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Effects of culture systems on growth and economic performance of *Oreochromis niloticus* (Linnaeus, 1758) in concrete tanks

Okonji, V. A.[1]*, Bayoko, T.[1] and Alufohai, G.[2]

[1]Department of Fisheries, Faculty of Agriculture, University of Benin, Benin city.
[2]Department of Agricultural Economics and Extension, Faculty of Agriculture, University Of Benin, Benin City.

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The effect of culture system on growth and economics performance of *Orechromis niloticus* (Nile tilapia) in concrete tanks was investigated. Four outdoor concrete tanks measuring 2.5 x 2 m was used for the study for 24 weeks culture period. The culture systems included the use of algae only at the stocking rates of 4 fishes/m^2 (T_1), algae plus commercial feed at the stocking rate of 10 fishes/m^2 (T_2), and commercial feed only at the stocking rate of 20 fishes/m^2 (T_3). The tanks were stocked with *O. niloticus* fingerlings with mean weight of 1.160, 1.030 and 0.255 g for T_1, T_2 and T_3, respectively. Each treatment was replicated twice. Data collected were analyzed using analysis of variance and mean comparison was carried out using Duncan Multiple Range Test (DMRT). All tests were carried out at 5% probability level. The result on growth performance show that the intensive system (T_1) was significantly different in some growth parameters ($P < 0.05$) such as yield (0.115, 0.830 and 1.260 kg/m^3 for T_1, T_2 and T_3, respectively), specific growth (1.975, 2.750 and 3.425% for T_1, T_2 and T_3, respectively), survival rate (90, 80 and 91% for T_1, T_2 and T_3, respectively), and feed conversion ratio (1.150 and1.030 for T_2 and T_3, respectively). Economically, the intensive system was more profitable with a gross margin of N 122, which was 40% more profitable than the extensive system (T_1 with Gross margin of ₦ 80), and 269% than commercial feed plus algae (T_2 with Gross margin of – ₦ 194). The cost of production (incidence of cost) showed that it cost more (₦ 447) to produce *O. niloticus* using commercial feed plus algae (T_2) in concrete tank than the use of algae only (T_1) (₦ 268) and the use of commercial feed only (T_3) (N380).

Key words: Culture system, growth performance, economic performance, *Oreochromic niloticus.*

INTRODUCTION

Food is a basic necessity of life, second only to air and water. The global food equation recognizes two major components namely; food crop component and animal protein component (Balogun, 1995). Animal protein source include fish, poultry and livestock. Fish consumption in Nigeria is higher due to its comparatively cheaper price compared to protein from other livestock. Available fish for consumption comes from aquaculture and capture fisheries with the capture fisheries becoming less sustainable. Aquaculture is the husbandry of aquatic food organisms (mostly fishes). It involves breeding new fish stock, holding them in captivity and feeding them (Agbebi and Fagbenro, 2006), and it is believed to be more sustainable source than capture fisheries. Report from the Food and Agriculture Organization (FAO) stated that Nigeria aquaculture industry produced over 30, 000 tonnes of fish in the year 2000; mostly tilapia (14,388 tonnes) cultivated under intensive and semi-intensive

*Corresponding author. E-mail: okovica@yahoo.com. Tel: +2348056072837.

production system. Despite this status, the yield from aquaculture is below optimum when compared with its potential, considering both ecological and socio-economic environment (Fagbenro et al., 2004). This is due to the fact that fish culture (mostly tilapia) in Nigeria is predominantly an extensive land-base (earthen pond) system practiced at subsistence level (Fagbenro, 2002), while commercial tilapia culture is yet to become popular and widespread mainly due to its natural tendency to reproduce excessively and generate so many small sized fish.

Tilapia is one of the most important species for the 21st century aquaculture and is produced in more than 100 countries (Fitzsimmons, 2000). It belongs to the cichlid family. Of this family, *Oreochromuis niloticus* is the most cultured specie because it has high reproductive and growth rate, relatively disease free, scaly and hardy in nature (Satya and Timothy, 2004).

The need to examine options to make *O. niloticus* culture system more efficient in terms of yield and returns is very important from environmental (water quality) and economical point of view. Options that will curb the excesses of tilapia in extensive systems (ponds) are necessary. The excesses includes uncontrolled breeding that leads to overcrowding and stunted growth, difficulties in harvesting and complete elimination of unwanted fishes after harvesting.

The success of the excessive reproduction is often supported by the presence of natural fish food in form of phytoplankton and zooplankton in the extensive culture system. This is because the young hatchlings often prefer and survive better on the plankton.

This success of excessive reproduction often bounces back on production cost and returns negatively (Satya and Timothy, 2004). Hence, little environmental modification of extensive system is needed to curb the excesses of tilapia population and increase profitability. The semi-intensive and intensive culture systems results in the reduction of the availability of natural fish food dependent on artificial diet.

Also water quality is managed through occasional flushing and regular flushing for semi-intensive and intensive culture systems, respectively, which results in the reduction of suspended particles in water including natural fish food and makes them less available for young hatchling excessive survival.

It is on this background that this study was designed with the general objective to evaluate the effect of three different culture systems on growth performance and economic efficiency of *O. niloticus* (Nile tilapia) cultured in concrete tanks.

The study specifically addressed the following: compared growth and survival rate of *O. niloticus* using the different culture systems in concrete tanks estimated the cost of production of *O. niloticus* using the different culture systems in concrete tanks and analyzed the effects of culture systems on profitability of *O. niloticus* culture in concrete tanks.

MATERIALS AND METHODS

The study was conducted at the Department of Fisheries, Faculty of Agriculture, University of Benin in the Faculty of Agriculture, Fisheries Experimental units. Two outdoor 20 m^2 concrete tanks partitioned into 4 units each with 2 m^2 mesh size nets were used as culture facilities. Three treatments were evaluated in the study, and were differentiated by their level of intensification which comprises of feed type and stocking density. The three treatments included extensive system, T_1 (that is, algae as feed at the stocking rate of 4 fishes/m^2), semi-Intensive system T_2 (algae + commercial feed at stocking rate of 10 fishes/m^2) and intensive system T_3 (commercial feed only at stocking of 20 fishes/m^2). The fingerlings of *O. niloticus* was stocked as mixed sex at the rate of 4 fisheries/m^2 in extensive system (T_1) with average weight of 1.16 g, 10 fishes/m^2 in semi-intensive system (T_2) with average weight of 1.030 g, and 20 fishes/m^2 in intensive system with average weight of 0.255 g, respectively. Each treatment was randomly assigned to tanks and replicated twice. Feed types used for the three treatments included: algae only for the extensive system (T_1) which was generated by the application of organic fertilizer (poultry droppings) in the concrete tanks; commercial feed plus algae for the semi-intensive system (T_2) and commercial feed only for the intensive system (T_3). Application of organic fertilizer was based on the recommendation of Okonji (2005). Water transparency was monitored and pond water under semi-intensive and intensive systems were flushed when transparency reading was above 60 cm (for T_2 which was occasional and T_3 which was regular). Fish fingerlings were stocked in the three systems two weeks after fertilization of T_1 and T_2 systems as recommended by Okonji and Obi (1999).

Fishes were weighed bi-weekly to obtain weight increment using Mettler PE 300 sensitive balance to evaluate the growth performance, and costs of inputs were recorded to evaluate economic performance. Fishes were cultured for 24 weeks, and water quality was monitored by taking water samples to laboratory to analyze dissolved oxygen, ammonia and pH readings, monthly. Temperature and transparency readings were taken daily on the farm using mercury-in-glass thermometer and seechi disc. Occasional flushing was applied to T_2 when water quality falls below standard (that is, when water transparency is less than 30 cm and regular flushing (weekly) was done to T_3 to ensure standard water quality. Data collected on growth performance was determined by the following parameter:

$$\text{Initial mean weight (g/fish)} = \frac{\text{Initial weight of fish (g)}}{\text{Number of fish stocked}}$$

$$\text{Final mean weight (g/fish)} = \frac{\text{Final weight of fish harvested (g)}}{\text{Number of fish harvested}}$$

$$\text{Bi-weekly mean weight gain (g)} = \frac{\text{Total bi-weekly weight gain}}{\text{Total surviving fish}}$$

$$\text{Absolute growth rate (g/day)} = \frac{\text{Final weight – initial weight}}{\text{No of days of culture period}}$$

$$\text{Specific growth rate (\%)} = \frac{\text{Log}_e \text{ final weight} - \text{Log}_e \text{ initial weight}}{t} \times \frac{100}{1}$$

Where, e is the base of natural logarithm and t, the cultured period (days).

$$\text{Survival rate (\%)} = \frac{\text{No. of survived fishes after culture period}}{\text{No of fishes stocked}} \times \frac{100}{1}$$

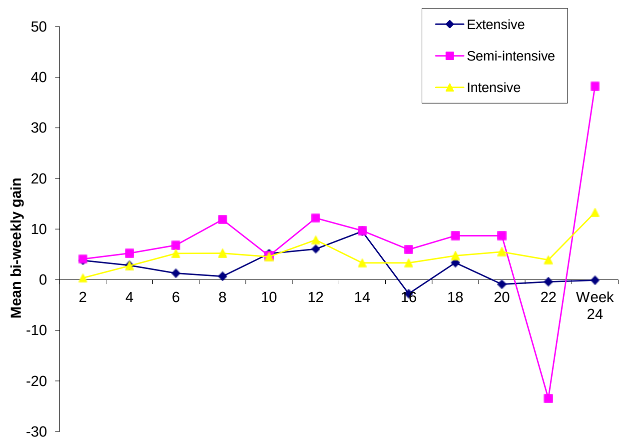

Figure 1. Mean bi-weekly weight of *O. niloticus* over time in three treatment types.

$$\text{FCR} = \frac{\text{Total weight of feed}}{\text{Total weight of fish produced}}$$

$$\text{Fish yield (kg/m}^2\text{)} = \frac{\text{Total weight of fish}}{\text{Area of tank}}$$

And also economic performance was estimated by the following:

GM = TR – TVC (Twenteen, 1989).

Where, TR is the total revenue (₦); TVC is the total variable cost (₦); GM is the gross margin (₦).

$$\text{Profit index} = \frac{\text{Total value of fish (₦)}}{\text{Cost of feeding type (₦)}}$$

$$\text{Incidence of cost ((₦/kg)} = \frac{\text{Cost of feeding type (₦)}}{\text{Kg weight of fish produce}}$$

The experiment was designed as complete randomized design (CRD) and data were analyzed using Genstat version 8, 2005. The analyzed data was tested using table of analysis of variance. Mean comparison was carried out using Duncan Multiple Range Test (DMRT) (Steel and Torrie, 1980). All tests were carried out at 5% probability level.

RESULTS AND DISCUSSION

The result on the study shows that water quality parameters varied only slightly among treatments as shown in Table 1. The parameters measured remained within the favourable range of culturing *O. niloticus* as indicated by Boyd (1979). However, water transparency was significantly higher in T_3 as a result of regular flushing($P<0.05$). This indicates that suspended materials such as algae were low in the intensive system than in the extensive and semi-intensive culture systems. Also ammonia was significantly lower in intensive system than the extensive and semi-intensive system ($P<0.05$). This also can be attributed to the regular flushing of the water which removes organic materials (algae fecal waste and unconsumed feed) which would have increase ammonia level. Similar trend was observed for dissolved oxygen. This indicates that growth performance may have been limited by the presence of organic particles in water in form of algae, fecal waste and unconsumed feed for each culture system. This was because occasional and regular flushing was used to regulate water quality in treatments, T_2 and T_3.

Growth performance

Table 2 shows the mean fish yields for T_3 (intensive system) with total physical produce (TPP) of 1.260 kg/m^2, and T_1 (extensive system) with the lowest yield of 0.115 kg/m^2, while T_2 (semi-intensive) was in-between with yield of 0.830 kg/m^2 ($P<0.05$). All were significantly different from each other, portraying that yield of *O. niloticus* increases with culture intensity. The growth performance of T_1 was lower than T_3 and T_2. This agrees with the findings of Dhirendra et al., (2007). This could be attributed to insufficient nutrients from algae only as source of food and the diversion of energy of growth to reproductive energy during breeding. Despite the result on final weight and absolute growth rate which appears to be highest for T_2 (104.8 g and 0.618 g/day), the result on yield was not commensurate with these values. This could be attributed to the fact that commercial feed input and abundance of natural food (algae) in the treatment brought about high organic matter loading in the system, resulting to mortality which in turn resulted to the lowest survival rate (80.0%) of the three systems. The result on Bi-weekly mean weight gain shows that there was significant difference among treatments with T_2 having the highest of 7.137 g, next was T_3 with 4.609 g, and T_3 was the least with 2.193 g. A graphical representation of the bi-weekly mean weight gain as shown in Figure 1,

Table 1. Water quality readings for the various treatments for 6 months culture period.

Water quality parameter	Sampling month	T_1 (Extensive)	T_2 (Semi-intensive)	T_3 (Intensive)
	September	27.6	28.4	28.6
	October	29.2	29.3	29.2
	November	29.5	29.7	29.5
Temperature	December	30.1	29.8	29.8
	January	27.5	27.1	27.3
	February	28.5	27.6	27.7
	Mean	28.7^a	28.7^a	28.7^a
	September	52.4	53.9	71.0
	October	53.2	48.9	57.3
	November	54.3	56.1	55.2
Transparency	December	44.6	47.1	68.2
	January	40.2	53.4	51.3
	February	58.6	67.7	69.3
	Mean	50.55^b	54.52^b	62.05^a
	September	5.26	5.26	5.21
	October	5.24	5.34	5.28
	November	5.24	5.33	5.27
pH	December	5.23	5.31	5.25
	January	5.17	5.30	5.25
	February	5.12	5.28	5.24
	Mean	5.21^a	5.30^a	5.25^a
	September	0.063	0.063	0.012
	October	0.062	0.055	0.058
	November	0.060	0.053	0.056
Ammonia	December	0.057	0.052	0.055
	January	0.055	0.049	0.052
	February	0.052	0.045	0.049
	Mean	0.058^a	0.053^a	0.047^b
	September	5.26	5.26	5.9
	October	5.49	6.28	5.22
	November	5.35	6.16	5.10
Dissolved oxygen	December	5.19	5.77	5.00
	January	5.15	5.60	4.73
	February	5.11	5.44	4.44
	Mean	5.26^a	5.95^a	5.00^b

Mean with same letters are not significantly different at 5% level probability by Duncan's multiple range test (horizontal comparisons only).

depicts increasing and decreasing mean weight. The decreasing bi-weekly mean weight could be related to the periods of gonadal maturity and breeding stage in the life of the experimental fish. This was observed from the 14 to 16th week and 18 to 24th week in T_1, 8 to 10th week and 20 to 22nd week in T_2, and in T_3, 12 to 14th week and 20 to 22nd week. From Figure 1, there was an initial decrease in bi-weekly weight in T_1; this may be due to the low natural food (algae) production at the onset of the experiment, unlike, the other two systems, which are not solely on or not algae feeding.

Economic performance

The profitability estimates obtained from the economic

Table 2. Growth performance of *O. niloticus* cultured with different feeding types for 24 weeks.

Growth parameter	T_1 (Extensive)	T_2 (Semi-Intensive)	T_3 (Intensive)
Initial weight (g)	1.160^a	1.030^a	0.255^b
Final weight (g)	32.2^c	104.8^{ab}	65.4^{bc}
Bi-weekly mean weight gain (g)	2.193^c	7.137^a	4.609^b
Absolute growth rate/g/day)	0.185^c	0.618^{ab}	0.387^{bc}
Specific growth rate (%)	1.975^c	2.750^{ab}	3.425^{bc}
F.C.R.	-	1.150^a	1.030^a
Survival rate (%)	90.0^a	80.0^a	91.0^a
Yield (kg/m^3)	0.115^c	0.830^b	1.260^a

Mean with same letters are not significantly different at 5% level probability by Duncan's multiple range test (horizontal comparisons only).

Table 3. Economic performance of *O. niloticus* cultured in concrete tanks with different feeding types for 24 weeks.

Economic parameter	T_1	T_2	T_3
Gross margin (G.M) ₦	80^a	-194^b	122^a
Incidence of cost (I.C)	268^b	447^a	380^{ab}
Productivity index (₦/kg)	0.025^a	0.082^a	0.229^a
Profit Index	1.520^a	0.895^a	1.045^a

Mean with same letters are not significantly different at 5% level probability by Duncan's multiple range test (horizontal comparisons only).

parameters are shown in Table 3. The result reveals that gross margin of T_1 and T_3 systems are similar (not significantly different), with T_3 having the highest (₦122). T_2 was found to be non-profitable meaning that the use of commercial feed plus algae in concrete tank culture of *O. niloticus* is not profitable (-₦194). The incidence of cost (I.C) shows that farmers will spend more (₦447) to produce 1 kg of the fish which is more than the ₦400 it could have been sold for T_2. The productivity index (APP) indicates that T_3 is the most productive of the three systems. This could be attributed to the number of fishes harvested as a result of the high stocking rate of the system. As shown by the result, productivity index increases as level of intensification increases; indicating that T_3 production system is the most economically efficient system of producing *O. niloticus*. The result on profit index indicates that T_1 has the highest profit ratio to the production cost (1.520 ₦/kg) of the three. This is due to the fact that the I.C is the least (₦268). The I.C. result of T_2 agrees with the gross margin (G.M) result which shows that T_2 is not profitable since its value is less than 1 (1 indicate breakeven point, above 1 is profit, and below 1 is loss). Reddy et al. (2005) define economic efficiency as the sum of technical (production) efficiency and allocative (price) efficiency under different level of technology. T3 system result shows that it is technically efficient (due to its high level of intensification) as a result of the high economic efficiency.

Conclusion

The result of the study on the effect of culture system on growth and economic performance of *O. niloticus* in concrete tank revealed that intensive culture of *O. niloticus* with only commercial feed at stocking rate of 20 fishes/m^2, produced higher yield and survival than commercial feed plus algae (semi-intensive) and algae only (extensive). In terms of cost/benefit analysis, the commercial feed plus algae had the highest cost and lowest profit, while algae only had the lowest cost and medium profit while commercial feed had medium cost and highest profit. Thus, based on fish yield and profit, the intensive culture of *O. niloticus* using commercial feed only was found to be better in yield/survival and higher in profit. This study has established that commercial feed can be used to culture *O. niloticus* in concrete tanks profitably. Also, maximizing production in terms of growth and economic efficiency of *O nitolicus* culture in concrete tank would require commercial feed only at higher stocking density.

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