remained constant. However, for ARDECFEED, ten percent (10%) was added to the original cost per kg of diet based on the price of ingredients, to cover the cost of labour used in preparing the diet.

### 2.7 Data Analyses

All data on fish growth performance and feed utilizations were tested for normality using the Kolmogorov-Smirnov test and homogeneity using the Levene's test. The tests were carried out to find out if the data were normally distributed and the variances were homogeneous. All percentages and ratios were arcsine transformed to normalize the data before analyses [14]. Statistical analyses were carried out using one-way analysis of variance (ANOVA) to test differences among the various parameters of the dietary treatments. Tukey's honest significant difference test was used to identify specific differences between pairs of treatments. Differences were regarded as significant when $P \leq .05$.

## 3. RESULTS

### 3.1 Proximate Compositions of Selected and used Ingredients

The proximate compositions of the ingredients (as-fed basis) used for the formulation and preparation of ARDECFEED are shown in Table 2. The results of the proximate compositions of the ingredients showed that fish meal had the highest crude protein (60.20%) whilst cassava flour had the least (1.48%). The gross energy for the ingredients ranged from 14.54 to 39.54 kJ $g^{-1}$, with palm oil containing the highest. Crude lipid content of palm oil was the highest (100.00%). The ingredient with the highest crude fibre content was wheat bran (9.87%) and fish meal had the highest (17.73%) ash content. Palm oil was the most expensive (3.74 GHS $kg^{-1}$) whilst wheat bran was the least expensive (0.64 GHS $kg^{-1}$).

### 3.2 Proximate Compositions of Experimental Diets

The proximate compositions of ARDECFEED, RAANAN and COPPENS are shown in Table 3. Proximate analyses of the diets showed that COPPENS had the least moisture content. The crude protein contents of the diets ranged from 31.21 to 34.58%, with COPPENS being the highest. The gross energy of the diets ranged from 16.31 to 18.70 kJ $g^{-1}$ with RAANAN having the least and COPPENS the highest. Values obtained for the analyses of ash ranged from 5.16 to 9.45%. COPPENS had the least whilst RAANAN had the highest. Crude fibre contents of the diets ranged from 3.91 to 5.21% with RAANAN having the least and ARDECFEED the highest. The unit costs of the diets ranged from 1.88 to GHS 5.00 with ARDECFEED being the least and COPPENS the most expensive.

**Table 2. Proximate compositions (% as-fed), gross energy (kJ $g^{-1}$) and prices (GHS $kg^{-1}$) of the selected feed ingredients used in the formulation and preparation of ARDECFEED**

| Ingredients | DM | CP | CL | CF | Ash | NFE | GE | Price |
|---|---|---|---|---|---|---|---|---|
| Cassava flour | 88.25 | 1.48 | 0.46 | 2.01 | 2.62 | 81.68 | 14.54 | 1.32 |
| Fish meal | 95.21 | 60.20 | 9.74 | 5.73 | 17.73 | 1.81 | 18.39 | 2.30 |
| Maize (white) | 88.93 | 9.31 | 3.38 | 2.80 | 1.39 | 71.58 | 15.81 | 0.72 |
| Palm oil | 100.00 | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 | 39.54 | 3.74 |
| Soybean meal | 91.54 | 43.25 | 8.55 | 6.36 | 9.54 | 23.84 | 17.69 | 2.40 |
| Wheat bran | 87.56 | 18.42 | 4.64 | 9.87 | 5.71 | 48.92 | 14.57 | 0.64 |

**DM = dry matter, CP = crude protein, CL = crude lipid, CF = crude fibre, NFE = nitrogen free extract, GE = gross energy. The average exchange rate of the Ghana cedis to the USA dollar in 2014 was: GHS 2.20 = 1.00 USD*

**Table 3. Proximate composition (% as-fed), gross energy (kJ $g^{-1}$) and prices (GHS $kg^{-1}$) of ARDECFEED, RAANAN and COPPENS**

| Diet | DM | CP | CL | CF | Ash | NFE | GE | Price |
|---|---|---|---|---|---|---|---|---|
| ARDECFEED | 89.60 | 31.29 | 10.36 | 5.21 | 8.80 | 33.94 | 17.31 | 1.88 |
| RAANAN | 90.40 | 31.21 | 4.78 | 3.91 | 9.45 | 41.05 | 16.31 | 3.25 |
| COPPENS | 96.58 | 34.58 | 6.94 | 4.48 | 5.16 | 45.42 | 18.70 | 5.00 |

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

*The average exchange rate of the Ghana cedis to the USA dollar in 2014 was: GHS 2.20 = 1.00 USD*

### 3.3 Growth Performance and Feed Utilizations of Cultured Fish

The growth performance of the fish in terms of final mean weight gain, percentage weight gain, specific growth rate, daily weight gain, survival rate, feed conversion ratio, feed intake, protein efficiency ratio, protein productive value and energy retention is presented in Table 4. The highest final mean weight of 187.6 g occurred in fish fed with RAANAN whilst the least final mean weight of 140.3 g occurred in fish fed with ARDECFEED. The final mean weight of fish fed with RAANAN was significantly higher ($P$ = .03) than those fed with the other diets. The values for mean daily weight gain ranged from 0.84 to 1.18 g $fish^{-1}$. Fish fed with RAANAN had significantly higher ($P$ = 0.04) daily weight gain. The highest survival (100.0%) was observed in fish fed with RAANAN whilst the least (86.67%) occurred in those fed with COPPENS. However, there were no significant differences ($P$ = .27) among dietary treatments.

The FCR values ranged from 2.35 to 2.96 at the end of the feeding trials and there were no significant difference ($P$ = .35) among dietary treatments. Feed intake ranged from 347.10 to 388.11 g $fish^{-1}$ and there were no significant differences among all the diets. There was no significant difference in protein efficiency ratio among all the diets and the values ranged from 1.18 to 1.67. The protein productive value was significantly higher ($P$ = .02) in fish fed with RAANAN and least in those fed with COPPENS. The percentage energy retention ranged from 8.32 to 15.32%, with fish fed with RAANAN being significantly higher whilst those fed with COPPENS being lower.

Fig. 1 shows the biweekly growth trend of *O. niloticus* fed with the various diets for twenty weeks. After the second week of culture, growth was rapid in all the treatments up to the sixth week. Growth was generally slow between the sixth and eighth week. However, growth peaked after the eighth week in all the treatments, but highest in fish fed with RAANAN till the eighteenth week. At the end of the twentieth week, the highest final mean weight of 187.6 g occurred in fish fed with RAANAN whilst the least final mean weight of 140.3 g occurred in fish fed with ARDECFEED.

### 3.4 Cost Effectiveness of the Diets

The costs per kilogramme of the commercial diets were higher compared to that of ARDECFEED (Table 5). COPPENS was the most expensive (GHS 5.00 $kg^{-1}$). The cost analyses showed that it was more expensive (GHS 12.35) to use COPPENS to produce a kilogramme of tilapia than any of the other diets whilst ARDECFEED cost least (GHS 5.12). The highest profit was made by using ARDECFEED, followed by RAANAN whilst the least was made by the use of COPPENS.

## 4. DISCUSSION

### 4.1 Proximate Compositions of Ingredients used in ARDECFEED

The highest crude protein content of fishmeal observed in this study agreed with other researchers who concluded that feed ingredients of plant origin often contain less protein than those of animal origin [15,16,17]. Fishmeal had relatively high crude fibre (5.73 %). The fishmeal used in the study was produced from tuna wastes (fillet remains) obtained from processed and canned tuna. Most often such fish wastes consist of trimmings, belly flaps, heads, frames, fins, skins and viscera [18]. The result is consistent with the findings of [19] who observed that the fibre contents of fillet remains of tilapia (*Oreochromis* spp) and those of North African catfish (*Clarias gariepinus*) were high and ranged from 6.7 to 7.3%.

**Table 4. Mean growth performance and feed utilization of the cultured Nile tilapia fed with ARDECFEED, RAANAN and COPPENS for 20 weeks**

| Parameter | Diet | | | *P* Values |
|---|---|---|---|---|
| | ARDECFEED | RAANAN | COPPENS | |
| Initial mean Weight (g) | 23.0 ± 2.0[a] | 22.6 ± 2.3[a] | 22.7 ± 1.9[a] | .79 |
| Final Mean Weight (g) | 140.3 ± 23.4[ab] | 187.6 ± 42.1[c] | 148.3 ± 25.4[b] | .03 |
| Weight Gain (%) | 511.0 ± 50.5[ab] | 728.8 ± 45.0[c] | 555.3 ± 29.0[b] | .02 |
| Specific Growth Rate (% day$^{-1}$) | 1.39 ± 0.07[a] | 1.63 ± 0.04[a] | 1.45 ± 0.03[a] | .56 |
| Daily Weight Gain (g fish$^{-1}$) | 0.84 ± 0.06[a] | 1.18 ± 0.19[b] | 0.90 ± 0.08[a] | .04 |
| Survival (%) | 96.7 ± 2.89[a] | 100.0 ± 0.00[a] | 86.67 ± 5.77[a] | .27 |
| Feed Conversion Ratio | 2.96 ± 0.19[a] | 2.35 ± 0.13[a] | 2.92 ± 0.12[a] | .35 |
| Feed Intake (g fish$^{-1}$) | 347.10 ± 13.28[a] | 388.11 ± 18.92[a] | 366.76 ± 14.31[a] | .81 |
| Protein Efficiency Ratio | 1.37 ± 0.84[a] | 1.67 ± 0.77[a] | 1.18 ± 0.64[a] | .41 |
| Protein Productive Value (%) | 24.89 ± 0.13[a] | 28.80 ± 0.03[b] | 21.15 ± 0.18[c] | .02 |
| Energy Retention (%) | 11.96 ± 0.29[a] | 15.32 ± 0.14[b] | 8.32 ± 0.18[c] | .04 |

*Values are means ± Standard Deviations of three replicates. Means within the same row with different letters are significantly different (*Tukey's HSDT, *$P < .05$)*

**Table 5. Cost effectiveness of diets fed to Nile tilapia**

| | Diet | | |
|---|---|---|---|
| | ARDECFEED | RAANAN | COPPENS |
| Cost per kg of diet (GHS) | 2.07 | 3.25 | 5.00 |
| Diet input (kg) | 20.12 | 23.29 | 19.05 |
| Cost of Diet used (GHS) | 41.65 | 75.69 | 95.25 |
| Harvested Biomass (kg) | 8.14 | 11.26 | 7.71 |
| Estimated value of Biomass | 52.03 | 75.04 | 50.07 |
| Incidence Cost (GHS kg$^{-1}$) | 5.12 | 6.72 | 12.35 |
| Profit Index | 1.25 | 0.99 | 0.53 |

**Cost per kg of ARDECFEED include labour, constituting 10% of the cost of producing the feed, **Sale of fish: < 150 g = GHS 6.20 kg$^{-1}$, 150-299 g = GHS 6.70 kg$^{-1}$, 300-400 g = GHS 7.50 kg$^{-1}$*

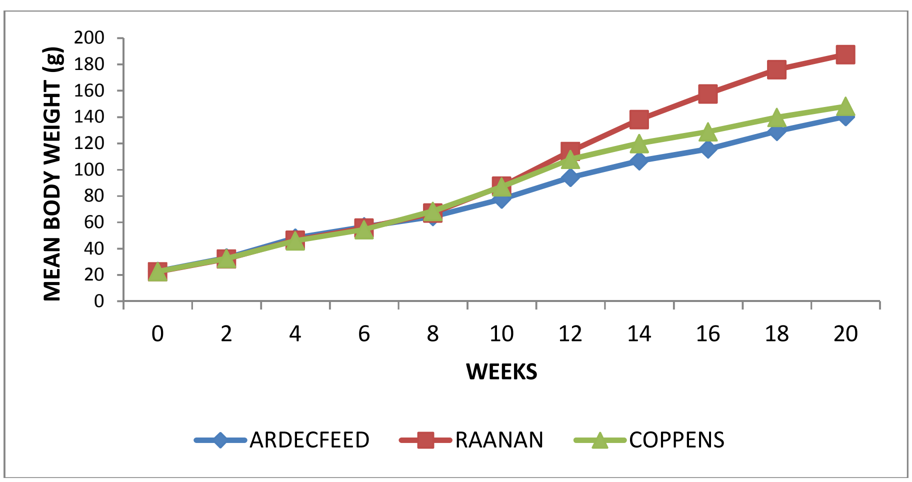


**Fig. 1. Growth performance of *Oreochromis niloticus* fed with farm-made and commercial tilapia diets for 20 weeks**

Plant proteins are less expensive than animal sources; however, their deficiency in methionine and lysine limits their use as main protein sources in fish diets [20,21]. Of all the plant protein feed ingredients, soybean meal is considered the most nutritious and is used as the major protein source in many fish diets to partially or totally replace fish meal [22]. The proximate compositions of white maize, soybean meal and wheat bran in the present study were in the same range as indicated by results of previous studies in Ghana [23]. Crude fibre content of wheat bran was high and it is considered a limiting factor in its use in fish diet.

### 4.2 Proximate Compositions of the Farm-made and Commercial Diets

The values for chemical analyses of the farm-made and commercial diets were similar to the calculated/declared crude proteins. In all cases, the analysed values were a little higher. These findings disagreed with those values of analysed crude protein levels of four commercial diets (Adolf calyx, Coppens, Dizengoff and Durate) by [24]. These researchers observed that all the analysed values on crude protein were less than the producers' declared values. The values of the analyses ranged from 0.7 to 38.4% less than expected. On the other hand, similar analyses carried out by [25] indicated that 3 commercial fish diets which were pointed out to contain 26.0% crude protein, proximate analyses showed that diets 1, 2 and 3 had crude protein levels higher by 32.7%, 16.0% and 28.0% respectively. In the present study, the crude proteins of the farm-made and commercial diets ranged from 1.71 to 4.03% greater than the expected with the greatest deviation occurring in the former. However, the analysed crude protein levels for all the diets were within the recommended range for juvenile and adult *O. niloticus* [9,26].

Lipids are primarily included in formulated diets to maximize their protein sparing effect by being a source of energy [27]. Dietary lipids facilitate the absorption of fat soluble vitamins, play an important role in membrane structure and function, serve as precursors for steroid hormones and prostaglandins, and serve as metabolizable sources of essential fatty acids. The observed lipid levels of the two commercial diets, RAANAN and COPPENS were below the minimum recommended values of 10-15% [26]. However, Luquet [28] stated that dietary lipid levels of 5 to 6% are often used in commercial tilapia diets.

### 4.3 Growth Performance and Feed Utilization of the Cultured *O. niloticus*

The growth performance and feed utilization efficiency of juvenile *O. niloticus* are affected by food quantity and quality, genetic make-up, sex of the fish and their interaction [29,30]. The mean initial body weights and body lengths of the experimental fish recorded at the commencement of the experiment were similar and were not significantly different (ANOVA, $P$ = .19). Hence, the performance differences observed among treatments at the end of the growth trial was due mainly to dietary effect. The growth performance and feed efficiency of animals fed extruded diets is thought to improve. Different processing techniques can reduce anti-nutritional factors and thereby increase palatability [31,32]. The differences in the quality of the diets could be due to the composition and the processing technique employed in their production which might have enhanced the palatability and nutrient digestibility of the different diets to varying extent. The extrusion of the commercial diets during their production compared to the farm-made one might have improved the performance of the former.

Extrusion conditions might significantly affect final weight, feed efficiency, protein productive value and energy retention particularly of *O. niloticus* fed with RAANAN in this study. Similar results were reported for rainbow trout [33], channel catfish [34] and carp [35]. A beneficial effect of heating of soya bean meal on weight gain, feed intake and feed efficiency of channel catfish was observed [34]. Growth rates of carp were reduced when fed diets containing under-heated soya bean meal [35]. The variations in growth performance and feed utilization efficiency in this study could also be attributed to differences in the quality of the various diets in terms of nutrient compositions [36].

Even though COPPENS had the highest crude protein content, this was not reflected in the growth performance and feed efficiency of the *O. niloticus* it was fed with. This could possibly be because the diet lacked sufficient essential amino acids to support fish growth. This supports the observation made by [37] that fish do not have a specific requirement for crude protein per se, but rather they need the right combination of essential amino acids. Essential amino acid requirements can be met by balancing both plant and animal proteins, and if necessary, by the inclusion of synthetic amino acids in the complete diet [38]. An indispensable amino acid deficiency may cause reduced growth and poor feed conversion [39,40]. Therefore, satisfying the indispensable amino acid requirements of a species is outmost importance in preparing well-balanced diets. This observation suggests that

*O. niloticus* performs better when fed a diet containing the complete requirements of amino acids for tilapia [41].

The low ash content of COPPENS (Table 3) could also be responsible for the poor growth performance of the fish it was fed with, as ash is a source of calcium and phosphorus [42]. Hence, essential mineral elements such as calcium and phosphorous that promote growth in fish were insufficient in COPPENS. A better growth performance of *C. gariepinus* was observed on diet containing 9.3% ash content [43], whilst [44] opined that ash content in the feed of *C. gariepinus* should not be less than 8.0%. High ash content of > 12.0% has been reported to produce better growth performance in *Clarias* species [45,46].

The results of the present study contradict that of other researchers in comparing COPPENS with farm-made fish diets. Findings of [47] indicated that *C. gariepinus* gave significantly better growth performance when fed with COPPENS than when fed with farm-made diet. COPPENS has been reported to produce better growth performance in various species of fish when compared with local fish diets. These include the work of [48] who compared growth performance of humpback grouper, *Cromileptis altivelis* fed farm-made diets and COPPENS, and [49] who showed that commercial fish diets enhanced better growth performance of fingerlings of *Labeo rohita*. The comparable performance of ARDECFEED to COPPENS in the current study could be attributed to the good quality of the former.

The highest survival rate was achieved in fish fed with RAANAN and the least in COPPENS. However, there were no significant differences among dietary treatments. Most of the mortality observed during the growth trials could not be due to dietary treatment as mortality was mostly experienced a day after measurements of fish growth. Hence, mortalities could be attributed to handling stress. This observation was consistent with findings of [50]. These researchers reported a survival of 86.50 to 87.43% in earthen ponds when Nile tilapia was fed with three different diets formulated from local agro-industrial by-products. They also attributed part of the mortality to predation particularly by predatory birds. In the current study, bird predation did not occur as the hapas used in culturing the fish were fully covered with nylon nets. Besides handling stress, another factor that affected survival in this study was escape of fish from some of the replicates (hapas) into the open pond waters as they were being taking out of the culture system to measure growth during the study period.

### 4.4 Cost-effectiveness of the Farm-made and Commercial Diets

The cost-effectiveness analyses of the various diets indicated that the farm-made diet, ARDECFEED was more profitable than the commercial ones (RAANAN and COPPENS). These findings are consistent with other studies which indicated that nutritionally balanced farm-made fish diets were cost-effective in the production of *O. niloticus* in semi-intensive fertilized ponds [25]. However, the results of the present study disagree with that of [51], who observed that although using farm-made diets appears to be the cheaper option, and switching to them reduces production costs, they are less efficient in terms of growth and FCR; thus, in terms of real production costs (cost/kg fish produced), they are more expensive to use. The findings of the current study also contradict that of this researcher, that although reverting to farm-made diets may reduce diet costs, farmers need to recognize that there will be a concomitant reduction in profits [51].

The least profit of COPPENS was mainly due to the high cost of the diet without commensurate increase in yields when compared to RAANAN. In the current study, there were no significant differences between the growth rate and feed efficiency of ARDECFEED and COPPENS, which was the most expensive diet among the three. Hence, the use of the two types of diets to raise a fish to a market size of 200 g by Ghanaian standards [13] may last over the same culture period. This suggests that using ARDECFEED will reduce the production cost of Nile tilapia and consequently increase the profit margin of small-scale fish farmers significantly.

## 5. CONCLUSION

The costs associated with the use of commercial fish diets by small-scale pond fish farmers are high, and in terms of fish growth and economic returns, the use of appropriately prepared farm-made diets will be a better alternative. The most obvious observation was the relatively poor performance of COPPENS although it was the most expensive but with the highest crude protein content. Therefore, cost of commercial fish diets cannot necessarily be translated into good quality. The ARDECFEED has the best prospects based on growth performance, nutrient utilization and economic benefits. Fish farmers should be trained on the formulation and preparation of nutritionally balanced and cost effective farm-made fish diets using locally available ingredients for small-scale fish farming instead of dependency on highly unaffordable commercial ones.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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