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RESEARCH PAPER

Profitability of Using Five Different Commercial Tilapia Starter Feeds on the Ghanaian Market in Nile Tilapia, *Oreochromis niloticus* Fingerlings Production

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Abstract

Choice and use of fish feed should not only depend on good fish growth but also, on higher returns on investment. Growth performance and cost-effectiveness of five tilapia starter feeds (*Aller Aqua*, *ARDECFeed*, *Koudijs*, *Naam Papa* and *Raanan*) to produce Nile tilapia, *Oreochromis niloticus* fingerlings were investigated. The feeds, with crude protein (CP) contents ranging from 42.0 to 60.0%, were randomly coded *A*, *B*, *C*, *D* and *E*. The study was conducted in fifteen fine mesh net hapas, each of dimensions 5.0x2.0x1.2 m, installed in three 0.2-hectare earthen ponds with each containing a replicate of each feed type. Nile tilapia fry, ranging from 0.05 to 0.08 g with an initial mean weight of 0.06±0.01 g were stocked at 500 fry hapa^{-1} and they were fed at 20.0% of their biomass; three times daily. The feeding rate was reduced to 10% when the fry attained mean weights ranging from 1.0 to 5.0 g and finally to 5.0% when they were greater than 5.0 g. The feeding trial lasted for nine weeks (63 days). Fry final mean weight ranged from 17.34±9.12 to 23.62±14.39 g, with B being significantly higher (Tukey's HSDT, P<0.05) whilst there were no significant differences (ANOVA, P>0.05) among *A*, *C*, *D* and *E*. The profit indices ranged from 4.13±0.55 to 14.63±0.38, with *D* being the highest and *B*, the least. Hence, tilapia hatchery operators should opt for feeds that give higher profit indices, lower production and incidence costs for fingerlings production.

Introduction

The Nile tilapia is the major tilapia species being cultured in Ghana. Currently, the average size of tilapia fingerlings mostly produced by commercial tilapia hatchery operators in the country ranges from 0.5 to 5.0 g, and production is carried out in earthen ponds, concrete/plastic/tarpaulin tanks or net hapas. The brand choice of starter feeds used by tilapia hatchery operators to produce *O. niloticus* fingerlings is influenced by cost, availability and fish growth performance.

Presently, different brands of commercial tilapia feeds of various categories viz. starter, grower and finisher are available on the Ghanaian market, and they vary in crude protein contents and costs. Tilapia starter feeds are mainly used by hatchery operators to produce fingerlings of mostly Nile tilapia, *Oreochromis niloticus*. Some of these feeds are produced locally, whilst others are imported. All brands of tilapia starter feeds for

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fingerling production are powdered or crumbled. The crude protein contents of these feeds are typically higher than 40% and their prices per kilogramme vary from brand to brand, with some being over 2.0 US$/kg (Anani *et al*., 2021).

A major challenge facing the aquaculture industry in Ghana and Africa as a whole, is unaffordable nutritionally balanced and cost-effective fish feeds, particularly those of the starter. The costs of these feeds are very high, as they strongly correlate positively with their crude protein contents.

Due to the high cost of starter feeds, most tilapia hatchery operators do not adhere to the least size of 5.0 g fingerling production and supply to farmers as recommended by the Fisheries Commission, the major regulator of the Fisheries and Aquaculture sector (Anani and Agbo, 2019). Hence, the sizes of tilapia fingerlings mostly produced by commercial tilapia hatchery operators in the country ranged from 1.0 to 3.0 g. However, in recent times, in an effort to avoid much investment into starter feeds; a number of commercial tilapia hatchery operators have resorted to the production and the release of fingerling sizes that are less than 1.0 g to grow-out producers.

Fish optimal growth and good health are obtained from feeds. Hence, feeds fed to culture fish at any stage must contain appropriate and sufficient quantities of the required nutrients. The fry stage is the most critical phase in the life history of most fish species as mortality rate could be high. Feeding fry with poor quality or nutritionally imbalanced feeds are the main causes for high fish mortality and stunted fish growth, which could persist to the grow-out phase. To ensure an improved fry growth and high survival, suitable artificial feed coupled with good water quality is highly essential.

There is no regular evaluation of the quality of fish feeds available in Ghana, fish farmers have to depend exclusively on the information provided; which is mostly based on the declaration on the labels of feed bags or containers. Therefore, there is an urgent need to assess the performance of fish feeds available on the Ghanaian market in terms of fish growth and cost-effectiveness, particularly the starter feeds so as to establish the most economic one to be used for fingerling production. Hence, this study was designed to investigate nursing of mono-sex all male *O. niloticus* fry in net hapa-in-pond systems, using different commercial tilapia starter feeds. The targeted feed brands for the study were *Aller Aqua*, *ARDECFeed*, *Koudijs*, *Naam Papa* and *Raanan*. Effects of each feed type on water quality was also assessed.

Materials and Methods

Study Area

The evaluation of the five tilapia starter feeds (*Aller Aqua*, *ARDECFeed*, *Koudijs*, *Naam Papa* and *Raanan*.) was carried out at the Aquaculture Research and Development Centre (ARDEC) of Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR), Ghana. The area lies between latitude 6° 13′ North and the longitude 0° 4′ East at Akosombo in the Eastern Region of Ghana.

Selection and Description of the Tilapia Starter Feeds

The four most commonly used commercial tilapia starter feeds for tilapia fingerlings production in Ghana, namely *Aller Aqua*, *Koudijs*, *Naam Papa* and *Raanan* as well as a yet to be commercialized one (*ARDECFeed*), developed by CSIR-WRI-ARDEC, Akosombo were selected for the study. The crude protein (CP) contents of the feeds as declared by the producers on the labels of the feed bags ranged from 42.0 to 60.0%. The particle size of the feeds ranged from 0.5 to 1.2 mm and mixed particle sizes existed in a bag. Apart from *Koudijs* that the feed was packaged 10.0 kg per bag, those of the others were 20.0 kg. The feeds were procured from commercial fish feed retail outlets near the study area, except that of ARDEC, which was obtained directly from a batch at the Centre's feed store.

The feeds were randomly coded *A*, *B*, *C*, *D* and *E*, and about 5.0 kg of each was weighed into labelled plastic containers each of volume 15.0 L. Samples of about 50.0 g of each feed were taken into about 300 ml containers for immediate proximate composition analyses. The excess feeds in their original bags were sealed and they were kept in a cool, dry and well-ventilated room which were inaccessible to unauthorized personnel.

Proximate Composition Determination of Feeds

Proximate composition analyses of the feeds were carried out in triplicates following standard methods (AOAC, 2005). The protocol was applied in 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 about 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 feed samples. 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 about 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 feeds were computed by using the average physiological fuel figures of 23.64, 39.54 and 17.15 MJ kg^{-1} for protein, fat and carbohydrate respectively (Kim *et al*., 2012; Anani *et al*., 2017).

Experimental Systems

Fish growth study was carried out in fifteen (15) fine mesh netting hapas, each of dimensions 5.0 x 2.0 x 1.2 m (i.e. length, width and height). The hapas were installed in three (3) earthen ponds, each of size 0.2-hectare (2, 000 m^2). Five hapas were installed along the lengths of each pond at a distance of about 15 m apart. All the hapas in the first of the 3 ponds were randomly labelled A_1, B_1, C_1, D_1 and E_1, those in the second were labelled A_2, B_2, C_2, D_2 and E_2 whilst those in the third were A_3, B_3, C_3, D_3 and E_3.

Stocking of Experimental Systems

Mono-sex male *O. niloticus*, the Akosombo strain fry ranging from 0.05 to 0.08 g was used in the study. The fry, with an overall initial mean weight of 0.06±0.01 g, were weighed in bulk of 50 fry per batch, using top loading electronic balance (KERN EMB Version 3.1 11/2009) and they were randomly stocked at a density of 50 fry m^{-2} in each of the 15 hapas (i.e. 500 fry per hapa).

Feeding Schedule

Feeding of the experimental fish with the various feeds commenced the day after fish stocking. All the fish in each hapa under each treatment were manually fed at 20.0% of their body weight (biomass) three times (between 8:00-8:30 am, 12:00-12:30 pm and 4:00-4:30 pm) daily. Feeding at 20.0% biomass continued until the fry in any of the hapas attained a mean weight of ≥ 1.0 g. It was adjusted to 10.0% when the mean weight was from 1.0 to 5.0 g, and finally to 5.0% when the mean weight was from 5.0 to 20.0 g. However, feeding frequency of 3 was maintained throughout the feeding trial.

Water Quality Monitoring

Water quality parameters [temperature, dissolved oxygen (DO), pH, ammonium-nitrogen, nitrite-nitrogen and total alkalinity] in the experimental hapas, as well as at the inlets and outlets of the ponds were determined weekly. Temperature, DO and pH were measured using pre-calibrated multi-parameter water quality meter, model HI 9828 (Hanna Instruments Ltd., Chicago, II, USA). Ammonium-nitrogen, nitrite-nitrogen and total alkalinity were measured using a spectrophotometer (UV mini-1240).

Fry Growth Monitoring

Measurements of the experimental fish during the feeding trial were carried out weekly between 6:30 and 10:30 am. Each hapa was partially withdrawn from the pond to confine the fish at the bottom of the hapa below 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 fry were weighed in bulk and as they grew bigger, the number per batch was reduced so as to reduce error. Hence, the weights of all surviving fish were taken in bulk batches of 50 during the first 3 weeks and these were reduced to 25 at the end of the fourth week. At the end of the fifth week, they were weighed in batches of 20. From the end of the sixth week to that of the eighth week, they were weighed in batches of 10. The biomass of fish in each hapa under each treatment was computed and subsequently the quantity of each feed type for each fish group was adjusted accordingly. At the end of the ninth week, all the fish from each of the replicates of each treatment were harvested, counted and weighed individually to determine survival and the final growth.

Determination of Growth Performance Indicators

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:

Growth Performance

Growth performance was evaluated by computing the mean weight gain by fish and specific growth rate (SGR).

Mean Weight Gain (MWG)

The MWG is the difference between the final mean body weight and the initial mean body weight of fish for a period of time and it was computed as follows:

$$MWG = fmbw\ (g) - imbw\ (g)$$

Where *fmbw* = fingerling final mean body weight
imbw = fry initial mean body weight

Specific Growth Rate (SGR)

The SGR is the instantaneous change in weight of fish expressed as the percentage increase in body weight per day over any given time interval. It was calculated by taking natural logarithms of the fish body weight, and expresses growth as percentage per day.

$$SGR = \frac{In\ (ffmbw) - In\ (fimbw)}{Culture\ period\ (63\ days)}\ x\ 100\%$$

Where *In* = natural logarithm
ffmbw = fingerling final mean body weight
fimbw = fry initial mean body weight

Survival Rate (SR)

$$SR = \frac{Initial\ number\ of\ fry\ stocked - Total\ mortality}{Initial\ number\ of\ fry\ stocked}\ \text{x}\ 100\%$$

Feed Conversion Ratio (FCR)

The FCR is defined as the quantity of dry feed fed per unit live weight of fish gain. It often serves as a measure of efficiency of a feed. It was computed as:

$$FCR = \frac{Total\ feed\ fed\ (g)}{Live\ weight\ gained\ by\ fish}$$

FCRs of 1.5-2.0 are considered 'good' growth for most fish species.

Feed Efficiency (FE)

FE is simply the reciprocal of FCR (i.e. 1/FCR) times 100%. It was computed as:

$$FE = \frac{Live\ mean\ weight\ gained\ by\ fingerlings\ (g)}{Total\ feed\ fed\ (g)}\ x\ 100\% = \frac{1}{FCR}\ x\ 100\%$$

FE greater than 50% is considered 'good' growth (Houlihan *et al*., 2001).

Cost-Effectiveness of the Feeds

For the assessment of the cost-effectiveness of the 5 feeds used in the growth study, simple economic analyses were employed. Only the cost of the feeds was used in the calculations with the assumption that all other operating costs (e.g. transport, hapa, fry and labour) remained constant (Agbo *et al*., 2011, Anani *et al*., 2017).

Incidence Cost (IC)

The IC is the cost of feed used to produce 1.0 kg of fish (relative cost per unit weight gain), and the lower the figure for a particular feed, the more profitable it is using that feed (Abu *et al*., 2010; Agbo *et al*., 2011; Anani *et al*., 2017).

This was computed as:

$$IC = \frac{Cost\ of\ feed\ (GHS)}{Weight\ of\ fingerlings\ produced\ (kg)}$$

Profit Index (PI)

$$PI = \frac{Value\ of\ fingerlings\ produced\ (GHS)}{Cost\ of\ feed\ used\ (GHS)}$$

The value of fingerlings was based on the prevailing hatchery price in the study area during the period of the study. The higher the PI, the more cost-effective (economical) a feed was (Abu *et al*., 2010; Agbo *et al*., 2011; Anani *et al*., 2017).

Data Analyses

Data analyses were carried out using the National Council for Social Studies, NCSS (Version 22.0.4) software. All data on fish growth performance and feed utilization 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 before analyses. After the tests for normality and homogeneity, as well as arcsine transformation, statistical analyses were carried out using one-way analysis of variance (ANOVA). Tukey's honest significant difference test was used as the mean separation procedure ($P < 0.05$).

Results

Proximate Composition of the Feeds

The proximate composition of the five tilapia starter feeds (*A*, *B*, *C*, *D* and *E*), their gross energy contents and their prices per kg during the study period (January to March, 2022) are shown in Table 1.

Proximate analyses of the feeds showed that their crude protein contents ranged from 43.40 to 56.48%, with that (43.40%) of feed *A* being the least whilst that (56.48%) of *B* was the highest. Feed *B* had the highest (15.15%) crude lipid/fat content whilst that (3.55%) of *A* was the least. Feed *A* had the highest (38.51%) carbohydrate content whilst *B* had the least (13.08%). The feed with the highest (21.59 kJ g^{-1}) gross energy content was *B* whilst the one with the least (18.27 kJ g^{-1}) was *A*. The unit cost of the feeds ranged from 6.24 to 19.90 Ghana cedis, with *D* being the least expensive whilst *B* was the most.

Table 1. Proximate composition (% as-fed), gross energy (kJ g^{-1}) and prices (GHS kg^{-1}) of feeds *A*, *B*, *C*, *D* and *E*

Feed	DM	Ash	CP	CL	CF	NFE	GE	Price
A	92.81±0.01	10.20±0.04	43.40±0.13	3.55±0.26	4.33±0.06	38.51±0.32	18.27±0.24	8.25
B	93.23±0.08	9.88±0.01	56.48±0.46	15.15±0.05	5.40±0.07	13.08±0.39	21.59±0.30	19.90
C	92.55±0.05	8.77±0.07	53.54±0.49	4.67±0.18	6.47±0.10	26.54±0.55	19.05±0.41	9.80
D	91.24±0.01	12.05±0.05	47.06±0.06	6.89±0.07	4.10±0.02	29.12±0.11	18.84±0.08	6.24
E	90.86±0.05	9.65±0.06	52.20±0.17	5.59±0.09	5.05±0.02	27.50±0.29	19.27±0.18	10.20

DM = dry matter, CP = crude protein, CL = crude lipid, CF = crude fibre, NFE = nitrogen free extract/carbohydrate, GE = gross energy
The average exchange rate of the Ghana cedis to the USA dollar from January to March 2022 was: GHS 6.32 = 1.00 USD

Growth Performance of the Nursed Nile Tilapia Fry Fed with the Various Starter Feeds

The weekly mean weight attained by *O. niloticus* fry fed with feeds *A*, *B*, *C*, *D* and *E* for 9 weeks is presented as mean living weight (± Standard Deviation) in Table 2. The growth performance of the fry among all the feeds were similar within the first week. However, there were arithmetic differences in growth among all treatments after the second week until the end of the ninth week. At the end of the ninth week, the highest (23.62±14.39 g) final mean weight was recorded in fry fed with feed *B*, followed by those fed with feed *A* (20.09±1.38 g) and the least (17.34±9.12 g), those fed with feed *C*. The final mean weight attained by fry fed with feed *B* was significantly higher (Tukey's HSDT, P<0.05) whilst there were no significant differences (Tukey's HSDT, P>0.05) among feeds *C*, *D* and *E*.

Feed and Nutrient Efficiency of Nursed Nile Tilapia Fry Fed with the Various Starter Feeds

Nile tilapia fry fed with feed *B* had the highest (23.56 g) weight gain followed by those fed with that of *A* (20.03 g) and the least (17.28 g) were those fed with *C* (Table 3). The mean daily weight gain ranged from 0.27 to 0.37 g fish^{-1}. Fish fed with feed *B* had the highest daily weight gain whilst those fed with *C* had the least, with that of *B* being significantly higher (Tukey's HSDT, P<0.05).
Feed intake ranged from 17.80 to 27.40 g fish^{-1}; the least occurring in fish fed with *C* whilst the highest in those fed with *B*, with the latter being significantly higher (Tukey's HSDT, P<0.05). The FCR figures ranged from 1.03 to 1.16 at the end of the feeding trial and there were no significant differences (ANOVA, P = 0.05) among all treatments. Feed efficiency was more than 90.0% in all the treatments and the figures ranged from 95.24% in *D* to 97.09% in *C* and *E*. Survival ranged from 56.53 to 70.0%. The highest survival was observed in fish fed with *A* whilst the least occurred in fish fed with *C*. Net fish produced (NFP) ranged from 0.49 to 0.80 kg m^{-2}, with the highest recorded in *B* and the least in *C*.

Cost-Effectiveness of the Feeds

The costs per kg of feeds *A*, *B*, *C*, *D* and *E* ranged from 6.24 to 19.90 Ghana cedis, with *D* being the least expensive whilst *B* was the most (Table 4). The cost analyses showed that it was least expensive (GHS 6.83) to use *D* to produce 1 kg of tilapia fingerlings whilst use of *B* cost most (GHS 24.18). The highest profit was made by the use of *D*, followed by *A* whilst the least was that of *B*.

Table 2. Mean living weight (± SD) per week of Nile tilapia fry fed with tilapia starter feeds *A*, *B*, *C*, *D* and *E* during the nine-week feeding trial

Week	Mean weight (g)				
	A	*B*	*C*	*D*	*E*
Initial	0.06±0.01	0.06±0.01	0.06±0.01	0.06±0.01	0.06±0.01
Week 1	0.38±0.03	0.38±0.03	0.35±0.01	0.34±0.02	0.35±0.04
Week 2	1.06±0.14	1.07±0.12	0.95±0.09	0.89±0.19	1.00±0.16
Week 3	2.01±0.05	2.08±0.15	1.76±0.10	1.64±0.17	2.01±0.22
Week 4	3.55±0.19	3.74±0.14	2.97±0.15	2.86±0.29	3.53±0.25
Week 5	5.73±0.37	6.68±0.33	4.79±0.25	4.77±0.22	5.91±0.48
Week 6	8.27±0.26	9.56±0.51	7.67±0.18	7.88±0.78	8.48±0.88
Week 7	11.14±0.51	13.53±1.14	9.89±0.76	10.34±1.33	11.18±1.12
Week 8	14.51±0.85	19.24±2.50	13.21±0.80	13.34±1.35	14.11±0.87
Week 9	20.09±1.38^{ab}	23.62±14.39^{a}	17.34±9.12^{c}	17.53±8.77^{c}	17.84±7.86^{c}

Table 3. Mean growth performance of the nursed Nile tilapia fry fed with tilapia starter feeds *A*, *B*, *C, D* and *E* for nine weeks

Parameter	Feed				
	A	*B*	*C*	*D*	*E*
Initial Mean Weight (g)	0.06±0.01	0.06±0.01	0.06±0.01	0.06±0.01	0.06±0.01
Final Mean Weight (g)	20.09±1.38	23.62±14.39	17.34±9.12	17.53±8.77	17.84±7.86
Mean Weight Gain (g)	20.03±1.37	23.56±14.38	17.28±9.11	17.47±8.76	17.78±7.86
Mean Daily Weight Gain (g fish^{-1})	0.30±0.15	0.37±0.23	0.27±0.14	0.28±0.35	0.28±0.12
Mean Specific Growth Rate (% day^{-1})	9.23±0.46	9.49±4.80	8.99±3.04	9.01±2.92	9.04±2.62
Mean Feed Intake (g fish^{-1})	20.83±0.56	27.40±0.99	17.80±0.32	18.34±1.37	18.38±1.14
Mean Feed Conversion Ratio	1.04±0.66	1.16±0.49	1.03±0.58	1.05±0.18	1.03±0.13
Mean Feed Efficiency (%)	96.15±1.52	96.21±2.04	97.09±1.72	95.24±1.73	97.09±1.88
Mean Survival (%)	70.00±1.31	68.00±13.50	56.53±19.42	57.87±12.70	63.80±15.62
Mean Net Fish Produced (Kg m^{-2})	0.70±0.04	0.80±0.25	0.49±0.15	0.51±0.07	0.57±0.08

Water Quality Analyses

The range and range figures mean obtained for the monitored water quality parameters [temperature, dissolved oxygen (DO), pH, ammonium-nitrogen, nitrite-nitrogen, and total alkalinity] at the inlets and the outlets of the ponds as well as within the hapas during the entire study period of 63 days are shown in Table 5. The recorded range figures at the inlets, outlets and within the hapas respectively were as follows: Temperature: 30.3 to 33.7 °C, 29.8 to 33.4 °C and 29.5 to 31.6 °C; Dissolved Oxygen (DO): 6.7 to 9.1 mg L^{-1}, 4.0 to 9.8 mg L^{-1} and 4.3 to 9.1 mg L^{-1}; pH: 7.33 to 7.62, 7.06 to 7.95 and 6.62 to 8.76; Ammonium-nitrogen: 0.336 to 0.473 mg L^{-1} , 0.255 to 0.360 mg $L^{-1}$and 0.118 to 0.449 mg L^{-1}; Nitrite-nitrogen: < 0.001 to 0.010 mg L^{-1}, < 0.001 to 0.027 mg L^{-1} and < 0.001 to 0.026 mg L^{-1}; Total alkalinity: 16.5 to 44.5 mg L^{-1}, 14.0 to 45.5 mg L^{-1} and 12.5 to 44.0 mg L^{-1}

The recorded range figures mean at the inlets, outlets and within the hapas respectively were as follows: Temperature: 31.2±1.2 to 33.2±0.8°C, 30.5±0.5 to 32.5±1.1 °C and 30.4±0.8 to 33.0±1.4 °C; Dissolved Oxygen (DO): 6.9±0.2 to 8.7±0.6 mg L^{-1}, 5.7±1.6 to 8.6±0.6 mg L^{-1} and 5.8±0.9 to 8.6±0.6 mg L^{-1}; pH: 7.74±0.41 to 7.78±0.16, 7.32±0.37 to 7.75±0.16 and 7.16±0.44 to 7.82±0.91; Ammonium-nitrogen: 0.360±0.01 to 0.419±0.08 mg L^{-1}, 0.299±0.04 to 0.320±0.05 mg L^{-1} and 0.252±0.12 to 0.345±0.02 mg L^{-1}; Nitrite-nitrogen: < 0.001 to 0.010±0.00 mg L^{-1}, < 0.001 to 0.014±0.012 mg L^{-1} and < 0.001 to 0.018±0.02 mg L^{-1}; Total alkalinity: 22.8±8.8 to 42.3±3.2 mg L^{-1}, 20.0±8.7 to 32.3±17.3 mg $L^{-1}$and 20.0±8.7 to 39.8±4.5 mg L^{-1}.

Discussion

Aside from feed *B*, the analysed crude protein contents of all the feeds were higher than the declared figures indicated on the feed bags. These findings disagreed with figures of analysed crude protein levels obtained by Ayuba and Iorkohol (2013) in their determinations of the proximate composition of four commercial feeds (*Adolf calyx*, *Coppens*, *Dizengoff* and *Durate*). These researchers observed that all the figures obtained for analysed crude protein contents of the feeds, were less than the producers' declared ones. Besides, in the present study, the analysed crude protein levels for all the studied feeds were within the usual range of 40.0 to 60.0% that tilapia starter feeds on the Ghanaian market contained (Anani and Agbo, 2019). Lipids are primarily

Table 4. Cost-effectiveness of tilapia starter feeds *A*, *B*, *C*, *D* and *E* fed to Nile tilapia fry for nine weeks

	Feed				
	A	*B*	*C*	*D*	*E*
Cost per kg of feed (GHS)	8.25	19.90	9.80	6.24	10.20
Feed input (kg)	7.29±3.67[a]	9.32±66.83[a]	5.04±31.07[b]	5.32±87.02[b]	5.86±89.03[b]
Cost of feed used (GHS)	60.14±10.09	185.47±443.31	49.39±101.50	33.20±181.00	59.77±302.70
Harvested biomass (kg)	6.75±4.30	7.67±2.46	4.72±1.48	4.86±0.69	5.86±0.81
Estimated value of biomass (GHS)	675.31±43.00	766.58±245.70	471.63±147.70	485.56±69.18	585.98±81.10
Incidence Cost (GHS kg^{-1})	8.91±2.35	24.18±180.21	10.46±68.58	6.83±262.32	10.20±373.70
Profit Index	11.23±4.26	4.13±0.55	9.55±1.46	14.63±0.38	9.80±0.27

Average cost of tilapia fingerlings in the study area within the first half of 2022: 0.10 GHS g^{-1} fingerling
The average exchange rate of the Ghana cedis to the USA dollar from January to March 2022 was: GHS 6.32 = 1.00 USD

Table 5. Range and range figures mean of water quality parameters recorded at the inlets and outlets of the ponds and in the hapas during the feeding trial

	Range Figures		
Parameter	**Inlet**	**Outlet**	**Hapa**
Temperature (°C)	30.3-33.7	29.8-33.4	29.5-31.6
pH	7.3-7.6	7.1-8.0	6.6-8.8
Dissolved Oxygen (mg L^{-1})	6.7-9.1	4.0-9.8	4.3-9.1
Ammonium-Nitrogen (mg L^{-1})	0.336-0.473	0.255-0.360	0.118-0.449
Nitrite-Nitrogen (mg L^{-1})	< 0.001-0.010	< 0.001-0.027	< 0.001-0.026
Total Alkalinity (mg L^{-1})	16.5-44.5	14.0-45.5	12.5-44.0
	Range Figures Mean		
	Inlet	**Outlet**	**Hapa**
Temperature (°C)	31.2±1.2-33.2±0.8	30.5±0.5-32.5±1.1	30.4±0.8-33.0±1.4
pH	7.74±0.41-7.78±0.16	7.32±0.37-7.75±0.16	7.16±0.44-7.82±0.91
Dissolved Oxygen (mg L^{-1})	6.9±0.2-8.7±0.6	5.7±1.6-8.6±0.6	5.8±0.9-8.6±0.6
Ammonium-Nitrogen (mg L^{-1})	0.360±0.01-0.419±0.08	0.299±0.04-0.320±0.05	0.252±0.12-0.345±0.02
Nitrite-Nitrogen (mg L^{-1})	< 0.001-0.010±0.00	< 0.001-0.014±0.01	< 0.001-0.018±0.02
Total Alkalinity (mg L^{-1})	22.8±8.8-42.3±3.2	20.0±8.7-32.3±17.3	20.0±8.7-39.8±4.5

included in formulated feeds to maximize their protein sparing effect by being a source of energy (Hasan, 2001). The recorded levels of lipids in the feeds used in the present study ranged from 3.55 to 15.15%, with *B* containing the highest and *A*, the least. Aside from that of *B,* all of the others were below the minimum levels of 10-15% recommended to maintain optimum protein to energy ratios required to maximize utilization of dietary protein in fry (Hasan, 2001). Although fibre in feeds permits better binding as well as moderating passage of feed through the alimentary canal, it is not desirable to have fibre contents above 8-12% in feeds for fish, as they decrease the quantity of usable nutrients in the feed (De Silva and Anderson 1995). Additionally, high fibre and ash contents reduce digestibility of other ingredients resulting in poor fish growth. The analysed crude fibre contents of all the studied feeds were within the dietary requirement for Nile tilapia fry.

The initial mean weight (0.06 ± 0.01 g) of the experimental *O. niloticus* fry prior to the feeding trial in all the treatments was the same and there was no significant difference (ANOVA, P>0.05) among them. Hence, the final mean weight differences observed among the treatments at the end of the feeding trial was due mainly to feed effect. However, all the starter feeds were of good quality as they supported good Nile tilapia fry growth as indicated by the final mean weights and weight gains. The specific growth rates (SGRs) recorded in all the feeds were within the range of 9.4-9.7 % day^{-1} observed by Anani and Agbo (2019) in a study in which both farm-made and commercial tilapia starter feeds were used to produce Nile tilapia fingerlings. Since there were no significant differences (ANOVA, P>0.05) in the means of specific growth rates, feed conversion ratios, feed conversion ratios, feed efficiencies and the survival rates among the feeds, it suggests that these parameters were not affected by the quality of the feeds. Hence, all the four tilapia starter feeds used in this study were suitable for Nile tilapia fingerling production. Besides, water quality conditions during the study period were suitable for nursing Nile tilapia fry. Recorded figures for the various measured water quality parameters indicated that all the feeds used in the present study did not have adverse effect on water quality. Temperatures between 20 and 36°C have been reported by various researchers as being suitable for tilapia culture. All recorded figures for water temperature in the current study fell within the range recorded by other researchers in tilapia ponds. Kausar and Salim (2006), recorded figures between 25 and 27°C for optimum tilapia. FAO (2011) reported the preferred temperature ranges of between 31 and 36°C, whilst Ngugi *et al*. (2007) stated a range between 20 and 35°C as ideal for tilapia culture. The pH figures, 7.16±0.44 to 7.78±0.16 recorded in the current study, fell within 6.5 to 9.0 reported by other researchers as ideal for tilapia survival, growth and reproduction (Crane, 2006; Santhosh and Singh, 2007; Bryan *et al*., 2011). At the lower limit, Ross (2002) noted that DO concentration of 3 mg L^{-1} should be the minimum for optimum growth of tilapia. In the current study, all the feeds recorded DO levels ranged from 5.8±0.9 to 8.6±0.6 mg L^{-1} throughout the study period, which were similar to 5.7±1.6 to 8.7±0.6 mg L^{-1} observed at the inlets and outlets of the ponds in which the experimental hapas were installed. Therefore, none of the feeds had negative impact in terms of the oxygen levels in any of the fry nursing systems. Ammonia is a by-product obtained from the metabolism of proteins excreted by fish and bacterial decomposition of organic matter such as uneaten feed, faeces, dead plankton among others (Bhatnagar and Devi, 2013). The relatively high levels (0.252-0.419 mg L^{-1}) of un-ionized ammonium recorded in all the experimental hapas of the various feeds as well as at the inlets and the outlets of the ponds used in the current study could be mainly due to the fact that starter feeds generally contain high crude protein levels which is a major source of un-ionized ammonia in fish culture systems, especially those for nursing of fry.

The cost-effectiveness analyses of using feeds *A*, *B*, *C*, *D* and *E* at their current unit weight prices, 8.25, 19.90, 9.80, 6.24 and 10.20 GHS kg^{-1} respectively, to produce Nile tilapia fingerlings, indicated that feed *D* was the most profitable whilst *B* was the least. Besides, in terms of production costs (feed cost/kg fingerlings produced), feed *B* was the least economical whilst that of *D* was the most. The least profit of feed *B* was mainly due to its high cost, although it recorded the highest (23.56±14.38 g) final mean weight as well as relatively good (68.00±13.50%) survival rate. In the current study, there were no significant differences (ANOVA, P>0.05) among the growth rates and feed efficiency of all the studied feeds, hence, the time period difference for any of the feeds to be used to produce a specified tilapia fingerling size would be short. This suggests using the less expensive starter feeds will reduce tilapia fingerling production cost and consequently increase the profit margin of tilapia hatchery operators considerably.

Conclusion and Recommendations

Growth performance as indicated by the computed growth performance indicators (final mean weights, specific growth rates, daily weight gains, feed conversion ratios and survivals) in the Nile tilapia fry that feeds *A*, *B*, *C*, *D* and *E* were fed with, showed that all the tilapia starter feeds were of good quality. For Nile tilapia fingerlings production costs (feed cost/kg fingerlings produced), feed *B* was the least economical whilst that of *D* was the most. All the five feeds did not impact water quality negatively. Although all the five feeds were found to be of good quality, those of lower production costs, lower incidence costs and higher profit indices should be opted by tilapia hatchery operators for fingerlings production. Since the crude protein content of fish feed is a major determinant in pricing the final product, tilapia starter feed producers should maintain optimal crude protein levels of their products to attract reasonably lower price, but offer good fingerlings growth performance.

Ethical Statement

There are no ethical issues in this manuscript.

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Koudjis Fish Feed Ghana Limited supported the study with feed and it borne the cost of water quality analyses.

Author Contribution

Conceptualization: FA Anani, Data Curation: FA Ayarika, PDKA, MJA, ETD. Formal Analysis: FA Anani, FA Ayarika, KKD, Investigation: FA Anani, FA Ayarika, PDKA, MJA, ETD. Methodology: FA Anani, Writing-original draft: FA Anani, PDKA, Writing-review and editing: FA Anani, FA Ayarika, PDKA, KKD, MJA, ETD.

Conflict of Interest

There are no conflict of interest issues in this manuscript.

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