Research Article

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Journal of Animal Research and Nutrition
ISSN 2572-5459

2015
Vol. 1 No. 1:2

DOI: 10.21767/2572-5459.100002

Evaluation of Locally-available Agro-industrial Byproducts as Partial Replacements to Fishmeal in Diets for Nile Tilapia (Oreochromis niloticus) Production in Ghana

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Citation: Obirikorang KA, Amisah S, Agbo NW, et al. Evaluation of locally-available agro-industrial byproducts as partial replacements to fishmeal in diets for Nile Tilapia (Oreochromis niloticus) production in Ghana. J Anim Res Nutr. 2015, 1:1.

Abstract

Objective: This study assessed the potential of three widely-available local oilseed byproducts, soybean (SBM), copra (CM) and palm kernel meals (PKM) as partial replacements of fishmeal in Nile tilapia (*O. niloticus*) diets in terms of their digestibility and effects on growth and nutrient utilization.

Methods: Apparent digestibility coefficients (ADCs) were determined using chromic oxide as an inert marker in test diets formulated to contain 30% of each of the test ingredients by weight and 70% of a fishmeal-based reference diet. The 8-week growth trial evaluated the effects of partial replacements of fishmeal by the oilseed byproducts at different dietary inclusions. The soybean meal diets were formulated with the soybean meal contributing 25% (SBM25) and 50% (SBM50) of total dietary protein. Copra and palm kernel meals each contributed 10 (CM10 and PKM10) and 20% (CM20 and PKM20) of total dietary protein in their respective diets. The test diets were compared to a control diet with fishmeal as the sole protein source.

Results: Nutrient digestibilities of the test ingredients were generally significantly higher for the soybean meal than the copra and palm kernel meals. The ADCs of the soybean, copra and palm kernel meals were; protein, 90.57%, 69.36% and 61.12; lipid, 96.14%, 95.64% and 95.85%; fibre, 96.74%, 77.61% and 55.07% and energy, 91.99%, 73.61% and 75.14% respectively. All the dietary treatment groups recorded significant growth at the end of the trials with the fish in the control and SBM25 groups more than tripling their respective mean initial weights. All the other treatment groups more than doubled their mean initial body weights. Daily growth rates ranged from 1.40% day^{-1} for the PKM20 group to 2.26% day^{-1} for the control group.

Conclusion: The study has shown that the test ingredients can partially replace fishmeal in Nile tilapia diets without considerably compromising diet digestibility and carcass traits although higher dietary levels of the oilseed byproducts negatively affects growth.

Keywords: Oilseed byproducts; Fishmeal replacement; Digestibility; Growth; *Oreochromis niloticus*; Ghana

Received: September 11, 2015, **Accepted:** November 12, 2015, **Published:** December 18, 2015

Introduction

The inability of Ghana's fish output from capture fisheries to meet national demand has placed aquaculture in a central position to make up for the supply deficit. Factors such as high cost of commercial pelletised feed have, however, hindered the growth of the aquaculture sector in Ghana, especially among the small and medium-scale operators. It is estimated that feed constitutes between 60 and 70% of the total cost of producing tilapia [1], and with the average price per kilogram of imported formulated feed in Ghana around US$2.00, the culture of fish solely on commercial fish feeds is not feasible. Most farmers in Ghana thus produce supplementary fish feeds at the farm level usually as one, or a mixture of two or more feed ingredients. According to the estimates of Attipoe et al. [2], approximately 90% of the fish farmers in Ghana rely on mixtures of agro-industrial by-products such as maize bran, wheat bran, rice bran, groundnut bran, copra cake, soybean and fish meal as fish feeds. These feeds are largely supplementary and unbalanced in essential nutrients usually results in poor fish growth and low productivity.

There is thus an urgent need to develop low-cost but nutritionally balanced diets that can support increased intensive and semi-intensive systems using locally available and low-cost plant resources. At the global level, alternative protein sources for fish culture have been studied intensively during the last few decades because of the declining availability and high cost of fish meal [3-5]. A large number of plant products have been evaluated as potential protein sources in the diets for fish including cottonseed meal, sunflower meal and corn meal [6], soybean meal, cassava leaf meal, sweet potato leaf meal, groundnut cake [7], pea, horsebean and rapeseed plant protein concentrates [8], Jatropha kernel meal [9], cowpea [10] and lupin meal [11]. Despite the abundance of a large number agro-industrial by-product in Ghana, their potential as cheap ingredients for fish feed formulation remains to be fully exploited. Boateng et al. [12] attributed this failure to the lack of information on chemical compositions and nutritive values, improvement methods of the nutritional profile and feeding responses of animals to these agro-industrial by-products. Some studies have, however, shown that substantial amounts of these low-cost and readily-available feed ingredients can be fed to Nile tilapia (*Oreochromis niloticus*) without negative impacts on growth and feed utilisation. According to Omoregie et al. [13] *O. niloticus* fingerlings can be fed up to 30% palm kernel meal-based diets. Feeding Nile tilapia fingerlings a diet containing up to 35% palm kernel meal for 120 days had no adverse effects on growth [14]. Similarly, Oliveira et al. [14,15] fed *O. niloticus* fingerlings a diet containing up to 35% palm kernel meal with no adverse effects on growth or apparent digestibility, and with no pathological effects on viscera or intestinal epithelium.

The high price of fishmeal in Ghana has created a situation which warrants a thorough evaluation and improved use of alternative protein sources, particularly the locally-available plant by-products in aquafeed formulations at farm and commercial levels to boost fish production especially in small-scale farms. This study thus evaluated the effects of the inclusion of three widely-available local agro-industrial byproducts, soybean, copra and palm kernel meals in diets for the Nile tilapia (*O. niloticus*) on digestibility, growth and nutrient utilization.

Materials and Methods

The soybean, copra and palm kernel meals used in this study were byproducts from the mechanical extraction of oil. Each ingredient was obtained as a single batch from an oil producing factory in Kumasi, Ghana. The test ingredients as well as all the other ingredients used in the formulation of the experimental diets were finely ground to obtain a homogeneous mixture and facilitate pelletising. The proximate composition of the test ingredients as well as the other major ingredient used in the diet formulations is presented in **Table 1** below.

Experiment I: Digestibility Trials

Experimental facilities

The digestibility experiment was conducted in an indoor flow-through system consisting of 20 rectangular transparent glass tank units, each with dimensions of 50 cm × 40 cm × 40 cm and a water-holding capacity of approximately 60 litres. The tanks are connected to a piping system that supplies water continuously through a 2-inch PVC pipe fitted overhead the experimental tanks. Water supply to the tanks was from a 1000-litre header tank through the common PVC inflow pipe. Water temperatures in the header tank and culture tanks ranged between 26 and 28°C during the study. Atmospheric air was supplied by a regenerative blower (Sweetwater S41) through air-supply valves fitted with tubes to each tank to maintain dissolved oxygen (DO) concentration of between 6.00 and 7.00 mgL^{-1} throughout the experiment. During the trials, pH ranged between 6.8 and 8.00. A light:dark regime of 12 h:12 h was maintained using artificial light from fluorescent tubes. All-male Nile tilapia (mean weight 25.0 ± 1.0 g) were used for the digestibility experiment at a stocking density of 20 individuals per tanks and acclimated for one week prior to the start of the experiment.

Diet formulation and preparation

The reference diet for the digestibility trial was formulated with the sole dietary protein source being fishmeal (aquaculture grade). The experimental diets were then prepared using 70% of the already formulated reference diet and 30% of each of the test ingredients (soybean, copra and palm kernel meals) as described by Cho et al. and Agbo [16,17]. Chromic oxide (Cr_2O_3) was used as an indigestible marker in the reference and test diets at a concentration of 0.5%.The diets were pelletized using an electric

Table 1 Proximate composition (gkg^{-1} as-fed) and energy ($kJ.g^{-1}$) of the feed ingredients used for the formulation of the different experimental diets.

Ingredients	DM	CP	CL	CF	Ash	Energy
Fishmeal	947.3	703.3	112.8	6.5	131.1	218.5
Soybean Meal	894	500.3	10.1	38.2	58.9	189.6
Palm Kernel Meal	912	178.1	132.4	184.1	33	192.6
Copra Meal	878.5	196.3	81	160	70.1	141.8
Wheat Bran	875.3	151.4	14.9	78.7	46.8	178.3
Rice Bran	912.1	86.9	11.5	162.9	110.8	156.2

DM: Dry Matter; CP: Crude Protein; CL: Crude Lipid, CF: Crude Fibre meat grinder (Sanyo MG-5000K) fitted with a 2 mm die plate and dried in a hot box oven with fan (Gallenkamp CHF097) at 40°C until sufficiently dried. The oven-dried test diets were analysed for their respective proximate compositions as well as their energy contents (**Table 2**).

Feeding and faecal matter collection

The reference and test diets were administered twice daily at 9:00 h and 16:00 h to their respective tanks. Each feed type was randomly assigned to 3 tanks and fish were fed with fixed rations (5% body weight) each day during the experimental period. Faeces were collected from each tank prior to each feeding event each day by slowly siphoning with flexible rubber tubings with an inside diameter of 0.45 cm into centrifuge tubes. The collected faeces were immediately centrifuged at 3500 rpm (Hettich Universal 16A) for 5 minutes and the supernatant discarded. The wet settled solid faeces were then emptied into labeled plastic bottles and stored at -20°C to retard bacterial decomposition. Faecal collection was continued until it was judged that sufficient sample had been collected for chemical analysis. The collected faecal samples were then later defrosted and oven dried at 60°C, ground and analysed for their proximate composition and gross energy (GE). The apparent digestibilities of the formulated feeds and test ingredients were then determined by comparing the quantity of each nutrient consumed with that left in faeces at the end of the digestive process.

Calculations of the ADCs of the diets and test ingredients

The apparent digestibility coefficients of the nutrients and energy of the test and reference diets were calculated as follows

$$ADC_{nutrient} = 100 \text{ X} \left[1 - \left(\frac{F}{D}\right) \text{X} \left(\frac{Di}{Fi}\right)\right] \quad [18,19]:$$

Table 2 Diet formulation (g.kg^{-1} as fed) and proximate composition (g.kg^{-1} dry weight basis) of reference and test diets used for the digestibility trial.

	Test Diets			
	Reference Diet	SBM Diet	CM Diet	PKM Diet
Ingredients				
Fishmeal	425	297.5	297.5	297.5
Soybean Meal	-	300	-	-
Copra Meal	-	-	300	-
Palm Kernel Cake Meal	-	-	-	300
Wheat Bran	385	268	268	268
Palm Oil	90	63	63	63
Vitamin Premix	40	28	28	28
Diphosphate	30	21	21	21
Cassava Flour	25	17.5	17.5	17.5
Chromic Oxide	5	5	5	5
Proximate composition				
Dry Matter	925.4	935.65	926.3	927.37
Crude Protein	322	348.7	284.37	272.56
Crude Lipid	103.34	96.75	115.63	139.44
Crude Fiber	33.67	46.65	94.68	117
Ash	108.45	82.19	91.23	88.67
Gross Energy (kJg^{-1})	18.1	18.16	18.97	20.23
Chromic Oxide	5.01	4.95	4.93	4.98

Where D=% nutrient of diet; F=% nutrient of faeces; Di=% Cr_2O_3 of diet; Fi=%Cr_2O_3 of faeces.

The apparent digestibility coefficients of the nutrients in the test ingredients were then calculated as follows:

$$ADC_{ingredient} = ADC_{testdiet} + \left[\left(ADC_{testdiet} - ADC_{refdiet}\right)\left(\frac{0.7xD_{ref}}{0.3xD_{ingr}}\right)\right] \quad [18]$$

Where D_{ref} = % nutrient (or kJg^{-1} gross energy) of reference diet (as fed); D_{ingr} = % nutrient (or kJg^{-1} gross energy) of test ingredient (as fed).

Experiment II: Growth Trial

Culture system and experimental species

The 56-day growth trials were conducted in hapas (1 × 1 × 1.5 m) set in an earthen pond at the fish production facility of the Faculty of Renewable Natural Resources (FRNR), Kwame Nkrumah University of Science and Technology in Ghana. This was to test the alternative feed ingredients under conditions that simulate commercial Ghanaian fish culture practices as closely as possible. The hapas were constructed using nylon mosquito netting with mesh openings of about 1.5 × 1.5 mm. The dietary treatments for each of the test ingredients were randomly assigned in triplicates to the hapas. Each hapa contained 20 homogeneous all-male Nile tilapia fingerlings with mean initial body weight of approximately 25 g. The fish were obtained from a commercial hatchery near Kumasi, Ghana for the growth trials and were acclimated for one week prior to the start of the experiment. During the acclimation period, fish were all fed a control diet containing none of the test ingredients.

Experimental diets

A control diet was formulated with fishmeal (aquaculture grade) as the sole source of protein and this was replaced at the different inclusion levels with soybean, copra and palm kernel meals. Milled wheat and rice bran served as the carbohydrate source. The diet containing soybean meal was formulated with the soybean meal contributing 25% (SBM25) and 50% (SBM50) of total dietary protein. Copra and palm kernel meals each contributed 10 (CM10 and PKM10) and 20% (CM20 and PKM20) of total dietary protein in their respective diets. In all, 7 isonitrogenous (320 g.kg-1 protein, crude protein), isolipidic (150 g.kg-1 lipid) and isoenergetic (18 KJ.g-1) diets were formulated for the experiment. These levels were based on requirements for Nile tilapia juveniles [17,20,21]. Proportions of all the ingredients used in the formulation of the different diets were computed and balanced using an Excel-Visual Basic Ration Formulator Spreadsheet. All ingredients used in the feed formulation were finely ground and sieved in order to obtain a homogenous mixture. Feeds were produced by thoroughly mixing all the dry ingredients together in a bowl, before adding water until a dough-like consistency was obtained. Each experimental diet was pelletized and dried the same way as the diets for the digestibility trial. The formulations and proximate compositions of the experimental diets are presented in **Table 3**.

Feeding and sampling

During the trial all groups of fish were hand-fed at the same fixed rate (5% of total bulk weight), twice daily at 9:00 and 16:00 h. Data on weight gains were recorded every week and feeding rates were accordingly adjusted to compensate for growth. All fish were individually weighed at the beginning of the trial to ensure uniformity in the initial weights. For all the other weekly weight measurements, fish were bulked together, weighed to the nearest 0.01 g on an electronic top pan balance. Ten individuals from the initial fish stock and 5 from each of the hapas at the end of the trial were randomly sampled and stored at −20°C for subsequent whole-carcass proximate composition and calculations of hepatosomatic indices. Due to the practical limitations in conducting this trial in an earthen pond, it was not possible to ensure that all the fed experimental diets were ingested or to collect uneaten feed from the experimental hapas. Thus for all calculations dependent on feed intake such as the food conversion and protein efficiency ratios, the amount of feed fed instead of the exact feed consumed/intake was used without adjustments being made for any wastages.

Calculations

Growth and feed utilization parameters were calculated for the duration of the trial using the following equations:

Specific growth rate: $SGR = \frac{(\text{InW1} - \text{InWo})}{\text{Trial duration}} x100$

Weight gain: $WG = \frac{(W1 - Wo)}{Wo} x100$

Feed conversion ratio: $FCR = \frac{(W1 - Wo)}{\text{Feed fed}} x100$

Where W_o and W_1 are the initial and final body weights respectively

Protein efficiency ratio: $PER = \frac{\text{Weight gain}_{(g)}}{\text{crude protein fed}_{(g)}}$

Hepatosomatic index: $HSI = \frac{\text{liverweight}}{\text{bodyweight}} x100$

Survival rate: $\text{Survival}(\%) = \frac{\text{Final number of fish}}{\text{Initial number of fish}} x100$

Chemical Analysis

Dry matter, crude protein, crude lipid, ash and fibre, gross energy contents of all the ingredients, diets, faeces and carcasses were determined following the procedures of the Association of Official Agricultural Chemists [22]. Dry matter was determined by the weight loss after a 24-hour drying at 105°C in an oven (Gallenkamp CHF097). The ash content was calculated from the weight loss after incineration of the samples for 6 hours at 550°C in a muffle furnace (Stuart Scientific S1203). The micro-Kjeldahl method (Gerhardt kjeldatherm system) was used for the determination of crude protein whiles crude lipid extraction and determination was done by solvent extraction using Soxhlet extraction. Crude fiber was determined using acid-base hydrolysis. The energy contents were determined using an Adiabatic Autobomb Calorimeter (Parr 6100) with benzoic acid as standard. Chromic oxide content of the test and reference diets as well as the faeces were determined by spectrophotometric methods (Spectronic 21). The differences in the ratios of the parameters of proximate composition and gross energy relative to chromic oxide in the feed and faeces in each treatment were calculated to determine the apparent digestibility.

Table 3 Composition and proportions of reference diet and the different inclusion levels of the three test ingredients (g.kg^{-1} as-fed) used in growth experiment and their proximate compositions (g.kg^{-1} as-fed) and energies (kJ.g^{-1}).

	Control	SBM25	SBM50	PKM10	PKM20	CM10	CM20
Ingredients							
	-	141	283	-	-	-	-
PKM	-	-	-	180	360		
CM	-	-	-	-	-	143	287
FM	400	300	202	355	334	370	340
WB	110	175	240	156	90	130	95
RB	350	244	135	169	76	217	138
CF	20	20	20	20	20	20	20
PO	50	50	50	50	50	50	50
VP	40	40	40	40	40	40	40
DP	20	20	20	20	20	20	20
Salt	10	10	10	10	10	10	10
Proximate Composition							
Dry Matter	910	920.7	920.8	930.2	930.1	930.4	930.4
Crude Protein	324.6	326.4	328.1	320.3	319.5	322	317.1
Crude Lipid	144.6	146.2	148.1	146.2	151.5	149.1	145.4
Crude Fibre	69.8	61.3	52.1	72.4	79.6	59	53.8
	97.5	83.4	68.9	79.7	69.5	89.8	85.6
Gross Energy	18.44	18.66	19.01	18.9	18.3	18.4	18.23

SBM: Soybean meal, PKM: Palm kernel meal, CM: Copra meal, FM: Fish meal, WB: Wheat bran, RB: Rice bran, CF: Cassava flour (binder), PO: Palm oil, VP: Vitamin premix, DP: Diphosphate

Statistical Analysis

Data from the trials were expressed as mean ± standard deviation in tables. The data was subjected to one-way ANOVA to test for differences among dietary treatments and Tukey's Multiple Comparison Test was further applied to evaluate differences between individual means. In all cases, differences were considered significant at p<0.05. All data were first tested for normality using the Kolmogorov-Smirnov test [23]. The descriptive statistics were executed using the GraphPad Prism (Version 5) statistical software.

Results

Diets digestibility

The apparent digestibility coefficients of dry matter, crude protein, crude lipid, crude fibre and gross energy of the diets are shown in **Table 4** below. The dry matter digestibility of the test diet containing the SBM (71.94%) did not vary significantly (p>0.05) from that of the reference diet (72.75%). The dry matter digestibility of the diets containing CM and PKM on the other hand were 65.99% and 65.31% respectively and varied significantly (p<0.05) from the dry matter digestibility of the reference and SBM diets. The crude protein digestibility of the reference and test diets were generally high ranging from 89.67% (PKM) to 96.48% (reference diet). There were, however, significant differences (p<0.05) in the crude protein digestibilities among all the diets, except between CM and PKM diets. No significant differences (p>0.05) were found in the lipid digestibility of the diets. There were reduced crude fibre digestibility of the diets containing CM (82.72%) and PKM (74.46%) compared to the reference diet (96.49%) and the diet containing SBM (96.55%). Trends in gross energy digestibility of the diets were similar to the crude protein digestibility with the reference and PKM diets recording the highest and lowest gross energy digestibilities of 95.50% and 89.14% respectively.

Test ingredient digestibilities

The apparent digestibility coefficients of dry matter, crude protein, crude lipid, crude fibre and gross energy of the test ingredients are shown in **Table 4** below. Generally, nutrient and energy digestibilities were highest in the SBM and there were significant differences (p<0.05) among all three ingredients with the exception of crude lipid digestibility. There were significant variations (p<0.05) among all three test ingredients in terms of dry matter digestibility with SBM recording the highest of 69.97% and PKC recording the lowest of 39.89%. The protein digestibilities of CM (69.35%) and PKC (61.12%) were relatively lower than that of SBM (90.57%) and there were significant differences (p<0.05) among all the test ingredients. Similar to the diets, there were no significant differences (p>0.05) in lipid digestibilities among the 3 test ingredients. Crude fibre digestibility was significantly different among the three test ingredients with PKC recording the lowest digestibility of 55.07% and SBM recording the highest of 96.74%. The crude fibre digestibility of CM was 73.61%. Gross energy digestibilities were similar for CM (73.61%) and PKM (75.14%) but significantly different (p<0.05) from SBM (91.99%).

Growth and feed utilisation

Table 5 details the growth and feed utilisation parameters of the fish groups fed the different experimental diets. Although all the dietary treatments resulted in appreciable fish growth at the end of the trial, the inclusions of the oilseed byproducts as protein sources in the tilapia diets significantly reduced fish growth and feed utilization and efficiency compared to the control diet. Feed intake was also significantly reduced in the fish groups fed the oilseed meal diets compared to the control diet group. At the end of the 8-week period, the control group and the SBM25 groups more than tripled in their respective initial weights. All the other treatment groups recorded mean final weights which were more than double their mean initial body weights. The final mean body weight of the control group (88.60 g) was significantly

Table 4 Apparent digestibility coefficients of the diets and test ingredients and digestible protein and energy (dry weight basis) in the test ingredients for *Oreochromis niloticus*

	Reference	SBM	CM	PKM
Diet Digestibility				
Dry Matter (%)	72.75 ± 0.08^a	71.94 ± 0.33^a	65.99 ± 0.44^c	65.31 ± 0.26^c
Crude Protein (%)	96.48 ± 0.14^a	94.10 ± 0.10^b	90.78 ± 1.45^c	89.67 ± 0.32^c
Crude Lipid (%)	96.58 ± 0.16	96.45 ± 0.16	95.83 ± 1.20	95.60 ± 1.12
Crude Fibre (%)	96.49 ± 0.47^a	96.55 ± 0.17^a	82.72 ± 1.10^b	74.46 ± 1.72^c
Gross Energy (%)	95.50 ± 0.15^a	92.42 ± 0.22^b	90.01 ± 1.19^c	89.14 ± 1.28^c
Ingredient Digestibility				
Dry Matter (%)	-	69.97 ± 1.34^a	49.71 ± 0.33^b	39.89 ± 0.16^c
Crude Protein (%)	-	90.57 ± 1.06^a	69.35 ± 0.34^b	61.12 ± 0.21^c
Crude Lipid (%)	-	96.14 ± 0.16	95.64 ± 1.15	93.85 ± 1.52
Crude Fibre (%)	-	96.74 ± 0.23^a	77.06 ± 1.10^b	55.07 ± 0.53^c
Gross Energy (%)	-	91.99 ± 1.02^a	73.61 ± 1.12^b	75.14 ± 1.37^b
Digestible Nutrients				
Crude Protein (gkg^{-1})	-	315.81		166.25
Gross Energy (kJg^{-1})	-	16.71		15.2

SBM: Soybean meal, CM: Copra meal, PKM: Palm kernel meal, Means within each row not sharing a common superscript are significantly different (p<0.05). Each value is the mean ± SD of data from triplicate groups

Table 5 Growth and feed utilization of Oreochromis niloticus fingerlings fed different inclusion levels of soybean meal (SBM), palm kernel cake (PKM) and copra meal diets over a 56-day period.

	Diets						
	Control	SBM25	SBM50	PKM10	PKM20	CM10	CM20
Parameters							
IBW	25.93 ± 0.38	25.50 ± 0.36	25.47 ± 0.32	25.50 ± 0.10	25.43 ± 0.12	25.00 ± 0.36	25.07 ± 0.32
FBW	88.60 ± 1.15^{a}	82.60 ± 0.36^{b}	70.60 ± 0.53^{c}	68.07 ± 0.55^{d}	55.87 ± 0.55^{e}	75.93 ± 0.38^{f}	58.30 ± 0.45^{g}
WG	255.44 ± 6.93^{a}	224.23 ± 4.46^{b}	176.56 ± 1.40^{c}	166.93 ± 1.92^{c}	119.67 ± 3.06^{e}	206.04 ± 6.23^{g}	132.59 ± 1.74^{d}
SGR	2.26 ± 0.03^{a}	2.00 ± 0.25^{b}	1.82 ± 0.01^{c}	1.76 ± 0.20^{c}	1.40 ± 0.03^{d}	1.98 ± 0.02^{c}	1.50 ± 0.02^{e}
SR	100.00 ± 0.00	93.33 ± 5.77	90.00 ± 0.00	86.87 ± 5.77	93.33 ± 5.77	93.33 ± 5.77	93.33 ± 5.77
FCR	2.74 ± 0.05^{a}	2.88 ± 0.03^{ab}	3.28 ± 0.07^{c}	3.45 ± 0.02^{d}	4.18 ± 0.05^{e}	2.97 ± 0.01^{b}	3.81 ± 0.01^{f}
FI	174.36 ± 0.64^{a}	164.25 ± 1.01^{b}	144.85 ± 2.25^{c}	147.13 ± 2.16^{ce}	127.20 ± 1.38^{f}	150.60 ± 0.61^{e}	126.37 ± 0.57^{f}
PER	1.14 ± 0.02^{a}	1.09 ± 0.01^{ab}	0.97 ± 0.02^{c}	0.83 ± 0.01^{d}	0.68 ± 0.01^{e}	1.03 ± 0.06^{bc}	0.82 ± 0.00^{d}
HSI	1.00 ± 0.09	0.98 ± 0.19	0.97 ± 0.13	0.99 ± 0.08	1.03 ± 0.04	1.01.09	0.94 ± 0.06

IBW (g): Initial body weight, FBW (g): Final body weight, WG (%): Weight gain, SGR (%.day^{-1}): Specific growth rate, SR: Survival rate (%), FCR: Feed conversion ratio, FI (g dry diet fish^{-1} 56 days^{-1}): Feed intake, PER: Protein efficiency ratio.
Each value is the mean ± SD of data from triplicate groups. Within a row, means with the same letters are not significantly different (P>0.05).
Absence of letters indicates no significant difference between all the treatments.

higher (p<0.05) than the final mean body weights of all the other dietary treatment groups. The PKM20 diet resulted in the lowest mean final body weight of 55.87 g. Daily growth rates were appreciable for all the treatment groups and ranged from 1.40% day^{-1} for the PKM20 group to 2.26% day^{-1} for the control group. Protein efficiency ratio was also significantly affected by the inclusion of the plant protein ingredients in the diets. Protein efficiency was lowest for the PKM20-based diet and highest for the control diet. General feed efficiency (FCR) was also significantly affected (p<0.05) by the different diets and ranged from 2.74 to 4.18 for the control and PKM20 diets respectively. Hepatosomatic indices were, however, not significantly affected (p>0.05) by the addition of the plant protein sources to the diets or the varying inclusion levels. In terms of feed cost, a comparison was made between the control and SBM25 since it was the plant-based diets that induced growth performance similar to the fishmeal-based control diet. The addition of soybean meal at 25% inclusion rates reduced the cost of that experimental diet by 20%.

Whole body proximate composition

The whole body proximate compositions of the fish groups fed the different dietary treatments are outlined in **Table 6**. With the exception of crude lipid, the whole body proximate composition (expressed on a wet weight basis) were not significantly affected (p>0.05) by additions of the different plant protein ingredients or their inclusion levels. There was a significant effect of the dietary manipulations with the test ingredients on the lipid contents of the fish flesh at the end of the growth trials despite the isolipidic nature of the experimental diets. Lipid retention in the tissues of the fish fed the control and soy-based diets were significantly lower (p<0.05) than that of the fish fed the copra and palm kernel diets at the end of the trial.

Discussion

The additions of copra and palm kernel meals significantly reduced nutrient dry matter, protein, fibre and energy digestibilities of their respective diets mainly due to their high crude fibre contents. Fibre is usually indigestible to most cichlids mainly because they do not possess the required enzymes for fibre digestion. Anderson et al. [24] recommended that for maximum fish growth, crude fiber levels in tilapia diets should not exceed 5%. The copra and palm kernel meal diets used for the digestibility trials had fibre contents of 9.5 and 11.7% respectively compared to 3.4% for the control diet and 4.7% for the soybean meal diet. The fibre of copra is high in the polymer mannan, which has a low digestibility and often has a laxative effect in animals and increases the rates of gastrointestinal transit of ingested feeds [21]. The presence of a high level of non-starch polysaccharides (NSPs) in palm kernel meal impairs the digestibility and utilization of nutrients present in them either by direct encapsulation of the nutrients or by increasing the viscosity of the intestinal content, thereby reducing the rate of hydrolysis and absorption of nutrients [25]. The ADCs of protein (90.57%), lipid (96.14%), fibre (96.74%) and energy (95.50%) recorded for soybean meal in this study compared fairly favourably to the protein (87.40%), lipid (92.10%), fibre (95.20%) and energy (83.70%) ADCs of soybean meal in *O. niloticus* reported by Köprücü and Özdemir [26]. Agbo [17] also recorded fairly similar nutrients and energy ADCs for soybean meal (dry matter: 77.47%; protein: 94.50%; lipid: 96.84% and energy: 85.99%) for Nile tilapia juveniles. The high protein digestibility of soy recorded in this study is supported by the findings of other works on soy digestibility by the Nile tilapia which include 92.72% [27], 91.56% [28], 89.28% [29] and 94.50% [17]. The dry matter digestibility for soybean for this study also compares favourably to the dry matter ADC of 71.04% reported by Pezzato et al. [28]. Boscolo et al. [30] observed that the addition of PKM in the diets of red tilapia resulted in significantly lower dry matter, protein, and lipid digestibilities, similar to what was found in this study. They recorded dry matter, protein and lipid ADCs of 30.3, 80.1 and 87.1% respectively. The digestible energy of 13.96 kJg^{-1} for copra in this study compares favourably with the digestible energy (14.8 kJg^{-1}) reported by Ng and Chong [31] for *O. niloticus*.

Table 6 The whole body proximate composition (% wet weight) and energy of the Nile tilapia (n=3) used for the growth experiment.

Parameters	Initial	Control	SBM25	SBM50	PKM10	PKM20	CM10	CM20
MC	77.01 ± 0.31	76.21 ± 0.29	76.30 ± 0.83	76.45 ± 0.57	75.24 ± 0.58	76.25 ± 0.88	76.05 ± 0.45	76.26 ± 0.96
CP	21.34 ± 0.24	23.15 ± 0.91	22.56 ± 0.46	22.84 ± 0.91	22.56 ± 0.51	22.63 ± 0.45	22.58 ± 0.44	22.72 ± 0.45
CL	4.25 ± 0.16	4.36 ± 0.17[a]	4.43 ± 0.21[a]	4.66 ± 0.34[a]	6.47 ± 0.32[b]	6.69 ± 0.27[b]	6.28 ± 0.14[b]	6.16 ± 0.16[b]
Ash	2.69 ± 0.23	2.57 ± 0.20	2.40 ± 0.11	2.53 ± 0.20	2.47 ± 0.08	2.45 ± 0.05	2.50 ± 0.04	2.62 ± 0.03
GE	6.01 ± 0.06	6.57 ± 0.08	6.41 ± 0.05	6.28 ± 0.11	6.36 ± 0.08	6.31 ± 0.03	6.31 ± 0.03	6.40 ± 0.09

MC: moisture content, CP: crude protein, CL: crude lipid, GE: gross energy. Values within the same row with the same superscripts are not significantly different (P>0.05). Absence of letters indicates no significant difference between all the treatments.

Growth and feed efficiency over the trial period were negatively affected by the addition of the plant ingredients to the diets particularly copra and palm kernel meals. The observed positive relationship between growth depression and increasing dietary inclusion levels of the oilseed byproducts found in this study is consistent with other studies on the inclusions of various oilseed meals in fish diets [17,32-34]. Properties of copra meal that have been reported to affect fish growth are the high fibre contents [35] and the presence of a number of antinutritional factors [36]. Although this study did not identify and quantify the levels of antinutritional factors in the test ingredients it is highly likely they contained substantial levels which depressed fish growth. Condensed tannins present in copra meal at a level of approximately 2.4% have been reported as possibly causing growth depression in tilapia (*Sarotherodon mossambicus*) and rohu (*Labeo rohita*) fingerlings at inclusion levels of 20 and 25% respectively [32,36]. Soaking defatted CM in water can significantly reduce tannin levels and increase feed intake responses of fish. The copra meal as well as all the other test ingredients used in this study were not soaked in water or heat-treated prior to their inclusion in the diets used for the digestibility and growth trials. Treating these test ingredients could have improved their nutritional values and reduced the levels of antinutritional factors as have been reported in some nutritional studies. Mukhopadhyay and Ray [36], for example observed reductions in tannin levels from 2.4 to 0.9% after soaking copra meal in water for 16 hours and fish fed diets containing the pre-soaked copra meal compared favourably with the fishmeal-based control group in terms of growth response, food conversion ratio and protein efficiency ratio. The nutritional potential of soybean meal has also been reported to increase after appropriate treatment to remove or inactivate the antinutritional factors present in them [37,38]. Similar to the findings of Rumsey et al. and Krogdahl et al. [39,40] it was observed at the end of the growth trials that fish fed diets high in SBM generally exhibit progressive impairment of growth and increased feed conversion ratios.

Despite the isonitrogeneous nature of all the diets used in the growth trial, a critical factor which could have affected fish growth is the reduction in protein quality with increasing inclusion levels of the test ingredients. The protein quality of copra meal is poor both in terms of its amino acid balance and digestibility [41]. It is deficient in important essential amino acids such as lysine, methionine, threonine and histidine but high in arginine, which is known to have antagonistic effect on lysine utilization [41]. Soybean meal although has one of the best amino acid profiles as far as plant aquafeed ingredients are concerned are usually deficient in methionine. All the diets used in the digestibility and growth trials were not supplemented with their respective deficient amino acids. Deficiencies in the essential amino acids profile of a feed can lead to poor utilization of the dietary protein and consequently reduces growth and decreases feed efficiency [42]. The positive effects of amino acid-supplementation of plant-based diets have been highlighted by some studies. The amino acid composition of diets is generally considered to affect the efficiency of protein utilization. Mukhopadhyay [43], for example reported that fish fingerlings can effectively utilise copra meal supplemented with the inherent lacking amino acids up to 50% replacement of fishmeal protein without significantly reducing growth if the meal is properly fermented. Aside the possible presence of ANFs and the poor amino acid profiles, the low nutrient digestibilities particularly of copra and palm kernel meal is a major factor that might have resulted in the lower fish growth rates and nutrient utilizations in the growth trials. There was a link between the nutrient ADCs of the test ingredients and the growth rates and feed utilisations recorded for their respective diets.

Conclusion

Although the inclusion of the oilseed byproducts in the *O. niloticus* diets resulted in significant differences in terms of growth and feed utilization and efficiency compared to the control diet, all the dietary treatment groups more than doubled their mean initial body weights over the 8-week period and recorded appreciable growth rates of between 1.40 and 2.00 %.day^{-1}. The study has also shown that the test ingredients can partially replace fishmeal in Nile tilapia diets without considerably compromising diet digestibility and carcass traits. High inclusions of copra and palm kernel meals can, however, have a deleterious effect on general fish growth because of their high fibre contents and low dry matter and fibre digestibilities. In other to get full acceptance into the Ghanaian aquaculture sector as low-cost aquafeed ingredients it might be necessary to treat these by-products to reduce their levels of crude fibre and anti-nutritional factors. Natural and/or chemical supplementation of their respective deficient amino acids can also enhance their effects on fish growth.

Acknowledgement

The first author is grateful for the Danish International Development Agency (DANIDA)-sponsored PhD fellowship at the Section for Aquaculture of the Technical University of Denmark (DTU) at the North Sea Research Centre in Hirtshals, Denmark.

References

1 ADB (Asian Development Bank) (2005) An evaluation of small-scale freshwater rural aquaculture development for poverty reduction. Asian Development Bank Publication.

2 Attipoe FYK, Agyakwah SK (2008) Status of catfish farming and research in Ghana. In: Ponzoni RW and Nguyen NH (eds). Proceedings of a Workshop on the Development of a Genetic Improvement Program for African catfish Clarias gariepinus. WorldFish Center Conference Proceedings Number 1889. The WorldFish Center, Penang, Malaysia. pp. 23-32.

3 Naylor RL, Hardy RW, Bureau DP, Chiu A, Elliott M, et al. (2009) Feeding aquaculture in an era of finite resources. Proceedings of the National Academy of Sciences 106: 15103–15110.

4 FAO (2010) Regional Review on Status and Trends in Aquaculture Development in Asia-Pacific −2010.FAO, Rome, Italy.

5 Hardy RW (2010) Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal. Aquaculture Research 41: 770–776.

6 Köprücu K Sertel E (2011) The effects of less-expensive plant protein sources replaced with soybean meal in the juvenile diet of grass carp (Ctenopharyngodon idella): growth, nutrient utilization and body composition. Aquaculture International 20: 399–412.

7 Da CT, Lundh T, Lindberg JE (2012) Evaluation of local feed resources as alternatives to fish meal in terms of growth performance, feed utilisation and biological indices of striped catfish (Pangasianodon hypophthalmus) fingerlings. Aquaculture 364–365: 150–156.

8 Lund I, Dalsgaard J, Rasmussen HT, Holm J, Jokumsen A (2011) Replacement of fish meal with a matrix of organic plant proteins in organic trout (Oncorhynchus mykiss) feed, and the effects on nutrient utilization and fish performance. Aquaculture 321: 259–266.

9 Harter T, Buhrke F, Kumar V, Focken U, Makkar HPS, et al. (2011) Substitution of fish meal by Jatropha curcas kernel meal: Effects on growth performance and body composition of white leg shrimp (Litopenaeusvannamei). Aquaculture Nutrition 17: 542–548.

10 Olivera-Castillo L, Pino-Aguilar M, Lara-Flores M, Granados-Puerto S, Montero-Muñoz J, et al. (2011)Substitution of fish meal with raw or treated cowpea (Vigna unguiculata L Walp, IT86-D719) meal in diets for Nile tilapia (Oreochromis niloticus L.) fry. Aquaculture Nutrition 17: 101-111.

11 Tabrett S, Blyth D, Bourne N, Glencross B (2012) Digestibility of Lupinus albus lupin meals in barramundi (Lates calcarifer) Aquaculture 364–365: 1–5.

12 Boateng M, Okai DB, Baah J, Donkoh A (2008) Palm kernel cake extraction and utilisation in pig and poultry diets in Ghana. Livestock Research for Rural Development 20: 7.

13 Omoregie E, Ogbemudia FI (1993) Effects of substituting fish meal with palm kernel meal on growth and food utilization of the Nile tilapia, Oreochromis niloticus. Israeli Journal of Aquaculture-Bamidgeh 453: 113-119.

14 Oliveira ACB de, Pezzato LE, Barros MM, Pezzato AC, Silveira AC, et al. (1997) African palm kernel meal on Nile tilapia production performance. Pesquisa Agropecuária Brasileira 324: 443-449.

15 Oliveira ACB de, Pezzato LE, Barros MM, Graner CAF (1998) Apparent digestibility and macro-microscopic effect on Nile tilapia (Oreochromis niloticus) fed palm kernel meal. Revista Brasileira de Zootecnia 272: 210-215.

16 Cho CY, Cowey CB, Watanabe T (1985) Finfish Nutrition in Asia. Methodological approaches to research and development. Ottawa: International Development Research Centre.

17 Agbo NW (2008) Oilseed meals as dietary protein sources for Juvenile Nile tilapia Oreochromis niloticus. PhD Thesis. University of Stirling, Stirling, UK.

18 Bureau DP, Harris AM, Cho CY (1999) Apparent digestibility of rendered animal protein ingredients for rainbow trout (Oncorhynchusmykiss). Aquaculture 180 3-4: 345-358.

19 Forster I (1999) A note on the method of calculating digestibility coefficients of nutrients provided by single ingredients to feeds of aquatic animals. Aquaculture Nutrition 52: 143-145.

20 Jauncey K, Ross B (1982) A Guide to Tilapia Feeds and Feeding. Stirling (UK): Institute of Aquaculture, University of Stirling.

21 NRC (1993) Nutrient Requirements of Fish.National Research Council. Washington D.C.: National Academy Press

22 AOAC (2006) Official Methods of Analysis of AOAC International. AOAC International, Maryland, USA.

23 Zar J.H (1984) Biostatistical analysis. 2 edn, Englewood Cliffs, New Jersey: Prentice-Hall, Inc. 1994.

24 Anderson J, Jackson AJ, Matty AJ, Capper BS (1984) Effects of dietary carbohydrate and fibre on the tilapia Oreochromis niloticus (linn). Aquaculture 37: 303–314.

25 Dusterhoft EM, Voragen GJ, Engels FM (1991) Non-starch polysaccharides from sunflower (Helianthus annuus) meal and palm kernel (Elaeis guineensis) meal-preparation of cell wall material and extraction of polysaccharide fractions. Journal of the Science of Food and Agriculture 55: 411- 422.

26 Köprücü K, Özdemir Y (2005) Apparent digestibility of selected feed ingredients for Nile tilapia (Oreochromis niloticus). Aquaculture 250: 308-316.

27 Furuya WM, Pezzato LE, Pezzato AC, Barros MM, Miranda ECD, et al. (2001) Coeficientes de digestibilidade e valores de aminoácidos digestíveis de alguns ingredientes para tilápia do Nilo (Oreochromis niloticus). Revista Brasileira de Zootecnia 30: 1143-1149.

28 Pezzato LE, Miranda ECD, Barros MM, Pinto LGQ, Furuya WM, et al. (2002) Digestibilidade aparente de ingredientes pela tilápia do Nilo (Oreochromis niloticus). Revista Brasileira de Zootecnia 31(4): 1595-1604.

29 Boscolo W.R, Hayashi C and Meurer F (2002) Digestibilidade aparente da energia e nutrientes de alimentos convencionais e alternativos para a tilápia do Nilo (Oreochromis niloticus, L.). Revista Brasileira de Zootecnia 31: 539-545.

30 Ng WK, Chong KK (2002) The nutritive value of palm kernel meal and the effect of enzyme supplementation in practical diets for red hybrid tilapia (Oreochromis sp.). Asian Fisheries Science 15: 167-176.

31 Pezzato LE, Miranda EC, Barros MM, Pinto LGQ, Pezzato A, et al. (2000) Valor nutritivo do farelo de coco para a tilápia-do-nilo (Oreochromis niloticus). Acta Scientiarum, Maringá 22: 695-699.

32 Jackson AJ, Capper B, Matty A.J (1982) Evaluation of some plant proteins in complete diets for the tilapia Sarotherodon mossambicus. Aquaculture 27: 97-109.

33 Hasan MR, Macintosh DJ, Jauncey K (1997) Evaluation of some plant ingredients as dietary protein sources for common carp (Cyprinus carpio L.) fry. Aquaculture 151: 55-70.

34 Iluyemi FB, Hanafi MM, Radziah O, Kamarudin MS (2010) Nutritional evaluation of fermented palm kernel cake using red tilapia. African Journal of Biotechnology 9: 502-507.

35 Sundu B, Kumar A, Dingle J (2009) Feeding value of copra meal for broilers. World Poultry Science Journal 65: 481-491.

36 Mukhopadhyay N, Ray A (1999) Utilization of copra meal in the formulation of compound diets for rohu Labeo rohita fingerlings. Journal of Applied Ichthyology 15: 127-131.

37 Viola S, Mokady S, Arieli Y (1983) Effects of soybean processing methods on the growth of carp (Cyprinus carpio). Aquaculture 32: 27-38.

38 van der Ingh TSGAM, Krogdahl A, Olli JJ, Hendriks HGCJM, Koninkx JFJG, et al. (1991) Effects of soybean-containing diets on the proximal and distal intestine in Atlantic salmon (Salmo salar) a morphological study. Aquaculture 94: 297–305.

39 Rumsey GL, Hughes SG, Winfree RA (1993) Chemical and nutritional evaluation of soy protein preparations as primary nitrogen sources of rainbow trout (Oncorhynchus mykiss). Animal Feed Science and Technology 40: 135–151.

40 Krogdahl A, Bakke-McKellup AM, Baeverfjord G (2003) Effects of graded levels of standard soybean meal on intestinal structure, mucosal enzyme activities, and pancreatic response in Atlantic salmon (Salmo salar L.). Aquaculture Nutrition 9: 361-371.

41 Swick RA (1999) Considerations in using protein meals for poultry and swine. American Soybean Association, Technical Bulletin p. 19.

42 Halver JE, Hardy RW (2002) Nutrient flow and retention. In: Halver, J.E. and Hardy, R.W., (Eds.) Fish nutrition, pp. 755–770 New York: Academic Press.

43 Mukhopadhyay N (2000) Improvement of quality of copra (dried kernel of Cocos nucifera) seed meal protein with supplemental amino acids in feed for rohu (Labeo rohita (Hamilton)) fingerlings. Acta Ichthyologica et Piscatoria 30: 21-34.