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RESEARCH PAPER

NUTRITIONAL COMPOSITION OF SHEA NUT (*Vitellaria paradoxa*, Gaertn) BY-PRODUCTS AND THEIR DIGESTIBILITY BY NILE TILAPIA (O*reochromis niloticus* L.) JUVENILE

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ABSTRACT

This study was conducted to determine the nutritional (proximate and energy) composition of selected shea nut by-products (SNPs) namely; shea nut meal (SNM, solvent extracted), shea nut cake (SNC, mechanically extracted) and shea nut cake (SNCW, water extracted) and their apparent digestibility coefficient (ADC) by Nile tilapia, Oreochromis niloticus. The ADC was determined using a reference diet with chromic oxide indicator and test diets that contained 70% reference diet and 30% of SNPs being evaluated. Nile tilapia (26.89 ± 3.19 g) was stocked in rearing tanks at 12 per tank and their faeces was collected from two replicate groups of fish by siphoning. Crude protein (CP), crude lipid (CL), crude fibre (CF) and gross energy (GE) of SNM, SNC and SNCW were 159.8, 70.0, 86.6 g.kg^{-1} and 17.4 kJ.g^{-1}; 145.3, 243.2, 49.3 g.kg^{-1} and 21.7 kJ.g^{-1}; 125.5, 304.0, 48.8 g.kg^{-1} and 22.9 kJ.g^{-1}, respectively. The ADC of dry matter (DM), CP, CL and GE of ingredients ranged from 73.0 – 83.8%, 47.3 – 72.0%, 74.7 - 98.9% and 61.2 - 96.3%, respectively. The SNC and SNCW had significantly higher DM, CP, CL and GE digestibility (P < 0.05) compare to SNM. Generally, protein composition and digestibility of the SNPs in this study were low and seem unsuitable as protein sources for Nile tilapia.

Keywords: *Nutritional composition, digestibility, nile tilapia, shea nut, by-product*

INTRODUCTION

Intensification in aquaculture practices and increase production in Ghana has resulted in high demand for manufactured fish feed in the country. Aquaculture production was estimated to have quadrupled within five years, from 7,154 mt in 2009 to 30,000 mt in 2013 (FAO, 2013; Frimpong and Fynn, 2014). Traditionally, protein used in the manufacture of fish feeds comes from marine sources. However, due to the high cost of these protein sources and the decline in marine catch worldwide, there is a push to find alternative sources of protein; sources that are sustainable and do not compete with human uses. Shea nut meals/ cakes, which are oilseed by-products, have

been identified as one such alternative. Oilseed by-products frequently constitute a major source of dietary protein in aquaculture feeds, particularly for omnivorous and herbivorous fish species such as the tilapias (Oreochromis spp.) and catfishes (Clarias spp.) commonly cultured in Ghana, due to their relatively high protein content and low cost (Agbo *et al.*, 2011). Although, plant ingredients are readily available at lower cost their use for fish feeds are usually restricted by poor quality protein, high fibre content and the presence of antinutritional factors (NRC, 1993).

The shea tree (*Vitellaria paradoxa*), which bears shea nuts, grows naturally in the wild in the dry Savannah belt of West Africa from Senegal in the west to Sudan in the east, and onto the foothills of the Ethiopian highlands (Hatskevich *et al.*, 2011; FAO, 2014). It occurs in 19 countries across the African continent including Ghana. In Ghana, shea nut production occur mostly in the Guinea savannah covering an area of about 77,670 square kilometers in Western Dagomba and Southern Mamprusi as well as drier areas of Brong-Ahafo, Ashanti, Eastern and Volta regions (Hatskevich *et al*., 2011). The nation's total annual production of shea nut was reported to be 73,500 metric tonnes in 2012 (FAOSTAT, 2013) although Dogbevi (2009) estimated potential production at 100,000 mt considering the 9.4 million shea trees that grow in the country. Increasing world demand for shea butter as a cocoa butter substitute, as well as for cosmetics (Hatskevich *et al.*, 2011; Hall *et al*., 1996) has increased the production of shea nut as well as the by-product in sub-Saharan Africa. Shea nut by-products (SNPs), which are the residues after shea butter production, are obtained in Ghana through different oil extraction methods namely; solvent extraction, screw-press extraction and water-based extraction (FAO, 2014; Oddoye *et al*., 2012) resulting in different by-products such as shea nut meal (SNM, solvent extracted), shea nut cake (SNC, mechanically extracted) and shea nut cake (SNCW, water extracted), respectively. According to Dei *et al*. (2007) the composition of SNPs may vary depending on handling prior to processing and method of oil extraction. These SNPs account for about 55% of the shea nut and are largely available in shea butter production areas and mostly discarded as waste with no economic value (Heuze´ and Tran, 2011).

A few studies conducted on (SNPs) shea nut meal/cake have shown that it contains substantial amount of nutrients (Agbo and Prah, 2014; Oddoye *et al*., 2012; Dei *et al*., 2008; Atuahene *et al*., 1998) although lower compared to other conventional oilseed meals used in fish feeds in terms of protein content in particular. However, SNPs are also reported to contain some antinutritional factors. SNPs have been used in some animal feed trials including; poultry (Zanu et al. 2012; Dei *et al*., 2008; Atuahene *et al*., 1998), pig (Rhule, 1999; Okai and Bonsi, 1989), sheep (Konlan *et al.*, 2012) and rabbit (Ansah *et al*., 2011) with authors reporting poor growth performances attributing this to the presence of antinutritional factors as well as poor palatability. There is very little information on the use of SNPs in fish feed. Uzoma (2010) fed catfish fingerlings with shea nut meal based diets and recommended 5% inclusion. The ability of a fish to digest and absorb feed ingredients depends primarily on the chemical composition of the ingredients and how digestible the nutrients are (McGoogan and Reigh 1996), therefore the first step in assessing their suitability in fish feed is to study their nutritional composition and digestibility. The present study was therefore designed to evaluate the nutritional composition of SNM, SNC and SNCW and their apparent digestibility by Nile tilapia, *Oreochromis niloticus.*

MATERIALS AND METHODS

Ingredients, diet formulation and preparation

Test ingredients used in this study were three shea nut by-products namely; shea nut meal, SNM (from solvent oil-extraction method), shea nut cake, SNC (from screw-press oil-extraction method) and shea nut cake, SNCW

(from water-based oil-extraction method). SNM was obtained from Ghana Nuts Ltd., Techiman, Brong Ahafo Region, SNC from Juaben Oil mills Ltd., Juaben, Ashanti Region and SNCW from Shebu-Loders Croklaan Ltd., Savelugu, Northern Region of Ghana.

A reference diet was formulated to satisfy the nutrient requirements of *Oreochromis niloticus* (Table 1). Three test diets were formulated to contain 70% of the reference diet and 30% of test ingredients (SNM, SNC and SNCW) following the method of Cho *et al.* (1985). Fish meal and wheat bran obtained from Department of Animal Science, Kwame Nkrumah University of Science and Technology, were used as the main dietary protein and energy sources respectively. A vitamin and mineral premix were used and cassava flour was used as a binder. Palm oil was used as a source of lipid in the diets. Chromic oxide was added to the experimental diets as an exogenous indigestible marker (De Silva and Anderson, 1995).

All ingredients were finely ground and were then weighed according to the formulation, placed in a bowl and thoroughly mixed using the hand until uniform mixture was obtained. Water was added (20%-30%) slowly to the mixture with continuous stirring until dough-like consistency was obtained. Pellets were obtained using a Moulinex electric mincer (Mincer HV6, Moulinex, France) with a 1mm die size. The pelletized feed was then oven-dried for 24 hours at 40^{o}C, packaged in air-tight polythene bags until used.

Fish were acclimated with the reference diet for a week before the start of the experiment. The four diets were randomly assigned to the 8 tanks, with each dietary treatment being given to two tanks. Fish were hand-fed to satiation twice daily at 0700 h and 1600 h. Fish were fed for 7 days before the onset of faeces collection. Faeces collection was done by siphon method as described by Cho and Slinger (1979). Before faeces collection the tanks were flushed one hour after feeding to remove any uneaten feed and faecal residues from the rearing tanks and cleaned then left for 2-3 hours for faeces to accumulate. Faeces were collected at 0800 h and 1700 h by siphoning carefully the deposited faeces into centrifuge bottles. Faeces were immediately centrifuged using Universal 16A,

Table 1: Composition of reference and test diets (g.kg^{-1}) fed to O*reochromis niloticus* for the digestibility study

Ingredients	Reference diet	Test diet
Test ingredient	0.00	298.50
Fish Meal	270.00	189.00
Soybean Meal	80.00	56.00
Wheat bran	520.00	364.00
Cassava flour	20.00	14.00
Palm oil	65.00	45.50
Vitamin & Mineral Premix*	10.00	7.00
Di-phosphate	20.00	14.00
Salt	10.00	7.00
Chromic Oxide	5.00	5.00

**DEX IBERICA, S.A. NUTRIDEX Premix*

Centrifuge (Hettich D-78532, Tuttingen, Germany) at 1,100 xg for 10 min and the supernatant discarded. Faeces were then oven dried at 40 ^{o}C for 24h, ground into a fine powder and stored in a dessicator. Faecal collection continued for 20 days, until it was judged that a sufficient sample had been collected for chemical analysis.

Biochemical composition

Ingredients, diets and faecal samples were analysed in triplicates for proximate composition (AOAC, 1990) and chromic oxide (Furukawa and Tsukahara, 1966). Dry matter was determined by oven-drying at 110^{o}C for 24 h, Crude protein (N x 6.25) by the Kjeldahl method. Crude lipid was determined by the ether-extraction method, crude fibre by incinerating a defatted sample at 550^{o}C in a muffle furnace for 12h after digestion by weak alkali followed by weak acid (Table 2). Gross energy was calculated after NRC (1993) as 23.6, 39.5 and 17.2 kJ.g^{-1} for protein, lipid and carbohydrate respectively.

Apparent digestibility coefficient

The apparent digestibility coefficient (ADC) for the nutrients of the reference and test diets as well as the test ingredients was calculated according to Bureau *et al*. (1999) and Forster (1999) as follows:

ADC (%) of diet = 100 × [1- (%nutrient in faeces/%nutrient in feed) × (%marker in feed/% marker in faeces)]

ADC (%) of test ingredient = $ADC_{test\ diet}$ + [($ADC_{test\ diet}$ - $ADC_{ref\ diet}$) x (0.7 x D_{ref})/0.3 x D_{ingr})]

Where D_{ref} is percentage nutrient of Reference Diet (as fed) and D_{ingr} is percentage nutrient of test ingredient (as fed).

Statistical analysis

The apparent digestibility coefficient of nutrients for the test ingredients were subjected to one-way ANOVA using SPSS Statistical Package (Version 16.0, SPSS Inc., Chicago, IL), and the Duncan's multiple range tests was applied to identify differences between means ($P<0.05$). The apparent digestibility coefficient of nutrients in this study are presented as means ± SE of two replicates. All percentages were arcsine transformed before analysis (Zar, 1984).

RESULTS

Nutritional composition of shea nut by-products

The nutritional composition of the shea nut by-products (SNPs) used in this study is presented in Table 3. Dry matter content of the SNPs

Table 2: Proximate composition (g.kg^{-1} as-fed) and gross energy (kJ.g^{-1}) of reference and test diets used in the digestibility trial

		Test diets		
Components	**Reference diet**	**SNM**	**SNC**	**SNCW**
Crude protein	311.0	265.4	261.1	255.2
Crude lipid	108.0	75.6	148.2	166.3
Crude fibre	83.6	58.6	73.3	73.1
Ash	59.4	41.6	58.7	60.5
Gross energy (kJ.g^{-1})	18.88	18.40	19.70	20.04

SNM= solvent fat-extracted shea nut meal diet, SNC=screw-press fat-extracted shea nut cake, SNCW=Water-based fat-extracted shea nut cake

differed slightly from 862.05 to 883.3 g.kg.$^{-1}$. Their ash content varied slightly from 53.31 to 63.40 g.kg^{-1} with SNCW recording the highest. SNM recorded the highest crude protein level (159.90 g.kg^{-1}) followed by SNC and SNCW was the least (125.60 g.kg^{-1}). The crude lipid levels followed the opposite trend compared to crude protein where SNM had the lowest level (70.03 g.kg^{-1}) and SNCW had the highest (304.02 g.kg^{-1}).

The crude fibre content of the SNPs ranged between 48.81 g kg^{-1} and 86.62 g kg^{-1} with SNM recording close to twice the levels for SNC and SNCW. The gross energy of the test ingredients ranged from 17.38 g.kg^{-1} to 22.85 g.kg^{-1}.

Apparent digestibility coefficient of shea nut by-products

Apparent digestibility coefficient (ADC) of the SNPs (SNM, SNC, SNCW) are presented in Table 4. The dry matter ADC of the SNPs ranged from 72.98% to 83.81% with SNCW and SNC being significantly higher ($p< 0.05$) than SNM. The crude protein (CP) ADC followed a similar trend with SNCW recording the highest value of 71.99%, however that of SNC was not significantly higher than SNM which recorded the lowest protein digestibility (47.28%). Crude lipid ADCs of the test ingredients were all high with SNC recording the highest (98.94%) and SNM the least (74.72%). Crude lipid ADCs were significantly different for the three test ingredients.

Gross energy ADCs of the feed ingredients differed significantly ($P< 0.05$) from each other between 61.21 g.kg^{-1} for SNM and 96.32% for SNCW. As the CL in the ingredients increased energy digestibility also increased (Tables 3 and 4).

DISCUSSION

Crude protein contents of the shea nut by-products (i.e. SNM, SNC, SNCW) used in this study were (125.5 - 159.8 g.kg^{-1} CP) similar to values of 135.9 g.kg^{-1} CP reported by Agbo and Prah (2014), 143.6g.kg^{-1} CP by Dei *et al.* (2008) and 162.4 g.kg^{-1} CP by Atuahene *et al.* (1998). Comparing the CP levels in the SNPs obtained in this study with other oilseed meals like CSM, SBM and GNC from the work of Agbo et al. (2009), the values were far lower. According to NRC (1993) an ingredient is considered a protein source when it has not less than 25% CP. The SNPs may, therefore not qualify as a protein source in a formulated feed.

Table 3: Proximate composition (g.kg^{-1} as-fed) and gross energy (kJ.g^{-1}) of the shea nut by-products and other ingredients used in diet formulation

Ingredient	DM	Ash	CP	CL	CF	NFE	GE
SNM	885.68	53.31	159.80	70.03	86.62	515.92	17.38
SNC	883.30	57.35	145.30	243.24	49.30	388.11	21.72
SNCW	862.05	63.40	125.50	304.02	48.81	320.35	22.85
Fish Meal	960.46	149.74	709.42	33.51	02.31	65.48	19.87
Wheat Bran	879.6	21.12	148.10	54.20	90.90	565.28	17.43
Soybean Meal	862.86	60.03	545.60	65.49	53.00	159.74	20.06

SNM= solvent extracted shea nut meal, SNC=mechanical extracted shea nut cake, SNCW=water extracted shea nut cake, DM= dry matter, MC= moisture content, CP=crude protein, CL=crude lipids, CL=crude fibre, NFE= nitrogen free extract

Table 4: Apparent digestibility coefficient (%) of dry matter, crude protein, crude lipid (gkg^{-1}) and gross energy (kJ g^{-1}) in test ingredients for *Oreochromis niloticus*

	Apparent digestibility coefficient (%)			
Ingredient	**Dry matter**	**Crude protein**	**Crude lipid**	**Gross Energy**
SNM	72.98 ± 0.0 ^{b}	47.28±3.6 ^{b}	74.72±1.44 ^{c}	61.21±1.11 ^{c}
SNC	79.81±1.67 ^{a}	60.68±0.36 ^{ab}	98.94±0.53 ^{a}	82.51±0.69 ^{b}
SNCW	83.81±0.58 ^{a}	71.99±2.64 ^{a}	95.53±0.06 ^{b}	96.32±0.44 ^{a}

SNM= solvent fat-extracted shea nut meal, SNC=screw-press fat-extracted shea nut cake, SNCW=Water-based fat-extracted shea nut cake. Values are means ±SE (n=2) and values within the same column with the same superscript are not significantly different (P>0.05).

The crude lipid in SNCW was more than 4 fold (304.02 g.kg^{-1}) higher than SNM (70.03 g.kg^{-1}). The obvious differences might be as a result of the different methods of oil extraction applied to their processing. It appeared that solvent oil extraction was more efficient than mechanical and the less efficient was the water extraction, which corroborates the results obtained by Dei *et al.* (2007). According to Lovell (1998) nutrient composition of feedstuffs depends on the origin, state and processing methods used. Gross energy level followed the same trend as the CL probably because CL is a very good source of energy in fish feed and high inclusions lead to higher energy feed.

Crude fibre in SNM was high almost double that of SNCW, this could be attributed to the removal of the shell in the case of SNCW before oil extraction compared with SNM where the nut and shell were crashed together and the shell added more fibre to its composition.

The present study showed that ADCs of dry matter, protein, lipid, and energy in the test ingredients for Nile tilapia were affected by the different ingredients used ($p < 0.05$). The differences in ADCs of nutrients and energy may be explained by differences in chemical composition, origin and processing of these feed ingredients (Table 3). Results in Table 4 indicated that SNCW was the most digestible with an apparent protein digestibility (APD) of 71.99% and the least was SNM with APD of 47.28%. Generally the protein quality of dietary ingredients is one of the leading factors, which affects the growth performance of fish. Therefore, protein digestibility is usually the first measure of its availability to fish. Protein quality of dietary protein sources depends on the amino acid composition and their digestibility. Deficiency of an essential amino acid leads to poor utilization of the dietary protein and consequently reduces growth and decreases feed efficiency (Halver and Hardy, 2002). The APDs (47.28 - 71.99%) in test ingredients for Nile tilapia in this study are generally low in contrast to reported APDs in various oilseed ingredients in this species, which range from 78.5 to 96% (Jauncey, 1998; Sklan *et al*., 2004; Guimaraes *et al.*, 2008; Agbo *et al*., 2009). The significantly low APD of SNPs may be attributed to their low protein content and poor amino acid profile. The digestion coefficients for protein-rich feedstuffs are usually in the range of 75 to 95% (NRC, 1993).

Lipid, when administered either alone or in a mixed diet, routinely gives digestibility values ranging from 85% to 95% for fish (Cho and

Slinger, 1979). Sklan *et al*. (2004) reported that for tilapia the ADCs of lipid range between 72 – 90% for corn gluten, soybean meal, rapeseed meal, sunflower seed meal, wheat, corn, sorghum and wheat bran. The ADCs of lipid (74.72 – 98.94%) in test ingredients for Nile tilapia in this study are generally in agreement with those reported by Sklan *et al*. (2004), Köprücü and Özdemir (2005) and Agbo *et al*., 2009. Lipid digestibility in other species ranged from 70% to 90% (Lupatsch *et al*., 1997) and 92.38 – 96.93% for plant products (Zhou *et al*., 2004) similar values were observed in this study.

Apparent digestibility coefficient (ADC) of dry matter (DM) was highest for SNCW (83.94%) and SNC (79.81%) and that of SNM (72.98%) was significantly lower for juvenile Nile tilapia. ADC of DM, which is the overall digestibility, of the ingredients decreased as fibre content of ingredients increased. Crude fibre in the diet is largely indigestible by fish (NRC, 1993); thus, the ADC of DM may be reduced by high fibre content. Some previous reports have demonstrated that DM ADCs of feed ingredients were negatively correlated to fibre content of feed ingredients (Hilton *et al*., 1983; Sullivan and Reigh, 1995).

Variation in ADC of GE of ingredients followed the same trend as that of DM digestibility. Crude fibre in feed ingredients, CL and carbohydrate content of plant protein sources could have an effect on ADC of GE (Lupatsch *et al*., 1997; Bureau *et al*., 1999). The ADC of GE of SNM was significantly lower than that of SNCW and SNC due probably to its high CF and low CL contents (Table 3).

CONCLUSION

In conclusion, the different Shea nut by-products (SNPs) showed considerable level of crude lipids (70.03 - 304.02 $g.kg^{-1}$) and gross energy (17.38 - 22.85 $kJ.g^{-1}$), however, the CP levels were low (125.50 - 159.80 $g.kg^{-1}$) and CF were high particularly for SNM (48.81 - 86.62 $g.kg^{-1}$). Crude protein digestibility was poor for the SNPs, however SNC and SNCW showed high level of ADC of DM (79.81 - 83.81%); CL (98.94 - 95.53%) and GE (82.51 - 96.32%) with the exception of SNM which performed poorly, although it contained the highest crude protein. Generally, due to low protein composition and poor protein digestibility of the SNPs in this study they seem unsuitable as protein sources for Nile tilapia, however SNC and SNCW have good DM, CL and GE digestibilities so could be used as sources of lipid and energy in feed particularly supplementary feeds. Comparing the availability of these SNPs, SNM is the most abundant but unfortunately performed poorly compared to SNC and SNCW. In order to include SNPs in fish feed it is important to improve their nutritional value through prior processing to get rid of antinutrients as has been tried in other animal feeds.

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