**Profitability of Small-Scale Grow-Out Production of Caged Nile Tilapia, *Oreochromis* *niloticus***

**in the Volta Lake of Ghana**

**ABSTRACT**

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| --- |
| The profitability of small-scale grow-out caged Nile tilapia, *Oreochromis* *niloticus* production in the Volta Lake of Ghana was investigated within a period of 6 months (from July to December, 2022). The study site was part of the CSIR-WRI-ARDEC research and commercial facilities which lies between latitude 6° 13ʹ North and the longitude 0° 4ʹ East at Akosombo within the Asuogyaman District in the Eastern Region of Ghana. The study was carried out in a four-in-one floating fish cage of effective volume 112.50 m3 each; identified as C1, C2, C3 and C4. The 4 compartments were stocked with a total of 10,876 mono sex male juvenile *O.* *niloticus*, ranging between 50.0 and 90.0 g. The fish were stocked in the cages at varied numbers (C1: 5,144; C2: 1,728; C3: 2,606 and C4: 1,398) based on weight ranges (50.0-60.0 g, 61.0-70.0 g, 71.0-80.0 g and 81.0-90.0 g) of the total fish available for stocking. The initial mean weights were 53.04 ± 7.19 g, 67.45 ± 10.59 g, 73.49 ± 9.86 g and 84.19 ± 8.90 g for C1, C2, C3 and C4, respectively. The cultured fish were fed at declining rates of 4.0 to 1.5% with floating extruded pelleted commercial feed of size 4.5 mm and 30.0% crude protein (CP﴿ content, three times daily. After 127 to 204 days, the fish were harvested, graded, counted, weighed and sold. Profitability was determined using production and price parameters. Mean survival was 83.40 ± 17.88% and that of gross yield was 787.69 ± 235.05 kg cage-1 (6.15 ± 1.64 kg m-3﴿. Feed constituted the major (66.70%﴿ production cost whilst a mean of 37.15 ± 11.18% return on investment (ROI) was generated. Production of caged Nile tilapia was economically rewarding and for higher profit margins, number of cages and stocked fish per cage must increase. |

*Keywords: Caged fish, Juvenile tilapia, Nile tilapia, Profitability; Returns on investment,*

**1. INTRODUCTION**

Fish cage is one of the major fish culture systems, aside from those of ponds, tanks, pens, raceways and re-circulating (Halwart *et al*., 2007; Devi *et al*., 2017; Aura *et al*., 2018; Orina *et al*., 2018; Kumar *et al*., 2023). A cage confines the cultured fish in a mesh enclosure and it has a completely rigid frame on all sides (SEAFDEC/IDRC, 1979). Cage culture uses existing water resources such as ponds, rivers, estuaries and open ocean, but it confines the fish inside some type of mesh enclosure. The mesh retains the fish, making it easier to feed, observe and to harvest (Halwart *et al*., 2007). Hence, water passes freely among the fish and the surrounding water resources to enhance good water quality and wastes removal (Devi *et al*., 2017). Floating cage farming is considered an alternative to obtaining fish from the wild fisheries and the utilization of available water resources for fish production (FAO, 2018). It is presented as the most appropriate production method to minimize the use of land and water resources for fish production.

Majority of cages consists of a floating unit, a framework and a flexible mesh-net suspended under it. The floating unit can consist of empty barrels, styrofoam polyethylene pipes or ready-made pontoons of plastic and metal (Masser, 1997; Masser, 2008; Ofori *et al*., 2010). The buoy units are often built into a framework, the material of which can be impregnated wood, bamboo spars, galvanized scaffolding or welded aluminium bar. Nylon is commonly used for the net, but weld mesh or woven split bamboos could be used (Olivares, 2003). Despite differences in technical efficiency, different types of materials continue to be used depending on availability and cost. The most sophisticated designs appear to be used for sea cage farms. Even though cage size can be anything up to 1000 m3, it is normally between 100 to 500 m3. A simple unit holds a net of four vertical sides and it is rectangular in cross-section, but the more popular ones mostly used in large-scale commercial farms are circular in cross-section (Masser, 1997; Masser, 2008; Ofori *et al*., 2010).

Reasonably sheltered areas, with sufficient water movement to effect adequate mixing and aeration, are mostly the selected sites for cage culture. The occurrence of strong winds and the vulnerability of the site to these are also major considerations in the design of cage farms. Polluted and poor water quality sites are generally avoided (Masser, 1997). Besides cost and safety of structures, a major consideration in designing cages is the ease with which they can be handled. It is common practice to have double netting, the outer one serving as a predator net to protect the inner one and the fish stocked in it. While the arrangement of cages in a battery is the most common practice, in cases where infection of diseases is feared, they may be moored separately (Masser, 1997). Workers then use boats to attend to stocking, feeding and care of the cages.

Good yield and satisfactory socio-economic profitability are the foundation of any production system without which an enterprise cannot survive in the long term. In fish farming, production efficiency depends on several factors including culture system, species performance and adherence to good aquaculture practices (Aïzonou *et al*., 2019). Yield is related not only to the depth that varies from one water body to another, but also the quality of the fish species strain and the stocking density (Islam *et al*., 2016). The production cost is influenced by factors such as cage size, stocking density, feed price, location of the cages, and quality of the fingerlings; which consequently, affect the economic profitability (Huguenin, 1997; Gooley, 1998, Ofori *et al*., 2010). Under the right conditions, caged fish culture remains a source of wealth due to the reasonable profit margin that it offers and it plays a vital role in meeting the demand for fish in the world (Olivares, 2003; Alagawany *et al*., 2020, 2021).

Even though different fish culture systems such as cages, earthen ponds, concrete tanks, tarpaulins, dugouts, pens and raceways are used by fish farmers in Ghana, highest annual fish production is obtained from cages (FC/MoFAD, 2023﴿. The Higher yields from cages have been attributed to use of intensive cage culture techniques with better management systems within the Volta Lake enclave, where most cage fish farms are located. Additionally, major production inputs such as fish feeds and fingerlings are easily accessible as they are highly concentrated within the environs. Mainly freshwater cage culture is practised in existing water resources, the major one being the Volta River/Lake and positive cash flows have been reported among producers (Abban *et al*., 2006; Ofori *et al*., 2010).

The substantial investment in cage culture coupled with emergence and increase in small- to large-scale commercial enterprises have resulted in increased aquaculture value over the years. The cage construction technology, installation, stocking, feeding and management of these farms have proven to be generally suitable to smaller-scale investors. Hence, caged fish farming is widely practised among small-scale fish producers between the Kpong and Akosombo Dams on the lower Volta River, a stretch where the facilities of the Aquaculture Research and Development Centre (ARDEC﴿ of the Water Research Institute (WRI﴿ of the Council for Scientific and Industrial Research (CSIR﴿, Ghana is located, the site where the current study was carried out.

**2. MATERIALS AND METHODS**

**2.1 Study area**

The site of cage location and fish production was part of the CSIR-WRI-ARDEC research and commercial facilities, latitude 6° 13ʹ north and longitude 0° 4ʹ east, Akosombo within the Asuogyaman district in the Eastern region of Ghana. The cages were located in open water of the Volta Lake between the Akosombo and the Kpong dams, about 20 m from shore.

**2.2 Production cages and stocked juvenile fish**

Four (4) cages, each of effective volume 112.50 m3 were rented for the Nile tilapia, *Oreochromis* *niloticus* grow-out production from July to December, 2022. For identification purpose, the cages were labelled C1, C2, C3 and C4. The stocked fish were obtained from a batch of 12, 000 plus mono sex male juvenile *O. niloticus*, ranging between 50.0 and 90.0 g produced in earthen ponds at the Centre. Due to the wide size range among the fish, they were categorized into four size groups, viz. 50.0-60.0 g, 61.0-70.0 g, 71.0-80.0 g and 81.0-90.0 g. Based on the size categories and numbers obtained within each group, the cages were stocked with varied numbers (i. e. C1: 5, 144; C2: 1, 728; C3: 2, 606 and C4: 1, 398, at initial mean weights of 53.04 ± 7.19 g, 67.45 ± 10.59 g, 73.49 ± 9.86 g and 84.19 ± 8.90 g, respectively. Dead fish found floating in the cages were removed and recorded daily during the production period (Ofori *et al*., 2010).

**2.3 Feeding schedule and feed ration**

Feeding of the stocked fish started two (2﴿ days after stocking with locally produced commercial floating extruded pelleted tilapia grower feed of size 3.0 mm, and of crude protein (CP﴿ content 30% as declared by the producer. The fish were fed manually 3 times daily (between 0800-0830, 1200-1230 and 1600-1630 GMT﴿ throughout the culture period. At attainment of at least 100.0 g by the cultured fish in any of the cages, they were fed with 4.5 mm pellet size feed of 30% CP content. Feeding was done at a declining rate of 4.0 to 1.5% of estimated biomass of the surviving fish based on biweekly weight of a sample of at least 50 fish from each cage. The total daily ration was divided among the three feeding sections and it was administered by hand.

**2.4 Fish sampling and monitoring of fish growth**

Samples of at least 50 fish were randomly scooped out from each cage fortnightly between 0800 and 1000 GMT, using a scoop net of 3.0 cm stretched mesh size. Process of obtaining the samples from the cages involved the use of a metallic pole (external diameter 4.0 cm) at the bottom of the opposite sides of each cage bag and the former was drawn towards one corner of the opposite side to crowd a number of the fish into a smaller volume; and subsequently, at least 50 live fish randomly scooped out. The scooped fish were put into a large bowl containing lake water and each fish was gently blotted on a soft towel to remove excess water from the body prior to measuring it. The total length (TL), standard length (SL) and individual live body weights were measured (to the nearest 0.1 cm and 0.1 g, respectively), using a fish measuring board and a top loading electronic balance (KERN EMB Version 3.1 11/2021), respectively. Then, each fish was returned into a bowl containing fresh water and subsequently the fish were put back into their respective cages.

The cages and their nets were inspected for any damages and they were cleaned of all fouling agents. The estimated biomass (total weight) of fish in each cage was computed and subsequently the quantity of feed for fish group in each cage was adjusted accordingly. The fish were not fed on sampling days; feeding continued at about 0800 GMT on the following day. The culturing of the fish lasted between 127 and 204 days.

**2.5 Harvesting, grading and marketing of cultured fish**

At the end of the culture period, fish in the various cages were separately harvested and they were graded according to weight range < 200 g (Grade D), 200 to 399 g (Grade C), 400 to 599 g (Grades B), and > 600 g (Grades A) based on grow-out tilapia grading at the Centre. Each weight range group was counted, weighed and sold to local fish traders and individual consumers.

The Grade D was sold at 38.0 GHS kg-1 (3.80 USD kg-1﴿, whilst those of C, B and A were sold at 40.0 GHS kg-1 (about 4.00 USD kg-1﴿, based on the prevailing selling price of fresh tilapia within the study area and its environs during the production period. Production parameters and prices were then computed and tabulated to analyse the profitability of caged Nile tilapia grow-out production.

**2.6 Determination of growth performance indicators**

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

**2.6.1 Growth performance**

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

 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:

 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 growth was expressed as a percentage per day.

Where *In* = natural logarithm

**2.6.2 Survival rate (SR)**

**2.6.3 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:

**2.7 Computation of economic parameters**

Production costs such as cage rental, feed, juvenile fish, transportation, labour and marketing during the production period were computed. Cost and return analyses were performed on total production cost and to achieve the objective of the study, a simple tabular analysis was done. The following profit (П) equation was used to assess the profitability:

Where: i = 1, 2, 3,………,n

Πi = profit from ith tilapia production (GHS Cage-1)

Qi = Quantity of the ith produce (kg)

Pi = Average price of the ith produce (GHS kg-1)

TC = Total production cost (GHS)

The total revenue, TR generated from the sales of fish produced was computed by multiplying the total weight of each category of fish produced by the corresponding unit price as:

 (Dilon and Hardaker, 1993; Zannatul *et al*., 2019).

Where: P and Q denote price per unit weight of fish (GHS) and quantity of fish produced (kg), respectively.

The rate of returns on investment (ROI) which measures the extent to which the tilapia grow-out produced generated adequate returns on the capital invested was determined as:

The higher it is, the more profitable is the venture (Wood, 1999).

**2.8 Data analyses**

All data on production cost, fish yield and return on the caged tilapia grow-out produced were entered into a database system using Microsoft Excel software (2020 version). The data were then summarized using descriptive statistics. Results obtained were used to carry out the cost and return analyses and for assessing the profitability of the caged tilapia grow-out production.

**3. RESULTS**

**3.1 Fish growth performance and yield**

Growth performance of the caged Nile tilapia in terms of final mean weight, mean weight gain, survival rate, specific growth rate, feed conversion ratio, gross and net yields are presented in Table 1. Cage C1 recorded the longest grow-out days of 204 whilst C4 recorded the least of 127 days.

Aside from C1, the recorded survivals were above 80% with that (95.93%﴿ of C3 being the highest. The specific growth rates ranged from 0.90 to 1.31% day-1, with a mean of 1.14 ± 0.19 % day-1. Feed conversion ratios (FCRs) ranged from 1.99 to 2.39 with a mean of 2.14 ± 0.19. Gross fish yields in the 4 cages ranged from 528.92 to 1,018.10 kg cage-1 (i. e. 4.70 to 9.05 kg m-3), with a mean of 787.69 ± 235.05 kg cage-1 (i. e. 7.00 ± 1.64 kg m-3).

**Table 1. Growth performance of grow-out production of caged Nile tilapia**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter  | C1 | C2 | C3 | C4 |
| Total juvenile tilapia stocked stocked | 5, 144 | 1, 728 | 2, 606 | 1, 398 |
| Initial mean weight (g) | 53.04 ± 7.19 | 67.45 ± 10.59 | 73.49 ± 9.86 | 84.19 ± 8.90 |
| Final mean weight (g) | 322.15 ± 114.39 | 398.64 ± 189.33 | 407.25 ± 214.70 | 441.78 ± 230.99 |
| Mean weight gain (g) | 269.11 ± 107.2 | 331.19 ± 178.74 | 333.76 ± 204.84 | 357.59 ± 222.09 |
| Grow-out days | 204 | 138 | 162 | 127 |
| Survival rate (%) | 57.47 | 94.56 | 95.93 | 85.64 |
| Specific growth rate (% day-1) | 0.90 | 1.29 | 1.06 | 1.31 |
| Feed conversion ratio | 2.39 | 2.04 | 1.99 | 2.17 |
| Gross yield (kg cage-1) | 952.36 | 651.38 | 1, 018.10 | 528.92 |
| Net yield (kg cage-1) | 679.52 | 534.83 | 826.59 | 411.22 |

C1 = Cage 1; C2, = Cage 2; C3 = Cage 3; C3 = Cage 4

The percentages of the various size groups (< 200, 200-399, 400-599 and > 600 g﴿ among the grown-out Nile tilapia produced are shown in Figure 1. The least (7.94%﴿ was below the 200 g group whilst the highest (38.97%﴿ was that of the 200-399 g.

**Figure 1. Percentage of size groups (< 200, 200-399, 400-599 and > 600 g﴿ that constituted caged Nile tilapia grow-out produced**

**3.2 Production costs**

The total production cost among the 4 caged Nile tilapia grow-outs varied, and the values ranged from 15,246.30 ($1,524.63) to GHS30,937.03 ($3,093.70) with a mean value of 23,235.17 ± 8,142.25 GHS cage-1 (2,323.52 ± 814.23 $ cage-1), (Table 2﴿.

**Table 2. Production cost, revenue and return on investment of grow-out production of caged Nile tilapia**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Item  | C1 | C2 | C3 | C4 | Mean ± SD |
| Cost Elements (GHS﴿ |  |  |  |  |  |
| Cage Rental | 408.00 | 256.00 | 324.00 | 254.00 | 310.50 ± 72.69 |
| Feed | 18, 959.43 | 11, 651.16 | 21, 465.90 | 9, 918.00 | 15, 498.62 ± 5, 583.66 |
| Juvenile Tilapia | 9, 773.60 | 4, 104.00 | 6, 188.85 | 3, 984.30 | 6, 012.69 ± 2, 703.88 |
| Labour  | 1, 020.00 | 690.00 | 810.00 | 635.00 | 788.75 ± 170.61 |
| Transportation | 300.00 | 200.00 | 243.00 | 190.00 | 233.25 ± 50.09 |
| Marketing  | 476.00 | 325.00 | 510.00 | 265.00 | 394.00 ± 117.73 |
| Total Production Cost (GHS﴿ | 30, 937.03 | 17, 226.16 | 29, 531.19 | 15, 246.30 | 23, 235.17 ± 8, 142.25 |
| Total Revenue (GHS﴿ | 38, 037.98 | 25, 887.80 | 40, 520.38 | 21, 065.83 | 31, 378.00 ± 9, 388.32 474609.40 |
| Profit (GHS﴿ | 7, 100.95 | 8, 661.64 | 10, 989.19 | 5, 819.53 | 8, 142.83 ± 2, 225.17 |
| Return on Investment (%﴿ | 22.95 | 50.28 | 37.21 | 38.17 | 37.15 ± 11.18 |

SD = Standard Deviation. Average GHS to USD exchange rate during the study period: GH₵1.00 = $0.10

Different variable costs were involved and these were cage rental, feed, juvenile tilapia, labour, transportation and marketing. The production costs were influenced mainly by initial mean weight of fish stocked; quantities of fish stocked and grow-out days. Feed cost (66.70%﴿ was the highest production cost, followed by that (25.88%﴿ of juvenile tilapia, whilst the least (1.00%﴿ was that of transportation (Figure 2﴿.

**Figure 2. Percentage cost inputs of grow-out production of caged Nile tilapia**

Human labour was required at various stages of production, starting from stocking to harvesting and finally, marketing. Comparatively highest labour cost was incurred in C1 fish production. Marketing cost included expenditures made on ice-block and packaging materials (mainly polythene bags﴿.

**3.3 Revenue and return on investment**

The highest revenue of GHS40,520.38 ($4,052.04) was generated from fish produced in C3, followed by that (GHS38,037.98), ($3,803.80) of C1, with an overall mean of GHS31,378.00 ± 9,388.32 ($3,137.80 ± 938.83), (Table 2﴿. The highest profit (GHS10,989.19), ($1,098.92) was made from the yield of C3 whilst the least (GHS5,819.53), ($581.95) was from that of C4, with an overall mean of GHS8,142.83 ± 2,225.17 ($814.29 ± 222.52) The highest return on investment (ROI), (50.28%) was recorded in C2 whilst the least (22.95%) was in C1, with an overall mean of 37.15 ± 11.18%.

**4. DISCUSSION**

**4.1. Fish growth performance and yield**

Both growth and survival of the grow-out caged *O. niloticus* produced were impacted by initial size and quantities of the juvenile fish stocked per cage. Higher survivals (> 80%﴿ were recorded in cages stocked with larger juveniles (> 70.0 g﴿ but smaller quantities (< 3000 individuals﴿ per cage, compared with that which was stocked at a lower initial size (< 60.0 g﴿ but larger quantity (> 5, 000 individuals﴿ per cage. This is in line with the observation that in fish farming, survival rate (SR﴿ is density-dependent (Chakraborty and Banerjee, 2012); and extreme stocking densities have negative effects on the survival of cultured fish (Garcia *et al*., 2013), as observed in Cage 1 (C1) in the current study. Generally, gross fish yield increased with increasing stocking densities of the cages. This finding was in agreement with those of other researchers who observed that as stocking density increases, fish yield at harvest also increased (Huguenin, 1997; Gooley, 1998; Islam *et al*., 2016; Ofori *et al*., 2010).

In the current study, stocking density correlated negatively with specific growth rates (SGRs﴿, with the least stocked cage, C4 recording the highest (1.35 % day-1﴿ SGR whilst the highest stocked cage, C1 recorded the least, 0.90 % day-1. This agreed with the findings of Asase (2013), Garcia *et al*. (2013) and Costa *et al*. (2017) which indicated an inverse relationship between stocking density and growth performance in tilapia cultured in floating net cages. Even though the highest stocked cage, C1 recorded the least SGR and SR, in terms of number of fish harvested, it was the highest. Besides, it also recorded a high gross yield (GY﴿ of 952.36 kg cage-1 whilst the least, 528.92 kg cage-1 was recorded in C4, even though it recorded a SR of 85.64%. These findings agreed with those of Sorphea *et al*. (2010) and Khatune-Jannat *et al*. (2012) that although high stocking densities in fish culture may have negative effect on SRs, it could consequently increase fish yield. In this current study, even though C1 recorded the least survival (57.47%), due to its highest stocking density, it recorded a higher yield (952.36 kg cage-1) compared to those (651.38 and 528.92 kg cage-1) of C2 and C4 in which SRs of 94.56 and 85.64%, respectively; were recorded.

Economic profitability is influenced by production yield which in turn is dependent on stocking density (Aïzonou *et al*., 2019﴿. In the current study, varying numbers of fish were stocked in each of the 4 cages based on the numbers obtained for each size group during stocking, with those between 50.0 and 60.0 g being the highest. Hence, C1 was expected to have given the highest yield. However, this was not realized due to the high mortality recorded from the said cage. This suggests that although stocking densities influence yield, the survival of the stocked fish is necessary to ensure this. In the current study, aside from the numbers stocked, production yields were also positively influenced by number of cages and the culture period.

The feed conversion ratio (FCR﴿ range (1.99-2.39﴿ obtained in the current study were reasonably lower and they fell within typical FCR range of 1.4 to 2.5 in Nile tilapia cage aquaculture systems in Africa (Beveridge, 2004). It was recommended that for a minimal profit, FCR should be less than 2.50 in a small-scale production (Ofori *et al*., 2010). However, other researchers recorded higher FCRs in Nile tilapia cultured in floating net cages. Ofori *et al*. (2010) recorded a range of 2.50 to 8.10 and Abaho *et al*. (2020) recorded a range of 3.16 to 3.68. Lower FCRs are indications of effective conversion of consumed feed into body flesh by the cultured fish. Hence, the lower FCRs obtained in the current study suggests that the cultured Nile tilapia converted much of the feed intake into flesh (Alhassan *et al*., 2018). The least survival observed in the highest stocked cage, C1 could be attributed to the resultant relatively higher (2.39) FCR it recorded (Ronald *et al*., 2014).

**4.2 Production costs**

Cost of production of the caged Nile tilapia influenced the net revenue generated. In the present study, the highest production cost was on feed which constituted about 66.70% of the total cost. Feed cost is recorded as the largest operational costs in the aquaculture industry and proper feed management is considered one of the most vital elements in commercial aquaculture production (Lovell, 1989; McGinty and Rakocy, 2005; Ferdous *et al*., 2014; Daudpota *et al*., 2016). The result is consistent with the findings of other researchers who observed that often feed is the most expensive operating cost item in fish farming; accounting for between 40 and 60% of the costs in semi-intensive aquaculture (De Silva, 1993; De Silva and Hasan, 2007; FAO, 2009) and up to 70% in intensive aquaculture (ADB, 2005; Thompson *et al*., 2005; Ofori *et al*., 2009; Amenyogbe *et al*., 2018; Anani and Agbo, 2019; Namukonge and Barakagira, 2024). The result of the current study also agrees with those of Adeparusi (2005﴿ and Torsabo *et al*. (2019﴿ that depending on the species and the culture environment, feed could account for between 60 to 80% of the total production cost.

Following the cost of feed in the current study was that (25.88%﴿ of juvenile tilapia stocked for the grow-out production. Although this is in agreement with the finding of Ofori *et al*. (2010﴿ who used juvenile Nile tilapia ranged between 13.0 and 40.0 g, accounting for about 27.0% of production cost; it disagreed with the results of other researchers who used Nile tilapia fingerlings of sizes less than 10.0 g (Boateng *et al*., 2013; Anani *et al*., 2023; Wainaina *et al*., 2023﴿. The least, about 1.00% cost of transportation in the current study was mainly due to the nearness of the cages (production site) to the juvenile tilapia source and other production inputs including labour (Huguenin, 1997; Gooley, 1998).

**4.3 Profitability analyses**

For any business enterprise, the measurements of its past, current and the future profitability is necessary (Hofstrand, 2006). Commercial profitability of fish farming depends on production cost which is generally affected by the feed (Daudpota *et al*., 2016﴿. In the current study, the performance indicators used to assess the profitability of the grow-out production of the caged Nile tilapia were total revenue, profit and return on investment (ROI﴿. Values obtained indicated that there were positive operating profits from the yields of all the 4 cages, since all production costs in each cage were fully covered (Engle and Neira, 2005; Boateng *et al*., 2013﴿. An average total production cost of GHS23,235.17 ($2,323.52) was incurred per cage during the production period with average total revenue of GHS31,378.00 ($3,137.80) realized; achieving average positive profit of 8,142.83 GHS cage-1 (814.28 $ cage-1 ).

The rate of return on investment (ROI) ranged from 22.95 to 50.28%; suggesting every GHS1.00 ($0.1) that was invested in the caged Nile tilapia grow-out production, a return ranging from about 1.23 ($0.12) to GHS1.50 ($0.15) was realized with a profit of about 0.23 ($0.02) to GHS0.50 ($0.05) and an average of about GHS0.37 ($0.04). The findings of the current study agreed with those of other researchers that there is a considerable level of profitability in tilapia farming and that fish farming in general is economically viable (Ashaolu *et al*., 2006; Adewuji *et al*., 2010; Ofori *et al*., 2010; Nunoo *et al*., 2012; Namukonge and Barakagira, 2024 ).

**5. CONCLUSION AND RECOMMENDATIONS**

Based on the benefit indicator values obtained in this current study, it can be concluded that small-scale caged Nile tilapia grow-out production in the Volta Lake of Ghana is economically viable and profitable. It is capable of contributing much to the revenue of farmers. Future works should focus on the use of smaller-sized fingerlings (between 5.0 and 10.0 g) in stocking cages, and investment into higher number of cages (at least 10﴿ for the purposes of comparing production costs and profit margins.

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**COMPETING INTERESTS**

Authors declared no competing interests exist.

**AUTHORS’ CONTRIBUTIONS**

Francis A. Anani designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Kelvin K. Donkor, Felix A. Ayarika, Mercy Johnson-Ashun and Samuel Birinkorang collected study data, managed the analyses and literature searches. All authors read and approved the final manuscript.

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