

*Full Length Research Paper*

# **Effect of replacing freshwater shrimp meal (*Caridina nilotica*) protein with a mixture of plant protein on growth, apparent digestibility, and economic returns of Nile tilapia (*Oreochromis niloticus* L.)**

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This study investigated the effects of substituting varying levels of a plant protein mixture (PPM) with freshwater shrimp meal (FSM) on growth, digestibility, and economic returns of Nile tilapia. Monosex male *Oreochromis niloticus* fingerlings (initial body weight,  $28 \pm 0.01$  g) were cultured in cages installed in an earthen pond and tanks for 180 and 60 days, respectively. The PPM comprised 50% soybean meal, 25% sunflower cake and 25% cotton seed cake. Replacement of FSM was done at 25, 50, 75 and 100% and diets labelled D1, D2, D3 and D4, respectively. Test diets were compared with a control diet (D0, 0% PPM). After 6 months, fish fed diets D0 and D1 did not differ ( $p > 0.05$ ) in growth performance. There was significant decrease ( $p < 0.05$ ) in fish weight gain as PPM levels increased. Crude protein digestibility decreased significantly ( $p < 0.05$ ) with increasing inclusion levels of PPM. Diet D0 had the highest digestibility followed by D1 and D2 although D0, D1 and D2 were not significantly different ( $p > 0.05$ ). Diet D0 and D1 were not significantly different ( $p > 0.05$ ) hence cost benefit analysis showed that D1 was economically viable than D0. Therefore, PPM could partially replace FSM up to 25% without adverse effects on growth performance.

**Key words:** *Caridina nilotica*, digestibility, economic returns, Nile tilapia, plant protein mixture.

## **INTRODUCTION**

The high cost of feeding fish has been identified as one of the major challenges in aquaculture. The demand for

quality protein fishmeal has increased because of the global supply of fish as aquaculture production rises

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(Tacon and Metian, 2008). Therefore, one of the major challenges limiting aquaculture growth is the shortage of cheap, readily available and nutritive sources of protein. The preference of fish meal in fish feeds has been due to its high levels of protein with better essential amino acids (EAA) profiles, high digestibility, and high palatability (Kasozi et al., 2019). Due to expensive and insufficient animal protein sources, there has been a growing interest among researchers to substitute animal-based feedstuffs with affordable alternatives of plant origin (Liti et al., 2006; Munguti et al., 2014; Tidwell and Allan, 2001). It is also noteworthy that fish feeds constitute over 60% of the total operational costs (Ngugi and Manyala, 2009). Therefore, there is need to reduce fish production costs to sustain high fish production levels. This requirement necessitates more research into finding other cheap alternative protein sources to replace fishmeal. Some of the examples of the plant protein sources that have been used include soybean, cotton, and sunflower seed cake, maize germ (Munguti et al., 2012). Previous studies have evaluated potential usage of these ingredients at various inclusion levels to replace fishmeal and have been found to be favourable although they lack one or more of the essential amino acids and have antinutritional factors which inhibit growth (Agbo et al., 2015; El-Saidy and Gaber, 2003; NRC, 1993). Usage of a single plant protein at higher inclusion levels have resulted in reduced feed intake and growth, which has been due to presence of anti-nutritional factors (Daniel, 2018). Therefore, there is need to reduce anti-nutritional and amino acid deficiency by using plant protein mixtures to ensure adequate amino acids profile and lower inclusion levels of anti-nutritional factors in the formulated fish feeds (Agbo et al., 2015; El-Saidy and Gaber, 2003; Soltan et al., 2008). Previous studies by Jiang et al. (2018) reported improved growth performance when the sturgeons *Acipenser baerii* and *Acipenser schrenckii* (juvenile hybrid) were fed on a soybean meal blend, rapeseed and cottonseed meal. Other experimental results involving rainbow trout, *Oncorhynchus mykiss* indicated that fishmeal could be substituted entirely with a blend of plant proteins namely soybean meal and cotton seed meal) without having adverse effects on the growth and feed utilisation (Soltan et al., 2008). Furthermore, Olukunle (1982) reported improved growth performance of *Oreochromis mossambicus* when fed on diets comprising of a blend of plant proteins namely sunflower and sesame seeds and groundnut as compared to single ingredient diets. Better growth performance was also observed in carp fry fed on diets containing a mixture of mustard, groundnut, linseed and sesame meals (Hasan, 1986). The highlighted results indicate positive effects of a mixture of plant proteins compared to single diets. *Caridina nilotica* (Roux) remains an important prey in Lake Victoria for most fish species in Lake Victoria (Budeba and Cowx, 2007). However, high presence of potential predators has led to its limited the abundance (Goudswaard et al., 2006) yet is

a potential source of protein (Kubiriza et al., 2018). In addition, *C. nilotica* is caught as by catch of *Rastrineobola argentea* fishery in L. Victoria but due to seasonal closure of breeding fish grounds, its supply has become exceedingly limited in many parts of Kenya thus affecting its utilisation as feed ingredient. The main aim of this study therefore was to evaluate the impacts of substituting varying levels of a plant protein mixture with freshwater shrimp meal on growth, apparent protein digestibility, and economic returns in *O. niloticus* culture.

## MATERIALS AND METHODS

### Study site and experimental facility

Two experiments for growth and apparent digestibility were conducted at the National Aquaculture Research Development & Training Centre (Sagana, Kenya) in cages and tanks, respectively. The growth experiment was conducted for 180 days and consisted of 15 net cages each with a top and bottom frame measuring 1.2 × 0.94 m and 0.9 × 0.9 m, respectively. Each cage had a height of 0.75 m, and all cages were installed in a single earthen pond with an area of 800 m<sup>2</sup> and a maximum depth of 1.0 m. Before stocking, the pond was subjected to liming at 2500 kg ha<sup>-1</sup> with calcium carbonate (CaCO<sub>3</sub>) and fertilization at a rate of 20 kg N and 8 kg P ha<sup>-1</sup> with Urea and diammonium phosphate (DAP), respectively enhance the growth of natural food. The digestibility experiments were conducted for 60 days in 15 glass tanks measuring 0.6 m × 0.3 m × 0.3 m. Both experiments were assigned similar experimental diets.

### Proximate composition of dietary ingredients and experimental diets

Soybean cake, cotton seed cake, sunflower cake, maize, wheat, and rice bran were sourced from a local feed manufacturer in Thika while freshwater shrimp meal was obtained from Kisumu. Prior to proximate analysis, all feed ingredients were ground into a fine powder. Proximate analysis was done prior to and after diet formulations (Tables 1 and 2) in triplicates. Analyses of moisture content, crude protein, fibre and lipid and ash were performed in accordance with standard methods of AOAC (2003). Moisture content was determined by drying the samples to a constant weight at 105°C in a drying oven. Crude protein (N × 6.25) was estimated using Kjeldahl method after acid digestion while crude lipid extraction was conducted following a procedure described by Bligh and Dyer (1959). Ash was estimated combusting samples in a muffle furnace at 550°C for 6 h. Crude fibre was determined by alkaline/acid digestion, followed by ashing of the dry residue at 550°C in a muffle furnace for 4 h. Gross energy was determined using a bomb calorimeter.

### Experimental diets

Five isonitrogenous and isocaloric diets (crude protein 30%, 3.5 kcal g<sup>-1</sup> gross energy) were formulated substituting FSM protein with PPM on the basis of CP as follows: D0 = 100% FM:0% PPM, D1= 75%FM:25%PPM, D2= 50%FM:50%PPM, D3= 25%FM:75%PPM, and D4= 0%FM:100%PPM. All dietary ingredients were ground and passed through a mesh of 200 µm. The ingredients were thoroughly mixed with fish oil then mixed, moistened, and then made into 3 mm pellets using an electric mincer. Chromic oxide (Cr<sub>2</sub>O<sub>3</sub>) was used as

**Table 1.** Proximate composition of the feedstuffs used in diet formulation (g kg<sup>-1</sup>).

Ingredient	MC	CP	CL	CF	Ash
Freshwater shrimp meal	9.1	62.7	5.7	3.7	19.8
Soybean meal	8.5	46.4	0.4	8	7
Cottonseed meal	10.1	24.7	6.7	16.7	1.5
Sunflower meal	8.9	19.5	7.1	12.1	15
Wheat bran	11.5	14.2	4.9	8.4	5.3
Rice bran	7.7	14.9	16.8	4.6	19
Maize bran	9.5	11.2	7	2.6	8.9

MC= Moisture content, CP=Crude protein, CL=Crude Lipids, CF=Crude fibre. All substances soluble in petroleum ether. Source: Authors, 2022.

**Table 2.** Composition and results of proximate analysis of experimental diets used to feed Nile tilapia during the six months culture period.

Experimental diets (g 100 g <sup>-1</sup> )	Content (%)				
	0%	25%	50%	75%	100%
<b>Ingredients</b>					
Freshwater shrimp meal	37.5	28.0	19.0	9.0	0.0
Soybean meal	0.0	6.5	12.5	19.5	25.7
Sunflower meal	0.0	2.9	5.5	8.6	11.4
Cottonseed meal	0.0	3.6	7.0	10.9	14.4
Rice bran	23.1	21.8	20.7	19.2	17.9
Wheat bran	22.0	20.8	19.7	18.3	17.1
Maize bran	16.7	15.7	14.9	13.8	12.8
Vitamin premix	0.2	0.2	0.2	0.2	0.2
Chromic oxide	0.5	0.5	0.5	0.5	0.5
<b>Proximate analysis (%)</b>					
Moisture	8.6	8.6	8.5	8.5	8.4
Protein	30.1	30.2	30.1	30.0	30.2
Crude lipids	9.2	8.6	8.1	7.9	7.4
Crude fibre	8.5	8.8	10.0	11.5	12.1
Ash	7.5	6.6	6.2	5.8	5.8
Gross energy (kcal g <sup>-1</sup> )	3.5	3.5	3.4	3.4	3.4

Source: Authors, 2022.

an inert marker in the formulated diets. Thereafter, the diets were dried (40°C) and then sealed in vacuum-packed bags. Table 2 shows proximate composition of the experimental diets.

#### Experimental fish and sampling procedures

Fish fingerlings were acclimatized using a control diet for two weeks. Thereafter, 600 fingerlings of monosex male *O. niloticus* (Initial mean body weight, 28 ±0.01 g) were randomly stocked in 15 cages and 15 glass tanks for growth and digestibility experiments, respectively. Each cage and tank were stocked with 30 and 10 fish, respectively. Each experimental diet was assigned to three cages and three aquaria. Feed was administered at 3% of body weight per day for 180 days. Each daily portion was divided into two equal parts and the portions hand fed between 10:00 and 16:00.

For growth experiment, sampling was done bi-weekly where 10

fish were randomly sampled from each cage and measured for total weight using a digital balance (0.01 g) model KERN 572-33 and length using a measuring board (0.10 cm). After every sampling, feed adjustments were made for each cage. After 180- day rearing period, all surviving fish from every cage were harvested, total length measured, weighed and counted. The concentration of free ammonia (NH<sub>3</sub>) in the water were analyzed weekly following the calculations of Emerson et al. (1975) while dissolved oxygen, temperature, and pH were monitored daily using a multi-parameter water quality meter (Model H19828, Hanna Instruments Limited, USA).

For the digestibility experiment, faecal matter was collected from every tank on weekly basis by siphoning at the bottom of the tank. Samples of faecal material from each tank were dried immediately after collection, labelled and frozen at -20°C until the end of 60 days when all faeces from each tank were pooled. The faecal samples were analyzed for crude protein following the procedures adapted.

**Table 3.** Water quality parameters measured in cages of *O. niloticus* fed on a mixture of plant proteins.

Parameter	Diets				
	D0	D1	D2	D3	D4
Dissolved oxygen (mgL <sup>-1</sup> )	5.71 ± 0.04	5.78 ± 0.07	5.78 ± 0.06	5.80 ± 0.07	5.70 ± 0.07
Temperature (°C)	25.95 ± 0.18	25.83 ± 0.11	25.14 ± 0.11	26.20 ± 0.18	26.01 ± 0.28
pH	8.27 ± 0.04	8.34 ± 0.04	8.36 ± 0.06	8.43 ± 0.07	8.38 ± 0.06
Ammonia (mgL <sup>-1</sup> )	0.06 ± 0.00	0.08 ± 0.05	0.08 ± 0.07	0.08 ± 0.02	0.08 ± 0.06

Source: Authors, 2022.

from the Association of Official Analytical Chemists (AOAC, 2003). Chromic oxide content was determined according to method adopted from Furukawa and Tsukahara (1966). A sample of 0.1 g of feed and faecal matter was weighed into a Kjeldahl flask. Approximately 5 ml of concentrated nitric acid was added in the flask and the mixture boiled for around 20 min, without boiling dry. After cooling the sample, 3 ml of 70% perchloric acid was added to the flask. The mixture was then gently heated again until the solution turned from green to an orange colour after which it was left to boil for a further 10 min to ensure complete oxidation. The solution was transferred to a 100 ml volumetric flask and topped up to the mark using distilled water. Chromic oxide content of the oxidized solution was then measured against chromate (IV) known standards directly by use of an atomic absorption spectrophotometer (Bulk scientific, Model 210 VGP) at a wavelength of 357.9 nm (Furukawa and Tsukahara, 1966). The apparent digestibility coefficient of protein (ADC<sub>p</sub>) was determined using chromic oxide as the indigenous inert marker. The following formula according to Maynard and Loosli (1962) was applied:

$$ADC_p(\%) = \frac{100 \times (1 - (\%MD) \times (\%NF))}{(\%MF) \times (\%ND)}$$

where NF= nutrient in faeces; ND= nutrient in the diet; MD= marker in the diets, and MF=marker in the faeces.

#### Economic analysis

Partial enterprise budgets were used to determine the economic performance of each experimental diet. The variable costs included the costs of feeds, labour, fingerlings, and fertilizers. The prices of the feeds were determined based on the retail prices of the feed ingredients on the market. Labour costs were determined in accordance with the prevailing rates at Sagana town. The US dollar exchange rate against Kenya shillings at the time of the experiment was at 1 US\$ = Ksh. 108.85. For each dietary treatment, fish were harvested and sold at US\$ 4.00 kg<sup>-1</sup> which was the prevailing market price for 1 kg of fresh weight tilapia.

#### Growth, nutrient utilization and cost-benefit analysis parameters

Growth performance parameters were evaluated by the following:

$$\% \text{ Weight gain} = [(W_f - W_i) / W_i] \times 100$$

$$\text{Specific growth rate (SGR)} = (100 \times [\text{Ln}(\text{Final individual weight (g)}) - \text{Ln}(\text{Initial individual weight (g)})] / \text{Days of experiment})$$

$$\text{Feed Conversion Ratio (FCR)} = \text{Weight of the feed fed to the fish}$$

$$(\text{g}) / \text{Live weight gained (g)}$$

$$\text{Survival (\%)} = (\text{Number of harvested fish} / \text{Initial number of fish stocked}) \times 100.$$

#### Data analysis

Statistical analyses were done using Minitab version 16 software. All the data was analysed using one-way analysis of variance (ANOVA). The Tukey's multiple range test was used as post hoc where ANOVA showed significant differences among treatment means. Significant differences were considered at  $p < 0.05$ .

## RESULTS

### Water quality

The results for water quality variables are indicated in Table 3. NH<sub>3</sub>, dissolved oxygen, temperature, and pH did not vary significantly ( $p > 0.05$ ) among treatments over the culture period. The levels of DO values were above 5 mg L<sup>-1</sup> and water temperature ranged from 25.5 to 26.6°C while pH values ranged from 8.2 to 8.4 in the experimental pond.

### Growth performance in cages

The fish growth performance parameters for *O. niloticus* in cages are presented in Table 4. After 180 days, there were significant differences ( $p < 0.05$ ) in final mean body weights among treatments. D0 and D1, had significantly ( $p < 0.05$ ) higher mean weights than the rest of the treatments. Treatment D2, D3 and D4 had values which were significantly different ( $p < 0.05$ ) from D0 and D1. Mean weight gain, daily weight gain and specific growth rate followed a similar pattern to final mean body weights. Survival rate was high and similar ( $p > 0.05$ ) among all treatments. The lowest FCR was recorded in diet D0 and D1 which was not significantly different ( $p > 0.05$ ) while diet D4 recorded the highest FCR.

### Digestibility performance and trends in tanks

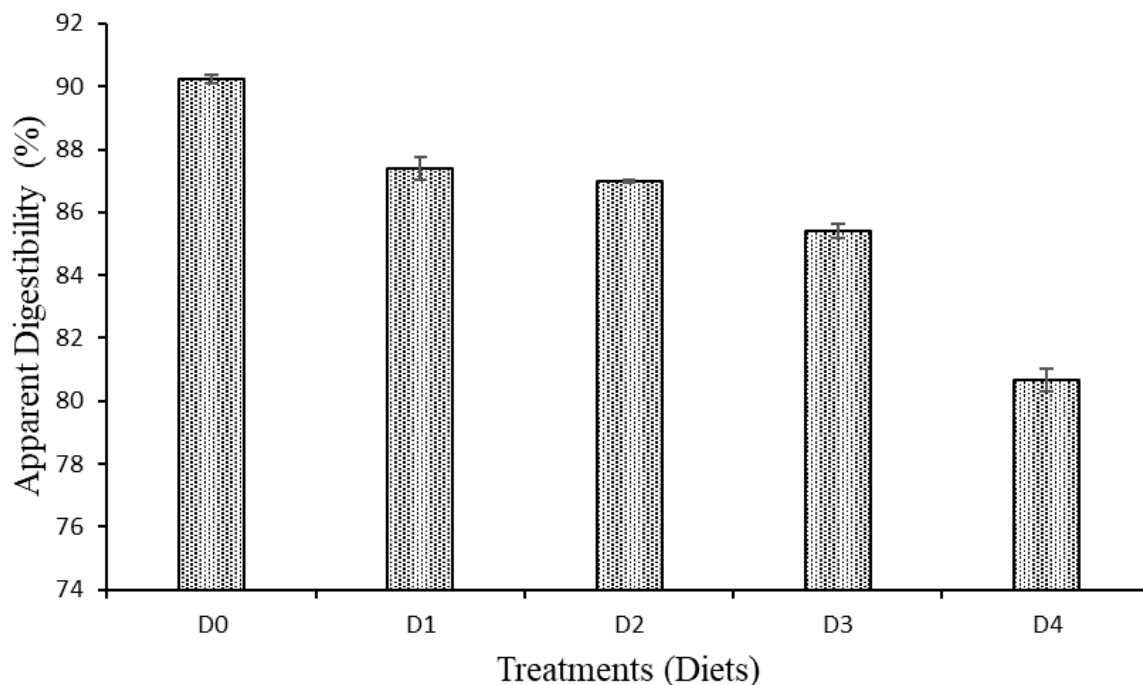
Data on apparent protein digestibility (ADC<sub>p</sub>) in aquaria

**Table 4.** Growth performance of *O. niloticus* fed on a mixture of plant proteins.

Experimental groups	D0	D1	D2	D3	D4
Rate of FSM substitution	0%	25%	50%	75%	100%
Initial length (cm)	11.11 ± 0.00 <sup>a</sup>	11.11 ± 0.00 <sup>a</sup>	11.11 ± 0.00 <sup>a</sup>	11.11 ± 0.00 <sup>a</sup>	11.11 ± 0.00 <sup>a</sup>
Initial body weight (g)	28.11 ± 0.01 <sup>a</sup>	28.11 ± 0.01 <sup>a</sup>	28.11 ± 0.01 <sup>a</sup>	28.11 ± 0.01 <sup>a</sup>	28.11 ± 0.01 <sup>a</sup>
Final mean body weight (g)	140.33 ± 3.27 <sup>b</sup>	130.18 ± 2.89 <sup>b</sup>	103.18 ± 2.03 <sup>a</sup>	99.20 ± 4.12 <sup>a</sup>	89.91 ± 2.33 <sup>a</sup>
Weight gain (%)	399.2 ± 1.79 <sup>c</sup>	363.1 ± 1.87 <sup>bc</sup>	267.1 ± 1.51 <sup>b</sup>	252.89 ± 1.28 <sup>b</sup>	217.3 ± 1.45 <sup>a</sup>
Daily weight gain (g)	0.68 ± 0.04 <sup>c</sup>	0.61 ± 0.06 <sup>bc</sup>	0.45 ± 0.04 <sup>b</sup>	0.42 ± 0.03 <sup>b</sup>	0.36 ± 0.07 <sup>a</sup>
Specific growth rate (% day <sup>-1</sup> )	2.38 ± 0.25 <sup>c</sup>	2.16 ± 0.27 <sup>bc</sup>	1.59 ± 0.22 <sup>b</sup>	1.51 ± 0.21 <sup>b</sup>	1.31 ± 0.18 <sup>a</sup>
FCR	1.63 ± 0.14 <sup>a</sup>	1.69 ± 0.14 <sup>a</sup>	1.75 ± 0.23 <sup>b</sup>	1.78 ± 0.20 <sup>b</sup>	2.08 ± 0.48 <sup>c</sup>
Condition factor	1.73 <sup>a</sup>	1.76 <sup>a</sup>	1.77 <sup>a</sup>	1.68 <sup>a</sup>	1.84 <sup>a</sup>
Survival (%)	99 ± 1.12 <sup>a</sup>	97 ± 1.22 <sup>a</sup>	99 ± 0.98 <sup>a</sup>	98 ± 1.28 <sup>a</sup>	97 ± 1.14 <sup>a</sup>

Values with the same superscript across rows are not significantly different ( $p < 0.05$ ). Values are expressed as mean ± SEM). D0=Control diet; D1=25% fishmeal replacement; D2=50% fishmeal replacement; D3=75% fishmeal replacement; D4=100% fishmeal replacement.

Source: Authors, 2022



**Figure 1.** Apparent protein digestibility of *O. niloticus* fed on a mixture of soybean meal, cottonseed meal and sunflower meal diets. D0=Control diet; D1=25% fishmeal replacement; D2=50% fishmeal replacement; D3=75% fishmeal replacement; D4=100% fishmeal replacement.

Source: Authors, 2022.

are as shown in Figure 1. There were significant differences ( $p < 0.05$ ) in  $ADC_p$  among treatments. The  $ADC_p$  values decreased with increasing levels of PPM in aquaria. The highest ( $90.23 \pm 0.12$ ) apparent protein digestibility was recorded in D0 followed by D1 and D2 ( $87.38 \pm 0.37$  and  $86.99 \pm 0.03$ ), respectively, which were not significantly different from each other ( $p > 0.05$ ). The lowest ( $80.66 \pm 0.35$ ) apparent protein digestibility coefficient was recorded in D4.

### Economic analysis

Data on Economic analysis is shown in Table 5. Fish that were fed on diet D1 (USD 14.87) recorded the highest production costs as compared to fish fed on diets D3 (USD 13.77) and D2 (USD 13.84) which had the lowest costs of production. Fish fed diet D0 recorded the highest total yield of 11.68 kg while fish fed on diet D4 had 7.30 kg. The break-even price over total cost was in the range

**Table 5.** Partial enterprise budget analysis per treatment of a mixture of plant proteins (PPM) diets for production of *O. niloticus* based on selling price of US \$4.00.

Parameter	Experimental Diets				
	D0	D1	D2	D3	D4
Variable Cost (USD)	11.21	11.43	10.40	10.33	10.66
Fixed Cost (USD)	3.44	3.44	3.44	3.44	3.44
Total Cost (USD)	14.65	14.87	13.84	13.77	14.1
Total Yield (kg)	11.68	10.59	8.55	8.09	7.30
Unit Selling price (USD)	4.00	4.00	4.00	4.00	4.00
Gross Revenue (USD)	46.72	42.36	34.2	32.36	29.20
Returns above Variable Cost (USD)	35.51	30.93	23.80	22.03	18.54
Returns above Total Cost (USD)	32.07	27.49	20.36	18.59	15.1
Break Even Price over variable cost (USD)	0.96	1.08	1.22	1.28	1.46
Break Even Price over total cost (USD)	1.26	1.40	1.62	1.70	1.93
Break Even Yield (total cost)	3.66	3.72	3.46	3.44	3.53

Source: Authors, 2022.

of USD 1.26 in fish fed on diet D0 to USD 1.93 in fish fed on diet D4. The prevailing market price was USD 4.00 kg<sup>-1</sup> during the study period.

## DISCUSSION

Results from this study indicated that growth performance of *O. niloticus* fed on diet D1 containing 25% fishmeal replacement were similar to that of the control diet (D0) an indication that 25% fishmeal substitution is possible using a mixture of plant proteins without causing adverse effects on the growth performance and nutrient utilization. Similar findings were reported by Olukunle (1982) and Richards (1983), who observed improved growth performance of *Oreochromis mossambicus* when fed on diets comprising a mixture of plant protein sources, namely, groundnut, sunflower seed and sesame meals compared with single ingredient diets. Additionally, Borgeson et al. (2006), reported that Nile tilapia fed on diets containing a mixture of plant proteins namely canola and pea or flax and pea performed better than those fed on diets containing the individual plant proteins. In addition, better growth performance was reported in carp fry fed diets containing a mixture of linseed, groundnut, mustard, and sesame meals (Hasan, 1986).

The higher growth performance recorded in D0 and D1 may be attributed to the complementary effects of blending plant protein mixtures which lowers the levels of anti-nutritional compounds and brings about a balanced amino acid profile as compared to using individual plant protein sources, adequate availability of the essential amino acids (Soltan et al., 2008; Ogello et al., 2017). However, D2, D3 and D4 had similar growth, though it was a blend, and this manifestates plant protein inferiority which may be due to increased levels of crude fibre, poor

palatability and presence of antinutritional factors (Soltan et al., 2018). Although D4 had the lowest final mean body weight, it was not significantly different from D2 and D3, an indication that plant-based protein mixture is highly effective as compared to single ingredients. FCR was affected when PPM inclusion levels were 100%. The reduction in growth may have been due to poor feed intake, antinutrients, insignificant amino acids and phosphorus levels (Ogello et al., 2017).

In this study, there was a declining trend in ADC<sub>p</sub> with increasing levels of dietary plant proteins across the treatments confirming similar results which have been reported for other fish species such as rainbow trout *Oncorhynchus mykiss* (Luo et al., 2006) and Japanese seabass *Lateolabrax japonicus* (Cheng et al., 2010). The highest digestibility coefficients were recorded in D0 at 90.2% and the lowest in D4 at 80.6%. These values were within the range of 75-95% for protein rich feedstuffs (Anani and Nortey, 2017). Moreover, these ADC<sub>p</sub> values obtained from the present study were slightly higher (80.6- 90.2%) than the values (80.30- 85.40%) for Nile tilapia obtained by El Saily and Gaber (2003). The variation may be attributed to the mode of faecal collection which can affect the ADC values obtained (Cho et al., 1982). Furthermore, digestibility estimations with faecal collection method from tanks have been shown to be 10% greater, compared with those obtained by stripping, indicating some nitrogen compounds are lost in water (Fenucci and Bolasina, 2005). Diet D4 which had the highest replacing levels of fishmeal with the plant protein mixture, recorded the lowest ADC<sub>p</sub>. This reduced digestibility may be as a result of incorporating plant proteins at high levels of inclusion which contain high levels of fibre, poor palatability, and presence of ANFs which can cause gastrointestinal tract pathogenesis and distort the digestion and absorption of nutrients

(Ginindza, 2012; Mzengereza et al., 2016).

From this study, the cost benefit analysis shows that profitability was affected by dietary treatments and at a fish price of US\$ 4.0 kg<sup>-1</sup>, all experimental diets resulted in positive returns above variable and total costs which indicated both short- and long-term economic viability. Highest total fish yield and gross revenue was achieved in D0 and this is explained by the higher growth performance and better fish weight for treatments fed on fish meal diet only. In addition, higher nutrient digestibility of D0 may explain the increased yields when fish were fed fish meal diets. Although D0 did not vary significantly from D1, diet D1 is much recommended than D0 because it's cheaper as compared to D0 due to usage of plant proteins at higher levels in D1 than D0. Similar findings were reported by Ngugi et al. (2016), who observed that formulated diets using a mixture of *C. nilotica* and rice bran and resulted in the best economic benefits as compared to fishmeal-only diets. Farmers with limited resources are more interested in bringing down the cost of fish feeds by extending the culture period (Middendorp and Verreth, 1991). However, the poor growth performance of plant protein feeds which can increase the culture period required to attain the desirable market size, can be countered through pond fertilization to enhance natural food production which will in turn reduce the entire cost of production and significantly enhance profitability (De Silva and Davy, 1992; Omondi et al., 2001).

This study demonstrates that the use of either pure fishmeal or fishmeal containing a mixture of 25% of plant proteins diets leads to similar growth performance in *O. niloticus*. Therefore, there is a possibility of replacing 25% of fishmeal by mixture of plant proteins for Nile tilapia. In addition, the fishmeal containing the mixture of 25% plant proteins remarkably reduces the production costs and achieves higher profits than when the pure fishmeal is used.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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