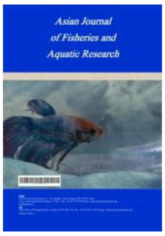

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Profitability of Using Commercial Tilapia Feed to Produce Three Different Sizes of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings in Ghana

F. A. Anani[1*], E. Agbeko[1], P. D. K. Atsakpo[1], M. Johnson-Ashun[1], L. K. Osei[1], K. K. Donkor[1], A. F. Ayarika[1] and E. Danquah[1]

[1]CSIR-Water Research Institute, Aquaculture Research and Development Centre (ARDEC), P.O.Box AB 139, Akosombo, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. Author FAA designed the study, wrote the protocol, performed the statistical analyses and he wrote the first draft of the manuscript. Author EA revised the manuscript. Author PDKA carried out the water quality parameters analyses. Authors MJA, LKO, KKD, AFA and ED managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the profitability of using a commercial tilapia feed to produce three different size ranges (1.0-1.9, 2.0-2.9 and 5.0-5.9 g) of Nile tilapia, *Oreochromis niloticus* fingerlings in hapa-in-pond system.
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 March to May, 2020.
Methodology: Fish growth study was carried out in three (3) fine mesh netting hapas, each of dimensions 5.0 x 2.0 x 1.2 m. Nile tilapia fry at initial mean weight 0.03 ± 0.01 g were stocked at a density of 50 fish m^{-2} and they were fed at 20 % body weight five times daily. The feeding of the fish continued until those in all the 3 hapas attained a mean weight of at least 5.0 g. Then the

**Corresponding author: Email: frananioo@yahoo.com;*

experiment was terminated and all the survived fish in each hapa were harvested, counted, and their individual body weights were measured. Growth performance indicators and profitability of producing the various size categories (1.0-1.9, 2.0-2.9 and 5.0-5.9) were determined.
Results: The fry attained the target size ranges of 1.0-1.9, 2.0-2.9 and 5.0-5.9 g in 4, 6 and 9 weeks respectively. There were significant differences (ANOVA, P = 0.03) among final mean weights, weight gains, feed intakes, daily weight gains, feed efficiencies and harvested biomass among all size ranges, with those of 5.0-5.9 g being significantly higher (Tukey's HSDT, P < 0.02). Sizes of fingerlings produced correlate positively with cost of feed used. The profit indices ranged from 2.57 to 10.22, with the highest recorded in the 1.0-1.9 g fingerlings and the least in those of 5.0-5.9 g.
Conclusion: The results indicated that, at the current Nile tilapia fingerlings cost and the time taken to produce the various size categories, the 1.0-1.9 g production is the most profitable.

Keywords: Farmed fish; fingerling cost; fish seed; hapa-in-pond system; profit index.

1. INTRODUCTION

The Nile tilapia, *Oreochromis niloticus* is the most cultured fish species in Ghana. The major source of the fingerlings for grow-out productions is commercial tilapia hatcheries [1]. Hatchery tilapia fingerling production is critical to the continuing increase in tilapia culture in Ghana [2]. More hatcheries are needed, particularly in the northern part of the country to produce tilapia fingerlings for supply to farmers in order to meet the ever increasing demand for tilapia seed.

Currently, the major system for the grow-out production of *O. niloticus* in terms of production level is floating fish cage. Countrywide availability of *O. niloticus* fingerlings for grow-out producers has been a challenge in recent times as most of the tilapia hatcheries are localized, particularly in the Eastern Region, the hub of cage fish farming in Ghana.

The major public tilapia hatchery operator in Ghana, is the Aquaculture Research and Development Centre (ARDEC) of the CSIR-Water Research Institute (WRI). Since 2012, the Centre has produced and supplied over 2.5 million tilapia fingerlings per year to small-scale fish farmers and over twenty thousand tilapia brood stocks of an improved strain of the Nile tilapia, the “Akosombo Strain” to medium and large-scale tilapia hatcheries in the country [3,4]. The quantities of these categories of the fish produced and made available to fish farmers by the CSIR-WRI, ARDEC, have increased substantially over the years.

Due to the greater pressure on commercial tilapia hatchery operators to produce and to supply fingerlings to the increasing grow-out producers, most of the hatchery operators do not adhere to the recommended size of at least 5.0 g fingerling production and supply to farmers by the Fisheries Commission, the major regulator of the Fisheries and Aquaculture sector [5]. Hence, the size range of tilapia fingerlings mostly produced by commercial tilapia hatchery operators in the country is 1.0-3.0 g, and even in some instances, sizes that are less than 1.0 g.

In recent times, CSIR-WRI-ARDEC has made a lot of effort to produce and to supply larger fingerlings (juveniles) up to over 50.0 g to fish farmers for grow-out production. Stocking of larger size fingerlings for grow-out production is known to shortened the production time period and consequently, reduction in feed input [6]. The objective of this study was to investigate the profitability of producing Nile tilapia fingerlings of size ranges 1.0-1.9, 2.0-2.9 and 5.0-5.9 g using a 40 % declared crude protein content commercial tilapia feed, with the view of establishing which of the tilapia fingerling ranges would be more profitable to produce and to sell by tilapia hatchery operators in Ghana.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Aquaculture Research and Development Centre (ARDEC) of Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR), Akosombo, in the Eastern Region of Ghana. The area is within the lake Volta enclave, where aquaculture production is dominant, and it lies between latitude 6° 13' North and the longitude 0° 4' East.

2.2 Proximate Composition and Gross Energy of Feeds Determination

Proximate analyses of the feeds were carried out in triplicates within a week after their procurements, following standard methods [7]. The gross energy content of the feed was computed using the average physiological fuel values of 23.64, 39.54 and 17.15 MJ kg^{-1} for protein, fat and carbohydrate respectively [6].

2.3 Experimental System and Fish

Fish growth study was carried out in three (3) fine mesh netting hapas, each of dimensions 5.0 x 2.0 x 1.2 m (i.e. length, width and height). A monofilament nylon gill net of stretched mesh size 30.0 mm was sewn over each of the hapas to prevent access by frogs and predatory birds [8]. The hapas were mounted in a 0.2-hectare earthen pond which was supplied with water from the Volta Lake to a mean height of about 1.4 ± 0.2 m; and each hapa was separated from others by about 6 m distance. A cohort of a post-treated all-male Nile tilapia fry, at an initial mean weight of 0.03 ± 0.01 g, were stocked at a total of 500 fry m^{-2} per hapa.

2.4 Water Quality Monitoring

Water quality parameters viz. water temperature, dissolved oxygen (DO), pH, nitrite, total ammonia and total alkalinity in the experimental hapas were determined weekly. In-situ measurement of water temperature was executed with a thermometer and DO was measured with oxygen meter (YSI Environmental model no: DO 200), whilst pH with a pH meter (HANNA model no: HI 98128).

2.5 Feeding Schedule and Monitoring of Fish Growth

All fish under each treatment were manually fed at 20 % of their body weight (biomass) five times (between 0800-0830, 1000-1030, 1200-1230, 1400-1430 and 1600-1630 GMT) daily throughout the culture period. The weights of all surviving fish in each hapa were measured weekly to the nearest 0.01 g. The feeding of the fish continued until all in the three hapas attained a mean weight of at least 5.0 g. Then the experiment was terminated and all the survived fish in each hapa were harvested, counted, and their individual body weights were weighed.

2.6 Computation of Growth Performance Indicators

Growth performance indicators were determined in terms of survival rate (SR), weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and feed efficiency (FE) when fish in all the three hapas attained mean weight ranges of 1.0-1.9, 2.0-2.9 and 5.0-5.9 g as follows:

SR (%) = number of fry stocked – number of fry died/number of fry stocked × 100;

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

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

FCR = total feed fed/live weight gain;

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

2.7 Profitability Determination

The profitability of producing the various sizes (1.0-1.9, 2.0-2.9 and 5.0-5.9 g) of tilapia fingerlings was determined by estimating the difference between the total variable cost and the total gross revenue. The main variable cost was that of the feed. Labour was not costed, as all activities regarding labour were carried out by a section of staff at ARDEC. The gross revenue was the estimated cost of survived fingerlings produced for each size category.

Gross Revenue = Quantity of fingerlings harvested (kg) x Unit market price

Gross Profit = Gross revenue – Total production costs

Incidence Cost (IC) = Cost of feed used (GHS)/weight of fingerlings produced (kg)

Profit Index (PI) = Value of fingerlings produced/cost of feed used

IC refers to the cost of feed used to produce a kg of the fingerlings (relative cost per unit weight gain), and the lower the value, the more profitable is the production, whilst for the PI, profitability is indicated by a higher figure [5,6].

2.8 Data Analyses

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

3. RESULTS AND DISCUSSION

3.1 Proximate Analyses of Experimental Feed

The figures for chemical analyses of the crude protein and the lipid contents of the feed showed negative deviations from the expected (Table 1). The recorded figures were 4.8 and 51.4 % lower for crude protein and lipid respectively than the declared figures by the producer. These results are in line with those obtained by [1] in a study in which four different crude protein contents (30.0, 33.0, 38.0 and 40.0%) of the same brand of tilapia feeds were used in Nile tilapia fingerlings production. In that study, the researchers recorded negative deviations in both the crude protein and the lipid contents; and the figures ranged from 0.6 to 4.8% less than the declared figures for crude protein contents and 41.7 to 58.3% for lipid contents.

Differences in analyzed and declared figures of feeds have been attributed to inconsistent proximate analyses of ingredients before feed formulation and production [9]. Variations in nutritional values of the same feed ingredients could also be due to regionalism and seasonality in availability of the ingredients [10]. Hence, the need for animal feed producers to carry out routine proximate analyses of feed ingredients, especially when new batches are procured from different sources. However, long term storage of feeds could lead to deterioration of feed quality which may result in lower nutritional values. This is not applicable to the feed used in the current study, as they were procured within a month after production without much storage (within two days) before analyses and use.

3.2 Water Quality

The recorded water quality parameters were within the following ranges: pH (6.03-6.36), temperature (29.2-31.4 °C), dissolved oxygen (4.7-8.7 mg L^{-1}), total alkalinity (17.5-32.5 mg L^{-1}), ammonia-nitrogen (0.208-0.445 mg L^{-1}) and nitrite-nitrogen (< 0.001-1.906 mg L^{-1}). There were no significant differences (ANOVA, P = 0.67) among measured figures during the production of each size category and all recorded figures were within the suitable ranges for *O. niloticus* [11,12,13].

3.3 Growth of Nile Tilapia Fry

The target mean weight ranges of 1.0-1.9, 2.0-2.9 and 5.0-5.9 g were first attained at the ends of the fourth, sixth and the ninth weeks, respectively (Fig. 1). The mean weights recorded were 1.17, 2.67 and 5.47 g for the size ranges 1.0-1.9, 2.0-2.9 and 5.0-5.9 g respectively. At the current stocking density of 50 fry m^{-2}, the nursed tilapia fry attained the targeted fingerling size ranges of 1.0-1.9, 2.0-2.9 and 5.0-5.9 g at different time periods, with the smallest size range attained within the shortest (4 weeks) and the largest size range, the longest (9 weeks). This suggests that, it would take hatchery operators longer period to produce the recommended tilapia fingerling size of at least 5.0 g compared with the production of smaller sizes (< 5.0 g). Hence, hatchery operators would spend more in terms of feed and labour to produce the recommended size. The time periods taken to produce size ranges of 1.0-1.9 and 2.0-2.9 g in the current study were longer compared with those taken to produce the same size ranges in a study carried out by [9] in using farm-made and commercial tilapia starter diets to produce Nile tilapia fingerlings [5]. This could be due to the differences in the initial stocking sizes and the densities of the fry, as well as the feeding rate. In the current study, the size at which the fry was stocked and the density were 0.03 ± 0.01 g and 50 fry m^{-2} respectively, whilst in that of [9], they were 0.20 ± 0.01 g and 33 fry m^{-2} respectively; even though in their study, the fry was fed at 10.0 % of their body weight, whilst in the current study, it was 20.0 %. High stocking density reduces fish growth performance and feed utilization due to competition for food and space, which may lead to increased stress and consequently increased energy requirements [5,14].

The computed growth performance and feed efficiency indices are shown in Table 2. There were significant differences (ANOVA, P = 0.03) among final mean weights, weight gains, feed intakes, daily weight gains, feed efficiencies and harvested biomass among all size ranges, with those of 5.0-5.9 g being significantly higher

(Tukey's HSDT, $P < 0.02$). However, there were no significant differences (ANOVA, $P = 0.69$) among initial mean weights and survival rates in all size ranges.

Mean specific growth rates decreased with increased size of fingerlings produced, and figures recorded in this study ranged from 8.26 to 13.08 % day^{-1}, with the production of 1.0-1.9 g fingerlings being the highest, whilst that of 5.0-5.9 g being the least. Mean daily weight gain ranged from 0.04 to 0.08 g day^{-1} with the production of 1.0-1.9 g fingerlings being the least, whilst that of 5.0-5.9 g was the highest. Feed conversion ratio increased as fingerlings size increases, and the recorded figures ranged from 1.43 to 3.22. Numbers of survived fingerlings reduced as size of fingerlings produced increased, the recorded figures were 83.50, 73.33 and 72.67 % for the size ranges 1.0-1.9, 2.0-2.9 and 5.0-5.9 g respectively. Mean harvested biomass increased with increased fingerling size, and figures recorded ranged from 0.05 to 0.20 kg m^{-1}. The high survival rates (>70 %) recorded in all the size categories could be attributed to the maintenance of good water quality, the good health condition of the Nile tilapia fry stocked; the quality, quantity and the acceptance by the fry of the feed used. In addition, predators such as birds and frogs were prevented from having access to the experimental fish as the experimental systems were fully covered.

Table 1. Percentage deviations of the observed from the expected crude protein and lipid contents, gross energy and price per kilogramme of the commercial tilapia feed

Parameter	Attribute	Figure
Crude protein (%)	Declared	40.0
	Analyzed	38.1
	Deviation	-1.9 (4.8%)
	Declared	7.0
Crude lipid (%)	Analyzed	3.4
	Deviation	-3.6 (51.4%)
Gross energy (kJ g^{-1})		16.46
Price (GHS kg^{-1})		6.00

The average exchange rate of the Ghana cedis to the USA dollar in 2020 was: GHS 5.68 = 1.00 USD

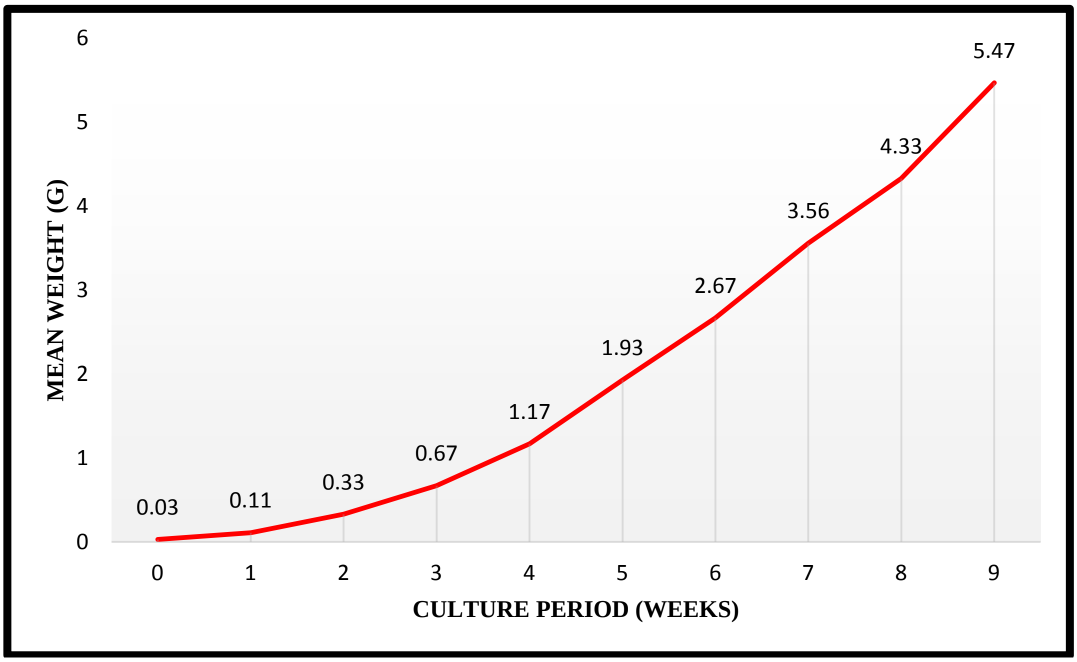

Fig. 1. Growth of Nile tilapia fry at a stocking density of 50 fish m^{-2} and it was fed with a 40% declared crude protein content commercial tilapia feed until they attained a final mean target weight of ≥ 5.0 g

Table 2. Growth performance and feed efficiency of Nile tilapia fry stocked at a density of 50 fish m^{-2} and fed with a 40 % declared crude protein content commercial tilapia feed to produce 1.0-1.9, 2.0-2.9 and 5.0-5.9 g size range fingerlings

Parameter	Fingerling size range (g)		
	1.0-1.9	2.0-2.9	5.0-5.9
Initial mean weight (g)	0.03 ± 0.01^a	0.03 ± 0.01^a	0.03 ± 0.01^a
Final mean weight (g)	1.17 ± 0.01^a	2.67 ± 0.07^b	5.47 ± 2.19^c
Mean weight gain (g)	1.14 ± 0.01^a	2.64 ± 0.07^b	5.44 ± 2.19^c
Mean feed intake (g $fish^{-1}$)	1.63 ± 6.49^a	4.61 ± 2.42^b	17.53 ± 1.60^c
Mean specific growth rate (% day^{-1})	13.08 ± 0.17^a	10.69 ± 0.15^a	8.26 ± 0.11^b
Mean daily weight gain (g day^{-1})	0.04 ± 0.01^a	0.06 ± 0.01^b	0.08 ± 0.01^c
Mean feed conversion ratio	1.43 ± 0.99^a	1.75 ± 0.17^a	3.22 ± 0.25^b
Mean feed efficiency (%)	69.93 ± 0.49^a	57.14 ± 0.09^b	31.06 ± 0.08^c
Mean survival rate (%)	83.50 ± 16.20^a	73.33 ± 4.00^a	72.67 ± 5.03^a
Mean harvested biomass (Kg m^{-1})	0.05 ± 0.04^a	0.10 ± 0.01^b	0.20 ± 0.05^c

Figures are means ± standard deviations of three replicates. Means within the same row with different letters are significantly different (Tukey's HSDT, P < .05)

3.4 Profitability of Size Ranges of Nile Tilapia Fingerlings Produced

The profitability analyses in the present study indicate positive net returns for the production of all the size ranges (1.0-1.9, 2.0-2.9 and 5.0-5.9 g) of the Nile tilapia fingerlings (Table 3). The production of 1.0-1.9 g Nile tilapia fingerlings was the most profitable, whilst that of 5.0-5.9 g was the least. The size range of tilapia fingerlings produced correlates positively with the cost of feed used and hence, that of the overall production costs. The estimated gross revenues were 125.30, 165.00 and GHS294.30 (equivalent average value of GHS5.68 per USD, 2020) for 1.0-1.9, 2.0-2.9 and 5.0-5.9 g respectively. The percentage gross profit for the various fingerling size ranges (1.0-1.9, 2.0-2.9 and 5.0-5.9 g) produced in this study were about 922.86, 442.23 and 156.69 % respectively. Incidence cost ranged from 8.37 to 19.23 GHS kg^{-1} with the least value occurring in 1.0-1.9 g tilapia fingerlings, whilst the highest was in that of 5.0-5.9 g. The profit indices ranged from 2.57 to 10.22, with the highest recorded in the 1.0-1.9 g Nile tilapia fingerlings.

The estimated feed costs to produce 1000 individual tilapia fingerlings of size ranges 1.0-1.9, 2.0-2.9 and 5.0-5.9 g would be approximately 9.78, 27.66 and GHS105.18 (equivalent to 1.72, 4.87 and 18.52 US Dollars) respectively, whilst the estimated gross revenue would be 100.02, 150.01, and GHS270.03 (equivalent to 17.61, 26.41 and 47.54 US Dollars) respectively. Although the gross revenue generated from the production of tilapia fingerling size range 5.0-5.9 was the highest, in the long run it would be more profitable to produce the lesser size ranges (1.0-1.9 and/or 2.0-2.9 g) fingerlings, taking into account the production period and the labour cost. In this study, it took a period of 4 weeks to produce 1.0-1.9 g tilapia fingerlings, 6 weeks to produce those of 2.0-2.9 g and 9 weeks for 5.0-5.9 g. This was also evident in values recorded for the incidence costs (ICs) and the profit indices (PIs) for the various fingerling size ranges, with the highest (19.23 GHS kg^{-1}) IC recorded in the size range 5.0-5.9 g, whilst the least (8.37 GHS kg^{-1}) was recorded in the size range 1.0-1.9 g. The least (2.57) PI was recorded in the size range 5.0-5.9 g, whilst the highest (10.22) was recorded in the size range 1.0-1.9 g. This suggests that commercial Nile tilapia hatchery operators would make higher gains by producing lesser (1.0-1.9 and/or 2.0-2.9 g) Nile tilapia fingerlings than larger (≥ 5.0 g) ones. Hence, the commercial production of the recommended ≥ 5.0 g Nile tilapia fingerlings by the Fisheries Commission of the country, may not be heeded to by commercial tilapia hatchery operators. The main reasons would be due to its high input costs (feed and labour) and the longer period it would take to produce this tilapia fingerling size if hatchery operators have to nurse post-treated fry at relatively high densities suited for commercial production. Another factor that could affect the profitability of all the size ranges is the number of survived fingerlings, as high survival would result in higher revenue whilst low survival would lead to lower revenue.

Table 3. Estimated production cost and returns using 40 % declared crude protein content commercial tilapia feed to produce different size range of Nile tilapia, *Oreochromis niloticus* fingerlings

Cost and Return	Fingerling size range (g)		
	1.0-1.9	2.0-2.9	5.0-5.9
1. Operational Cost (GHS)			
Feed	12.25	30.43	114.65
Labour*	0.00	0.00	0.00
2. Total variable cost (GHS)	12.25	30.43	114.65
3. Gross Fingerlings Sales (GHS)			
Quantity of fingerlings produced	1, 253	1, 100	1, 090
Price of fingerling category (GHS)	0.10	0.15	0.27
4. Gross Revenue (GHS)	125.30	165.00	294.30
5. Gross Profit (GHS)	113.05	134.57	179.65
6. Percentage Gross Profit (%)	922.86	442.23	156.69
7. Incidence Cost (GHS kg^{-1})	8.37	10.36	19.23
8. Profit Index	10.22	5.42	2.57

**Not costed as feeding and management were carried out by a section of ARDEC staff*
The average exchange rate of the Ghana cedi to the USA dollar in 2020 was: GHS 5.68 = 1.00 USD

An enterprise could be declared profitable in the short run, if the gross revenue is greater than the total variable cost. Alternatively, the gross margin, which is the difference between the gross revenue and the total variable cost, must be positive [15]. In the long run, this would inform hatchery operators whether to invest in the production of at least 5.0 g Nile tilapia fingerlings or in the production of those of smaller sizes (≤ 5.0 g). However, Nile tilapia hatchery operators who are also into grow-out production, could nurse their fingerlings to ≥ 5.0 g before stocking them in the grow-out production systems, which in most cases are cages or ponds. Hence, the willingness of hatchery operators to produce at least 5.0 g Nile tilapia fingerlings, may largely depend on the profitability of its production.

The lower profit index recorded in the production of the size category 5.0-5.9 was mainly due to the higher feed cost input and the concomitant low feed efficiency (about 31.06 %), which increased the production cost, and subsequently affected the profit index from the gross revenue generated.

4. CONCLUSION

At the current costs of selling the different Nile tilapia, *Oreochromis niloticus* fingerling size ranges (1.0-1.9, 2.0-2.9 and 5.0-5.9 g) and the time period taken to produce each category, it is more profitable to produce the 1.0-1.9 g fingerling size range than those of larger ones. However, further studies need to be carried out to ascertain the survival and the growth performance of the various size categories of the fingerlings when they are stocked in different culture systems for grow-out production. Additionally, tilapia hatchery operators may be encouraged to produce the recommended size of ≥ 5.0 g if the current value of this size range could be revised based on the feed cost and the time taken to produce them.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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