Comparative growth performance of marine Tilapia (*Oreochromis niloticus*, L.) cultured in *hapa* nets at different stocking densities using animal and plant protein diets

Anthony M. Kamau[1]*, Esther W. Magondu[2] and Fredrick L. Tamooh[1]

[1]Kenyatta University, P.O. Box 16778-80100, Mombasa, Kenya.

[2]Kenya Marine and Fisheries Research Institute, P.O. Box 81651-80100, Mombasa, Kenya

*Corresponding author: kamaumbuthia30@gmail.com, (+254) 0 797 327161

Abstract

Aquaculture as an enterprise is hampered by the high cost of fish-based protein diets which account for 30 - 70% of the production cost. Alternative plant-based protein diets are paramount in guiding fish farmers on feed efficacy and fish stocking densities. This study analyzed the growth performance of marine acclimatized Nile tilapia (*Oreochromis niloticus*) using fish meal (animal protein), soybean (plant protein) and wheat bran (control) formulated diets. Nile tilapia fingerlings weighing 13 -17 g were cultured in *hapa* nets in three concrete-based ponds at stocking densities of 15 fish/m^3, 10 fish/m^3 and 5 fish/m^3 for each feed treatment. Monitoring of water quality parameters (temperature, dissolved oxygen (DO), and salinity), as well as the initial and final fish body length and weight, was done fortnightly during the experimental period. Two-way ANOVA was used to determine if stocking density and feed treatment(s) had a significant effect on fish growth performance. Weight gain was highest in fingerlings cultured using the soybean-formulated diet (10.28 ± 2.44 g). Marine acclimatized *O. niloticus* fingerlings had a high feed utilization for soybean meal. The stocking density of 5 fish/m^3 recorded the highest percentage survival rate of 85.6% on wheat bran treatment. An optimal stocking density of 5 fish/m^3 is therefore recommended to optimize and maximize their fish production.

Keywords: fish meal, alternative proteins, optimal stocking density, Nile tilapia

Introduction

Globally, human population is on the rise and is projected to hit the 8 billion mark by the year 2030 (Khan *et al.*, 2013). According to the UN-FAO (2000), seafood consumption is projected to reach between 150-160 million tons per year in 2030. However, with the rampant decline in wild capture fisheries due to the overexploitation of fisheries resources, achieving this target is not possible without calling upon the aquaculture sector to fill in the gap (Khan *et al.*, 2013). Aquaculture is expected to compensate for the decreasing fish protein from the capture fisheries and hence bridge the gap between demand and production.

In the aquaculture industry, fish feeds comprise the main input in fish production, accounting for 30 - 70% of the cost of production (El-Sayed *et al.*, 2004). Therefore, efficient feeds are a necessity for profit realization in aquaculture. Additionally, balanced diet feeds, sound nutrition and adequate feeding are essential to the production and culture of fish in captivity (Khan *et al.*, 2013). With an estimated more than 1 billion people relying on fish as the major protein source in their diets, aquaculture is likely to play a critical role in food security by combating hunger and boosting human health by contributing towards the elimination of malnutrition (Pradeepkiran, 2019).

For optimum fish growth, lipids, carbohydrates and proteins are essential macronutrients required in the rearing of Nile tilapia, *Oreochromis niloticus*. Most importantly, protein is critical to good health, nutrition and the physiological processes of fish including energy production (Banrie, 2013). In the intensive farming of *O. niloticus*, proteins are provided in form of shrimp meal, fish meal and fish oil.

As an animal-based protein, fish meal has been the main source of protein in the aqua feed industry due to its palatability and well-balanced amino acid profile (Al-Thobaiti *et al.*, 2017). Imbalances may however be created among animal-based proteins due to lack of one or more essential amino acids (Tacon, 1993). Moreover, volatility in fish meal supply and the high demand by the livestock feed industry has led to prolonged efforts in seeking alternatives. Plant-based proteins such as soybean meal can be viable alternatives due to their relatively low cost, availability and their capability to partially or completely reduce reliance on high-cost fish meal. However, plant-based proteins are deficient in essential amino acids such as methionine, lysine, tryptophan and isoleucine.

Overdependence on fish meal as a feed constituent has resulted in increased pressure on natural marine resources especially the reduction of pelagic fisheries known for their source of fish meal and fish oil (Kaushik and Hemre, 2008). This can lead to a disruption in the marine ecosystems' food chain. Therefore, there is need for concern over striking a balance between reducing the overdependence on fish oil and fish meal in the aqua feed industry, while at the same time meeting the amino acid and protein requirements of fish (Kaushik and Hemre, 2008). For future development of the aquaculture sector, fish meal replacement with locally available and cheap feedstuffs is recommended (Khan *et al.*, 2013).

The government of Kenya has played a significant role in boosting aquaculture since the year 2006. The stagnation of the sector since its inception in 1950 was due to lack of efficient feeds for various stages of fish development and the availability of low-quality seed (Munguti *et al.*, 2014). Aquaculture in Kenya has made tremendous progress and is expected to grow even further with the government's and other stakeholders' support. However, this may only be achieved if a response is made to address the compelling need for restructuring the fish feed industry. Over time, lack of quality feeds has been the main challenge among the fish farmers in Kenya and when quality feeds are available, they remain unaffordable for fish farmers (Shitote *et al.*, 2013). However, as the long wait for the right information continues, the government should continue playing its oversight role on agrovet-supplied feeds to determine their compliance with the stipulated quality standards (Munguti *et al.*, 2014). In addition, farmers' partnership with the private sector can help boost their access to reliable information through extension messages via local media.

Common plant and animal protein sources used in feed formulation include fish meal, shrimp meal, cottonseed meal, sunflower seed, soybean meal, and rice and wheat bran. Currently, fish meal has dominated as a major source of protein by providing more than 50% of the fish protein requirements for fries and juveniles (Montoya-Camacho *et al.*, 2018). Shrimp meal is a high nutritional quality animal protein source and can be substituted with its counterpart fish meal. However, like fish meal, it is scarce and hence not readily available in some countries, making fish production even more expensive (Liti *et al.*, 2006). Wheat bran is a carbohydrate source obtained from the grinding of wheat cereals and is suitable for culturing acclimatized Nile tilapia, *O. niloticus*, for a weight below 140 g (Liti *et al.*, 2005).

The efficiency of plant-based proteins depends on several factors which include the levels of inclusion (complete or partial substitution) and toxicity levels. For instance, higher amounts of soybean meal in the *O. niloticus* diet may compromise fish growth performance (Webster *et* *al*., 1999). This is due to the slow digestion rate of high concentrations of soybean meal by the fish (Ambardekar *et al*., 2009). However, this may vary between feeding regimes, strains, sex, age and health status of fish amongst other factors. Moreover, as inclusion levels of plant-based proteins increase, fish growth performance decreases and vice versa (Khan *et al*., 2013).

Stocking density denotes the carrying capacity of a fish culturing facility and potentially has an effect on fish growth performance. Although the stocking densities of *O. niloticus* range from 3,000 to 4,000 fry/m^3, densities, beyond 2,670 fry/m^3 significantly affect fish growth performance and survival (Ntanzi *et al*., 2014). Moreover, densities as high as 20,000 fry/m^3 are viable depending on the water quality management technique throughout the fish-rearing period and feed efficiency is realized at the highest stocking densities (Yildiz and Bekcan, 2017). Generally, stocking density potentially affects heterogeneity and homogeneity of growth among fish. A lower stocking density is associated with heterogeneity due to the aggressive behaviour of *O. niloticus*. Some fish show territorial dominance and grow at a faster rate than those that show low dominance. This leads to appetite suppression and low food intake. A high stocking density promotes homogeneity in fish growth due to reduced territorial dominance hence reducing chronic stress among the low-dominating fish (Ntanzi *et al*., 2014). The improved growth however signifies reduced growth for the fast growers and increased growth for the slow growers rather than fast growth for every individual fish. Thus, the current study was conducted to test the growth performance of marine acclimatized *O. niloticus* using plant and animal protein sources in diet formulation. The effects of stocking density on growth performance were also investigated.

Materials and methods

Experimental Site

The experiment was carried out using concrete ponds located at the Kenya Marine and Fisheries Research Institute (KMFRI) in Mombasa, Kenya (-4.054757° S and 39.682621° E; Fig. 1). It is located along the shoreline of the Indian Ocean.

Figure 1. A map showing the experimental site at KMFRI (Google Maps, 2023).

Experimental design and stocking

The experiment was conducted in three concrete-based tanks of dimensions 4 m x 3 m x 1 m. The tanks were fitted with three *hapa* nets of dimensions 1 m x 1 m x 1 m to accommodate the three levels of fish stocking densities, i.e., 15 fish/m^3, 10 fish/m^3 and 5 fish/m^3. A total of 90 mixed-sex *O. niloticus* fingerlings with average weights of 13 ± 0.06 g, 14 ± 0.06 g and 17 ± 0.06 g were selected from a holding tank, and stocked in densities of 5, 10, and 15 fish/m^3 respectively per concrete tank. Figure 2 illustrates the setup of the experiment.

Initial fingerling weight and length measurements were taken using an analytical weighing balance (Sartorius TE4100 Talent Analytical Balance) and a fish sticker length ruler respectively to the nearest gram and cm, respectively before stocking. The treatments were then acclimatized for 24 hrs before feeding commenced (Khan *et al*., 2013). The experiment was conducted for 57 days from 15th June to 11th August 2021.

Experimental diets and feeding

Three culture diets were formulated i.e., fish meal, soybean meal and wheat bran using cassava, fish meal (*Omena*), soybean and wheat bran as ingredients. Fish meal and soybean meal were formulated to contain a 30% crude protein level. The control diet was formulated using wheat bran as the single main ingredient. Ratio determination for various feed proportions was done using the Pearson square method (Catacutan, 2002). In the formulation process, dry feed ingredients were mixed thoroughly before adding water to moisturize the feeds. Diets were then passed through an improvised pelleting machine, made into "spaghetti-like" strands (Thompson *et al*., 2020) and sundried for 24 hrs to obtain dry pellet feeds which were used to feed the fingerlings. Fish meal formulated diet, soybean meal diet and the wheat bran diet (control) were fed to fingerlings in tank 1, tank 2 and tank 3 respectively. The fish fingerings were fed manually twice a day at 9.00 a.m. and 3.00 p.m. at 3% body weight to apparent satiation at each feeding with feeding adjustments during the experimental period (Mapenzi and Mmochi, 2016).

Proximate composition analysis of experimental diets

The proximate composition of diet feeds and their respective ingredients was analyzed to determine their percentage moisture, crude protein, crude lipids, crude fibre, ash content, carbohydrate, calcium and phosphorus using standard procedures defined by the Association of Official Analytical Chemists (AOAC, 2000). Analysis of crude protein level was done using the Kjeldahl method. Samples were digested in a digestion unit for approximately 45 minutes. The digester was then distilled and titrated using 0.2 M HCl and crude protein was obtained by multiplying nitrogen with a conversion factor of 6.25. Moisture content was determined by AOAC procedure 930.15, by oven-drying feed samples at 105°C until a constant weight was obtained.

Ash content was determined by AOAC procedure 942.05 by obtaining calcinations in a muffle furnace at 550°C for 4 hours. Determination of crude lipid was done through the

Figure 2. Setup of the experiment using *hapa* nets for marine tilapia rearing (Source: Authors).

extraction of a weighed sample with acetone in a Soxhlet extraction unit. Crude fibre was determined through AOAC procedure 962.09 by digesting weighed samples with sulphuric acid and with a few drops of octane in the digestion unit for 30 minutes. The acid was then removed through filtering and washing and thereafter a residue was obtained. The residue was then boiled with potassium hydroxide and then washed in boiling water and acetone before oven-drying at 130°C and ignited in a muffle furnace at 500°C. Crude fibre content was then determined based on the weight difference. The results of the proximate analyses are presented in Table 1.

Table 1. Proximate composition of the formulated diets. Key: FM-fish meal; SB-soybean meal; WB-wheat bran

	Treatment Diet		
Component	Diet 1 (FM)	Diet 2 (SB)	Diet 3 (WB)
Moisture	11.6	10.8	11.7
Crude protein	25.71	22.74	14.2
Crude Lipids	7.92	5.58	2.31
Ash content	9.01	6.81	5.7
Crude Fiber	4.3	5.23	7.6
Carbohydrate	21.72	21.7	18.17

Table 2. Proximate composition of the feed ingredients

	Feed ingredients			
Composition %	Fish meal	Soybean	Wheat bran	Cassava (binder)
Moisture	10.21	9.21	9.7	10.14
Crude protein	51.36	38.23	16.34	2.1
Crude Lipids	5.53	28.2	5.1	1.34
Ash content	33.74	4.29	3.62	3.32
Crude Fiber	1.42	5.34	8.6	1.71
Carbohydrate	-	16.48	23.48	89.62

Sampling protocol

Sampling to monitor the growth of individual fingerlings was done fortnightly (Mapenzi and Mmochi, 2016). Sample weight and length were measured using an analytical weighing balance and a fish sticker length ruler respectively. Water quality control was done manually by use of an outlet system in each of the concrete ponds which served as a continuous filtration system throughout the experimental period. Water quality parameters (temperature, oxygen, pH, salinity and dissolved oxygen) were measured twice a week throughout the experimental period using a hand-held portable multi-parameter (YSI ProQuatro model).

Determination of growth performance

The following fish growth parameters were used to determine growth performance.

i. Specific growth rate (%)= $\frac{\ln W_f - \ln W_i)}{T} * 100$

ii. Survival rate (%)= $\frac{N_f}{N_i} * 100$

iii. Food Conversion Ratio (FCR) = $\frac{\text{Total feed/Diet consumed}}{\text{Total weight gain}} * 100$

Where, T is the number of days of the experiment; W_i and W_f are the initial and final mean body weights and N_f and N_i are the numbers of harvested fish at the end of the experiment and the initial number of stocked fish respectively.

Data analysis

Collected data were tabulated in a MS Excel worksheet and analyzed using two-way ANOVA to determine if stocking density and feed treatments had significant effects on the growth performance of *O. niloticus*. All statistical analyses were computed using SPSS (version 22).

Results and discussion

In situ measurements of water quality parameters

Most of the water quality parameters were within the acceptable range for *O. niloticus* culture. The mean values for *in situ* (inside the *hapa* nets) water quality parameters monitored throughout the experiment including temperature, oxygen (mg L^{-1}), pH, salinity and total dissolved solids (TDS) were computed (Table 3). pH and DO had a comparable effect on the FCR. Increasing pH by one unit would improve FCR by about 0.5 unit. On the other hand, decreasing DO from the highest level investigated i.e., 11 mg L^{-1} to 3 mg L^{-1}, which is the minimum level required for tilapia production, would lead to an increase of 0.9 unit FCR (Mengistu *et al.*, 2020).

Table 3: Mean water quality (mean ± SE) parameters inside the *hapa* nets for feed treatments at different stocking densities.

Water quality parameters	Diet			Density		
	Fish meal	Soybean	Wheat bran	15	10	5
Temp (°C)	26.87 ± 0.15	26.84 ± 0.07	26.78 ± 0.07	26.69 ±0.08	26.84 ± 0.94	26.95 ± 0.03
Dissolved Oxygen (DO)	4.03 ± 0.05	5.30 ± 0.10	4.69 ± 0.05	4.66 ± 0.28	4.65 ± 0.43	4.71 ± 0.42
Total Dissolved Solids (TDS)	26937.24 ± 35.56	27075.28 ± 18.87	26937.23 ± 35.56	26936.56 ± 67.89	27006.64 ±18.77	27006.56 ± 51.39
Salinity	26.57 ± 0.01	26.58 ± 0.08	26.55± 0.01	26.59 ± 0.04	26.59 ± 0.03	26.53 ± 0.55
pH	6.74 ± 0.01	6.74 ± 0.01	6.75 ± 0.01	6.75 ± 0.01	6.75 ± 0.03	6.74 ± 0.01

Efficiency of diet on fish growth performance and survival rate

After 57 days of culture, mean individual weight gain was highest in the Soybean treatment (10.28 ± 2.44 g) while the survival rate was highest in the wheat bran (control diet) treatment (85.55%). There were no statistically significant differences in average stocking weight for both stocking density ($p > 0.05$) and feed treatment ($p > 0.05$). The food conversion ratio (FCR) was not significantly different in samples exposed to the different treatments ($p > 0.05$). The growth performance of *O. niloticus* fingerlings is as presented in Table 4. Results are presented as mean ± standard error of the mean (SE).

Table 4: Calculated means of growth and yield (Mean ± SE) of *O. niloticus* fed on three different diets and cultured at different densities.

	Treatment Diet			Density (Fish/m³)		
Growth and yield parameters	Fish meal	Soybean	Wheat bran	15	10	5
Individual stocking length (cm)	9.06±0.07	9.6±0.39	9.46±0.13	9.30±0.22	9.71±0.29	9.11±0.16
Individual final length (cm)	11.82±0.21	11.96±0.16	11.27±0.28	11.35±0.23	11.68±0.31	12.03±0.12
Individual stocking weight(g)	17.67±4.32	14.86±1.14	13.78±0.61	13.8±0.81	19.41±3.48	13.09±0.633
Individual final weight (g)	23.7±0.81	25.14±1.63	21.84±1.99	21.48±1.42	24.18±1.60	25.02±1.43
Individual weight gain (g)	6.03±3.71	10.28±2.44	8.06±2.42	7.67±1.84	4.77±3.09	11.93±2.06
Survival rate (%)	83.33±16.67	64.44±12.37	85.55±2.93	86.67±7.69	60±15.28	86.67±6.67
SGR (% day)	1.3±0.45	1.29±0.32	1.09±0.29	1.23±0.49	0.98±0.167	1.5±0.26
FCR	13.63±6.96	17.5±5.64	1.77±5.64	4.03±9.48	24.78±16.60	4.10±4.10
DGR	0.11±0.07	0.19±0.05	0.22±0.04	0.14±0.03	0.09±0.06	0.22±0.04

Stocking density potentially influences fish growth performance and the overall yield in aquaculture. In this study, a positive growth of fish occurred in all treatments. The 5 fish/m^3 stocking density had a marginally higher SGR, weight gain and a slightly higher survival rate than other density treatments including the control treatment. FCR was lower in the 10 fish/m^3 than in the 15 and 5 fish/m^3 densities. However, the parameters did not vary significantly between the treatments ($p > 0.005$). Figures 2 and 3 depict the growth trend curves for *O. niloticus* under different densities and dietary feed treatments. In Figure 2, growth trend curves depicted growth declines after fish attained approximately 23 g, with the 5 fish/m^3 density depicting a higher positive and consistent growth response compared to 10 and 15 fish/m^3 densities. In figure 3, growth declines were observed at approximately 24 g with soybean meal (SBM) depicting a positive growth response compared to other dietary feeds i.e., wheat bran and fish meal.

Effects of stocking density on growth performance and survival rate

Stocking density of 5 fish/m^3 had the highest weight gain, SGR and survival rate compared to densities of 15 fish/m^3 and 10 fish/m^3 while stocking density of 10 fish/m^3 had the least weight gain (4.77 ± 3.09 g) and the lowest survival rate (60 ± 15.28%). Weight gain, SGR and survival rate did not vary significantly. Stocking density had no significant effect on fish growth performance ($p > 0.187$).

Results from the study demonstrate that soybean treatment had the highest growth response in terms of weight gain (10.28 ± 2.44 g) compared to fish meal and wheat bran diet treatments. Soybean meal had a moderate fibre content. Despite both fish meal and soybean diets having a 30% crude protein level, moderate content of crude fibre in soybean may have aided in its digestibility compared to fish meal and wheat bran. A study by Phumee *et al.* (2011) however, reports that the high fibre content in soybean meal affects its digestibility. The findings of the present study concur with Obirikorang *et al.* (2020) in which Nile tilapia fry was used to test the effects of soybean meal on its growth performance and concluded that low contents of soybean meal can improve feed digestibility. However, the presence of anti-nutritional factors such as phytic acid, trypsin inhibitors and saponins in soybean meal can inhibit growth (Francis *et al.*, 2001). Wheat bran treatment had a significant effect on growth performance compared to fish meal. Soybean had a balanced chemical composition based on the diet feeds' proximate analysis compared to fish meal and wheat bran.

Dissolved oxygen is one of the main limiting environmental variables that potentially affect fish growth performance and can possibly affect feed intake by reducing digestibility (Tran-Duy *et al.*, 2012). Feed assimilation is improved at high DO due to improved blood flow to the gastrointestinal tract (Axelsson *et al.*, 2002) and lower energy cost of feed digestion and absorption of nutrients (Duan *et al.*, 2011). Energy for growth will therefore be available. According to Tran-Ngoc *et al.*, (2017), Nile tilapia recorded significantly lower performance in terms of SGR, FCR and final body weight, under hypoxia (3 mg L^{-1}) compared to its performance under normoxia (5 mg L^{-1}) which represents 50% of DO saturation. In addition, the study found that hypoxia affected intestinal morphology negatively. Optimum DO is therefore an important environmental factor for improving FCR. Dissolved oxygen in this study was within the optimum range between hypoxia and normoxia and was statistically significant ($p = 0.000$) and highest on treatments fed on Soybean (5.30 ± 0.10 mg L^{-1}) and lowest on treatments fed on fish meal (4.03 ± 0.05 mg L^{-1}). This may have aided a high feed consumption for soybean compared to fishmeal and wheat bran treatments. Lower concentrations of DO on treatments fed on fish meal might have caused stress in fish or constrained fish metabolism which might have led to a reduction in growth performance. Oxygen

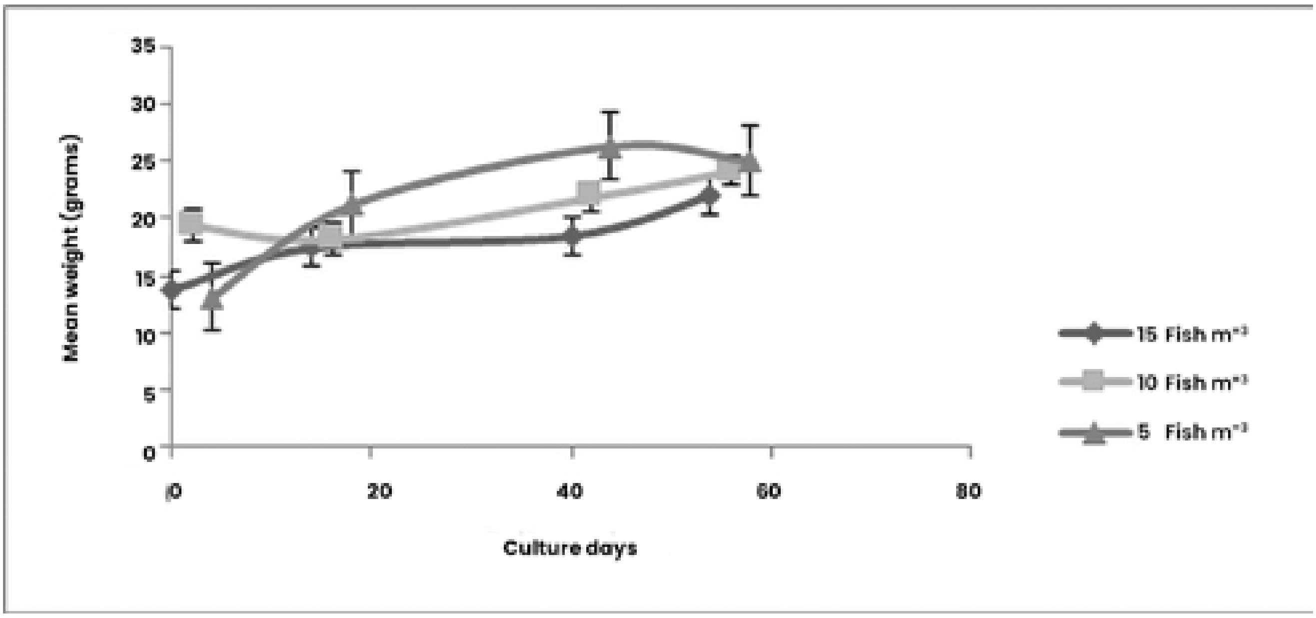

Figure 3. Mean weights of *O. niloticus* in different stocking densities during the experimental period. Values are means (± SE) for the different feed treatments per sampling date.

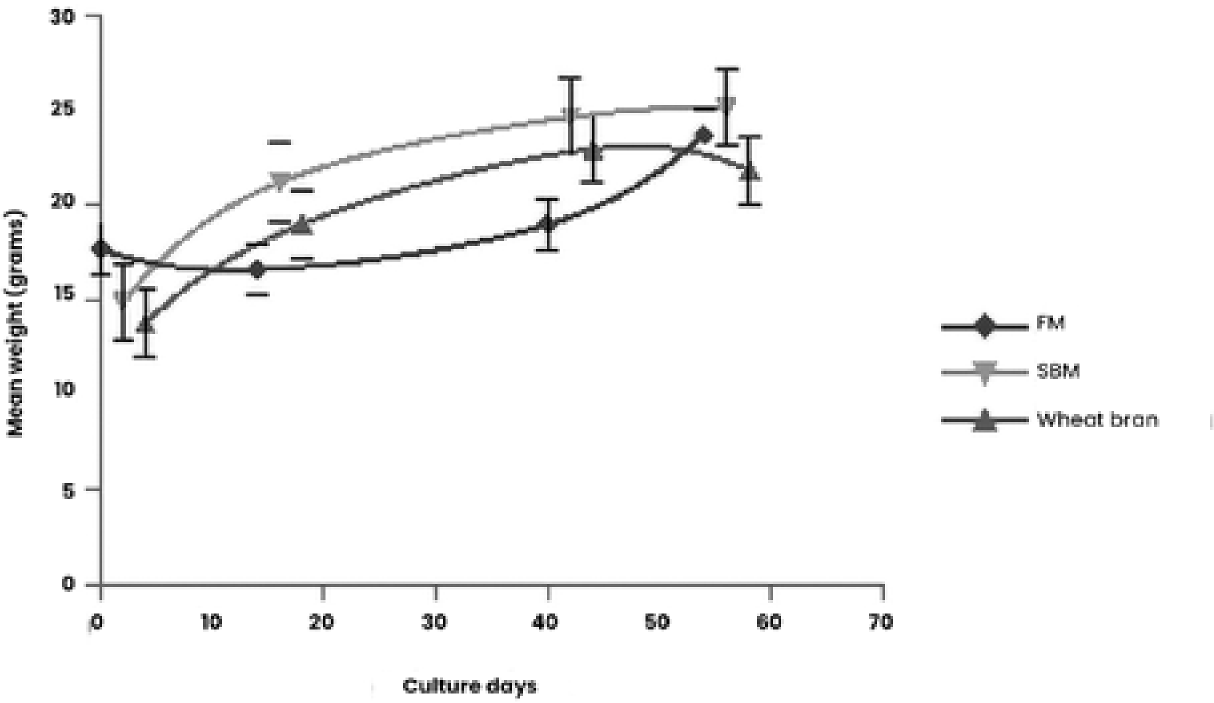

Figure 4: Mean weights of *O. niloticus* fed on different diet treatments. Values are means (± SE) for different feed treatments per sampling date.

concentration levels have been shown to have a positive effect on fish growth performance (Mallya, 2007).

Survival rates were greater on fishmeal (83.3%) and wheat bran (64.4%) treatments compared to soybean (64.44%) but were not statistically significant (p =0.361). The maximum survival rate in this study, 86%, differed from that of Mapenzi and Mmochi (2016), which reported a maximum survival rate of 90%. A low survival rate in this study may have been due to poor acclimation to saline conditions as the fish tried to adapt. Some may have been unable to cope with the harsh salty conditions and hence resulting in the higher mortalities observed in the present study. In addition, the handling method during sampling might have led to a low survival rate, to some extent. The higher survival rates observed in this study may be due to the ability of the fish to tolerate adverse conditions of low temperature and oxygen. This is as was observed by Ahmed *et al*. (2013) who observed a slightly lower survival rate (75.55%) for monosex tilapia compared to this study while evaluating the production performance of monosex tilapia under homemade feed in earthen mini ponds. Furthermore, the results of this study fall within the range of research findings of Kohinoor *et al*. (2007) who observed that the survival rate of monosex tilapia varied from 79 - 92%.

Stocking density has the potential ability to influence fish growth. Stocking density of 5 fish/m^3 had the highest mean survival rate, weight gain and SGR compared to 15 fish/m^3 and 10 fish/m^3 densities. However, stocking density in this study was not statistically significant (p =0.187). The results agree with those of Mapenzi and Mmochi (2016) who found a nonsignificant result on stocking density. Furthermore, nonsignificant findings on stocking density also concur with Mengistu *et al*. (2020) who found a nonsignificant result in two of the three models used for analysis. Moreover, Mengistu *et al*. (2020) cite that, as part of what is generally observed in aquaculture, as stocking density increases, FCR is negatively affected and that an increase in one unit of stocking density would lead to an increase in FCR by about 0.01 kg feed per kg biomass harvest. However, stocking density and stocking size differs from country to country under small-scale tilapia production systems.

Specific Growth Rate (SGR) varied for wheat bran but not between fish meal and soybean. This may be attributed to the 30% crude protein level in the two diets, fish meal and soybean. Protein and ash content levels relate to fish size. Specific Growth Rate of wheat bran might have been affected by a low content of crude protein and ash content. Specific Growth Rate was however not statistically significant (p =0.905), with its values in this study (0.98 - 1.5) being lower than those reported by Mapenzi and Mmochi (2016) (8.33, 8.3, 7.8) but in range with values reported by Iluyemi *et al*. (2010) (0.77 - 1.49) for red tilapia. However, the SGR values reported by Iluyemi *et al*. (2010) were statistically significant and decreased with feed supplementation. High SGR values in the Mapenzi and Mmochi (2016) study were attributed to the use of hybrids of *O. niloticus* and *O. urolepis*. The hybrids might have had enhanced genetic traits inherited from both of their parents that promoted high SGR values.

Food Conversion Ratio, the fish's ability to convert food into biomass was not significantly affected by stocking density and feed treatments. The optimum feeding rate is the rate that gives the lowest FCR (Mengistu *et al*., 2020). Best FCR values were observed at densities of 15 fish/m^3 and 5 fish/m^3 and on wheat bran treatment. The recommended FCR range for *O. niloticus* is 3.4 - 4.0 (Liti *et al*., 2006). In this study, FCR was higher than the recommended FCR range for *O. niloticus*. Reasons for a poor FCR may have been due to stress. Stress causes inappropriate dietary energy utilization attributable to physiological alterations, which leads to poor growth (Mapenzi and Mmochi, 2016). Factors such as pH and DO have a comparable effect on FCR. The Mengistu *et al*. (2020) study found the best FCR and growth to be within a pH range from 7 to 9. The pH levels in this study were below the range requirements for optimizing FCR.

Weight gain and final mean weight, on the other hand, were highest at the lowest stocking density, 5 fish/m^3. This was similar to observations made by Ferdous *et al*. (2014) and Mapenzi and Mmochi (2016). However, mean weight gain did not vary significantly in this study.

Conclusion and recommendation

Marine acclimatized *O. niloticus* fingerlings have a high feed utilization for soybean meal compared to fish meal and wheat bran. The results indicate that soybean meal had a higher growth performance as a diet for the fingerlings of marine acclimatized Nile tilapia. Furthermore, Nile tilapia are capable of utilizing plant protein sources in their diets, achieving growth in their early life stages. Therefore, growth and feed utilization results from the study can serve as a basis for recommending the formulation of cost-effective feeds for the nursery culture of fingerlings of Nile tilapia using locally available plant ingredients.

Stocking density of 5 fish/m^3 promoted fish growth due to less or no energy expenditure on food and space competition compared to 15 fish/m^3 and 10 fish/m^3 densities that promoted a high expenditure on space and food competition resulting in a low growth rate. Soybean meal and a stocking density of 5 fish/m^3 can therefore be adopted by fish farmers for optimization and maximization of their fish produce. However, there is need for further research on soybean meal efficiency.

On seasonality, the study was carried out during the Southeast Monsoon season. There are no arguments on whether seasonality significantly affects fish growth performance since similar yields may still be obtained no matter the season. However, conditions such as temperature and availability of water for experimental ponds may affect yield in the long run. Consequently, male and female *O. niloticus*, have different growth rates. In this study a mixed-sex population was used, thus, there is need to monitor growth using monosex tilapia.

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