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Comparative growth study of *Oreochromis niloticus* and *Sarotherodon galilaeus* under two different culture regimes (Hapa-In-Pond and cage systems).

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ABSTRACT
Nile tilapia and the mango tilapia are two most dominant cultured tilapia species in Ghana and have contributed significantly to the aquaculture development of the country. A 24 week trial was conducted to study the growth of these two species under two different culture regimes (cages and hapa-in-pond). Mixed sex fingerlings of average weight 26.90 ± 0.21 g were stocked in cages and hapa-in-pond at a rate of 32 fish/m³ and 5 fish/m² respectively. Fingerlings were fed a 36% crude protein commercial fish diet. A comparison of growth performance of fish under the two culture regimes in terms of weight gain was in the following order; *O. niloticus* (in cage) > *S. galilaeus* (in cage) > *O. niloticus* (in hapa) > *S. galilaeus* (in hapa). There were significant differences in final mean weights, mean daily weight gain, specific growth rate and mean relative weight gain between the culture regimes except for the culture between *S. galilaeus* (in cage) and *O. niloticus* (in hapa). Although the net yield was high in *O. niloticus* under the 2 culture regimes, survival was relatively high among *S. galilaeus* under the same culture systems. A high value of fish crop was realized in *O. niloticus* under the two culture regimes, however, profit index did not vary significantly from each other. In the sexes, *O. niloticus* showed a distinct variation in male to female population in which the males were found to grow twice more than the female population, however, population of *S. galilaeus* in all culture regimes showed an almost equal growth. In general, although *O. niloticus* shows distinct variation in sizes among its sexes other than *S. galilaeus*, it showed superior growth with an appreciable feed conversion rate, hence its sex reversal is highly encouraged for its culture to be more profitable.

Keywords: *Oreochromis niloticus*, *Sarotherodon galilaeus*, feed conversion ratio, profit index, net yield.

1. Introduction

Tilapias are known to be an important component of subsistence fisheries for thousands of years and are being described as the second most important farmed fish globally next to carps and also as the most important aquaculture species of the twenty-first century [1].

There are over 70 species of tilapias [2] but 9 are used mainly in farming [3]. There are now many strains of the parent species along with many hybrid strains available to growers [4]. They are easy to culture and reproduce, with rapid sexual maturity at 6/7 months from hatch and marketable at this age.

Nile tilapia, *Oreochromis niloticus* is the main cultured species in many parts of the world and responsible for the significant increase in global tilapia aquaculture production due to its suitability for farming in a wide array of culture systems, ranging from extensive, low-input culture to intensive systems [5]; and accounted for about 83% of total tilapias produced worldwide [3]. Most of the genetically improved strains reaching the aquaculture industry were developed through traditional selective breeding (selection, crossbreeding and hybridization). *Sarotherodon galilaeus* have not matured yet, but hold much promise [6]. Genetically modified organisms now offer the opportunity to improve both the production and characteristics of conventional strains of animals and plants currently exploited in agriculture and aquaculture.

In Ghana, these two species of tilapia are of economic importance in freshwater capture fisheries [7].

The growing popularity of tilapia among consumers and the ever increasing need to improve food production, imposes the need to seek production system alternatives to culture tilapia. Such is the use of earthen ponds and cages.

The cultural practices of tilapia can be extensive, semi-intensive and intensive [8]. There has been a gradual shift in tilapia culture from traditional semi-intensive to non-traditional intensive farm systems [9]. But, deciding the optimal culture method for tilapia farming can be quite complex [10]. Traditionally, tilapia is often cultured in earthen ponds without supplemental feeding [11]. Intensive monoculture of the fish in concrete tanks is carried out in a few countries.
Although practiced in some countries, cage culture of tilapia is yet to be commercialized on a wide scale basis. Pen culture of tilapia in open waters of lakes is practiced in other countries on an appreciable scale [12]. Flow-through culture of tilapia is also done on a very limited scale, for producing marketable fish. Extensive evaluations of various management strategies are required to select the optimal culture procedure under certain socio-economical conditions.
Among the various culture systems, integrated aquaculture is considered as a sustainable small scale aquaculture system. The nature of integration may be of various types, the integrated cage-pond fish culture technique is a new and innovative one. Cage aquaculture has certain advantages over other aquaculture systems that are potentially important in terms of uptake by rural poor and landless people.
This study was conducted to compare some production performance traits in the culture of *O. niloticus* and *S. galilaeus*. The primary objective of the study was to determine which of the two species is more suitable for culture in cages and hapa-in-pond.

2. Methodology

2.1 Study Area

The experimental work is being carried out at Aquaculture Research and Development Centre (ARDEC) of the Water Research Institute, Akosombo, between December, 2011 and June, 2012. Fingerlings of *O. niloticus* and *S. galilaeus* used in the study were obtained in separate 0.2 hectare ponds at the centre.

2.2 Culture System

Four cages of size 14 m³ each used were constructed using galvanized pipes, welded into a cage frame and floated on the river using rubber drums. The inner netting (1 inch) and outer netting (2.0 inches) were securely fixed in and out of the cages respectively on the Volta River. The cages were anchored to prevent it from drifting by the current from its original position.
Four hapas of size 10 m^2 each made of mosquito netting were sewn and securely fixed in a 0.2 hectare pond using bamboo sticks. The pond was adequately prepared prior to the fixing of the hapas.

2.3 Stocking of fingerlings

The two treatment fish, *O. niloticus* and *S galilaeus* mixed-sex fingerlings were randomly allocated to each culture regime, so the trial was run in duplicate. The fish were kept for acclimatization at the experimental conditions for seven days before the trial began. After the groups were allocated and fish acclimatized, samples of fish were weighed using a digital scale and measured using a measuring board to obtain the initial samples of the groups.
The initial stocking average size for all groups was 26.90±0.21 g and stocked in cages at a rate of 32 fish per cubic metre (average of 450 fish per cage) and 5 fish per square metre in hapas (50 fish per hapa).

2.4 Feeding and Sampling

Fish were fed initially with a commercial extruded pellet of crude protein level 36%. The feeding was conducted manually three times a day (8.30 am, 12.00 pm and 4.00 pm) at an initial rate of 4% to 3% and 2% towards the end of the experiment. Daily feed consumption (feed given to fish) and mortalities were recorded. Dead fish were replaced immediately with similar size specimens within the first ten days of culture.
The amounts of feed in respective fish type were determined through the sampling that was carried out biweekly throughout the culture period to monitor growth performance. At least 50 fish in each cage and 30 fish in each hapa-in-pond were randomly sampled on a biweekly basis by partially lifting the cage netting and removing fish with a dip net. The standard and total length was measured to the nearest ± 0.1 mm and the weight of fish measured to the nearest ± 0.1 g.

2.5 Water Quality Sampling

Weekly water quality parameters such as temperature, dissolved oxygen, pH and turbidity were measured *in situ* using a thermometer, WTM Inolab Oxi Level 2 Oxygen metre, Suntex Model SP-701 pH metre and turbidity metre respectively. The ammonia nitrogen content of the water was also analyzed biweekly using a visible spectrophotometer. All these tests were analyzed using the AOAC [13] standard methods. Sample collections were made between 8.00 am and 9.00 am on each sampling day.

2.6 Growth Monitoring Parameters and Yield

Specific growth rate for each treatment group was calculated using the formula:

$$SGR = (\ln W_f - \ln W_i \times 100) / t,$$

Where, $\ln W_f$ = the natural logarithm of the mean final weight (g), $\ln W_i$ = the natural logarithm of the mean initial weight (g), t = time (days) between $\ln W_f$ and $\ln W_i$ [14].

The condition factor was calculated as:

$K = BW / SL^3$, [15], [16], where *K* = condition factor, BW = body weight of fish (g), SL = standard length of fish (cm).

The food conversion ratio was obtained from: FCR = dry weight of feed consumed (g)/wet weight gain (g), [17].

Mean Daily Weight Gain was calculated as $W_f - W_i / t$, where W_f is the final weight at harvest, W_i is the initial weight at stocking and *t*, the duration of culture.
The yield, feed consumed and the survival at the experiment was being estimated. The sex ratios of the species as well as the grades of fish were also determined. The value of fish crop and the profit index were also determined.

2.7 Statistical Analysis

Statistical analyses were carried out to determine whether significant differences existed between the different treatments and the parameters tested. All results were analyzed using a one-way variance analysis and Tukey's multiple comparisons of means using GraphPad Instat, [18]. Graphical presentations were done using Microsoft excel programme.

3. Results

3.1 Growth and Yield Parameter

The growth performance of *O. niloticus* and *S. galilaeus* cultured under the two culture systems (cage and hapa-in-pond) in terms of weight gain, specific growth rate, mean daily weight gain, condition factor, mean relative weight gain and food conversion ratio are presented in Table 1.

Initial average stocking weight did not differ significantly (p>0.05) from each other. The variations in growth in terms of mean weight gain of *O. niloticus* and *S. galilaeus* cultured under the two culture regimes is graphically presented in Fig. 1. *O. niloticus* cultured in cages attained the highest mean weight of 299.67±16.40 g, with a mean daily weight gain of 1.38±0.08 g whiles the *S. galilaeus* cultured in hapa-in-pond had the lowest mean weight of 71.09±18.47 g with a mean daily weight gain of 0.23±0.09 g.

There were significant differences in final mean weights, mean daily weight gain, specific growth rate and mean relative weight gain between the culture regimes except for the culture between the *S. galilaeus* cage and *O. niloticus* hapa (at p>0.05). Although condition factor was high in the culture of *O. niloticus* in cages (3.83±0.09) but there was no significant difference between species in all the culture regimes.

Table 1: Growth Parameters of *O. niloticus* and *S. galilaeus* cultured under the 2 regimes

GROWTH PARAMETER	*O. niloticus*		*S. galilaeus*	
	CAGE	HAPA	CAGE	HAPA
Initial Mean Weight (g)	27.02±0.42^a	27.12±0.34^a	26.72±0.63^a	26.72±1.04^a
Final Mean Weight (g)	299.67±16.40^b	128.39±9.04^c	137.51±6.22^b	71.09±18.47^c
Final Av. Condition Factor, K	3.83±0.09^a	3.80±0.05^a	3.73±0.09^a	3.77±0.06^a
Mean Daily Weight gain (g)	1.38±0.08^b	0.52±0.05^{ab}	0.56±0.03^{ab}	0.23±0.09^b
Specific Growth Rate (g)	1.22±0.03^b	0.80±0.04^{ab}	0.83±0.04^{ab}	0.49±0.13^b
Mean Relative Weight Gain (%)	90.88±0.50^b	80.33±1.20^b	79.12±1.44^b	61.10±5.11^b
Feed Conversion Ration	1.58±0.16^b	3.57±0.49^b	1.83±0.08^b	4.19±0.23^b

*mean ± standard deviation, ^{a} = no significant difference, ^{b,c} = significant difference

The highest mean FCR value was recorded by *S. galilaeus* cultured in hapa (4.19±0.23), followed by *O. niloticus* cultured in hapa (3.57±0.49) with the least being recorded by *O. niloticus* in cage (1.58±0.16). There were significant differences (for FCR) among and between the culture of *O. niloticus* and *S. galilaeus* in both cages and hapa-in-pond culture systems.

The stocking rate, density, yield and survival in the two culture regimes were analyzed differently because of the differences in stocking rate (Table 2). The stocking rate and density of the two species for the different culture regimes were not significant. High gross and net yield were recorded in *O. niloticus* stocked in cages at 88.04±9.32 kg and 75.75±9.32 kg respectively than their *S. galilaeus* counterparts. In the hapa-in-pond system, high yield was achieved in the culture of *O. niloticus*. The statistical analysis (one-way ANOVA) revealed that the net and gross yield for the culture in cages were significant, whereas the culture of the species in hapa-in-pond were not significant at p>0.05.

The survival rate in the culture of *S. galilaeus* in cage was high with a value of 80.11±14.61% with the least being the *O. niloticus* in hapa with a value of 65±7.07%. Between these culture regimes, survival and recovery (although high in *S. galilaeus* cultured in both cages and hapa-in-pond) were not significant at p<0.05.

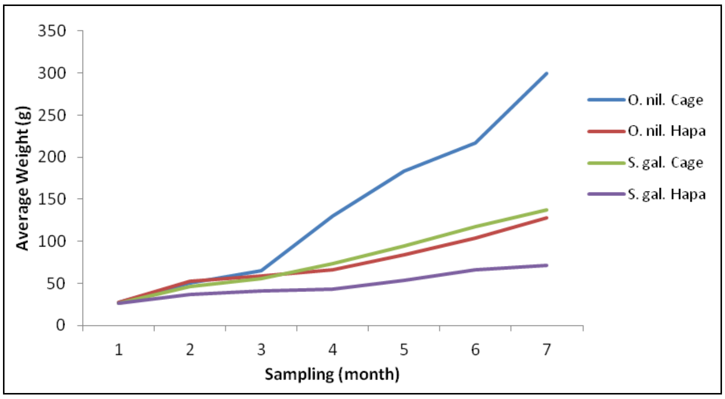

Fig 1: Graph of mean weight of *O. niloticus* and *S. galilaeus* sampling under the 2 regime.

3.2 Fish Grading

The figure below (Fig. 2) shows the grading of the yield of the two species from the two culture regimes. Fish were graded into five categories according to a weight range (Size 3: > 650 g; Size 2: 480-649 g; Size 1: 350-479 g; Regular: 250-349 g and Economy: <250 g). *O. niloticus* culture in cages recorded all different size grades. *S. galelaeus* cultured in both cage and hapa-in-pond and *O. niloticus* in hapa-in-pond did not record grades of sizes 1 and above.

Table 2: Yield estimate of *O. niloticus* and *S. galilaeus* cultured under the 2 regimes

Yield Estimate	*O. niloticus*		*S. galilaeus*	
	Cage	Hapa	Cage	Hapa
Stocking Density	450	50	450	50
Stocking Rate (fish/m³)	32	5	32	5
Recovery	295±13.44[a]	33±3.54[c]	361±15.76[a]	36±4.95[c]
Gross Yield (kg)	88.04±9.32[b]	4.34±0.48[a]	46.58±11.70[b]	2.49±0.88[a]
Net Yield (kg)	75.75±9.32[b]	2.99±0.50[a]	34.41±11.87[b]	1.15±0.88[a]
Survival (%)	65.45±2.99[a]	65±7.07[a]	80.11±14.61[a]	71±9.90[a]

[*]mean ± standard deviation, [a] = no significant difference, [b] = significant difference, [c] = no significant difference.

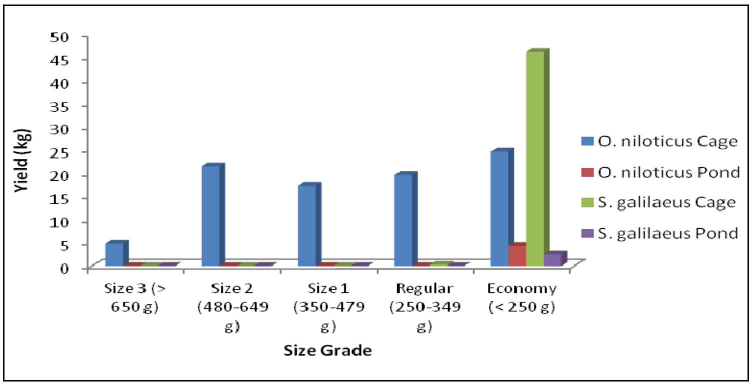

Fig 2: A bar chart showing size grades of yield of fish in the two culture regimes.

3.3 Sex Ratio

The figures (a, b, c, d) below shows the sex ratios of the two species under the culture regimes at the end of experimentation. In all, species in the culture regimes, the ratio of male to female showed a greater percentage of females to males. By sex determination, male species of *O. niloticus* grew bigger than their female counterparts, however, *S. galileaus* population showed an almost equal growth rate of male to female ratio.

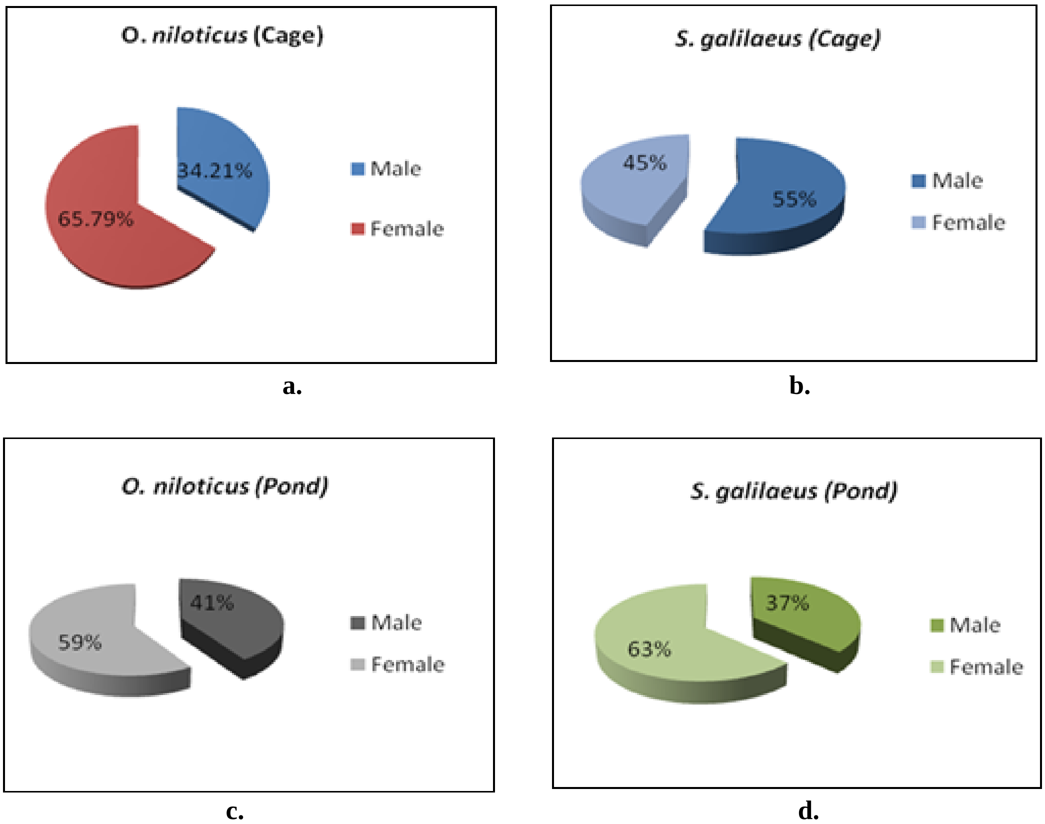

Fig 3: Sex ratios of the two species under the two culture regimes.

3.4 Economic Analysis

Table 3: Economic Parameters of the 2 species under the 2 culture regimes

Economic Parameter	*O. niloticus*		*S. galilaeus*	
	CAGE	HAPA	CAGE	HAPA
Price of Fingerling (GH¢)	0.5	0.5	0.3	0.3
Cost of Fingerlings (GH¢)	225	25	135	15
Prize of Feed/kg (GH¢)	2.04	2.04	2.04	2.04
Total Feed Fed (kg)	139.62	16	85.25	10.77
Total Cost of Feed (GH¢)	284.82	32.64	173.91	21.97
Value of fish Crop (GH¢)	651.98	76.18	396.50	50.08
Profit (GH¢)	142.16	18.54	87.59	13.11
Profit Index	2.29^a	2.33^a	2.28^a	2.28^a

* ^{a} = no significant difference, ^{b} = significant difference, GH¢ 1 = USD 1.74

The cost of fingerlings, feed and sale from the two fish species are presented in Table 3 above. The price of fingerlings for *O. niloticus* and *S. galilaeus* used for stocking was GH¢ 0.5 and GH¢ 0.3 respectively. Total feed used and the cost was high in *O. niloticus* stocked in cages and hapa-in-pond, with the least being their *S. galilaeus* counterparts.

The table below (Table 4) shows the value of the fish crop from the two different fish species from different culture regimes for the various size grades. Both culture regimes for *O. niloticus* attained the highest value generated from the sales and a high profit index. Grades of 'size 2' and 'economy' attained the highest value of GH¢ 140.08 and GH¢ 111.06 respectively, for *O. niloticus* cultured in cage with grades of 'economy' making the bulk sales for *S. galilaeus* in cage and hapa-in-pond as well as *O. niloticus* in hapa-in-pond.

Table 4: The value of fish crop in the two culture regimes.

Size Grades	*O. niloticus*		*S. galilaeus*	
	Cage (GH¢)	Pond (GH¢)	Cage (GH¢)	Pond (GH¢)
Size 3	36.15	0	0	0
Size 2	140.08	0	0	0
Size 1	95.205	0	0	0
Regular	98.45	0	1.3	0
Economy	111.06	19.53	208.44	11.21
Total	**480.94**	**19.53**	**209.74**	**11.21**

3.5 Water Quality

The mean (± SE) values of the water quality parameters for the cage and hapa-in-pond at selected stations are presented in Table 5. The water temperature ranged from 27.5–30.8 ºC, with the mean values being in hapa-in-pond higher than the cage. No significant differences were observed between the culture regimes. Dissolved oxygen ranged from 2.15–5.5 mg/l with mean values in both culture regimes not significant. The pH and total dissolved solids analyzed showed no significant difference among culture regimes at $p>0.05$. All nutrients analyzed showed no significant difference except the levels of nitrate among culture regimes.

Table 5: Mean of water quality parameters at the 2 culture regimes during the experimental period.

Water Parameter	Cage	Hapa-In-Pond
Temperature (°C)	*27.8±0.08^a	30.43±0.11^a
pH (pH unit)	7.2±0.18^a	6.6±0.16^a
Dissolved Oxygen (mg/l)	4.37±0.54^a	4.38±0.36^a
Total Dissolved Solids (mg/l)	30.8±0.16^a	43.17±5.13^a
Nitrite (NO_2-N) (mg/l)	0.002±0.0002^a	< 0.001^a
Nitrate (NO_3-N) (mg/l)	0.16±0.006^b	0.02±0.01^b
Ammonia (NH_4-N) (mg/l)	0.02±0.005^a	0.05±0.03^a
Phosphate (PO_4-P) (mg/l)	0.01±0.002^a	0.03±0.01^a

*mean ± standard error, ^{a} = no significant level, ^{b} = significant level

4. Discussion

Growth rate and survival are recognized traits of economic importance in aquaculture. A comparison of growth performance of fish under the two culture regimes showed that experimental fish grew differently and growth response in terms of weight gain in the following order; *O. niloticus* cage > *S. galilaeus* cage > *O. niloticus* hapa > *S. galilaeus* hapa.

The high growth rate recorded for the fishes cultured in cages suggest that, the fish grows faster in cages than in hapa-in-pond system which can be attributed efficient water exchange and discouragement in breeding. This is evident in the food conversion ratio (1.58) and specific growth rate (1.22) achieved (with *O. niloticus* in cages) which indicated effective feed utilization. This is also in conformity with [19] who observed an increase in the growth rate of tilapia in cage than

in open pond when cultured.
The fish cultured in the hapa-in-pond systems were found breeding during the third month of culture, hence might have contributed towards their slow growth rate. The bulk of the population of fish was dominated by females, and probably ceased feeding during their spawning periods. Also that ration given to fish was also consumed by their offsprings, hence less satiation.
In hapa-in-pond system, all uneaten feed remains at the bottom and decompose with time. This is evident in the high feed conversion ratio in fish cultured in the hapa-in-pond system, which resulted in low mean weight for fish which is also an indication of less feed utilization. These results also indicate considerable stress tolerance in both species, because rearing systems made from net enclosures, especially in ponds are characterized by fouling, which stresses fish, especially by impairing water exchange and reducing dissolved oxygen [20, 21].
Stocking rate and density did not differ significantly from the culture regimes for the two different species. However, high survival rate in two culture regimes was attained by the culture of *S. galilaeus* which indicates that, *S. galilaeus* is a hardy species and can survive stressful conditions. This is in conformity with the work done by [7].
The gross and net yield of *O. niloticus* cultured in both cages and hapa-in-pond were higher than their *S. galilaeus* counterparts although *S. galilaeus* achieved a higher survival rate. This can be attributed to the high growth rate of *O. niloticus* which grew at a rate of about 2.5 times higher than *S. galilaeus*. The high survival rate of *S. galilaeus* suggests that it is a hardy species and can survive stressful conditions better than *O. niloticus*.
There were variations in sizes of sexes of experimental fish as found also by [7], who reported that the sexes of the two species reveals that *O. niloticus* males grows faster than females, but for *S. galilaeus* there was no difference in growth rate between the sexes and takes a much longer time to reach an appreciable market size as compared with *O. niloticus*.
S. galilaeus appears to be a potential culture species since both male and female populations can be hand-sorted and raised in the monosex culture because of their equal growth potential. Hand sorting is a simple and inexpensive technique that the small-scale tilapia producer can easily apply. A major problem is a diagnosis error [22, 23], but the effect can be minimized by the addition of predatory fish to control unwanted reproduction especially in ponds.
In a mixed population of *O. niloticus*, the ratio of male to female is skewed positive towards the females, however, males show superior growth and hand sorting is not cost-effective because the females are wasted. It is rather suitable for sex reversal because females can express the growth potential of males when the male phenotype is imposed [24], hence high yield and high grades of fish sizes can be achieved.
The total feed consumed and estimated biomasses were analyzed differently for the two culture regimes as a result of the different stocking rates. The biomass showed significant difference among the culture systems which indicated that species grew differently in the different culture system and was also affected significantly by the survival rate. The culture of *O. niloticus* in the 2 culture systems gave a high yield and high profit index (although not significant from the others) hence makes it economical for culture.
All the physical-chemical parameters of the water in the culture area where the cages, hapa-in-pond were located were within the acceptable optimal range for fish culture [25]. It was reported that lower than 1mg/l of ammonia gas content in pond water was acceptable for pond fish culture [26]. The concentration of ammonia-nitrogen was within acceptable limits, and there was no significant difference of mean ammonia, nitrite and phosphate among the treatments except for nitrate but did not negatively affect the growth of fish. All values obtained were within the optimal ranges conducive for aquaculture growth and negatively affect the culture of fish.
The results of the study showed that *O. niloticus* shows superior growth than *S. galilaeus* in cage culture with an appreciable feed conversion ratio value. Although the hapa-in-pond system is also suitable for the culture of the two species, it should be practiced on a semi-intensive system to decrease the cost of production.

5. Conclusion
The improved strain of *O. niloticus* clearly demonstrates a faster growth growing at a rate of two times higher than *S. galilaeus* especially when cultured in cages hence more economical to farmers.
The size of male to female ratio of *O. niloticus* showed a distinct difference in growth, hence sex reversal is highly encouraged, however, sexes of *S. galilaeus* shows almost equal growth rate, hence if growth performance is improved, there would be no need for sex reversal which comes with an additional cost to farmers.

5.1 Recommendation
Future research should be geared towards the genetic improvement of the *S. galilaeus* strain for good growth performance for profitability to be achieved.

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