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Research Article

The Potential of Whole Soya Bean Meal in Raising Nile Tilapia (*Oreochromis Niloticus*, L.) Fingerlings

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Abstract

An eight-week experimental study was undertaken to determine the effect of whole soya bean meal (SBM) with reference to common fish feed ingredients, consisting of Omena (*Rastineobola argentea*) meal (RAM), Freshwater shrimp (*Caridina niloticus*) meal (CNM) and commercial fish meal (CFM, control diet) on water quality, growth performance and survival of *O. niloticus* fingerlings. Fifty fry weighing 0.4 + 0.01 g were randomly stocked in triplicate glass aquaria tanks (67.5 cm by 34.4 cm by 32.0 cm) and fed on whole RAM, SBM, CNM or CFM. Feeding was performed twice daily at 3% of fry wet body weights. Water quality parameters were monitored daily. Growth parameters and survivals of all fry per tank were assessed weekly. There was no significant difference ($p>0.05$) in water quality parameters between the experimental groups and were within acceptable limits. No significant difference ($p>0.05$) was observed in the growth performance of fingerlings fed on SBM and any of the other diets. However, fingerlings fed on SBM exhibited considerably higher growth performance than those fed on RAM or CNM. Although there was no significant difference ($p>0.05$) in the survival of fingerlings fed on SBM and RAM, survival of fingerlings fed on SBM was significantly higher ($p<0.05$) than those fed on CNM. Whole SBM is not only considerably better than RAM and CNM but is also comparable to CFM in terms of its effects on water quality, growth performance and survival; hence, could be a replacement for expensive and low-quality commercial feeds in raising *O. niloticus* fingerlings.

Keywords: Imported feeds; Locally-made fish feeds; Nile tilapia; Whole soya bean meal

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Introduction

Globally, Nile tilapia (*Oreochromis niloticus,* Linnaeus, 1757) is an important aquaculture species due to its fast growth, firm and tasty flesh, resistance to adverse environmental conditions and ease of fingerlings production under captivity [1,2]. *O. niloticus* has a high plasticity in its food habits [3] and represents 75% of the total fish produced from aquaculture in Kenya [4].

The poor performance of the aquaculture production in Kenya is largely attributed to lack of quality seeds and affordable feeds [5,6]. The survival rates in most hatcheries in Kenya are relatively low [4], hence unable to meet the demand for *O. niloticus* fingerlings by farmers. Thus, there is urgent need for quality fish feeds that would lead to quality *O. niloticus* seeds that would guarantee optimal production.

Fish feeds are usually formulated from a combination of various ingredients to give a desirable crude protein (CP) level. In Kenya, most fish feeds contain *R. argentea* and/or *C. caridina* as the major component(s). However, *R. argentea* lacks critical components such as vitamins and omega-3 fatty acid, hence may not prove suitable as an independent whole *O. niloticus* diet [7]. *R. argentea* is overexploited for various uses hence may not be sustainable for large scale fish feed production [8]. *C. nilotica* is seasonally harvested in Lake Victoria hence is not always available for feed manufacturers. Therefore, a fish feed ingredient that would supply the requisite nutrients and is readily available is warranted.

Soya bean is the best plant protein source that is favoured as a supplement in diets of most farmed animals, especially *Oreochromis* species [8,9]. Whole SBM contains CP level comparable to CP levels of standard fish feeds (40 - 45% CP) in Kenya [6]. However, despite the shortage of *R. argentea* [8,10], which is a major source of proteins in many commercial feeds, the potential utility of SBM in raising quality and large numbers of *O. niloticus* fingerlings has not been fully investigated. Thus, there is need to evaluate the effect of whole SBM on growth performance and survival of *O. niloticus* fingerlings. The use of whole SBM could reduce the cost of raising high quality *O. niloticus* fingerlings, which is a major challenge in aquaculture industry.

Therefore, the effect of whole SBM on water quality, growth performance (weight, length, feed conversion ratio and specific growth rate) and survival of *O. niloticus* fingerlings with reference to commonly used fish feed ingredients [whole *R. argentea* meal (RAM) and *C. niloticus* meal (CNM)] and CFM (control diet) was evaluated.

Materials and Methods

Study site

This study was carried out at the Kenya Marine and Fisheries Institute (KMFRI), National Aquaculture Research Development and Training Centre (NARDTC), Sagana in central Kenya. 0° 40' 0.01" N, 37° 12' 0.00" E.

Experimental design

Oreochromis niloticus fry were sourced from brooders ponds within NARDTC and stocked into acclimatization tank measuring 1 m x 0.5 m x 0.5 m for 14 days while being fed on a commercially formulated fish feed. Fifty uniform-sized (0.4 ± 0.01 g) healthy fry were randomly distributed, in triplicate, to glass aquarium experimental (treatments) tanks measuring 67.5 cm, 34.4 cm and 32.0 cm. There were four treatment groups i.e. T1 (SBM), T2 (RAM), T3 (CNM), and T4 (CFM, commercial control diet). The fry were starved for 24 hours to eliminate variation in weight due to residual food in the gut, prepare the gastro-intestinal tract for the experimental diets and increase the appetite of the fry. Each of the feed was administered daily to the fry twice daily at 10.00 hrs and 16.00 hrs and was done manually at 3% of wet body weights for 8 weeks. Each tank had an inlet and outlet connected to a water drainage system. The pumping unit consisted of two water pumps which ran alternatively for twenty-four hours to ensure continuous water flow and aeration.

Processing of raw materials and preparation of test diets

All the raw materials used for diet preparations were purchased from the local markets in Nairobi, Kenya. Soya bean seeds were sorted, roasted, cooled and milled into flour. The flour was sieved to remove larger particles that could hinder the palatability of the feed to fingerlings. The sieved soya bean flour was further dried in an oven at 105°C for 6 hours and allowed to cool. Fresh *R. argentea* and *C. nilotica* fish meals from Lake Victoria, were sorted out to remove all the unwanted materials and dried for two days on the sun. The two were separately milled using the normal flour miller and sieved to remove large particles. The sieved *R. argentea* and *C. niloticus* flour was further dried in an oven at 105°C for 6 hours and allowed to cool. The prepared feeds were packaged and stored in a cool dry place.

Proximate analyses were performed as described previously [11]. The analyses included in this group, are applied firstly to materials to be used in formulating a diet as a protein or energy source and to finished feedstuffs, as a control to check that they met the specifications established during formulation. The analysis done included; moisture, CP (total nitrogen), crude fats/ lipids, and ash content of the samples.

Water quality measurements

Key water quality parameters, which included temperature, pH and dissolved oxygen (DO) were measured daily in situ using a multi-purpose model Hi-9024 microcomputer (Hanna Instruments Ltd., Chicago, and IL., USA) following the manufacturer's instructions.

Data collection

At stocking, individual *O. niloticus* fry for each treatment were weighed using an analytical balance (Shimadzu Analytical Balance AUW320 series) to determine the initial weight (W_{t1}). Total length (Ln_{t1}) was measured using a ruler after placing a fry on a glass petri dish. Each week between 8.00 hrs and 9.00 hrs, all fry/fingerlings were weighed (W_{t2}) and total lengths (Ln_{t2}) were measured to determine the size at that time then restocked. The water quality in the aquarium tank i.e. temperature (˚C), pH, and DO (mg L^{-1}) were recorded daily. The survival rates were based on the number of deaths recorded on daily basis from each tank and was calculated per test treatment.

Growth parameters for *O. niloticus* fingerlings

The following formulae were used to calculate variables in this study:

$$\text{Length gain} = \text{Average final total length} - \text{Average initial total length}$$

$$\text{Weight gain} = \text{Average final weight} - \text{Average initial weight}$$

$$\%\ \text{SGR in weight per day} = \frac{W_{t2}}{W_{t1}} \times 100$$

$$\%\ \text{SGR in length per day} = \frac{Ln_{t2}}{Ln_{t1}} \times 100$$

$$\text{FCR} = \frac{\text{Total feed given (g)}}{\text{Body weight gain (g)}}$$

$$\%\ \text{Survival rate} = \frac{\text{Total number survived}}{\text{Total number stocked}} \times 100$$

Where; W_{t2} = final live body weight (g) at time T_{t2}

W_{t1} = Initial live body weight (g) at time T_{t1}

Ln_{t2} = Final total body length

Ln_{t1} = Initial total body length

Statistical analysis

Statistical analyses were performed using GraphPad Prism version 5.03 (GraphPad Software Inc., California, USA). Data normality was confirmed using D'Agostino and Pearson omnibus K2 test. Data were presented as mean ± standard error of mean (SEM). Statistical differences between SBM and each of the other three diets were performed using one-way analysis of variance (ANOVA) with Dunnett's post-hoc. A p-value ≤ 0.05 was considered significant.

Results

Proximate analysis of the fish diets

In this study, the potential of raising *O. niloticus* fingerlings on whole SBM was evaluated in reference to RAM, CNM and CFM. Prior to the evaluation in terms of effect on water quality, growth performance and survival, the proximate contents of the feeds such as CP, lipid, moisture and ash were analyzed and reported in table 1.

Effect of different diets on water quality parameters

The physico-chemical parameters of water, such as DO, temperature and pH in each treatment tank was measured to determine if the diets had any effect on water quality.

Parameters	SBM	RAM	CNM	CFM
Moisture content	11.2	12.1	6.94	12.2
Ash	11.5	13.6	10.4	11.6
Fat/lipid	10.5	8.8	5.11	8.5
Crude protein	43.6	62.8	38.4	28

Table 1: Proximate content (%) of fish diets used in this study.

There was no significant difference ($p = 0.8516$) in the water temperatures of the aquaria supplied with the four feeds. The temperature of water supplied with SBM was slightly lower than that supplied with RAM, CNM or CFM. However, the differences were not significantly different ($p > 0.05$) (Table 2). Further, no significant difference ($p = 0.2802$) was observed in the DO of water supplied with the four feeds. However, DO of water supplied with SBM was slightly higher than that supplied with RAM, CNM or CFM. The differences were not significantly different ($p > 0.05$) (Table 2). On the contrary, there was a significant difference ($p = 0.0152$) in the pH of water supplied with the four feeds. The pH of water in aquarium tank supplied with SBM was significantly lower ($p < 0.05$) than that supplied with RAM. Although not statistically different ($p > 0.05$), the pH of water supplied with SBM was slightly lower than that supplied with CNM or CFM (Table 2).

Parameters	SBM	RAM	CNM	CFM
Temperature (°C)	24.94 ± 0.82^{a}	25.82 ± 0.37^{a}	25.71 ± 0.96^{a}	25.55 ± 0.79^{a}
DO (mg/L)	6.79 ± 0.36^{a}	6.02 ± 0.32^{a}	6.37 ± 0.19^{a}	6.01 ± 0.32^{a}
pH	8.83 ± 0.15^{a}	8.52 ± 0.11^{a}	8.90 ± 0.14^{b}	8.58 ± 0.15^{a}

Table 2: Effect of various diets on water quality.

Four feeds SBM, RAM, CNM or CFM were applied on aquarium tanks in triplicate for 8 weeks. The temperature, DO and pH of water in the aquarium were measured weekly. The values represent mean ± SEM. Statistical comparison was performed using one-way ANOVA with Dunnett's post-test. Different letters per row depict statistical significance between SBM and any of the other diets ($p < 0.05$).

Growth performance of *O. niloticus* fingerlings in response to various diets

Weights

There was no significant difference ($p = 0.2231$) in the weights of fingerlings fed on the four diets. The weights of fingerlings fed on SBM was slightly higher ($p > 0.05$) than those fed on RAM or CNM. The weights of fingerlings fed on CFM was considerably higher than those fed on SBM, but not significantly different ($p > 0.05$) (Figure 1A).

No significant difference ($p = 0.1846$) in the weight gains of fingerlings fed on the four diets was observed. However, the weight gains by fingerlings fed on SBM was slightly lower ($p > 0.05$) than those fed on CFM. Although not significantly different ($p > 0.05$), weight gains by fingerlings fed on SBM were higher than those fed on RAM or CNM (Figure 1B). The weight gain by the fingerlings fed on the four diets increased gradually over the eight-week period (Figure 1C).

It was observed that the percent SGR in weight per day was not significantly different ($p > 0.05$) for the fingerlings fed on the four diets. Dunnett's post-test revealed that the percent SGR in weight per day of fingerlings fed on SBM was considerably higher ($p > 0.05$) than those fed on either RAM or CNM (Figure 1D). Taken together, the findings indicated that the growth performance (weights and SGR) of *O. niloticus* fingerlings fed on whole SBM is comparable to that of commercial feed and is better than that of RAM and CNM.

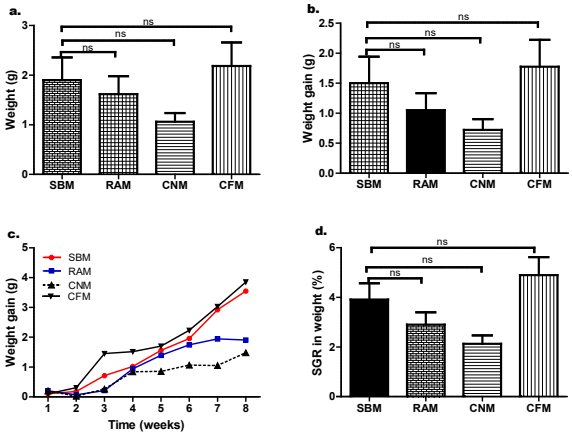

Figure 1: Weights of *O. niloticus* fed on different diets. The comparison of weight (**a**), weight gain (**b**) and weight gain over time (**c**) and percent SGR in weight per day (**d**) of fingerlings fed on SBM, RAM, CNM or CFM for 8 weeks. The experiment was performed in triplicates. Bars or plots represent mean ± SEM. Statistical comparison between SBM and each of the three diets was performed using one way-ANOVA with Dunnett's post-test (ns, $p > 0.05$).

Lengths

There was no significant difference ($p = 0.1749$) in the lengths of fingerlings fed on the four diets. However, the lengths of fingerlings fed on SBM was considerably higher ($p > 0.05$) than those fed on RAM or CNM but not CFM (Figure 2A). In addition, no significant difference ($p = 0.1738$) in the length gains by fingerlings fed on the four diets was observed. However, the length gains of fingerlings fed on SBM was considerably higher ($p > 0.05$) than those fed on RAM or CNM but not CFM (Figure 2B). The length gain of the fingerlings fed on the four diets increased gradually over the 8-week period (Figure 2C).

The percent SGR in length per day was not significantly different ($p > 0.05$) for the fingerlings fed on the four diets. Dunnett's post-test revealed that the percent SGR in weight per day of fingerlings fed on SBM was considerably higher ($p > 0.05$) than those fed on either RAM or CNM, but not CFM (Figure 2D). Taken collectively, the findings implied that the growth performance (lengths and SGR) of *O. niloticus* fingerlings fed on whole SBM is comparable to that of commercial feed and is higher than that of RAM and CNM.

Feed conversion ratio

There was no significant difference ($p = 0.6575$) in the FCR of fingerlings fed on the four diets. Dunnett's post-test showed that the FCR of *O. niloticus* fingerlings fed on SBM was lower than that of fingerlings fed on CNM, RAM or CFM. However, the differences were not statistically significant ($p > 0.05$) (Figure 3). These findings implied that none of the four diets was converted into fingerling's body weight better than the other thou fingerlings fed on SBM exhibited better conversion into body weight.

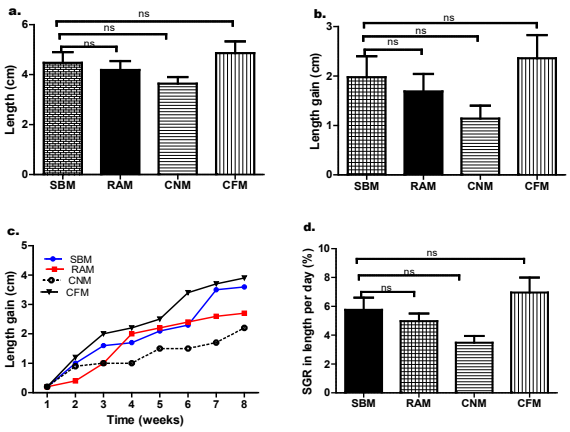

Figure 2: Lengths of *O. niloticus* fed different diets. The comparison of length (**a**), length gain (**b**) and length gain over time (**c**) and percent SGR in length per day (**d**) of fingerlings fed on SBM, RAM, CNM or CFM for 8 weeks. The experiment was performed in triplicates. Bars or plots represent mean ± SEM. Statistical comparison between SBM and each of the three diets was performed using one way-ANOVA with Dunnett's post-test (ns, $p > 0.05$).

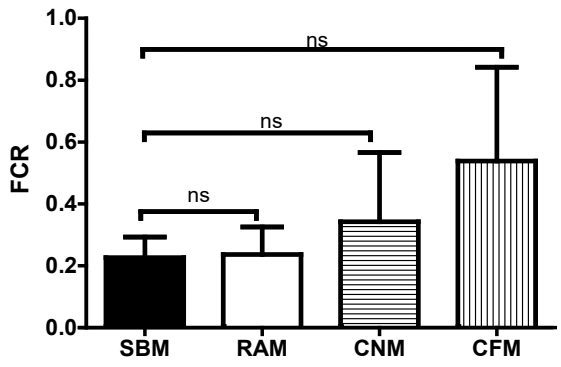

Figure 32: Feed conversion ratio of *O. niloticus* fingerlings fed on different diets. The FCR of fingerlings fed on SBM, RAM, CNM or CFM. The experiments were conducted in triplicate. Bars represent the mean ± SEM. Statistical comparison was performed using one way-ANOVA with Dunnett's post-test (ns, $p > 0.05$).

Survival of *O. niloticus* fingerlings fed on different diets

In the present study, the survival of *O. niloticus* fingerlings fed on the four diets was evaluated weekly for 8 weeks. A significant difference ($p < 0.05$) in the survival of the fingerlings fed on the four diets was observed. Dunnett's post-test revealed that a significantly lower ($p > 0.05$) percentage of the fingerlings survived when fed SBM than when fed on CFM. Although there was no significant difference ($p > 0.05$) in the survival of fingerlings fed on SBM and RAM, the survival of fingerlings fed on SBM was significantly higher ($p < 0.05$) than those fed CNM (Figure 4A). Further analysis of the survival rate over the eight-week period showed that the survival of fingerlings fed on CFM was nearly constant throughout the experimental period. For the fingerlings fed on SBM, RAM or CNM, the survival dropped between weeks one to three then remained nearly constant for the rest of the period (Figure 4B).

Discussion

Stocking densities, feeding frequencies and monitoring water quality parameters in fish culture systems is critical as the variables

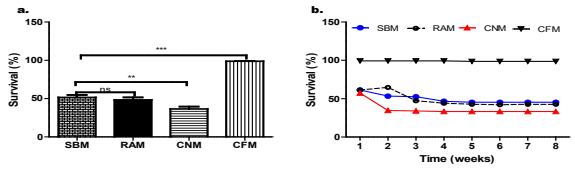

Figure 4: Survival rate of *O. niloticus* fingerlings fed on different diets. The comparison of survival rate (**a**) and survival over the 8-week period (**b**) of fingerlings fed on SBM, RAM, CNM or CFM. The experiments were conducted in triplicate. Bars or plots represent the mean ± SEM. Statistical comparison was performed using one way-ANOVA with Dunnett's post-test (ns, $p > 0.05$; **, $p < 0.01$; ***, $p < 0.001$).

influence fish physiological processes. These cues are critical components in fish culture and ensures optimal growth and survival [12-14]. Thus, in this study, water quality was monitored throughout the experimental period.

The physico-chemical parameters of water were not adversely affected by the fish diets used. Feeding rate is known to affect the level of DO [15]. The high level of DO in this study indicated that the optimal feeding rate was adopted. Feed wastes may lead to water deterioration, thus bringing significant changes in ecosystem structure and functioning [16]. The physico-chemical parameters obtained in this study were within the standards required for the growth of freshwater fish i.e. a temperature between 17°C and 32°C [17]; pH between 6.5-9.0 [18]; DO content ≥ 3 mg L^{-1} [19]. Taken together, the present findings demonstrated that whole SBM is suitable for *O. niloticus* fingerling production since it does not adversely affect the quality of water.

In the present study, *O. niloticus* fingerlings fed on whole SBM exhibited comparatively higher growth performance (weights, lengths, SGR and FCR) than RAM and CNM and was comparable to CFM. The present findings are in agreement with several previous reports, which showed that soya bean contributes to good *O. niloticus* growth performance [20-22]. In contrast, the present findings are not consistent with previous reports [23,24]. The discrepancy between the present and two previous reports could be related to differences in their diet composition and also to different rearing conditions. Notably, the previous reports only evaluated soya bean as supplement, hence, may not fully inform on the potential of whole SBM on *O. niloticus* growth performance. The soy bean's nutritional balance (34% to 53%, proteins, 35% carbohydrate, 20% fat on dry matter basis, about 5% ash) [25] could have given it a higher chance of maintaining fingerling's growth increment throughout the study period. The soy bean performance could also be attributed to its high digestibility and increased bioavailability of protein and minerals in the plant [26,27]. The present findings demonstrated whole SBM acceptance amongst the *O. niloticus* fingerlings compared to RAM and CNM. The outcome suggests that SBM promotes and subsequently leads to increased growth and high yield of *O. niloticus* fingerlings. Thus, whole SBM could be utilized for raising *O. niloticus* fingerlings in hatcheries as an alternative to the costly commercial fish feeds.

One of the important factors in the hatchery venture is the survival rates of fingerlings. An efficient hatchery system should provide physical – chemical conditions including temperature that minimize fingerling mortalities as much as possible. Such cues if not monitored can affect the physiology of the fish to the extent of influencing their sex and growth rates [28]. In view of this, the present study evaluated

the effect of whole SBM on fingerling survival. The survival rate over the eight-week period of *O. niloticus* fingerlings fed on CFM was nearly constant throughout the experimental period. For the fish fed on SBM or RAM, the survival dropped between weeks one to three then remained nearly constant for the rest of the period. Further, the results presented demonstrated that the fingerling survival is dependent on the diet fed with SBM exhibiting higher survival rates RAM and CNM. The present findings are consistent with previous findings in which soya bean diet and fishmeal diets were shown to have almost similar survival rates of Juvenile Red Snapper, *Lutjanus campechanus* [29]. However, the previous report only focused on solvent-extracted soya bean supplements and do not inform on the full potential of whole SBM in raising *O. niloticus* fingerlings. The drop-in survival in the first three weeks could be attributed to the poor uptake of the newly introduced diets to fish fingerlings. It is not clear why the survival rates of fingerlings fed on CNM continued to drop from week one to the seventh week of the study period. A possible explanation for this observation is that CNM could be lacking some essential nutrients required for *O. niloticus* fingerlings survival. Whole SBM exhibited survival rates lower than CFM. A potential explanation for this could be related to lack of some essential minerals in soya bean limiting its efficient utilization of by *O. niloticus* [30], With mineral supplementation, whole SBM could result in higher survival rates of *O. niloticus* fingerlings in the hatcheries. Feeding frequencies are also an important part of growth and survival of Nile tilapia fingerlings as demonstrated by [12]. Therefore, future studies should also focus on feeding frequencies as a variable in similar experiments.

Conclusion

In summary, water quality parameters in both experimental groups remained within the recommended range throughout the experimental period. The growth performance of *O. niloticus* fingerlings fed on whole SBM was comparable to those fed on CFM. The *O. niloticus* fingerlings fed on whole SBM had higher survival rates than those fed RAM and CNM. Taken together, these findings implied that the *O. niloticus* fingerling survival is dependent on the diet fed. Thus, whole SBM could potentially be utilized in raising *O. niloticus* fingerlings as a replacement for the expensive commercial fish feeds. Further studies are necessary to determine the growth trends and survival to maturity of *O. niloticus* in response to whole SBM.

Conflict of interest

The authors declare that there is no conflict of interest.

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