

Effect of monoculture and polyculture different stocking density on production economics of Nile tilapia (*Oreochromis niloticus*) and African Catfish (*Clarias gariepinus*) cultured in concrete ponds

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Abstract

Information on the economic viability of aquaculture is crucial for investors when assessing the feasibility of an aquaculture investment. Unfortunately, such information has been scarce in Sudan. This article evaluates the effects of two fish culture systems and four different stocking densities on the production economics of Nile tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) fingerlings reared in indoor concrete ponds under low water-exchange conditions. Nile tilapia (*O. niloticus*) and catfish (*C. gariepinus*) were cultured in monoculture and polyculture at different stocking densities (SD) (SD12, SD24, SD36 and SD48 fish/m³) and stocked into seven treatments (1T:0C, 0T:1C, 1T:1C, 2T:1C, 3T:1C, 1T:2C and 1T:3C) for the experiment. Fingerlings were cultured for sixteen weeks. The evaluation showed all culture practices to be economically viable, although to varying degrees. Culture of Nile tilapia (*O. niloticus*) showed the highest viability and profitability of the seven evaluated culture practices (mono and polyculture). This was attributed to its higher turnover rate and price compared to the catfish *C. gariepinus*. Monoculture of catfish *C. gariepinus* showed lower viability compared to the Nile tilapia *O. niloticus*. However, economic analysis showed that this could be improved by enhancing productivity per unit value of input by using better fish breeds, feed with higher conversion ratios and efficient production management practices. Also, the different stocking densities (SD), the treatment SD36 fish/m³ showed production indicating best values for financial ratios. Despite there were no significant differences ($p > 0.5$) between SD36 fish/m³ and other stocking densities (SD12, SD24 and SD48 fish/m³). The success of aquaculture in Sudan will not only depend on the use of higher yielding species and efficient aquaculture production technologies, but also on the confidence of investors. For this reason, the Federal Ministry of Livestock and Fisheries (FMoLF), Sudan, needs to have appropriate information available to investors in their process of making economic decisions on aquaculture investments.

Keywords: Monoculture, polyculture, *O niloticus*, *C gariepinus*, stocking density and profitability

Introduction

Aquaculture is one of the fastest growing sectors of animal protein production in the world. Excluding algae, total world fisheries and aquaculture production showed a 45 percent growth between 2000 and 2021, reaching 182 million tons in 2021 and setting a new production record (the previous one was 179 million tons in 2018) (FAO, 2023) ^[1]. This represents an overall expansion of 56 million tons compared to 2000. In 2021, the total fisheries and aquaculture production (excluding algae) rose significantly (+2.7 percent) compared with 2020 after two years of relative decline contributing to the reduction of population poverty, hunger and malnutrition, generating economic growth and guaranteeing natural resources (FAO, 2023) ^[1]. The full utilization of space for maximum fish production through intensive culture can improve the profitability of the fish farm (Ellis *et al.*, 2002) ^[2]. Higher growth rate and yield of aquaculture species can be attained when farmers culture fish at an optimum stocking density, which will eventually result into high growth for economic benefits (Shoko *et al.*, 2016) ^[3]. Although high stocking density in aquaculture systems may be led to increase of fish production, but it may have some negative effects on physiological, hormonal and immune responses of aquatic species (Kpundeh *et al.*, 2013^[4]; Jumah, 2020) ^[5].

The polyculture system has an important role in the nutrition and economic aspects (Ali *et al.*, 2017) ^[6]. This is because land and high feed costs can cover the difference between demand and supply for cultivated products. The polyculture system is more profitable than the monoculture system because polyculture is a cultivation method for the maintenance of more than one type of biota. This shows that at harvest time, more than one type of fish will be obtained with different prices so that it can boost the selling price. In addition, polyculture can help increase land productivity to be high. This is because in the same container can be maintained more than one type of biota so that it does not need a large container and large capital (Setiadi *et al.*, 2018) ^[7]. The eating habits of fish kept in polyculture are different so there is no competition in nutrient consumption. That is because one type of fish will utilize waste from biota from other types that have been processed into a form that can be consumed by other biota so that the utilization of feed is more efficient (Asadujjaman *et al.*, 2016) ^[8]. According to Prasetiyono & Syaputra (2018) ^[9], polyculture can produce optimal profits because the potential of capital, feed and facilities resources can be minimized. In addition, production capacity is higher in polyculture maintenance systems. Polyculture activity is the cultivation of organisms of more than one type in the same container but has

different eating habits (Setiadi *et al.*, 2018) [7]. Economically, fish of different types have a certain species selling price (Moray *et al.*, 2014) [10]. Therefore, it can be seen that polyculture produces higher profits compared to monoculture (Husain *et al.*, 2016) [11]. The factors that cause the polyculture system to be more profitable are because on one land optimization can be carried out by cultivating more than one type of organism. In addition, the different eating habits of the organisms that are nurtured help improve the efficiency of feeding so that it can save the input provided. The selling price of polyculture products is higher because there is more than one type of fish. The selling price of catfish consumption size is 1,46 USD/kg, while the price of consumption tilapia is 1,9 USD. High productivity shows that the biomass of each unit of land volume is high so that the number of fishes harvested is high (Muarif & Rosmawati, 2011) [12]. Therefore, the current study objective to evaluate the effect of monoculture and polyculture different stocking density on costs of economics production of tilapia *O. niloticus* and catfish *C. gariepinus*, reared under seven different stocking densities 1T:0C, 0T:1C, 1T:1C, 2T:1C, 3T:1C, 1T:2C and 1T:3C in concrete ponds.

Materials and Methods

1. Study Area

The experimental work was conducted in College of Animal Production Science and Technology (CAPST), at Laboratory of Department of Fisheries and Wildlife Science (DFWS), and Hatchery of Freshwater Aquaculture Research Centre (FARC), Kuku Camp.

2. Experimental design and fish stocking

The experimental fish Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) fingerlings mean weight 15.02 ± 0.4 g and 25.23 ± 1.3 g respectively) were adapted in Hapas for two weeks. The hapas were made of nylon mosquito net with mesh size 0.5×0.5 mm. After the adaptation period, each fish species was weighted, then randomly distributed, and stocked in seven groups (1T: 0C, 0T: 1C, 1T: 1C, 2T: 1C, 3T: 1C, 1T: 2C and 1T: 3C in concrete ponds; each Hapa (1 m² height \times 1 m² width \times 2 m² length) at different stocking density (SD) (SD12, SD24, SD36 and SD48 fish/m³) in triplicates. Hapas were constructed and implanted in an inside of the concrete ponds (1.2 m² height and 2 m² diameter, total volume 3.8 m³). The experiment was conducted on concrete ponds in which are in an indoor a building covered on the sides with Expenda and on top with zinc sheets.

3. Economics analysis

The average values methods were used. The total cost of production for experimental was calculated as described by Faturoti and Lawal (1986) [13]:

- **Variable cost components include (VC):** fingerlings cost, feed cost, labor wages, electricity.
- **Average total cost (ATC):** Average variable cost + Average fixed cost
- **Revenue (R):** quantity harvested (kg) \times price per kg.
- **Benefit cost Ratio (BCR):** which is the total revenue divided by the average variable cost.

4. Statistical analysis

The means of economic analysis of Nile tilapia *O. niloticus* and catfish *C. gariepinus* fingerlings experiment; monoculture and polyculture different stocking density were subjected to statistical comparisons using one-way ANOVA. All statistical analyses were carried out using the SPSS program (SPSS v 26 Inc. 1997). In addition, Microsoft Excel (2013). Results and Mean differences were compared with analysis of variance and considered significant at $p < 0.05$. LSD test was used to identify statistically significant differences among treatment means.

Results and Discussion

1. Fish production and selling

The results showed that polyculture cultivation resulted in higher productivity compared to monoculture treatments. The highest productivity is treatment (1 *O. niloticus*: 3 *C. gariepinus*) with a value of 6432g/m³, while the (1 *O. niloticus*: 0 *C. gariepinus*) treatment has a lower value of 1524g/m³. According to Dewi *et al.* (2016), high productivity is directly proportional to high profitability so that treatment (1 *O. niloticus*: 3 *C. gariepinus*) is more profitable when compared to monoculture treatments (tilapia *O. niloticus* and African Catfish *C. gariepinus* (1430g and 1601g/tank, respectively). The observations showed that the productivity of catfish in treatment A (75% catfish and tilapia 25%) was highest at 6432g/m³, while the smallest productivity was seen in treatment 1 *O. niloticus*:1 *C. gariepinus* (55% catfish and tilapia 45%) that is 3313 g/m³. Each treatment was tested using the One-Way ANOVA Test and showed significant differences ($P < 0.05$) at a 95% confidence level.

2. Economics analysis

Profitability SGD of Nile tilapia *O. niloticus* and African Catfish *C. gariepinus*, monoculture and polyculture systems different stocking density; the results of fish species and polyculture systems profitability SGD presented in tables 1 and 2. Are significantly different ($p < 0.05$; the result in table 3. shows no significant difference ($p > 0.05$) in all parameters of fish's profitability SGD. Result of fish species presented in (Table 3.1) shows that *C. gariepinus* had the highest value of Cost production (125.62 SDG) with *O. niloticus* having the least (89.67 SDG). fish species with the highest Income SDG was *O. niloticus* (381.10 SDG) whilst *C. gariepinus* had the least (295.74 SDG). In terms of fish Profit, *O. niloticus* has the highest (278.43 SDG) while *C. gariepinus* had the least (170.12 SDG). The cost of fish production presented in (table 3.2) ranged from 102.69 to 124.87 SDG; 0T: 1C has the highest (124.87 SDG) while 1T: 0C had the least (102.69 SDG). The income of fish parameters ranged from 288.53 to 381.10 shows that 1T: 0C has the highest (381.10 SDG) while 1T: 0C had the least (288.53 SDG). The treatments profitability was higher for 1T: 0C (278.43 SDG) followed by 1T:3C, 1T:2C, 2T:1C, 1T: 1C, 3T:1C and 0T: 1C; with 236.70, 236.65, 234.13, 232.70, 230.47 and 163.67 SDG respectively. The results of present study of stocking density in table 3, and figure 3. Showed was no significance different $p > 0.05$ between treatments (SD12, SD24, SD36 and SD48 fish/m³) measured at the end of growth study on Profitability SGD.

Table 3.1: Effect fish species (Nile tilapia *O. niloticus* and African Catfish *C. gariepinus*) on production economic cultured in concrete ponds (means ± SD)

Parameters	Cost per fish (SDG)	Income per fish (SDG)	Profit per fish (SDG)
Tilapia <i>O. niloticus</i> (N=12)	89.99±1.2 ^b	385.93±8.3 ^a	295.94±7.4 ^a
Catfish <i>C. gariepinus</i> (N=12)	125.62±1.2 ^a	295.74±5.4 ^b	170.12±4.7 ^b
Sg.	*	*	*

Means with similar superscripts in same Colum are statistically insignificantly different (p>0.05). NS, No significant (p> 0.05). *, Significant different at (p< 0.05). **, Significant different at (p< 0.01).

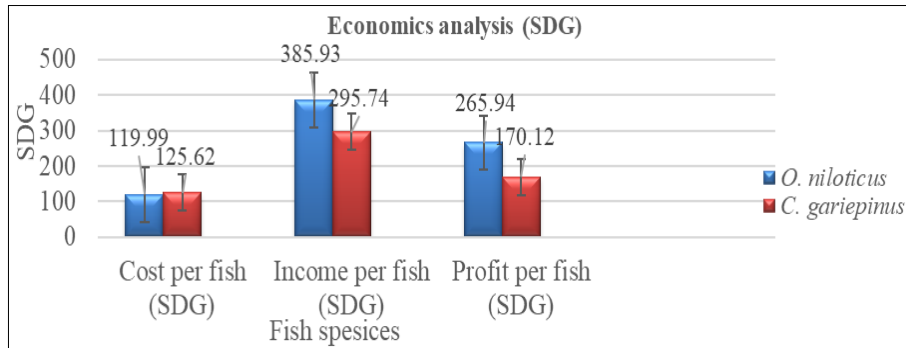


Fig 1: Economics analysis of Nile tilapia *O. niloticus* and Catfish *C. gariepinus* reared in concrete ponds

Table 3.2: Effect of mono and polyculture systems on fish production economics of Nile tilapia *O. niloticus* and African Catfish *C. gariepinus* cultured in concrete ponds under Sudanese conditions (means ± SD)

Parameters Treatments	Cost per fish (SDG)	Income per fish (SDG)	Profit per fish (SDG)
1T: 0C (N=12)	102.67±0.8 ^b	381.10±7.8 ^a	278.43±7.3 ^a
0T: 1C (N=12)	124.87±0.8 ^a	288.53±3.1 ^b	163.67±3.8 ^b
1T: 1C (N=12:12)	108.40±18.9 ^{ab}	341.10±53.9 ^{ab}	232.70±72.6 ^{ab}
2T: 1C (N=24:12)	108.00±20.1 ^{ab}	342.13±46.4 ^{ab}	234.13±66.4 ^{ab}
3T: 1C (N=36:12)	107.50±19.9 ^{ab}	337.97±42.2 ^{ab}	230.47±62.4 ^{ab}
1T: 2C (N=12:24)	108.67±18.7 ^{ab}	345.32±48.9 ^{ab}	236.65±68.8 ^{ab}
1T: 3C (N=12:36)	107.00±18.7 ^{ab}	343.70±55.3 ^{ab}	236.70±73.8 ^{ab}
Sg.	*	*	*

Means with similar superscripts in same Colum are statistically insignificantly different (p>0.05). NS, No significant (p> 0.05). *, Significant different at (p< 0.05). **, Significant different at (p< 0.01).

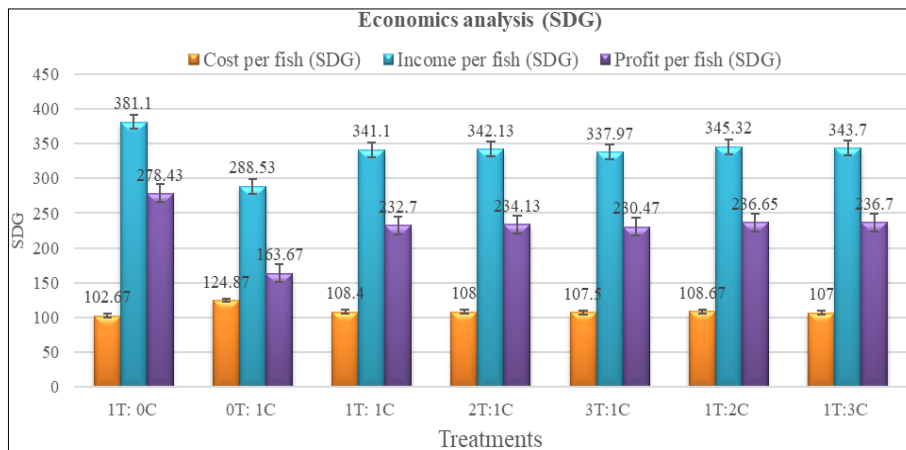


Fig 2: Economics analysis of monoculture and polyculture systems on fish production economics of Nile tilapia *O. niloticus* and African Catfish *C. gariepinus* cultured in concrete ponds

Table 3.3: Effect of stocking density on fish production economics of Nile tilapia *O. niloticus* and African Catfish *C. gariepinus* cultured in concrete ponds under Sudanese conditions (means ± SD)

Treatments	Cost per fish (SDG)	Income per fish (SDG)	Profit per fish (SDG)
12	107.27±19.3 ^a	334.82±51.0 ^a	227.55±70.2 ^a
24	108.40±18.9 ^a	341.10±53.9 ^a	232.70±72.6 ^a
36	108.33±19.1 ^a	343.73±45.5 ^a	235.39±64.5 ^a
48	107.25±18.6 ^a	340.83±47.0 ^a	233.58±65.3 ^a
Sg.	Ns	Ns	Ns

Means with similar superscripts in same Colum are statistically insignificantly different (p>0.05). NS, No significant (p> 0.05). *, Significant different at (p< 0.05) **, Significant different at (p< 0.01).

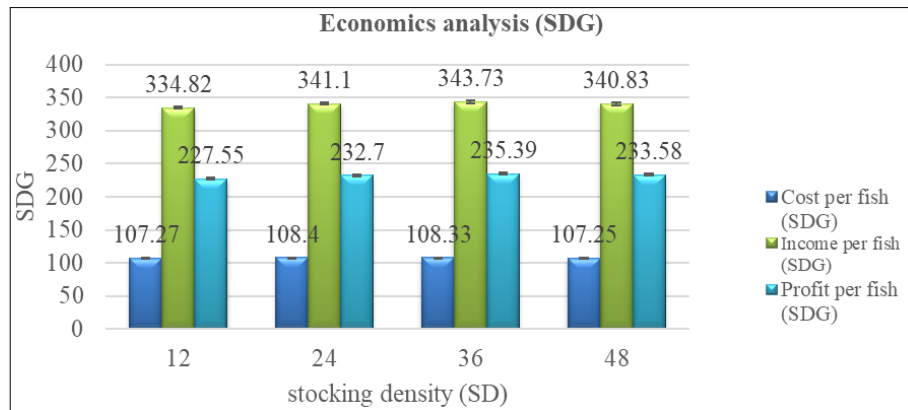


Fig 3: Economics analysis of stocking density on fish production economics of Nile tilapia *O. niloticus* and African Catfish *C. gariepinus* cultured in concrete ponds

Discussion

At the end of the experiment, it was noticed that the growth parameters of Nile tilapia *Oreochromis niloticus* decreased with the increase of tilapia in its stocking density ($P < 0.05$) and the highest growth was obtained at 1 Tilapia *O. niloticus*: 3 catfish *C. gariepinus* and 1 Tilapia *O. niloticus*: 1 catfish *C. gariepinus*, whereas the lowest one was obtained at 3 Tilapia *O. niloticus*: 1 catfish *C. gariepinus*. In contrast to results were obtained with catfish *Clarias gariepinus* was the highest growth was obtained at 1 Tilapia *O. niloticus*: 2 catfish *C. gariepinus*, while the lowest ones were obtained at 0 Tilapia *O. niloticus*: 1 catfish *C. gariepinus*. The growth responses of fish species in all stocking groups were generally satisfactory. Profitability SGD of Nile tilapia *O. niloticus* and African Catfish *C. gariepinus*, monoculture and polyculture systems; the results of monoculture and polyculture systems profitability SGD presented in tables 1 and 2. Are significantly different ($p < 0.05$) the result in table 3. shows no significant difference ($p > 0.05$) among parameters at different stocking densities. In terms of fish Profit, *O. niloticus* has the highest (278.43 SGD) this result agrees with Muneer A. and Pramod Kiran R.B. (2024) [14] who studied the economics of Nile tilapia and striped catfish polyculture was calculated and the total revenue was estimated. The net profit margin against recurring cost was calculated as 49.25%. Considering the commercial value of the fish cultured, the semi-intensive practice with the cheapest biosecurity measures for the culture of exotic aquatic candidates will ensure biosecurity and profitability. The present result obtained by this study shown higher production in polyculture 1 tilapia and 3 catfish but the higher economic profit in monoculture of Nile tilapia this result related to result of Mansour, *et al* (2021) [15] who studied monoculture of striped catfish (100%), Nile tilapia (100%) and polyculture in different proportions of striped catfish and Nile tilapia 25%:75%; 50%:50%; 75%:25%, respectively; thus, ecologically, the farming of tilapia and striped catfish is applicable, however, for higher production and economic profit, the monoculture of striped catfish is recommended. the discrepancy between the results of the current study and Mansour, *et al* (2021) [15] results may be due to differences in prices between the two farmed species and nutritional culture in the two countries. the result in table & fig. 3. shows no significant difference ($p > 0.05$) among parameters at different stocking densities this result agrees with (FAO, 1996) [16] that reported; Economic comparison between monoculture and polyculture of catfish indicates that polyculture is slightly better due to a higher economic rate of return. However, the

net cash flow for the farmer is more or less the same. The main difference between the culture systems is in farm costs that are much higher for monoculture because formulated feed is required to cover for the protein requirements at the given production level. Polyculture has a lower catfish density than monocultures. However, the variable costs in monoculture systems are lower compared to polyculture systems. Variable costs are costs that amount in accordance with the volume of activities (Winarko & Astuti, 2018) [17]. This is indicated by the amount of density of organisms used and the need for lower pellet feed. Tilapia maintenance activities indicate that the use of feed because tilapia can eat biofloc grown on media and biofloc formed is the result of the conversion of catfish residual waste so it shows the existence of feed efficiency.

Conclusion

The evaluation showed all culture practices (monoculture, polyculture, and different stocking density) to be economically viable although at varying degrees. Analysis of variable costs suggest improved economic benefits when using the monoculture of Tilapia and; polyculture 1 Tilapia *O. niloticus*: 2 catfish *C. gariepinus* under the conditions of this study. Also, Results suggest that (1 Tilapia *O. niloticus*: 3 catfish *C. gariepinus*) can be reared in an indoor pond at a stocking density of 36 to 48 fish/m³ due mainly to reduce feed cost and to achieve acceptable growth performance, health condition and best quality of fish.

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