Pakistan J. Zool., vol. 54(3), pp 1385-1396, 2022 DOI: https://dx.doi.org/10.17582/journal.pjz/20191014101045

Substitution of Fish Meal with Shea Nut Meal in Diets of Nile Tilapia Fry on Growth, Feed Utilization, Tissue Histology and Economic Analysis

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Article Information
Received 14 October 2019
Revised 22 November 2019
Accepted 12 December 2019
Available online 27 January 2022 (early access)
Published 01 March 2022

Authors' Contribution
MGD, CLA and EHA presented the concept of the study and analysed the data. MGD and CLA collected the data. MGD wrote the manuscript. CLA and EHA reviewed and edited the manuscript.

Key words
***Oreochromis niloticus*, Shea meal, Growth, Histology, Economic analysis**

ABSTRACT

The purpose of this study was to evaluate the effects of substituting fish meal with shea meal in diet of *Oreochromis niloticus* fry on growth, feed efficiency as well as proximate composition of the whole body. In addition, the effects of the diets on liver histology were studied. Three experimental diets were formulated to contain shea meal as a substitute for fish meal at 0%, 25% and 50%. The diets were designated as SNM0, SNM 25 and SNM 50 to reflect the inclusion level of shea meal. Two hundred fry of *O. niloticus* (initial weight of 0.82g) were obtained from Water Research Institute of Ghana (WA center) and transported to the Spanish Laboratory of University for Development Studies where they were acclimatized for two weeks. The fry were then stocked in 60 litre bowls (50 cm X 40 cm X 40 cm) at a density of 20 fry per bowl. The results show that substituting fish meal with shea meal affects final weight, weight gain, final length and specific growth rate significantly. The highest final mean weight (8.09±0.37g) was recorded in fish fed SNM 25 whilst the least (5.71±0.54g) was recorded in fish fed SNM 50. SGR (%) was significantly different amongst the three experimental diets ($p<0.05$). Feed conversion ratio was significantly different amongst treatment ($p<0.05$) and ranged between 1.33 (SNM25) and 1.90 (SNM 50). Whole body lipid content of fish fed SNM 0 was significantly higher than fish fed SNM 25. All other groups were not significantly different. The mean lipid content for fish fed SNM 0, SNM 25 and SNM 50 were 9.54, 8.44 and 9.31 respectively. The economic conversion ratio (ECR) recorded for this ratio was significantly different amongst treatments and ranged between 4.42±0.04 to 6.19±0.14. Overall, the findings indicate that shea nut meal can be used as a substitute for fish meal up to 25% without negative effects on growth and feed utilization in *O. niloticus*.

INTRODUCTION

Protein is the most important component in aquaculture feed; therefore, the formulation of fish feed attempts to provide a certain level of protein that will supply essential amino acids for the growth and good health of the farmed fish (Naz and Javed, 2013).

Fishmeal are grounded dried fish used as fertilizer or animal feed. It is a commercial product mostly made from fish that are not generally used for human consumption. A small portion is made from the bones and offal left over from processing fish used for human consumption, while larger percentage is manufactured from wild caught.

Fish meals can be divided into 3 categories: fish meal made from fish, which are not suitable for human consumption (sand eel, Norway pout), fish meal made from fish, which can be consumed by human (blue whiting, sprat, capelin) and fish meal produced from fish, which are commonly consumed by human, but any surplus may be used for fish meal production (herring, mackerel) (Karalazos, 2007).

Generally, fish meal has been recognized as the major protein source due to its abundance of essential nutrients, unknown growth factors and well-balanced amino acid profile (Sun *et al*., 2015). However, as a result of the increase in demand for fish meal (FM) as well as its unstable supply and escalating price, there are calls for suitable protein sources that can enhance the development of aquaculture (Bu *et al*., 2017).

A variety of plant meals such as canola meal (Luo

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0030-9923/2022/0003-1385 $ 9.00/0

and Liu, 2012; Zhou and Yue, 2010) Amaranth leaf (Ngugi *et al*., 2017) and Soybean meal (Sayed, 1999; El-Said and Gaber, 2002; Lin and Luo, 2011) have been tested as possible substitutes for fishmeal in tilapia. Plant protein meals and fishmeal, however, differ in their nutrient composition and because the former contains varying levels of anti-nutritional factors, it is important to include plant protein in tilapia diets at levels that will not affect feed utilization and subsequently growth performance.

Tilapia is the common name for nearly a hundred species of cichlid fish from the tilapine cichlid tribe. They are mainly freshwater fish inhabiting shallow streams, ponds, rivers and lakes and less commonly found living in brackish water. In 2010 cultured tilapia exceeded 3.2 million metric tons per annum in the year making it the most widely cultured fish (Fitzsimmons, 2000) with an expected production of 8.9 million metric tons by 2020 (Tacon and Meitian, 2008). As a result of tilapias extraordinary production traits, it has been termed as "aquatic chicken" (Huecht, 2000). Some of the characteristics of tilapia that has made it a preferred cultured species includes but not limited to good-quality flesh and consumer demand, high fecundity, fast growth as well as disease resistance (Younis *et al*., 2018). It has been reported that at the minimum, 85 countries across the globe culture tilapia.

Shea nut (*Vitellaria paradoxa*) cake is the by-product of shear butter extraction which is widely distributed in west Africa, the nuts are harvested primarily for their fat content, it has good nutrition quality, rich in protein, fat, vitamin, crude fiber and little moisture (Ojebiyi *et al*., 2007).

There is currently no available information on the effects of dietary shea meal on growth, feed utilization, proximate and amino acids composition in tilapia. The present study is therefore conducted to assess the feasibility of using shea meal in the mentioned parameters evaluated.

The aim of this research is to evaluate the effects of replacing fish meal with shea nut meal on Nile tilapia fry *(Oreochromis niloticus)* on growth performance, feed utilization and efficiency. In addition, the effects of the three experimental diets on whole body proximate composition, liver and intestinal histology as well as the economics of using shea meal as a substitute for fish meal.

MATERIALS AND METHODS

Feed preparation

Three isonitrogenous (crude protein, 30.77%) and isolipidic (crude lipid, 9.63%) experimental diets were formulated to contain 100% fish meal and 0% shea nut meal (SNM 0), 75% fish meal and 25% shea nut meal (SNM 25) as well as 50% fish meal and 50% shea nut meal (SNM 50). The composition and chemical analysis of the experimental ingredients and diets are shown in Tables I and II, respectively.

Table I. Formulation and proximate composition of experimental diets (g kg^{-1} dry weight).

Ingredients	SNM0	SNM25	SNM50
Fish meal	30.00	22.50	15.00
Shea meal	0.00	7.50	15.00
Soybean meal	10.00	20.50	28.00
Wheat bran	49.50	39.00	31.50
Soybean oil	2.00	2.00	2.00
Palm oil	2.00	2.00	2.00
Fish oil	2.00	2.00	2.00
Vitamin mix	1.00	1.00	1.00
Mineral mix	1.00	1.00	1.00
Salt	1.00	1.00	1.00
Starch	1.50	1.50	1.50
Total	100.00	100.00	100.00

FM, Fish meal; SNM, Shea nut meal.

Table II. Proximate composition of experimental diets.

Proximate composition (% dry matter)	SNM 0	SNM 25	SNM 50
Dry matter	84.19	84.23	84.27
Protein	30.10	30.58	30.39
Lipid	9.85	9.78	9.27
Ash	5.71	5.67	5.70

A sieve was used to separate unwanted materials from the ingredients used to prepare the feed. The feed and multi vitamins were weighed using an electronic weighing scale. Spoons were used to pick most of the ingredients into the bowl for a uniform mixture as well as gloves were worn on the hand while mixing the ingredients to prevent direct contamination.

Fish and husbandry

Two hundred Nile tilapia fry was purchased from Water Research Institute, Tamale, Ghana and transported to the Spanish Laboratory of University for Development Studies, Tamale-Ghana. The fish was stocked in two 60-L tanks and fed a commercial diet purchased from Ranaan feed twice daily for two weeks to adapt them to the experimental facilities and conditions.

The experiment was conducted in duplicate with fish stocked at 10 fish per tank and fish fed their respective diets to apparent satiation two times a day (8:30 and 17:00 pm) for eight weeks.

Sampling

Feeding was stopped twenty-four hours before sampling. This ensured that the stomach is empty and also to reduce stress during sampling. The weight (g) and length (cm) of the fish that survived were measured. Also, the total number of fish in each tank was counted. Liver of five fish per tank were sampled and stored in a fridge at -20 °C.

Growth and feed utilization

The objective of the study was to evaluate the effects of the diets on growth and feed efficiency by Nile tilapia, the following were therefore be used to measure the above mentioned parameters.

Weight gain=Final weight – Initial weight

Specific growth rate (%)=FW - ln W /T×100

where T is the number of experimental (feeding) days

Condition factor (K) = [body weight / total length ^{3}] × 100%. total length is in cm.

Feed intake (FI) is the total feed consumed (g) during the 56 days' trial.

Feed conversion ratio (FCR) = Feed intake (g)/weight gain (g)

Protein efficiency ratio (PER) = wet weight gain (g) /protein intake (g)

Protein productive value (PPV) = protein gain (g) /protein intake (g)

Hepatosomatic index (HSI) = 100 × (liver weight/body weight)

Protein intake (PI) = Protein content of feed × feed intake

Protein retention (PR) = 100 × [(Final body weight × final body protein) – (Initial body weight × initial body protein)] / Total feed intake × dietary protein

Protein productive value (PPV) = Protein gain (g) / protein intake (g)

Apparent net protein utilization % (ANPU) = 100 × (Final fish body protein – initial fish body protein / Crude protein intake (g)

% Weight gain (%WG) = 100 [Final weight (g) – initial weight (g)]/ Initial weight

Proximate composition

Samples of experimental diets and fish (five fish per tank) were sent to the Spanish Laboratory of University for Development Studies, Nyankpala Campus for analysis of moisture, ash, lipids and protein. The standard methods of AOAC (2003).

Liver and intestinal histology

Liver and intestine samples from three fish per treatment were collected from each experiment to enable show and explain the pattern of lipid deposition and the longitudinal sections of the epithelium (size and shape and distance from cell wall) of the intestinal sections. Differences in size of hepatocytes and their nuclei (swelling and displacement) and degree of hepatocyte vacuolization in the liver of fish receiving feeds with different lipid contents were analyzed. Liver and intestine samples were fixed in 10% buffered formalin, dehydrated in graded ethanol series and embedded in paraffin. Approximately 5 µm thick sections of the intestinal sections (anterior, middle and posterior) and also an estimated 5 µm thick of the liver were stained with hematoxylin and eosin and the sections were then observed under microscope (Kowalska *et al*., 2010; Martoja and Martoja-Pierson, 1970).

Economic estimates

The economic conversion ratio (ECR) was calculated as previously used by Piedecausa *et al.* (2007). The calculations were based on the prices of the raw materials (USD) used to formulate each diet. This is basically the cost involved in producing a kg of each diet. The raw material prices during the experimental period, due to the fact that there may be significant changes throughout the year. The ECR will be determined using the equation:

ECR = Cost of diet x Feed conversion ratio

Statistical analysis

Data obtained was statistically analysed using Graph Pad Prism (V.5.03). The data is presented in graphs and tables using the mean ± standard error of the mean (SEM). One-way Analysis of Variance and Tukey's multiple tests was used to analyse all data to compare treatment means. Differences are considered significant at 0.05 probability level ($p<0.05$) for all data.

RESULTS

Growth performance

Table III shows growth performance of fish fed the three experimental diets. Fish fed SNM 25 diet had a mean weight of 8.09±0.37g; whilst fish fed SNM 0 (control) and SNM 50 recorded a final weight of 6.57±0.69g and 5.71±0.54g respectively. Fish fed the control diet was significantly lower than fish fed SNM2525, but was significantly higher than fish fed SNM 50 ($P<0.05$).

Table III. Growth parameters of Nile tilapia (*O. niloticus*) fed different levels of shea meal.

Parameters	Dietary SNM inclusion level			p- value
	SNM 0	SNM 25	SNM 50	
Initial body length (cm)	1.15±0.20	1.14±0.17	1.14±0.17	0.9903
Initial body weight (g)	0.82±0.14	0.83±0.00	0.82±0.01	0.4648
Final weight (g)	6.57±o.69^{b}	8.09±0.37^{c}	5.71±0.54^{a}	0.0001
Final length (cm)	7.58±0.83	8.55±0.56	7.08±0.89	0.4060
Weight gain (g)	5.75±0.24^{a}	7.26±0.23^{b}	4.89±0.26^{a}	0.0051
% Weight gain	716.3±20.86^{b}	869.1±34.55^{c}	596.5±21.02^{a}	0.0044
Specific growth rate	3.74±0.04^{b}	4.05±0.07^{c}	3.47±0.06^{a}	0.0063

All values are mean ± *SEM*. Different superscript in each row represents significant differences ($p < 0.05$) determined by one-way ANOVA.

Table IV. Feed utilization and efficiency of *O. niloticus* different levels of shea meal.

Parameters	Dietary SNM inclusion level			p-value
	SNM 0	SNM 25	SNM 50	
Feed conversion ratio	1.66±0.02^{b}	1.33±0.04^{a}	1.90±0.10^{b}	0.0077
Protein efficiency ratio	2.06±0.05^{b}	2.43±0.07^{c}	1.72±0.05^{a}	0.0033
Hepatosomatic index	1.11±0.03	1.04±0.00	1.05±0.10	0.5432
Condition factor	1.50±0.09^{ab}	1.29±0.02^{a}	1.61±0.08^{b}	0.0490
Protein productive value (PPV)	9.46±0.28	9.31±0.56	8.83±0.98	0.6656
Apparent net protein utilization (%)	946.0±28.71	931.1±56.21	883.2±98.43	0.6633
Feed efficiency	2.06±0.06^{b}	2.43±0.07^{c}	1.72±0.05^{a}	0.0033
Feed intake	10.88±1.69	10.94±1.98	11.08±1.95	0.8441

All values are mean ± *SEM*. Different superscript in each row represents significant differences ($p < 0.05$) determined by one-way ANOVA.

Feeding Nile tilapia with the three experimental diets had a significant difference on the final total length. Fish fed SNM 25 was significantly higher than the control group (SNM 0) and SNM 50 (P<0.05). Final length of the SNM 0, SNM 25 and SNM 50 were 7.58±0.83 cm, 8.55±0.56 cm and 7.08±0.89 cm respectively.

Feeding Nile tilapia with shea meal at different levels influenced weight gain significantly (P<0.05). Fish fed SNM 0 was significantly lower than fish fed SNM 25. Also, fish fed SNM 25 was significantly higher than fish fed SNM 50. Increasing shea nut meal in diet of Nile tilapia from 0% to 25% led to an increase in weight gain from 5.58g to 7.09g. A further increase to 50% resulted in the least weight gain of 4.71g.

This study recorded a percentage weight gain of 596.5%, 716.3% and 869.1% which are attributed to fish fed SNM 50, SNM 0 and SNM 25 respectively. Fish fed SNM 0 was significantly lower than fish fed SNM 25 but significantly higher than fish fed SNM 50 (p<0.05).

The specific growth rate of fish fed the control diet was 3.74±0.04 whilst that of SNM 25 was 4.05±0.07. In addition, fish fed SNM 50 recorded a specific growth rate of 3.47±0.06. The statistical analysis of the SGR% revealed that fish fed SNM 25was significantly higher than those fed the SNM 0 and SNM 50, whilst those fed SNM 0 diet was significantly higher than those fed SNM 50 (P<0.05).

Feed utilization, condition factor and hepatosomatic index

Table IV shows feed utilization, condition factor and hepatosomatic index of the three experimental diets after 8 weeks of feeding. The highest feed conversion ratio (1.90) recorded in was recorded in fish fed SNM 50, the least was however recorded in fish fed SNM 25 (1.33). There was no significant difference in the feed conversion ratio of fish fed the control diet (1.66) and fish fed SNM 50 (1.90) (P>0.05). There was however, a significant difference between fish fed the SNM 0 and SNM 25 as well as SNM 25 and SNM 50 (P<0.05).

Protein efficiency ratio (PER) of the 3 experimental diets ranged between 1.72 and 2.43. The highest PER was recorded in fish fed SNM 25 with least recorded in SNM 50. PER recorded in the control diet was 2.06±0.05. There was a significant difference amongst the 3 treatments (P<0.05). Fish fed SNM 0 had PER significantly lower than SNM 25 but significantly higher than SNM 50 (P<0.05).

The mean Hepatosomatic index recorded for the control diet, SNM 25 and SNM 50 were 1.10±0.03, 1.04±0.00 and 1.05±0.10 respectively. There was no significant difference in the Hepatosomatic index of the 3 experimental groups (P>0.05)

Condition factor of fish fed SNM 25 was significantly lower than fish fed SNM 50. There was however no significant difference in the control diet (SNM 0) and fish fed SNM 25. Condition factor of this present study ranged between 1.29 and 1.61. The highest condition factor was recorded in fish fed SNM 50 (1.61), followed by SNM 0 (1.50) and SNM 25 (1.29).

Feeding Nile tilapia with the 3 experimental diets had no significant difference on the protein productive value (p>0.05). Fish fed SNM 0 recorded the highest PPV (9.460), whiles fish fed SNM 50 recorded the least PPV (8.835).

Apparent net protein utilization (ANPU) was not significantly different amongst the group irrespective of the shea nut meal inclusion level (p>0.05). The mean ANPU were 9.46, 9.31 and 8.83 which are attributed to SNM 0, SNM 25 and SNM 50 respectively.

Proximate composition (Whole body)

Protein, lipid, moisture and ash content of the whole body of fish fed the three experimental dies is shown in Table V. There was no significant difference in protein amongst fish fed the 3 experimental diets (p>0.05) It is worth noting that fish fed SNM 50 recorded the least protein content of 59.01%, followed by SNM 0 (60.28%) and SNM 25 (61.58%). Lipid content of fish fed SNM 0 was significantly higher than fish fed SNM 25. All other groups were not significantly different. The mean lipid content for fish fed SNM 0, SNM 25 and SNM 50 were 9.54, 8.44 and 9.31 respectively. There was no significant difference in moisture amongst fish fed the 3 experimental diets (p>0.05). Moisture content in the fish ranged between 70.10 and 74.27. Ash content was not significantly different across all treatments. It is worth noting that ash increased as shea nut meal increased in the experimental diets.

Liver and intestinal histology

Figure 1A-1C shows the liver histology of fish fed the three experimental diets. There was no difference in the size and shape of hepatocytes of fish fed SNM 0, SNM 25 and SNM 50. Fish fed SNM 25 however had some degraded hepatocytes. All three groups had congested blood vessels. There were no pancreatic acini recorded in fish fed SNM 50. Fish fed SNM 25 however recorded pancreatic acini larger than that of fish fed SNM 0. Fish fed SNM 50 had more picnotic nuclei compared to fish fed SNM 0 and SNM 25. There was no inflammation, tumors nor lesions in any of the groups. Histology of anterior-intestine (AI), mid-intestine (MI) and posterior intestine (PI) respectively of Oreochromis niloticus fed SNM 0 (A), SNM 25 (B) and SNM 50 (C) are shown in Figures 2, 3 and 4, respectively. There were no significant alterations amongst groups in all sections.

Economic analysis

Table VI show the economic analysis of fish fed the three experimental diets. There was no significant difference in the cost of producing a kg of feed. A kilogram of diet SNM 0, SNM 25 and SNM 50 cost GH 3.35, GH 3.33 and GH 3.26, respectively. The economic conversion ratio (ECR) recorded for this ratio ranged between 4.42±0.04 to 6.19±0.14. The highest was recorded in fish fed SNM 50 and was significantly higher than fish fed SNM 0, which was also significantly higher than fish fed SNM 25 (p<0.05).

Cost of reduction per kilogram weight gain was 1.14 and -0.63 for SNM 25 and SNM 50, respectively.

Table V. Effects replacing fish meal with shea meal on proximate composition of *O. niloticus* fed experimental diets for 8 weeks.

Parameters	Dietary SNM inclusion level			p-value
	SNM 0	SNM 25	SNM 50	
Protein	60.28±1.59	61.58±1.74	59.01±2.71	0.4382
Lipid	9.54±0.21[b]	8.44±0.37[a]	9.31±0.45[b]	0.0267
Moisture	70.10±5.74	74.27±1.69	73.35±0.47	0.5276
Ash	4.17± 0.50	4.32±0.43	4. 82± 0. 74	0.4127

Table VI. Economic efficiency for 1 kg gain with feeds different content of SNM O. niloticus.

Parameters	SNM 0	SNM 25	SNM 50
Cost of feed (GH/ Kg)	3.35	3.33	3.26
FCR*	1.66[b]	1.33[a]	1.90[c]
ECR**	5.56[b]	4.42[a]	6.19[c]
Cost of reduction/kg weight gain	0.00	1.14	-0.63

FCR, Feed conversion ratio; ECR, Economic conversion ratio.

DISCUSSION

Growth performance

In fish, growth implies the deposition of lipids and proteins into fish body (Guto, 2015). One of the most important factors to consider during fish feed formulation and commercial production is the selection of right ingredients (Koumi *et al*., 2009; Khan *et al*., 2013). The purpose of this study was to evaluate the effects of replacing fish meal with shea meal on growth, feed utilization and economic analysis. Substituting fish meal with 25% SNM led to an increase in better weight gain. There was however a reduced weight gain after the 8-week feeding trial when FM was replaced by 50% SNM. This could be attributed to the fact that plant-based diets are noted to be deficient in essential amino acid, specifically lysine and methionine (Marković *et al*., 2012), even though the amino acids of the experimental diets were not analyzed. The reduction in growth performance when fish were fed SNM 50 diet is in agreement to previous study when fish meal was substituted with groundnut meal in *O. niloticus* (Fagbenro and Davis, 2000). Also, the reduction in growth of fish fed higher levels of plant protein sources had been reported in some fish species prior to this study; rainbow trout (Snyder *et al*., 2012) and turbot (Bonaldo *et al*., 2011). The reduction in growth when fish were fed SNM 50 could be speculatively attributed to the presence of anti-nutritional factors such as saponins theobromine and tannins (Dei *et al*., 2007). It could also be attributed to the reported lack of essential amino acids such as methionine, lysine in plant-based protein sources. Again, this could be attributed to the high fibre content of shea meal. Agbo *et al*. (2014) had reported that the fibre content of shea meal is 86.62%. Contrary to the decline in growth performance when *O. niloticus* was fed SNM 50 diet, a report suggested that fish meal can be completely replaced by plant protein sources without adversely affecting growth (Lee *et al*., 2010). The difference in results is however as a result of supplementation of these plant-based proteins with essential amino acids.

The best growth performance in this study was observed in *O. niloticus* fed SNM 25. This is a confirmation of previous study by Bazili (2015) who documented that fish meal can be replaced with cotton seed meal up to 25% in diets of *O. niloticus* without any adverse effects on growth performance.

Whereas specific growth rate (SGR%) of this study ranged between 3.47 and 4.05. Boussou *et al*. (2017) recorded an SGR ranging between 4.54 to 5.50 when fish meal was replaced with soybean meal in diets of *O. niloticus*. In contrast to our results, Nyadjeu *et al*. (2018) documented that SGR was not significantly different when fish meal was replaced with lima bean meal in diets of *Cyprinus carpio* (Nyadjeu *et al*., 2018).

In this study, % weight gain ranged between 596.47% and 869.07%. the values are higher than that of Sharda *et al*. (2017) who reported a % weight gain ranging between 79.55% to 170.23% when they replaced fish meal with soybean meal in diets of *O. niloticus*. The significance difference is in agreement to the previous report of Lin *et al*. 2004 but contrary to that of Sharda *et al*. (2017) which reported no significant difference.

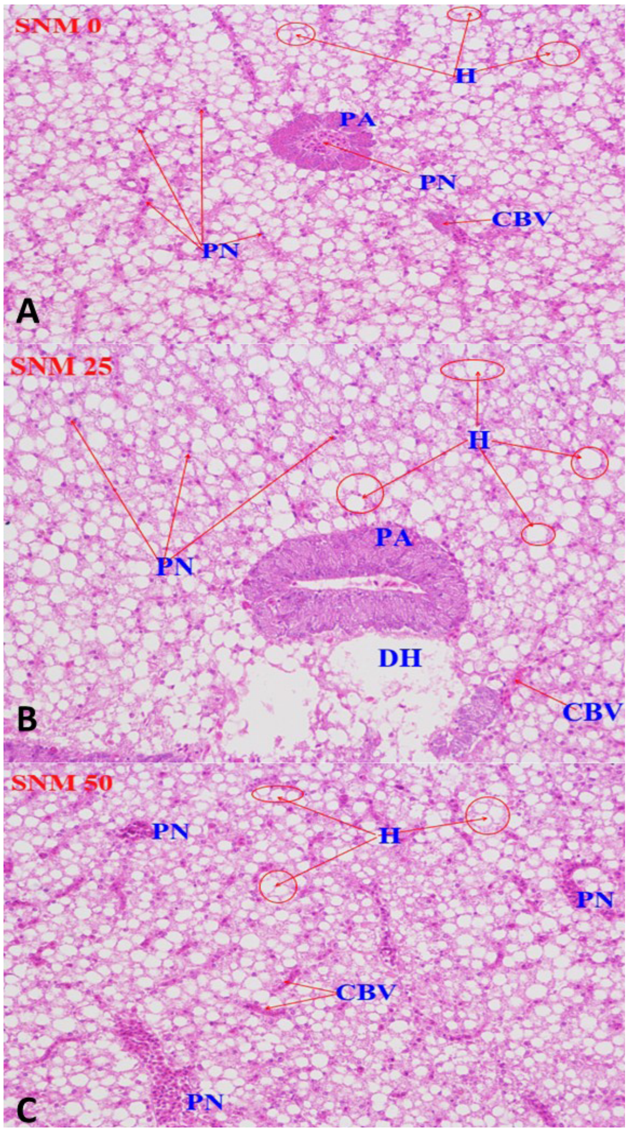

Fig. 1. liver histology of *Oreochromis niloticus* fed SNM 0 (1A), SNM 25 (1B) and SNM 50 (1C). PN, picnotic nuclei; H, hepatocyte; CBV, congested blood vessels; PA, pancreatic acini; DH, degraded hepatocytes.

Feed utilization, condition factor and hepatosomatic index

Feed utilization efficiency of formulated diets has been assessed in fish using feed conversion ratio (FCR) as an indicator. It has been reported in several studies that fish with low FCR have better feed utilization efficiency. The mean values of FCR recorded in this study ranged between 1.33 and 1.90. The values are lower than the values (3.22-11.60) reported by Sharma and Saini (2017) when fish meal was replaced with soybean meal in diets of *O. niloticus*. In addition, Hossain *et al*. (2018) substituted fish meal with sunflower cake in diets of *O. niloticus* and reported an FCR of 1.37 to 1.68 which was similar to the values obtained in this study. The values of FCR recorded in this study was lower than that of Khan *et al*. (2013) which reported an FCR values ranging between 2.27 and 2.31 when plant protein sources were used as an alternative to fish meal in diets of *Oreochromis niloticus*. Comparing the three experimental diets, fish fed diet SNM 25 recorded the least FCR value and was significantly lower than fish fed both the control (SNM 0) and SNM 50. This indicates that feeding Nile tilapia with fish meal supplemented with shea nut meal at 25% would increase efficiency in feed utilization. It also implies that, whereas Nile tilapia will need 1.33 g of diet to produce 1 g of flesh when fed SNM 25, it will require 1.66 g and 1.90 g of feed to produce 1 g of flesh when fed diets containing SNM 0 and SNM 50 respectively. The differences observed in the various studies could be attributed to differences in age of fish, different sources, concentrations and qualities of plant protein sources can lead to significant differences in FCR and SGR (Hossain *et al*., 2018).

Another major indicator used to evaluate feed efficiency is protein efficiency ratio (PER). It is mostly used together with FCR since they are both directly related to intake of dietary protein as well as its conversion into fish weight gain (Koumi *et al*., 2009). PER was significantly affected by the different experimental diets. PER was better in fish fed SNM 25 compared to fish fed SNM 0 and SNM 50. Previously, Zhang *et al*. (2018) had documented that feeding Japanese seabass (*Lateolabrax japonicus*) with soybean meal in place of fish meal led to a reduction in PER.

Davies and Ezenwa (2011) fed *Clarias gariepinus* fry with groundnut cake as an alternative to fish meal. They reported a significant difference in the condition factor; which ranged between 0.66 and 1.09. The results of this present study showed that feeding *O. niloticus* with shea meal as an alternative to fish meal affected condition factor significantly. The condition factor (1.29-1.61) reported in this study was however slightly higher than that of Davies and Ezenwa (2011).

Feed intake to some extent is determined by the palatability and acceptability of the diet. The palatability of diet or feed is one of the most commonly encountered problems with respect to alternative plant protein sources in fish feeding (Nyadjeu *et al*., 2018). Feed intake as reported in this study increased with increasing shea meal content. This implies that SNM 25 and SNM 50 might be more palatable compared to the control diet (SNM 0). This is in agreement to the results reported by Nyadjeu *et al*. (2018) which showed that diets with plant protein sources (lima beans) were more palatable compared to the fish meal-based diet.

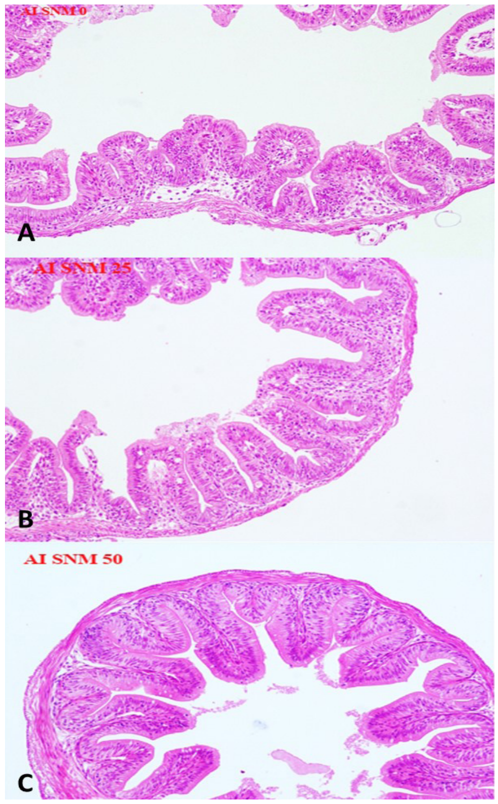

Fig. 2. Anterior-intestine histology of *Oreochromis niloticus* fed SNM 0 (A), SNM 25 (B) and SNM 50 (C).

Apparent net protein utilization (ANPU) was used as a measure of how protein was used in this study. ANPU reported in this study reduced as dietary shea meal increased in the experimental diets. There was however no significant difference amongst the treatment. ANPU ranged between 883.2 to 946. This shows that substituting fish meal with shea meal does not affect utilization of protein negatively.

Protein productive value (PPV) reported in this study was not significantly influenced by the different inclusion levels of shea meal. This was however not the case when fermented soybean meal was used to replace fish meal in diets of Japanese seabass (*Lateolabrax japonicus*) (Liang *et al*., 2017).

Proximate composition

According to Zhou and Yue (2010), the diet as well as nutritional composition influences the biochemical composition of aquatic animals. With the exception of lipid content of the whole body, there was no significant difference in protein and moisture contents. This imply feeding *O. niloticus* with different levels of shea meal as a substitute for fish meal has negligible effects on moisture and protein content although it can influence lipid content to some extent.

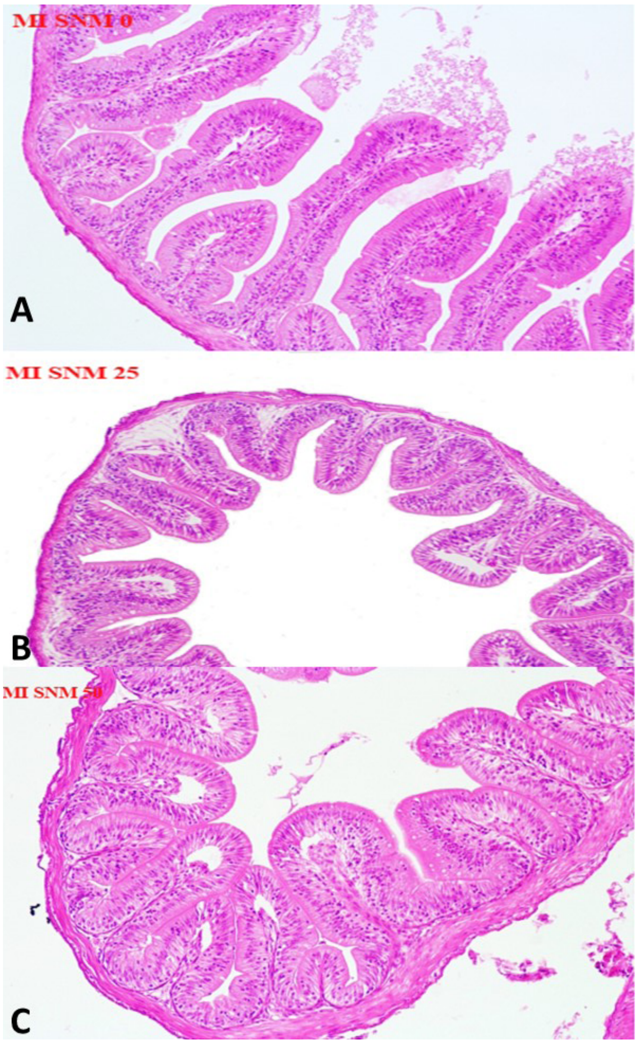

Fig. 3. Mid-intestine histology of *Oreochromis niloticus* fed SNM 0 (A), SNM 25 (B) and SNM 50 (C).

The non-significance difference in whole body protein and moisture is in agreement to an earlier report by Rodiles *et al*. (2015) which documented that replacing fish meal with plant protein sources such as soybean meal, soybean protein concentrate and wheat gluten did not affect the proximate composition of muscle of Senegalese sole. It also agrees to the study of Ovie and Ovie (2007) which documented that fish meal can be replaced with 10% ground nut cake without adversely affecting proximate composition. Also, Agbo *et al*. (2014) and El-Saidy and Gaber (2003) reported that feeding Nile tilapia with alternative protein sources did not have significant influence on protein and moisture contents.

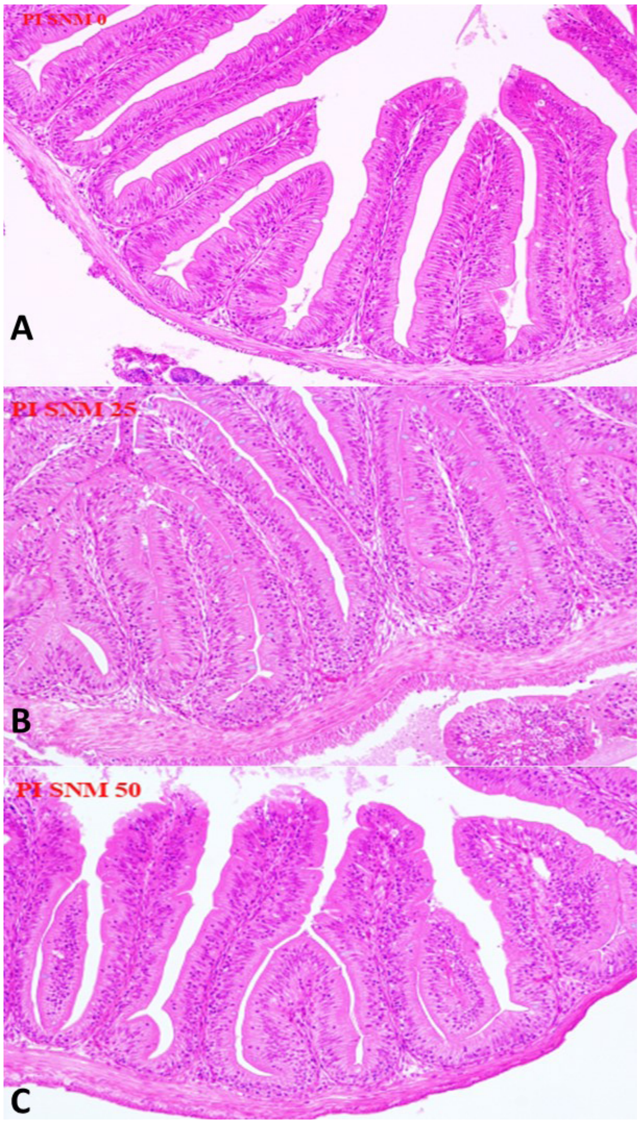

Fig. 4. Posterior intestine (PI) histology of *Oreochromis niloticus* fed SNM 0 (A), SNM 25 (B) and SNM 50 (C).

Liver and intestinal histology

Histological structures of the digestive organ is evaluated during feeding trials to provide important information on the possible health effects of the new diets as well as digestive ability of the fish (Caballero *et al*., 2003; Diaz *et al*., 2006). Growth retardation has been associated with changes in the morphology of distal intestines of fish (Krogdahl *et al*., 2003; Uran *et al*., 2008; Knudsen *et al*., 2008). There were no major alterations in the morphology of the distal/posterior intestine of this present study. This suggests that the difference in growth performance has no direct relationship with the intestinal morphology.

Physiological and nutritional status of a fish can be predicted using alterations in the histology of its liver (Abarra *et al*., 2010). Generally, the liver is responsible for detoxification and can be destroyed easily (Bernet *et al*., 1999; Velmurugan *et al*., 2007). Some studies have studied the effects of dietary nutrients on liver histology (Aziza *et al*., 2013; Apraku *et al*., 2019) Hansen *et al*. (2006) reported normal hepatic morphology in cod fed a combination of plant protein (i.e. wheat gluten and soybean protein concentrate) at levels up to a maximum of 44%. In addition, sunflower meal replacing 30% of protein from fish meal showed no histological alteration in sharpsnout sea bream *Diplodus puntazzo* (Mérida *et al*., 2010). This present study is in agreement to these previous studies since feeding *O. niloticus* with SNM had little influence on intestinal and liver histology. Power *et al*., 2000 and Ostaszewska*et al*. (2005) reported vacuolated hepatocytes in some liver samples fed soybean meal the vacuolization might be as a result of the deficiency of soya bean meal in lysine and methionine. There was however no vacuolization and no difference in the size and distribution of hepatocytes in this study.

Economic analysis

The economic analysis showed that the price of producing the experimental diets decreased as SNM levels increased. This same observation was made when sunflower cake was used as a substitute for fish meal in diets of Nile tilapia (Hossain *et al*., 2018).

CONCLUSION

In conclusion, this study reports that fishmeal to a larger extent can be replaced with shea nut meal. Feeding *O. niloticus* fry with SNM 25 recorded the highest growth performance. However, it is evident that increasing shea nut meal in diets of *O. niloticus* would compromise growth performance and feed utilization. Feed conversion ratio which is an indicator of how much feed is required to produce 1g of fish was significantly influenced by the different diet similar to growth performance (SGR, weight gain and final weight). The best feed conversion ratio was recorded in fish fed SNM 25. Also, Protein efficiency ratio for this study ranged between 1.72 and 2.43, the highest was however observed in fish fed SNM 25. Different dietary lipid sources as evaluated in this study had no influence on both hepatosomatic index and condition factor.

Moisture and protein in the whole body of *O. niloticus* fed the 3 different experimental diet were not significantly different, lipid was however influenced by the different lipid sources.

From the economic perspective, it is cheaper to formulate diets with higher shea nut meal levels. The amount of money required to produce 1kg of SNM 0, SNM 25 and SNM 50 were 3.35 Ghana cedis, 3.33 Ghana cedis and 3.26 Ghana cedis, respectively. The best economic conversion ratio (4.42) was observed in fish fed SNM 25. This was followed by fish fed SNM 0 (5.56) and SNM 50 (6.19).

RECOMMENDATION

This work to the best knowledge of the author is the first study to assess the effects of replacing fish meal with shea nut meal in tilapia (*O. niloticus*). Further studies on the effects of shea nut meal diets on other important parameters are recommended. One major challenge of aquaculture is the outbreak of diseases. Based on this background, it is recommended that further studies be carried out on how replacement of fish meal with shea nut meal affects the immune system of *O. niloticus* and other fish species. Again, the nutritional requirements of tilapia vary with age. It is therefore important that additional studies be carried out using fish of different sizes. This study recommends SNM 25 to small scale farmers who find it difficult to assess commercial diets which are normally expensive; this is because, it is cheaper compared to the fish meal diet and has the best feed conversion ratio and economic conversion ratio.

Statement of conflict of interest

The authors have declared no conflict of interest.

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