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Charles C Ngugi
Mwea Aqua Fish Farm Nairobi, Kenya

Hillary Egna
Feed the Future Innovation Lab (Aqua Fish Innovation Lab), Oregon State University, Corvallis, Oregon USA

Elijah Oyoo-Okoth
Department of Natural Resources, Karatina University, Kenya

Julius O Manyala
University of Eldoret, Eldoret, Kenya

Correspondence
Charles C Ngugi
Mwea Aqua Fish Farm Nairobi, Kenya

Growth, yields and economic benefit of Nile tilapia (*Oreochromis niloticus*) fed diets formulated from local ingredients in cages

Charles C Ngugi, Hillary Egna, Elijah Oyoo-Okoth and Julius O Manyala

Abstract
Small-scale aquaculture in Africa is limited by cost of protein ingredient in fish feeds, which requires continuous research in ways of improving protein ingredients. We evaluated the suitability of replacing fishmeal with rice bran alone or rice bran in combination with atyid shrimp (*Caridina nilotica*) on growth performance and economic benefits of Nile tilapia (*Oreochromis niloticus*) cultured in cages suspended of statistic ponds. The best growth performance and feed conversion ratio (FCR) occurred in fish fed fishmeal followed by those fed a combination of rice bran and *C. nilotica*, while rice bran alone resulted in lowest fish growth performance. The best economic benefit was obtained from fish fed a combination of rice bran and *C. nilotica*. We therefore demonstrate that it is possible to replace expensive fishmeal in the diet of *O. niloticus* using combination of cheaper rice bran and *C. nilotica* without compromising economic benefits for the small-scale aquaculturists.

Keywords: Low cost formulation, fish feed, Caridina nilotica, rice bran, small scale aquaculture, cages

1. Introduction

Use of on-farm resources such as agricultural byproducts for increased fish production is a low-cost means of developing rural aquaculture in many low income countries. A constraint to the intensification of fish farming is the scarcity of inexpensive and nutritive fish feeds (Gatlin *et al*. 2007) [15]. Fish meal (FM) has traditionally been used as the major protein source for formulated fish feed due to the high protein content, balanced amino acid profile, high digestibility, palatability, and as a source of essential n-3 polyenoic fatty acids (Hardy and Tacon 2002; Jackson 2006) [17, 19]. Nevertheless, the shortage in world production of fish meal (FM), which is the main conventional protein source coupled with its increased demand in livestock and poultry industry is likely to reduce the dependence on it as a single protein source in aquafeeds (El-Saidy *et al*. 2003; Bendiksen *et al*., 2011; Ytrestøyl *et al*. 2015) [11, 3, 30]. Again, fishmeal has become more expensive over time (Tacon and Metian 2008; IFFO 2008) [18].

Efforts to promote growth of the aquaculture industry have moved towards using quality affordable feed resources derived from cheaper local ingredients that are available and affordable to farmers as fishmeal replacements (Azim and Little 2006; MacWere *et al* 2006; Tacon and Forster 2010) [2, 21, 28]. Cereals are the most widely cultivated and consumed crops globally. Rice (*Oryza sativa*, is one of the most extensively grown crop worldwide. Rice as a multipurpose crop provides food and fuel for human being and feed for animals (poultry and livestock). Rice therefore can be a primary source of energy supplement but can contribute protein in an animal's diet. While rice bran theoretically consists of the bran coating removed in the early stages of processing, the rice bran sold for animal feeding is usually a mixture of the bran fraction and other by-products and is, therefore, a very loosely defined product of highly variable composition (RFA 2008) [26]. Rice bran typically contains 8 to 12% crude protein and therefore has found use in livestock production worldwide (Bhosale and Vijayalakshmi 2015) [4]. However, little is still known about the role of rice bran as fishmeal replacement in the diet of fish.

Caridina nilotica (Roux) is currently a prey item for many fish species in Lake Victoria (Budeba and Cowx 2007) [6]. Since 1986, the abundance of *C. nilotica* in the waters of Lake Victoria has increased tremendously, (Cowx *et al*. 2003) [8]. The average *Caridina* biomass for the whole lake was estimated at 22694 metric tones by hydroacoustic surveys (Getabu *et al*.

2003) [16]. In Kenya, the livestock feed industry recognized the underutilized status of *C. nilotica* and have incorporated it as a dietary protein on subsistence scale (Munguti *et al*. 2009) [23]. Previous attempts at using the ingredient in aquaculture were highly promising for both the adult Nile tilapia (*Oreochromis niloticus*) (Liti *et al*. 2006; Mugo-Bundi *et al*. 2015) [20, 22] and larval stages of the African catfish (*Clarias gariepinus*) (Rasowo *et al*. 2008; Chepkirui-Boit *et al*. 2011) [25, 7]. This by-catch as yet is underutilized and can be profitably exploited as a source of protein in the aquaculture industry. The objective of this study was to investigate the suitability of replacing fish meal with low-cost feeds either rice bran alone or rice bran in combination with atyid shrimp (*Caridina nilotica*) on growth performance, nutrient utilization and economic benefits in Nile tilapia (*Oreochromis niloticus*). *Oreochromis niloticus* is an omnivorous warm water fish species, and the production of tilapia had been over 2500,000 metric tonnes per year in the world (FAO 2006) [13]. The fish feed on variety of food items (Pullin 1996) [24] thus offering a possibility for testing the suitability of locally formulated feeds in the fish diet.

2. Materials and Methods

2.1 Experimental facility and fish

The study was conducted at Mwea Fish Farm in Kenya from February to August 2016. Floating cages measuring 3 m^3 consisting of a wooden frame (2 × 1.5 × 1 m) covered with a 0.5” wire mesh was used in this study. Each cage had a polyvinyl chloride (PVC) ring of 30 cm diameter feeding tray to prevent direct spillage of the experimental feed (sinking pellets). These cages were suspended in three, 300 m^2 earthen ponds of 1.0 m depth in the shallow end and 1.5 m depth in the deeper ends. Cages were placed into water, giving a submerged volume of 3m^3 and suspended 20 cm above pond bottom. Liming ($CaCO_3$) was applied at 2500 kg/ha to all the experimental ponds at the beginning of the experiment and fertilizer applied as per the Aquafish Global experiments protocols (N:P at the ratio of 4:1).

Tilapia fry were hatched and held in round plastic tanks (12 m^3) in the Hatchery for two months. While in the hatchery they received feeds laced with 17 alpha-methyltestosterone (MT) hormone so as to sex reverse them and produce monosex fish. All male fingerlings (mean weight 24.0 ± 2.0 g) were then transferred from the hatchery and stocked randomly in cages. Each cage was stocked with 300 tilapia fingerlings. Water was added weekly as required to the ponds to replace water loss due to seepage and evaporation.

2.2 Formulation of experimental feeds

The experimental diets were formulated to contain rice bran and a mixture of rice bran and *C. nilotica,* which were locally, obtained ingredients. The fishmeal, control diet (D0) was formulated to contain 45% crude protein. Rice bran used for this study was obtained from nearby Mwea Market; Mwea is the rice-growing zone in Kenya. Ingredients were analyzed for crude protein (N_2×6.25), crude lipid content, moisture, and ash content using standard methods detailed in AOAC (1995) [1]. Gross energy was calculated using conversion factors for protein, lipids and carbohydrates provided in Tacon (1990) [27]. Amino acid composition of the feed ingredients and the feeds were determined by automated amino acid analyzer after hydrolyzing the sample for 24 h with 6 M HCl at 110 ˚C. Sulphur-containing amino acid were oxidized using performic acid before acid hydrolysis. The proximal compositions and the analyzed chemical composition, including amino acid profiles of the three experimental diets are as shown in table 1. The prepared feeds were preserved in a refrigerator (4 °C) until used for feeding fish.

Table 1: Ingredient composition, formulation, proximate composition (g kg^{-1}) and essential amino acid profiles (μm/mg) of experimental diets used for feeding *O. niloticus*

	Ingredient composition (g/kg diet)		
Ingredients	**D0 (Fish meal diet)**	**D1 (Rice bran)**	**D2 (formulated diet)**
Sardine fish meal	640.0	0.0	0.0
Caridina nilotica	0.0	0.0	475.0
Rice bran	120.0	760.0	285.0
Wheat bran	0.0	0.0	0.0
Perch oil	40.0	40.0	40.0
Binder (Cassava)	40.0	40.0	40.0
Vitamin premix	30.0	30.0	30.0
Mineral premix	30.0	30.0	30.0
Cellulose	80.0	80.0	80.0
Salt (NaCl)	20.0	20.0	20.0
Chemical composition			
Dry matter	92.3	92.5	92.1
Crude protein	45.0	9.1	27.0
Crude lipid	9.4	2.8	2.8
Ash	6.2	6.2	6.1
Crude fiber	5.8	5.7	5.9
NFE	28.4	71.0	58.6
Gross energy (MJ kg-1)	1857.0	1478.6	1548.7
Amino Acids (μm/mg)			
Arginine	2.30	1.74	1.44
Isoleucine	3.35	1.30	1.51
Lysine	3.51	1.19	2.49
Leucine	2.15	1.25	1.74
Methionine	3.45	1.31	1.96

2.3 Feeding regime

Fish were fed on Aller Aqua Starter feeds (0.2 mm to 0.5 mm) complete diet for the first two months before transfer to cages. At the end of the acclimation period, the fish were weighed prior to initiation of feeding the experimental diets. During the experiment, fish were hand fed at 2.5% of their body weight twice a day (0900 h and 1700 h) and weighed, every month. The study was conducted in triplicate. Daily feed intake was recorded throughout the study period. On termination of the experiment, the final weight of each fish was taken following 24-h starvation.

2.4 Analysis of growth performance and survival

Growth in weight of the fish was expressed as the specific growth rate (SGR, % day^{-1}) using the formula:

SGR (% day^{-1}) = 100 ($\ln W_2 - \ln W_1$)/Δt where:

W_1 and W_2 = initial and final body weights (g) and

Δt = time intervals in days.

Survival was determined at the end of the experiment by counting the remaining fish in the cages (taking into consideration any fish that died during weighing exercise) and percent survival calculated based on the number of fish remaining in the cages as a percentage of the stocked fish. % Survival = number of fish in the cages/Initial stocking number

2.5 Data analysis

Statistical analyses were done using GenStat (GenStat Release 4.24DE). The effect of feed types on growth, survival and FCR were performed by analysis of variance (One-way ANOVA). When significant differences were discerned, treatment means were compared using Post-Hoc Tukey's HSD test. In all the above analysis significant was accepted at $P < 0.05$.

3. Results

3.1 Growth performance

Data on growth performance, survival and Food Conversion Ratio (FCR) for *O. niloticus* fed the three different diets are shown in Table 2. There was a significant difference in the final body weight between the experimental groups ($F = 6.734$, df = 2, $P = 0.0007$). Fish fed fishmeal-based (D0) diet exhibited the highest increase in final average body weight, followed by those fed a combination of rice bran and *C. nilotica* (D2) and the lowest growth was observed for fish fed rice bran di*et al*one (D1). Fish fed fishmeal diet, rice bran and *C. nilotica* and rice bran alone had an approximate 12-, 11- and 7- fold, increase in weight after 5 months of feeding respectively. The specific growth rate (SGR) values further support this trend with significant differences ($F = 14.554$, df = 3, $P = 0.0001$). The SGR decreased from 1.73%/day for the control fish to 1.67%/day for the fish fed rice bran and *C. nilotica* (D2) diet while fish fed rice brain alone (D1) had very low SGR ranging from 1.21 to 1.48%/day. Survival was highest in fish fed fishmeal-based diet (D0) followed by those feed D2 and lowest in D1. Daily mean feed intake was also highest in diet D0 followed by D2 and lowest in D1. In terms of food conversion, lowest (and the best FCR) was observed in fish fed diet D0 followed by those fed diet D2 while fish fed diet D1 had the lowest FCR, these values followed the same apparent trend as with final weight gain and specific growth rate.

Table 2. Growth performance, survival and Food Conversion Ratio (FCR) of *Oreochromis niloticus* in different treatments (means ± SE) during the study period

Parameters	D0	D1	D2
Initial mean fish stocking weight (g)	24.4 ± 0.3	24.7 ± 0.2	23.8 ± 0.5
Final mean fish harvest weight (g)	327.4 ± 31.3^c	210 ± 14.5^a	291 ± 23.5^b
Mean fish weight gain (g)	303.4 ± 21.3^c	185.3 ± 11.3^a	267.2 ± 16.9^b
Weight gain (%) in ponds	1241.80^c	750.20^a	1122.69^b
SGR (%/day)	1.73 ± 0.43^c	1.43 ± 0.22^a	1.67 ± 0.31^b
% Survival	86.2^c	46.0^a	76.5^b
Daily feed intake (g/day)	9.38^c	6.34^a	8.64^b
FCR	1.06^a ± 0.21	2.99^c ± 0.44	1.27^b ± 0.23

[1]Means with the same letters as superscripts are not significantly different ($P > 0.05$).
[2]SE: Standard Error, calculated from the mean square for error of the ANOVA
[3]SGR: Specific growth rate
[4]FCR: Food conversion ratio

Trend curves for growth of *O. niloticus* under different feed treatments for the entire growth period are shown in Figure 1. Diets D0, maintained the highest trends followed by D2 and lowest in D1.

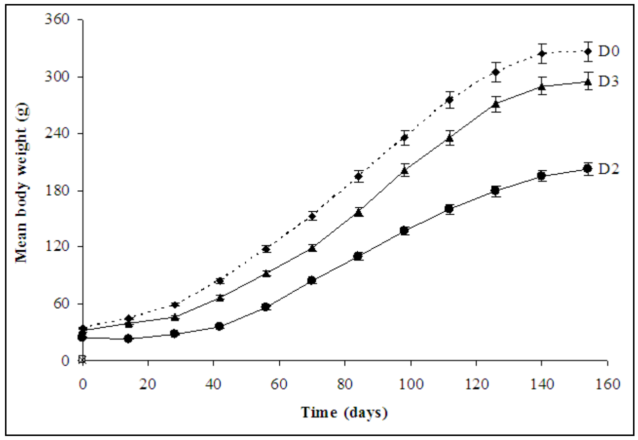

Fig 1: Growth curves for *O. niloticus* in various feed treatments during the study period

3.2 Economic benefit

Projected mean fish yield at the end of the culture period and the enterprise budget for different treatments is shown in Table 3. The lowest yield, net returns above Total Variable Cost (TVC) and Total Cost (TC) was obtained in rice bran alone treatment (D1). The yield and gross revenue was highest in the fishmeal treatment (D0) compared to fish fed diet D2. However, the highest cost of fish meal based feeds resulted in lower net returns on TVC and TC in diet D0 and D2. In terms of break even, selling fish fed using diet D0 at US $ 0.81 and that of fish fed diet D2 at US $ 0.52 would still enable the farmer to cover their variable costs. Nevertheless, fish fed rice bran alone resulted in negative net returns above TC and would require selling fish above the prevailing market price to break even.

Table 3. Enterprise budget (in US $) of different frequency of fish meal replacement on the returns and breakeven prices

Parameters	D0	D1	D2
Final weight of fish	327	210	291
Survival	86.2	46.0	76.5
Yield (kg)	8,950	3,478	7,250
Unit cost/kg	3.00	3.00	3.00
Gross receipts	26,850	10,433	21,750
Variable costs			
Tilapia fingerling costs	2,480	2,480	2,480
Cost of feeds	11,436	2,604	3,287
Field labour	1,050	1,050	1,050
Cost of equipment	500	500	500
Electricity	420	420	420
Miscellaneous	500	500	500
Sub-total variable costs	16,386	7,554	8,237
Interest on operating cost	2,622	1,209	1,318
Total variable cost (TVC)	19,007	8,762	9,555
Fixed costs			
Cost of Constructing Cages	1200	1200	1200
Pond Amortization	800	800	800
Interest on fixed cost	120	120	120
Total fixed cost	2,120	2,120	2,120
Total cost (TC)	21,127	10,882	11,675
Net returns above TVC	7,843	1,670	12,195
Net returns above TC	5,723	-450	10,075
	0.81	3.81	0.52

4. Discussion

Previous studies have extensively investigated the use of alternative protein sources to substitute fishmeal in fish feed. However, a number of researchers have demonstrated the feasibility of using a variety of non-fishmeal based protein at varying levels to feed fish. In the present work with *O. niloticus*, the results demonstrated that rice bran and *C. nilotica* can effectively replace high quality fish meal with slight reduction in growth performance compared to fish meal diets but still comparable to other studies in terms of weight gain, survival and FCR. For example, other studies have established that *C. nilotica* can be used to replace fishmeal in the diet of Nile tilapia (Mugo-Bundi *et al*. 2015) [22] as well as useful in the early feeding stage of African catfish (*Clarias gariepinus*) (Chepkirui-Boit *et al*. 2011) [7]. The possible reason for the poor performance associated with the use of rice bran than the fishmeal-based control diet is the imbalance of nutrients, particularly protein composition. This may be related to a less adequate dietary amino acid profile when rice bran is used because this ingredient is considered deficient in lysine. However, Fasakin *et al*. (2006) [14] have found an improvement in the performance indices of *O. niloticus* with increasing levels of L-lysine supplementation in bran diets. There are a number of other causes for decreased growth rates and feed consumption observed, when feeding was done using rice bran. These investigators observed that diets containing animal protein sources, such as meat and bone meal, supported higher feed intake than those containing a similar level of brans. A second reason for decrease in feed utilization of rice bran is the lower digestibility of plant proteins as well as carbohydrates and the interaction of specific nutrient components during the course of digestion (Davies *et al*. 2011) [9]. It is therefore an attractive proposition to use high lysine rice bran instead of normal corn to reduce the need for other protein supplements (Wu *et al*. 1999) [29]. Due to the application of heat treatment and subsequent extraction of the carbohydrates, rice has relatively lower levels of anti-nutritional factors (ANFs) compared to other plant protein sources, such as soybean meal and in addition to the *C. nilotica* as a source of protein resulted in better growth performance. While the Anti-nutritional Factors (ANF) content of rice is at least partially responsible for the poor growth performance of tropical fish fed the rice bran test diets, it should not necessarily be interpreted as a primary reason for the suppression of growth. Fagbenro (1999) [12] has reported that the presence of anti-nutritional factors in winged beans did not pose a nutritional problem if the beans were adequately heat treated before inclusion in fish diets.

Growth trend curves in the present study differentiated at different sizes in *O. niloticus* during the growth trial periods suggesting that the different test diets had differential critical standing crops (the point at which growth declines for each individual). Diets containing rice bran incorporation on the feeds become less efficient in sustaining growth of *O. niloticus* compared to fish meal and diets containing both *C. nilotica* and rice brain. Earlier Diana *et al*. (1994) [10] has reported that in ponds receiving fertilization alone, the Critical Standing Crop (CSC) of *O. niloticus* occurred at individuals of mean weight 35 g. Later Liti *et al*. (2006) [20] has found that with supplementation of various feeds containing maize, wheat and rice brans, the CSC improved to 40 g. Presently, diets containing *C. nilotica* and rice bran feeds in the cages improved the CSC to 60 g. Higher CSC recorded in fish consuming fish meal diets and those combining rice bran and *C. nilotica* point to a higher intake efficiency due to combination of lower quantity of raw plant proteins in presence of animal protein sources. The efficiency in nutrient utilization between the feed treatments seemed to occur as a result of supplementation of energy generated due to combination of lower quantity of animal and plant protein sources.

The total investment, operational costs as well as profitability were affected by dietary treatments. Highest total fish yield and gross revenue was achieved in control diet accounted for by higher growth performance and better fish weight consuming the fish meal formulated diet. Also higher nutrient digestibility of the diets could explain the increased yields when fish were fed fish meal diets. However, diets formulated using a combination of rice bran and *C. nilotica* resulted in the best economic benefits because of the high cost of fish meal based diets that are currently more expensive to the farmers. The enterprise budget analysis of diets in this study indicates that the best economic benefits occurred when feeding fish with diets formulated using rice brain and *C. nilotica*. Nevertheless, it is economically feasible to culture *O. niloticus* based on diets formulated using rice bran and *C. nilotica* inclusion.

5. Conclusion

Formulating feeds using rice bran and *C. nilotica* in the diet of *O. niloticus* produces growth performance lower than those fed fish meal diets alone but clearly higher than those fed rice bran alone, but result in the best economic returns. This finding lends credence in the continued research on utilization of cheaper protein ingredients to replace fishmeal based feeds, which are increasingly becoming scarce and whose prices continue to skyrocket on daily basis. Since, rice is grown extensively by many farmers, fish farmers from such countries practice more intensification in the use of plant proteins to replace large proportion of the animal protein sources in the diets of the fish without affecting the fish performance. However, the inability to establish further growth improvements using rice bran meal, could signal the need for further research into pre-treatment and essential amino acid supplementation before feed formulation, which could open a new research frontier in ways of improving the quality of cheaper local ingredients before inclusion in the feeds.

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