Variability of nutritive value of shea nut (*Vitellaria paradoxa*) meal for poultry

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Shea nut meal is an agro-industrial by-product obtained from the processing of the nuts of the shea tree (*Vitellaria paradoxa*, Gaertn.) for fat. It is available for use by the poultry feed industry. There is a dearth of information on its nutritive value for poultry. The objective of this study was to evaluate the chemical and nutritive value of six samples of Ghanaian shea nut meal, which were produced by either expeller or traditional method in 2004 and 2005. Ross 308 male broiler chicks were placed in metabolism cages (30 x 30 x 36 cm) singly and fed one of the 17 experimental diets (10 replicates) from 12 to 20 days of age. Each shea nut meal sample including defatted sample was substituted at levels of 20 and 40 g kg^{-1} in a basal diet that was composed of maize, dehulled soya bean meal, fishmeal and wheat feed. During the last 4 days, the amounts of feed eaten and droppings voided were recorded. Samples of the shea nut meal, diets, and droppings were analysed for their nutrient and gross energy contents using AOAC (2000) methods. There was no significant difference (P>0.05) in the dry matter contents of the samples, which ranged between 907.6 and 946.2 g kg^{-1}. The mean ether extract (EE) of the expeller samples (145.0 g kg^{-1}DM) was lower (P<0.01) than that of traditionally-extracted samples (379.0 g kg^{-1}DM) due to efficiency of fat extraction. The free fatty acid content of the residual fat in the samples was lower (P<0.05) in the expeller samples (89.0 g kg^{-1}EE) than the traditionally-extracted samples (364.0 g kg^{-1}EE). The mean crude protein level of the traditionally-extracted samples (110.8) was lower (P<0.05) than that of expeller samples (134.5g kg^{-1}DM). There were significant differences in the levels of the mean lysine (P<0.05), methionine+cystine (P<0.01) and tryptophan (P<0.05), which were 40.1 versus 33.1, 39.1 versus 34.3, and 14.1 versus 13.2 g kg^{-1}CP in the expeller and traditionally-extracted samples respectively. However, there was a strong and consistent relationship between the crude protein level and lysine (r^2=0.8825), methionine+cystine (r^2 = 0.9728) and tryptophan (r^2 = 0.8322) in the samples. Mean total dietary fibre in the expeller samples (445.4 g/kg DM) was lower (P<0.05) than that of traditionally-extracted samples (507.5 g/kg DM). Mean gross energy content of the expeller samples (23.7 MJ/kg DM) was lower (P=0.01) than that of traditionally-extracted samples (26.7 MJ/kg DM). No significant differences (P>0.05) were observed in mean digestibility coefficients of expeller and traditionally-extracted samples in terms of dry matter (0.645 vs 0.638), crude protein (0.584 vs 0.582) and crude fat (0.664 vs 0.660), but differed (P<0.05) in gross energy utilisation (0.668 vs 0.664). The defatted samples gave similar nutrient digestibility as their corresponding intact samples. The variation observed among samples strongly indicates that industrial source of shea nut meal should be preferred, but requires improvement for use in poultry rations.

Keywords: shea nut meal; nutritive value; variability; broilers

Introduction

The world's growing population coupled with increasing demand for poultry products in the face of shortages of major feed ingredients may require utilisation of less conventional raw materials including shea nut meal in poultry feeds. Shea nut meal is the residue from the nuts of *Vitellaria*

paradoxa after extraction of the edible fat. It is widely and traditionally regarded as waste and its increasing output of late has become an environmental issue. The few experiments that have examined growth responses of poultry to shea nut meal based diets (Atuahene *et al*., 1998; Olorede and Longe, 1999) have found poor and variable growth performances. Even though, this has been attributed to the presence of anti-nutritive factors such as tannins and saponins (Annongu *et al*., 1996), there is a relative lack of detailed information on utilisation of nutrients contained in the shea nut meal samples produced in the West African sub-region, and how processing methods (i.e. traditional or expeller) affect these variables. There is, therefore, a need to evaluate and explain the variability of nutrient supply in the different types of shea nut meal presently available in the industry.

Materials and methods

Experimental birds and diets

Ross 308 male broiler chicks were reared in a litter-floored pen and fed a proprietary broiler starter feed for 12 days. One hundred and eighty birds (90 birds per run of 5 replicates) of similar weights were then randomly selected and placed in metabolism cages (30 x 30 x 36 cm) singly and fed one of the 17 experimental diets (10 replicates) in a mash form from 12 to 20 days of age. The basal diet was fed in duplicate. Six samples of Ghanaian shea nut meal, which were produced by either expeller or traditional method in 2004 and 2005, were tested. The screw-press method of fat extraction was used. This involved preheating of the kernels at 90ºC by steam application and then two stages of extraction of the fat in a screw-press machine. The traditional method involved roasting of the kernels in a clay oven at 150ºC for 1-2 hours, milling and then kneading of the finely-ground kernels by hand using cold water to extract the fat. The residue obtained was then sun-dried. Four expeller samples and two traditionally-extracted samples were used.

A sample of each type of shea nut meal was defatted using petroleum spirit in Soxtec system (Foss UK Ltd). Each shea nut meal sample including defatted samples was substituted at levels of 20 and 40 g kg^{-1} in a basal diet that was composed of maize, dehulled soya bean meal, fishmeal and wheat feed (*Table 1*). During the last 4 days of the 8-day experiment, the amounts of feed eaten (70% restricted daily intake to ensure complete intake of feed offered) and droppings voided (total collection method) were recorded. The droppings were collected daily and stored at 4°C until the total sample was dried in a force-draught oven at 60°C.

Table 1: Calculated composition (g kg^{-1}) of the basal feed

Ingredients	Amount (g kg^{-1})
Maize	400
Dehulled soya bean meal	300
Fishmeal	30
Wheatfeed	220
Lysine (HCl)	3
Methionine	4
Limestone	4
Dicalcium phosphate	13
Vitamin and trace element premix*	22
Salt	4
Calculated composition (g kg^{-1})	
Crude protein	239.4
Crude fibre	36.9
Calcium	11.4
Phosphorus	7.6
Sodium	2.0
Lysine	15.2
Methionine	7.6
Methionine + Cystine	11.6
ME (MJkg^{-1})	11.5

**Vitamin-trace mineral premix for broilers (Ian Hollows Feed Supplement, UK) added per kg: 800 mg Retinol, 150 mg Cholecalciferol, 1.25 g Tocopherol, 150 mg Thiamin, 500 mg Riboflavin, 150 mg Pyrodoxine, 750 mg Cyanocobalamin, 3 g Nicotinamide,0.5 g Pantothenic acid, 75 mg Folic acid, 6.25 g Biotin, 12.5 g Cholinechloride, Iron 1 g, 50 mg Cobalt, 5 g Manganese, 0.5 g Copper, 4 g Zinc, 50 mg Iodine, 10 mg Selenium, and 25 mg Molybdenum.*

Chemical analyses

The shea nut meal samples, diets, and droppings were ground in a laboratory mill fitted with 1mm-mesh size screen. Dry matter content of samples was determined by drying the samples in an oven at 100°C overnight. The nitrogen content of samples was determined by the combustion method (AOAC, 2000) using Leco (FP-528 N; Leco Corp., St. Joseph, MI) with EDTA as a standard. The crude protein content of samples was calculated as Nx6.25. Amino acids were determined by HPLC (Biochrom 20; Amersham Pharmacia Biotech, USA) using AOAC (2000) methods involving oxidation of the protein with performic acid and acid hydrolysis to analyse all total amino acid contents except for tryptophan and tyrosine. Tryptophan was determined following alkaline hydrolysis in an autoclave, and tyrosine after acid hydrolysis without prior oxidation. The gross energy content of samples was determined by adiabatic bomb calorimetry (Model 1261; Parr Instrument Co., Moline, IL) with analar sucrose as a standard. Crude fat content of samples was determined by the ether extraction method (AOAC, 2000) using Soxtec system (Foss UK Ltd) after the samples were digested by hydrochloric acid (4M) using the wet digestion method (AOAC, 2000). The ash content of samples was determined by combustion in a muffle furnace for 24 h at 500°C. Calcium and phosphorus contents of samples were determined using Atomic Absorption Spectrophotometer (Smith-Hieftje 1000; Thermo Electron Corp., Hampstead) and Spectrophotometer (DU 640; Beckman, USA) respectively. Total dietary fibre content of samples was determined by AOAC Method 991.43 using Megazyme assay kit (Megazyme International Ireland Ltd). Duplicate analyses were performed on all samples.

Statistical analyses

Analysis of variance of data was carried out using the GENSTAT (8th version). Type of shea nut meal and rate of inclusion as well as blocking (tier level of cages) were considered as factors. Orthogonal comparisons of nutrient digestibility were made between types of shea nut meal. Outliers were removed from the data sets. The apparent metabolisable energy content of the samples was not determined due to the very small quantity of the shea nut meal that was used in order not to unduly compromise feed intake of the birds. A strong negative correlation between dietary level (>25 g kg^{-1} diet) and feed intake has been reported (Atuahene *et al*., 1998). Nutrient digestibility coefficient

estimate of each sample was derived according to calculation of digestibility of a single feed of a mixed ration (Lloyd *et al*., 1978).

Results and discussion

There was no significant difference (P>0.05) in the dry matter contents of the samples, which ranged between 907.6 and 946.2 g kg^{-1} (*Table 2*). The mean ether extract (EE) of the expeller samples (145.0 g kg^{-1}DM) was lower (P<0.01) than that of traditionally-extracted samples (379.0 g kg^{-1}DM) due to efficiency of fat extraction. The free fatty acid content of the residual fat in the samples was lower (P<0.05) in the expeller samples (89.0) than the traditionally-extracted samples (364.0 g kg^{-1}EE). The mean crude protein level of the traditionally-extracted samples (110.8) was lower (P<0.05) than that of expeller samples (134.5g kg^{-1}DM). There were significant differences in the levels of the mean lysine (P<0.05), methionine+cystine (P<0.01) and tryptophan (P<0.05), which were 40.1 versus 33.1, 39.1 versus 34.3, and 14.1 versus 13.2 g kg^{-1}CP in the expeller and traditionally-extracted samples respectively. However, there was a strong and consistent relationship between the crude protein level and lysine (r^2 = 0.8825), methionine+cystine (r^2 = 0.9728) and tryptophan (r^2 = 0.8322) in the samples. All the samples contained high amounts of dietary fibre, but the mean total dietary fibre in the expeller samples (445.4 g/kg DM) was lower (P<0.05) than that of traditionally-extracted samples (507.5 g/kg DM).

Considerable variation in residual fat content of shea nut meal has been noted in previous studies; as a result of variable efficiencies of fat extraction methods (Hall *et al*., 1996). The higher residual fat in the traditionally-extracted samples was expected since the traditional method of fat extraction was known to be inefficient, and as such were higher in their gross energy contents (*Table 2*). The crude protein contents recorded in this study varied within a narrow range. However, the traditionally-extracted samples were noticeably darker than any of the others, suggesting that over-heating can be a serious problem. The traditional method involved higher heat treatment than the expeller method. High processing temperatures of oilseeds has deleterious effects on proteins and amino acids due to formation of Maillard reaction products (Hurell, 1990). In general, concentrations of lysine in all samples were low at levels similar to most plant protein sources.

No significant differences (P>0.05) were observed in mean digestibility coefficients of expeller and traditionally-extracted samples in terms of dry matter (0.645 vs 0.638), crude protein (0.584 vs 0.582) and crude fat (0.664 vs 0.660), but differed (P<0.05) in gross energy utilisation (0.668 vs 0.664). The defatted samples gave similar nutrient digestibility as their corresponding intact samples. Nutrient digestibility of shea nut meal in general was very poor, particularly proteins. Poor utilisation of the shea nut meal in poultry diets have been reported (Atuahene *et al*., 1998; Olorede and Longe, 1999). Possible factors limiting nutrient utilisation include presence of tannins and saponins (Annongu *et al*., 1996) and non-starch polysaccharides. The polysaccharides in the samples used in this study were largely non-starch polysaccharides (*Table 2*), which are known to have negative effects on nutrient digestion and absorption in poultry (Annison and Choct, 1991). The need to counteract the anti-nutritive factors such as tannins and saponins in shea nut meal to improve nutrient utilisation have been suggested by Annongu *et al*. (1996) through the use of fermentation and tannin-binding agents. It would be possible to use exogenous enzymes such as carbohydrases to improve the digestion of non-starch polysaccharides in the shea nut meal.

Table 2: Variation in nutrient composition of shea nut meal samples (g kg^{-1} DM)

Component	Expeller shea nut meal				Traditionally-extracted shea nut meal		Mean	±SD
	2004	2004	2005	2005	2004	2005		
Dry matter (g kg^{-1})	932.9	924.6	925.7	941.2	946.2	907.6	929.7	13.7
Crude protein	143.6	133.3	132.4	128.8	117.7	103.9	126.6	13.9
Amino acid (g kg^{-1} CP)								
Methionine	22.5	22.1	22.6	22.1	20.5	21.4	21.9	0.8
Cystine	17.2	16.3	17.039	16.3	12.9	13.8	15.6	1.8
Methionine+Cystine	39.7	38.5	39.6	38.4	33.4	35.1	37.4	2.6
Lysine	41.7	41.4	39.6	37.7	30.0	36.2	37.8	4.3
Threonine	41.2	41.1	42.6	40.8	38.3	41.3	40.9	1.4
Tryptophan	14.0	14.0	14.6	13.9	13.1	13.2	13.8	0.6
Arginine	89.1	85.4	90.3	87.4	71.7	75.6	83.3	7.7
Isoleucine	46.5	46.6	46.9	45.9	43.1	45.6	45.8	1.4
Leucine	78.6	78.1	80.3	77.5	75.0	78.3	78.0	1.7
Valine	57.2	57.4	57.8	56.5	53.8	57.1	56.6	1.4
Histidine	28.5	28.2	28.6	27.6	24.3	26.4	27.3	1.7
Phenylalanine	37.6	37.8	38.6	36.9	36.5	38.9	37.7	0.9
Glycine	50.0	49.5	51.2	49.5	48.7	53.7	50.4	1.8
Serine	44.7	44.0	46.6	44.4	40.5	43.9	44.0	2.0
Proline	52.8	52.2	53.3	50.6	47.7	51.2	51.3	2.0
Alanine	57.9	57.4	59.3	57.4	55.1	57.8	57.5	1.4
Asparagine	116.8	114.5	119.0	115.8	100.6	106.1	112.1	7.2
Glutamine	169.4	164.2	172.0	166.8	155.4	158.7	164.4	6.4
Ether extract	101.4	208.3	120.2	151.6	363.8	394.8	223.3	126.5
FFA (g kg^{-1} EE)	160.0	123.0	8.40	66.0	491.0	237.0	193.5	157.9
TDF (g kg^{-1} DM)	440.7	452.2	442.2	446.5	481.1	533.9	466.1	36.4
Ash	52.3	50.6	54.2	46.9	75.6	51.6	55.2	10.3
Calcium	3.1	2.6	1.8	1.6	3.8	3.0	2.6	0.9
Phosphorus	2.6	2.3	2.5	2.4	2.6	2.4	2.5	0.1
GE (MJ/kg DM)	22.8	24.0	23.8	24.3	26.0	27.4	24.7	1.8

PV-peroxide value, EE- ether extract, FFA-Free fatty acids, Total dietary fibre, SD-standard deviation

TABLE 3: Variation in estimated nutrient and gross energy digestibility coefficients of shea nut meal samples

Component	Expeller shea nut meal				Traditionally-extracted shea nut meal		Defatted expeller SNM	Defatted traditionally-extracted SNM
	2004*	2004	2005	2005	2004*	2005		
Dry matter	0.650	0.645	0.641	0.643	0.640	0.635	0.640	0.637
Crude protein	0.590	0.583	0.580	0.584	0.582	0.582	0.584	0.573
Lipid	0.666	0.664	0.666	0.658	0.661	0.658	0.666	0.664
Gross energy	0.668	0.668	0.666	0.668	0.665	0.662	0.667	0.664

Statistical significance of contrasts (means of interest)

Contrasts	Difference between means	SE	Significance probability (*P*) *Residual d.f.=125*
Dry matter			
Expeller SNM vs Traditionally-extracted SNM	0.075	0.0156	<0.001
Defatted expeller SNM vs Defatted traditionally-extracted SNM	0.0116	0.00639	NS
Defatted expeller SNM vs Expeller SNM	-0.025	0.0202	NS
Crude protein			
Expeller SNM vs Traditionally-extracted SNM	0.046	0.0315	NS
Defatted expeller SNM vs Defatted traditionally-extracted SNM	0.039	0.0129	<0.01
Defatted expeller SNM vs Expeller SNM	0.015	0.0407	NS
Lipid			
Expeller SNM vs Traditionally-extracted SNM	0.049	0.0374	NS
Defatted expeller SNM vs Defatted traditionally-extracted SNM	0.002	0.0153	NS
Defatted expeller SNM vs Expeller SNM	0.022	0.0483	NS
Gross energy			
Expeller SNM vs Traditionally-extracted SNM	0.048	0.0161	<0.01
Defatted expeller SNM vs Defatted traditionally-extracted SNM	0.0105	0.00656	NS
Defatted expeller SNM vs Expeller SNM	0.007	0.0207	NS

**Samples which were defatted. SNM - shea nut meal. The ether extracts contents of defatted samples subjected to acid hydrolysis: Expeller SNM (3.6 g kg^{-1}), traditionally-extracted SNM (7.0 g kg^{-1})*

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