JFLS | 2017 | Vol 2(2) | Pp 50-59

OPEN ACCESS

Journal of Fisheries and Life Sciences
International Peer-Reviewed Biannual Journal
www.fishlifesciencejournal.com

Research Article

Evaluation of tilapia grower diets of farm-made, commercial and their 1:1 mixture for small-scale hapa production of Nile tilapia (*Oreochromis niloticus* L.) in Ghana

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ISSN: 2456-6268

ARTICLE INFO
Received: 17 October 2017
Accepted: 30 December 2017
Available online: 31 December 2017

KEYWORDS
Commercial fish diet,
Incidence cost,
Profit index

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ABSTRACT

An increasing number of small-scale pond fish farmers in Ghana produce and use farm-made fish diets due to the farmers' inability to afford the costs of commercial diets. Whilst some farmers alternate the use of the former with the latter, others mix the two types in equal proportions to feed cultured fish. This study was carried out to evaluate a farm-made tilapia diet, a commonly used commercial tilapia diet (*Raanan*) in Ghana and an equal mixture of the two diet types for Nile tilapia (*Oreochromis niloticus*). The study was conducted in net hapas installed in a 0.2 hectare earthen pond over a 140-day growth period at the Aquaculture Research and Development Centre (ARDEC), Akosombo, Ghana. The fish, initial mean weight 22.8 ± 2.1 g were stocked at 2 fish m^{-2} and fed at 4 to 3% body weight three times a day including weekends. After the culture period, the final mean weights of *O. niloticus* were 131.0 ± 24.4, 187.6 ± 42.1 and 140.7 ± 28.5 g for Farm-made, *Raanan* and Mixed diet respectively. The best incidence cost and the highest profit index were obtained with the Farm-made diet. The results indicated that small-scale pond fish farmers in the country would cut down on their production cost and make more profit if they produced and used nutritionally balanced farm-made tilapia diets alone than using either the commercial one or mixing equal portions of the two diet types to feed cultured fish.

INTRODUCTION

Most small-scale fish farmers in Ghana use earthen ponds whilst others use cages, pens and raceway systems which are not commonly used nationwide. In terms of numbers, cages come after ponds. However, fish production in cages are higher than in ponds (FD, 2016), and of all tilapia production in the country, over 80% of it is derived from cage farms where commercially complete floating fish diets are used (Ahmed, 2013).

For earthen pond fish production, fish farmers use both commercial and farm-made fish diets. Of the commercial diets, *Raanan* is the commonest and it constitutes about 86% of the used commercial fish diets (Anani, 2015). A large number (about 63%) of small-scale pond fish farmers produce and use farm-made feeds as a result of the continuous increase in the prices of the commercial diets making the latter highly unaffordable to the farmers (Anani *et al*., 2016). The farmers used locally available ingredients to prepare the farm-made feeds. However, the nutrient compositions of the ingredients used were not a consideration in terms of formulation (Ahmed, 2013). The inclusion levels of ingredients were based on availability, and those such as wheat bran and maize which to a large extent are available all year round were widely used by most farmers at high inclusion levels whilst fishmeal, the most expensive ingredient is used sparingly.

Most of the farm-made feeds consisted of ingredients that were not combined in a specified proportions. Some were raw agricultural wastage that was directly fed to the cultured fish. Formulations are often based on past experience (what the farmers themselves have found to work), feed ingredient availability and their costs; advice from other farmers, feed ingredient suppliers and occasionally Fisheries Extension Officers (Anani *et al*., 2016). In order to reduce fish feed cost and also to improve upon the quality of farm-made fish feeds, some famers mixed farm-made and commercial diets in equal proportions to feed cultured fish (Anani *et al*., 2016). The prepared farm-made feeds were not supplemented with supplements such as essential amino acids, vitamins and minerals.

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 (Anani *et al.*, 2017). This study was therefore carried out to evaluate an un-supplemented farm-made tilapia grower diet, *Raanan* (the most commonly used commercial tilapia diet in Ghana) and an equal mixture of the two diets for a small-scale hapa production of Nile tilapia (*Oreochromis niloticus*), the most cultured fish in Ghana (FD, 2016)

MATERIAL AND METHODS

Description of the study area

The formulation, preparation and evaluation of the tilapia diet types (Farm-made, *Raanan* and their equal Mixture) were carried out at the Aquaculture Research and Development Centre (ARDEC) of Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR). The area lies between latitude 6° 13′ North and the longitude 0° 4′ East at Akosombo in the Eastern Region of Ghana.

Feed ingredients and commercial fish diet selection

The ingredients used in the formulation and preparation of the farm-made diet 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, palm oil (*Elaeis quineensis*) and common salt (sodium chloride). The ingredients were found to be locally available in all regions of Ghana (Anani, 2015). The most commonly used commercial fish diet (*Raanan*, 30% crude protein content) by fish farmers in Ghana was selected.

Proximate compositions of ingredients and diets determination

Proximate analyzes of the ingredients and the diets for the study 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 fiber (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. Percentage 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 was computed by using the average physiological fuel values of 23.64, 39.54 and 17.15 MJ kg^{-1} for protein, fat and carbohydrate respectively (Anani *et al.*, 2017).

Farm-made diet formulation and preparation

The farm-made diet was formulated and prepared to contain 300 g kg^{-1} protein, 18 kJ g^{-1} energy, and 100 g kg^{-1} lipid to meet the nutrient requirements of Nile tilapia (NRC, 2011) using the selected ingredients. Common salt was added at 2 g kg^{-1} (Table 1).

Table 1: Inclusion levels (%) of ingredients used in the farm-made diet

Ingredient	Inclusion Level (%)
Fish meal	25.0
Soybean meal	26.8
Maize (white)	27.0
Wheat bran	5.0
Cassava flour	10.0
Palm oil	6.0
Common salt (sodium chloride)	0.2

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 palm oil was 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.

The commercial diet, *Raanan* which was originally extruded before procurement was milled into powdered form and then pelleted as for the farm-made diet so as to ensure consistency in the forms and sizes of all the diets (Anani *et al.*, 2017). 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 labeled transparent plastic containers of each having a capacity of about 10 litres. The excess diets were then packaged in labeled polythene bags and stored in a well-ventilated room. Samples of the prepared diets were analyzed 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. The mixed diet was prepared by mixing the farm-made and *Raanan* diets in a ratio of 1:1.

Experimental system used in evaluating the diets

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 were used for the feeding trials. Each hapa was separated from others by about 6 m distance to avoid easy drifting of contents of one system into another (Anani *et al*., 2010). 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 (Anani *et al*., 2017). The cover net was to keep predatory birds from injuring or picking the experimental fish and also 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.

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.

Conditioning and stocking of experimental fish

A total number of hundred and eighty (180) of the ninth generation of mono sex male *O. niloticus* known as the "Akosombo Strain" developed by CSIR WRI-ARDEC through selective breeding was used in the growth study. The fish were denied of feed for 24 hours. 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. Feeding of the stocked fish commenced the day following stocking with the experimental diets.

Feeding and measurements of fish during growth study

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 sizes. 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 culture period.

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 easy 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 systems.

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 0830 GMT. The fish were not fed on the day they were handled, feeding commenced at 0800 GMT of the following day. The feeding trials were carried out for 20 weeks (140 days). The day after the 140 days, all the fish from each treatment was harvested, counted and measured individually to determine the final growth and survival.

Biological parameters determination

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 $fish^{-1}$) = Total feed given per fish/no. of days fed, 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

Cost-effectiveness of the diets

The cost-effectiveness of the diets was determined using Incidence Cost (IC) and Profit Index (PI) (Anani *et al*., 2017) 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 farm-made diet was calculated using market prices of the ingredients used whilst for *Raanan*, the price per kilogram (kg) as existed in the study area was used. For the mixed diet, half the cost of the farm-made and that of *Raanan* were added. Only the cost of the diets was used in the computations with the assumption that all other operating costs (e.g. transport, hapa, fingerlings and labor) remained constant. However, ten percent (10%) of the original costs per kg of the farm-made diet based on the price of the ingredients used was added to the diet to cover the cost of labor used in preparing the diet (Anani *et al*., 2017).

Data analyzes

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 analyzes (Zar, 1984). Statistical analyzes 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 $P \leq 0.05$.

RESULTS AND DISCUSSION

Proximate compositions of the diets

The proximate compositions of the farm-made diet, *Raanan* and the mixed diet are shown in Table 2.

Table 2: Proximate compositions (% as-fed), gross energy (kJ g^{-1}) and prices (GHS kg^{-1}) of the tilapia grower diets of farm-made, commercial and their 1:1 mixture

	Farm-made diet	*Raanan*	Mixture
DM	90.59 ± 0.02	90.40 ± 0.02	89.66 ± 0.06
CP	31.53 ± 0.04	31.21 ± 0.07	33.80 ± 0.03
CL	12.39 ± 0.03	4.78 ± 0.06	10.00 ± 0.07
CF	4.46 ± 0.02	3.91 ± 0.06	4.01 ± 0.08
Ash	8.39 ± 0.04	9.45 ± 0.02	8.02 ± 0.05
NFE	33.82 ± 0.07	41.05 ± 0.08	33.83 ± 0.09
GE	18.15 ± 0.04	16.31 ± 0.03	17.75 ± 0.05
Price	1.75	3.25	2.50

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 2015 was: GHS 3.88 = 1.00 USD

A good fish diet should contain protein, lipids (fats), ash (minerals), fiber, moisture, nitrogen free extracts (carbohydrates) and vitamins in the right proportion and formulated in a balanced ration which will be acceptable, palatable and durable to the fish for its optimum growth (Ayuba and Iorkohol, 2013). The proximate analyzes of the diets showed that they had similar moisture contents with the farm-made diet being the least (9.41%). The mixed diet had higher (33.80%) crude protein content than any of its constituent diets. All the analyzed crude protein levels for all the experimental diets were within the recommended range for juvenile and adult *O. niloticus* (NRC, 1993; Shiau, 2002; Fitzsimmons, 2005; El-Sayed, 2006; Lim and Webster, 2006). Protein is the main growth promoting factor in fish diet, and its requirement is influenced by fish size, water temperature, feeding rate, availability and quality of natural foods and overall digestible energy content of the diet (Satch, 2000; Wilson, 2000; Ayuba and Iorkohol, 2013). *Raanan* contained the least (4.78%) crude lipids whilst farm-made diet contained the most (12.39%). Lipids are primarily included in formulated diets to maximize their protein sparing effect by being a source of energy (Hasan, 2001). 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 gross energy of the diets ranged from 16.31 to18.15 kJ g^{-1} with *Raanan* having the least and farm-made diet the highest. Values obtained for the analyses of Ash ranged from 8.39 to 9.45%. The mixed diet had the least whilst *Raanan* had the highest. Crude fiber contents of the diets ranged from 3.91 to 4.46% with *Raanan* having the least and farm-made diet the highest. Fiber provides physical bulk to the diet. An appreciable amount of fiber in the diet permits better binding and moderates the passage of feed through the alimentary canal. However, De Silva and Anderson (1995) noted that it was not desirable to have fiber content above 8-12% in diets for fish, since the increase in fiber content would consequently result in the decrease of the quality of usable nutrient in the diet. A high fiber and ash contents reduce the digestibility of other ingredients in the diet resulting in poor growth of the fish. The analyzed crude fiber contents of all the diets evaluated in this study were within the dietary requirement for *O. niloticus*. Although the mixed diet was prepared by mixing equal portions of the farm-made diet and *Raanan*, the values obtained for the chemical analyses of the mixed diet were not equal to those of the mean of the two mixed diets. However, all the parameters were similar to those of the other diets. The unit cost of the diets ranged from 1.75 to 3.25 GHS kg^{-1} with *Raanan* being most expensive and the farm-made one being least.

Growth performance of cultured O. niloticus

The growth performance of the fish in terms of final mean weight gain, percentage weight gain, specific growth rate, daily weight gain, survival rate, total fish yield and net fish yield is presented in Table 3.

The highest final mean weight of 187.6 g occurred in fish fed with *Raanan* whilst the least final mean weight of 131.0 g occurred in fish fed with the farm-made diet. The final mean weight of fish fed with *Raanan* was significantly higher (Tukey's HSDT, $P < 0.05$) than those fed with the other diets. The percentage weight gain and specific growth rate were highest for fish fed with *Raanan* (728.8% and 1.63% day^{-1} respectively). However, there was no significant difference in specific growth rate among dietary treatments. The values for mean daily weight gain ranged from 0.77 to 1.18 g $fish^{-1}$. Fish fed with *Raanan* had significantly higher (Tukey's HSDT, $P < 0.05$) daily weight gain. The growth performance differences observed among the various dietary treatments at the end of the growth trial could be due mainly to dietary effect as the 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, $P > 0.05$). Food quantity and quality affect growth performance and feed utilization efficiency of a fish (Noor *et al.*, 2010). Since the same amount of each diet type was given to the fish in each dietary treatment, the growth differences observed could be attributed to the diet quality. Gjedrem (1997) observed that genetic make-up, sex of fish and their interaction affect the growth performance and feed utilization efficiency of fish. These observations could not be applicable to the results of the present study as the *O. niloticus* used were of the same strain, all males and they were stocked at the same density in all the dietary treatments.

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 diet (*Raanan*) during its production compared to the farm-made one might have improved the performance of the former.

Different processing techniques can reduce anti-nutritional factors and thereby increase palatability (Azzaza *et al*., 2008; Workagegn *et al*., 2013). The growth performance and feed efficiency of animals fed extruded diets was observed to improve. Heat treatment involved in typical moist extrusion processing used for fish diet may be sufficient to inactivate most of the trypsin inhibitor activity in unheated soybean meal, and to increase digestibility of the protein in untoasted defatted soybean meal (Romarheim *et al*., 2005).

Extrusion conditions might significantly affect final weight, feed efficiency, protein productive value and energy retention particularly of *O. niloticus* fed *Raanan* in this study. Similar results were reported for rainbow trout (Barrows *et al*., 2007), channel catfish (Peres *et al*., 2003) and carp (Viola *et al*., 1983). A beneficial effect of heating of soya bean meal on weight gain, feed intake and feed efficiency of channel catfish was observed (Peres *et al*., 2003). Growth rates of carp were reduced when fed with diets containing under-heated soybean meal (Viola *et al*., 1983). 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 composition (Workagegn *et al*., 2014).

The highest (100.0%) survival was observed in fish fed with *Raanan* whilst the least (90.0%) occurred in those fed with the mixed diet. However, there were no significant differences (ANOVA, $P > 0.05$) 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 agreed with findings of Attipoe *et al*. (2009). 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 contributed to mortality in this study was escape of fish from some of the replicates (hapas) as they were being taking out of the culture system to measure growth during the study period.

The total fish yield (TFY) ranged from 0.25 to 0.38 kg m^{-2} whilst net fish yield (NFY) ranged from 0.20 to 0.33 kg m^{-2}. Both TFY and NFY were significantly higher in *O. niloticus* fed with *Raanan* whilst there were no significant differences among the other dietary treatments. Even though the farm-made diet had the least yield of 4, 856.00 kg ha^{-1} yr^{-1}, it was about double the productivity of 2, 500 kg ha^{-1} yr^{-1} by Ghanaian small-scale fish farmers (Awity, 2005). This was against the background that the current study was carried out in hapas with a stocking density of 2 fish m^{-2}. Hence, under semi-intensive culture systems commonly practised in earthen ponds in Ghana where fish stocking could be up to 4 fish m^{-2}, the performance of the farm-made diet could be up to about four times the current production levels of small-scale pond fish farmers in the country. Further, farmers could increase yield and their profit margin by combining feeding with fertilizing (Liti *et al*., 2005; Gabriel *et al*., 2007; Opiyo *et al*., 2014).

Generally, growth of *O. niloticus* was rapid in all the dietary treatments after the second week of feeding trials up to the sixth week (Fig. 1). Growth was 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. Fish fed with *Raanan* recorded the highest final mean weight of 187.6 g whilst those fed with the farm-made diet gave the least of 131.0 g at the end of the culture period.

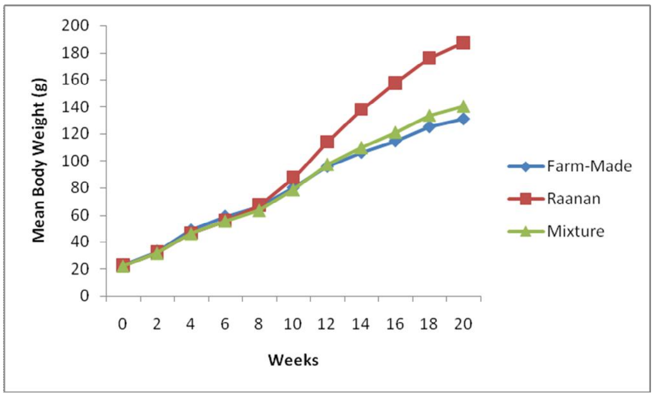

Fig. 1: Growth of Nile tilapia fingerlings fed with tilapia grower diets of farm-made, commercial and their 1:1 mixture for 20 weeks in hapas

Although specific feeding trial durations are not universally specified, they generally need to last long enough for any potential significant differences among the diets to materialize (Weatherup and McCracken, 1999). In a study by De Francesco *et al*. (2004), differences in trout growth performance between fish meal and plant-based diets became apparent after 12 weeks. In the present study significant differences occurred after 16 weeks. In a study by Barnes *et al*. (2012) in which fish meal was replaced with high protein distillers dried grain (HPDDG) in juvenile rainbow trout diets, the experiment lasted over 10 weeks for significant differences to occur.

Feed and nutrient efficiency of cultured O. niloticus

Data on feed and nutrient efficiency of the fish in terms of feed conversion ratio, feed efficiency, feed intake, protein efficiency ratio, protein productive value and energy retention are shown in Table 4.

The feed conversion ratio (FCR) values ranged from 2.35 to 3.26 at the end of the growth study and that of the farm-made diet was significantly higher (Tukey's HSDT, $P < 0.05$). Feed efficiency was less than 50.0 % in all the dietary treatments and the values ranged from 30.10% in the farm-made diet to 43.03% in *Raanan* with the latter being significantly higher. The most efficient feed conversion was observed in fish fed with *Raanan* diet whilst the least occurred in fish fed with the farm-made diet. The unexpected poor growth performance and feed efficiency observed in fish fed with a 1:1 mixture of the farm-made diet and *Raanan* could be due to the adulteration of the *Raanan* diet. The farm-made diet used in the present study was not supplemented with essential amino acids, vitamins and minerals. It might contain some anti-nutritional factors by virtue of the ingredients used in its preparation and besides, it was not processed by any means (particularly heating). Hence, the mixing of the farm-made diet with *Raanan* in a ratio of 1:1 diluted the latter to the extent that there was reduction in nutrient availability as observed by Hajos *et al*., 1995; Reddy and Pierson, 1995; Aderibigbe *et* *al*., 1997; Azzaza *et al*., 2011, who reported that diets with higher concentration of anti-nutritional factors reduces the availability of nutrients which in turn reduces the growth performance of fish. Feed intake ranged from 344.83 to 388.11 g fish^{-1} and there were no significant differences (ANOVA, $P > 0.05$) among all the diets. There were no significant differences in protein utilization efficiency among all the diets and the values ranged from 1.27 to 1.67. The protein productive value was significantly higher (Tukey's HSDT, $P < 0.05$) in fish fed with *Raanan*. The percentage energy retention ranged from 10.30 to 15.32%, with fish fed with *Raanan* being significantly higher. Reduced growth response and feed utilization in various warm-water aquaculture species fed with diets in which fish meal was replaced with oilseed meals have been explained by sub-optimal amino acid balance, inadequate levels of phosphorus, inadequate energy, low feed intake caused by poor palatability, presence of endogenous anti-nutrients or dietary level of fish oil (Lim and Dominy, 1991). The poor performance of the mixed diet compared with *Raanan* could be due to any of these factors. Also, De Silva *et al*., (1989) observed that acceptability of feed by fish could be affected by increasing levels of plant material since the texture and taste of the diets are bound to differ.

Cost-effectiveness of the diets

The cost of *Raanan* was the highest (3.25 GHS kg^{-1}) followed by that (2.59 GHS kg^{-1}) of the mixed diet and the least was that (1.93 GHS kg^{-1}) of the farm-made diet (Table 5).

The cost-effectiveness analyses showed that it was more expensive (6.72 GHS kg^{-1}) to use *Raanan* to produce a kilogram of tilapia than either the farm-made (5.16 GHS kg^{-1}) or the mixed diet (6.34 GHS kg^{-1}). The highest profit was made by using the farm-made diet, followed by the mixed diet whilst the least was by using *Raanan*. These findings agreed with other studies which indicated that nutritionally balanced farm-made fish diets were cost-effective in the production of *O. niloticus* in semi-intensive systems (Liti *et al*., 2005; Gabriel *et al*., 2007; Opiyo *et al*., 2014; Anani *et al*., 2017). However, the results of the present study are in disagreement with that of Nguyen (2013) 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^{-1} fish produced), they are more expensive to use. His study demonstrated that the total cost of production using farm-made diets was US$0.88/kg fish, whereas it was US$0.79/kg fish for farmers using commercially manufactured diets or a combination of commercially manufactured and farm-made diets (Nguyen, 2013). The findings of the current study also contradict that of this researcher, who reported that although reverting to farm-made diets may reduce diet costs, farmers need to recognize that there will be a concomitant reduction in profits.

In the present study, even though the *Raanan* diet was highest in extrapolated fish yield (7, 920 kg ha^{-1} yr^{-1}) it was about 23% less profitable than the farm-made diet which gave the least yield (4, 856.00 kg ha^{-1} yr^{-1}). The least profit of *Raanan* in this study was likely due to the high cost of the diet. It was more profitable to feed Nile tilapia with the un-supplemented amino acid and vitamin/mineral premixes diet than an equal mixture of it and *Raanan*. Hence, using the farm-made diet will reduce the production cost of Nile tilapia and consequently increase the profit margin of the fish farmer. This will immensely benefit the small-scale semi-intensive farmers who constitute the majority of fish farmers in Ghana.

The results of this study also revealed that it was more profitable to use the farm-made diet alone than mixing it in equal proportions with *Raanan*. Use of the farm-made diet was about 23% more profitable than that of the commercial one and about 21% more profitable than the mixed diet whilst the use of the mixed diet was just about 2% more profitable than the use of the commercial diet. 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 farm-made diet used in this study could be used to produce acceptable fish growth and feed conversion ratios of Nile tilapia in semi-intensive production systems, where autotrophic and heterotrophic food material may supply the deficient amino acids. Simple heat processing of the diet under field conditions as suggested by Agbo (2008) will improve on the performance of the diet and thereby reducing the cost of fish production since the additional cost of including supplements will be eliminated.

Table 3: Mean growth performance of the cultured Nile tilapia fed with tilapia grower diets of farm-made, commercial and their 1:1 mixture for 20 weeks

Parameter	Diet		
	Farm-made	***Raanan***	**Mixture**
Initial mean weight (g)	23.2 ± 1.9^{a}	22.6 ± 2.3^{a}	22.5 ± 2.2^{a}
Final mean weight (g)	131.0 ± 24.4^{a}	187.6 ± 42.1^{c}	140.7 ± 28.5^{b}
Initial standard mean length (cm)	89.1 ± 2.5^{a}	88.4 ± 2.6^{a}	88.1 ± 3.2^{a}
Final standard mean length (cm)	159.9 ± 9.2^{a}	177.6 ± 13.7^{c}	163.6 ± 11.2^{b}
Weight gain (%)	466.2 ± 38.8^{a}	728.8 ± 45.0^{c}	526.6 ± 36.6^{b}
Specific growth rate (% day^{-1})	1.33 ± 0.05^{a}	1.63 ± 0.04^{a}	1.41 ± 0.05^{a}
Daily weight gain (g/fish)	0.77 ± 0.07^{a}	1.18 ± 0.19^{b}	0.84 ± 0.06^{a}
Survival (%)	95.0 ± 8.66^{a}	100.0 ± 0.00^{a}	90.0 ± 10.00^{a}
Total fish yield (Kg m^{-2})	0.25 ± 0.18^{a}	0.38 ± 0.23^{b}	0.25 ± 0.19^{a}
Net fish yield (Kg m^{-2})	0.20 ± 0.17^{a}	0.33 ± 0.23^{b}	0.21 ± 0.17^{a}

Values are means ± standard deviations of three replicates. Means within the same row with different letters are significantly different (Tukey's HSDT, $P < 0.05$)

Table 4: Feed and nutrient efficiency of the cultured Nile tilapia fingerlings fed with tilapia grower diets of farm-made, commercial and their 1:1 mixture for 20 weeks

Parameter	Diet		
	Farm-made	***Raanan***	**Mixed diet**
Feed conversion ratio	3.26 ± 0.21[a]	2.35 ± 0.13[b]	2.92 ± 0.07[b]
Feed efficiency (%)	30.10 ± 2.10[a]	43.03 ± 2.00[b]	34.04 ± 1.21[a]
Feed intake (g fish^{-1})	351.32 ± 12.87[a]	388.11 ± 18.92[a]	344.83 ± 13.63[a]
Protein efficiency ratio	1.27 ± 0.88[a]	1.67 ± 0.77[a]	1.34 ± .76[a]
Protein productive value (%)	20.44 ± 0.34[a]	28.80 ± 0.03[b]	22.07 ± 0.21[a]
Energy retention (%)	10.30 ± 0.20[a]	15.32 ± 0.14[b]	10.78 ± 0.31[a]

Values are means ± standard deviations of three replicates. Means within the same row with different letters are significantly different (Tukey's HSDT, $P < 0.05$)

Table 5: Cost-effectiveness of diets fed to Nile tilapia fingerlings

Diet	Cost per kg of feed (GHS)	Feed input (kg)	Cost of feed used (GHS)	Harvested biomass (kg)	Estimated value of biomass (GHS)**	Incidence Cost (GHS/kg)	Profit Index
Farm-made*	1.93	19.93	38.46	7.46	47.00	5.16	1.22
Raanan	3.25	23.29	75.69	11.26	75.04	6.72	0.99
Mixture	2.59	18.59	48.15	7.60	48.83	6.34	1.01

*Cost per kg of diet include labour, constituting 10% of the cost of producing the feed (Anani *et al*., 2017),
**Sale of fish: < 150 g = GHS 6.20, 150-299 g = GHS 6.70, 300-400 g = GHS 7.50
The average exchange rate of the Ghana cedis to the USA dollar in 2015 was: GHS 3.88 = 1.00 USD

CONCLUSION

It can be concluded from the present study that selection of appropriate ingredients to formulate and prepare nutritionally balanced farm-made fish diets was cost-effective and will boost growth and sustainability of aquaculture in most regions of Ghana where semi-intensive pond fish farming is mainly practised. It was more profitable to feed Nile tilapia with farm-made diet not supplemented with amino acid and vitamin/mineral premixes than mixing an equal amount of it with a commercial tilapia diet (*Raanan*). In the present study, the use of the farm-made diet gave a higher profit index (1.22) than (1.01) when it was mixed with *Raanan* in a ratio of 1:1. Hence, farmers will make a higher profit and cut down on production cost when they use appropriately prepared farm-made diets alone than mixing a prepared diet with a commercial one.

In the present study, growth trials of the experimental fish were carried out in hapas as against the semi-intensive system commonly practised in earthen ponds by small-scale fish farmers in Ghana. Hence, similar study should be carried out under field conditions in earthen ponds. Under the pond condition the stocking density could be increased to 4 fish m^{-2} as against 2 fish m^{-2} that was used in this study.

ACKNOWLEDGEMENT

The authors are most grateful to all staff, particularly the farm-hands of the Aquaculture Research and Development Centre (ARDEC), Akosombo, Ghana for their immeasurable support during the period of the study.

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