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Proximate traits of the seed and seed cake of shea butter tree (*Vitellaria paradoxa* C. F. Gaertn.) in Nigeria's savanna ecozone

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ABSTRACT
Objective: To study the nutritional content of the seed, particularly the seed cake, of shea butter in Nigeria.
Methodology and results: Proximate traits of the seed and seed cake of 8 accessions of *Vitellaria paradoxa* growing in the guinea and sudan savanna of Nigeria were investigated. Results indicated significant variation in all seed proximate traits except ash, moisture and fiber of the seed cake, across the agro ecological zones. All proximate traits of the seed/cake varied remarkably across accessions. Principal component analysis identified energy related traits and fiber of the seed and all but fat of the seed cake as more discriminate traits for product classification. There were 5 and 9 significant correlations between the proximate traits of the seed and seed cake, respectively.
Conclusions and application of findings: Generally, the study established that shea seeds from Jalingo and Kachia locations had higher fat content. However, seed cake from Jalingo, Makurdi, Lokoja, Yola and Minna gave higher values of one or more of the energy related proximate traits of carbohydrate, protein and fat as well as energy. Results of this work will be of interest to stakeholders seeking shea resources with high fat content in Nigeria and will provide a basis for recommendation of shea seed and cake for the animal feed industry. It will also prove useful in the effort to genetically upgrade the species in Nigeria.
Key words: Agro ecology, nutritional content, shea kernel, trait correlations.

INTRODUCTION
One of the key agro forestry species in Africa is the shea butter tree, *Vitellaria paradoxa*. It occupies a 500 – 700 km wide and 5000 km long stretch of African savanna from Senegal to Ethiopia and Uganda (Umali & Nikiema, 2002). In Nigeria, the major area of occurrence is the guinea and sudan savanna zones (Keay, 1989).
On the global scale, the species has made remarkable contributions in the food and cosmetic industries by reason of its seed fat extract known as shea butter (Boffa *et al*., 1996). Locally, *V. paradoxa* is invaluable in traditional medicine, provision of fuel wood and in the production of soap, candle and pomade (Awoleye, 1995). Its dietary importance at the local level is derived from the fat extract which is used for cooking as well as the fruit pulp which is consumed by humans and livestock (ICRAF, 2000). Similarly, the protein-rich caterpillars of *Cirina butyrospermi* associated with the species are considered a delicacy among the

Yoruba and Nupe (Ande, 2004) as well as the Tiv (Ugese *et al*., 2005) ethnic groups in Nigeria. Popoola and Tee (2001) reported that a prospect of harvesting the caterpillars was the only reason some farmers allowed the tree to remain on their farmlands.

Although the seed fat extract of shea seed has helped to bring the crop to global limelight, not much seems to be known about the proximate chemical constitution of the seed as a whole. The same may be said of the seed cake, a by-product of fat extraction. This is evident from the dearth of scientific report on this aspect, particularly in Nigeria. Interestingly, the seed cake is already finding use as a livestock and poultry feed (ICRAF, 2000). In Nigeria, the livestock feed industry is heavily dependent on, among others, oilseed resources such as groundnut cake, soybean cake, cotton seed cake and palm kernel meal (RMRDC, 2003). The upsurge in the use of oilseeds and grains such as soybean, maize and wheat for biofuel is already taking its toll on global food security (Spore, 2008). It has therefore become imperative to explore other alternatives for the feed industry in order not to worsen the current food supply situation. Exploring the nutritional content of shea kernel cake in Nigeria, the world's leading producer of shea nuts (Umali & Nikiema, 2002; Umobong, 2006) is viewed as a step in the right direction. Similarly, it is our conviction, that a more elaborate understanding of the nutritional make-up of the seed could, among others, afford a better assessment of the possible uses to which it can be put. This study was therefore undertaken to determine the proximate qualities of shea seed and seed cake across Nigeria's Savanna region.

MATERIALS AND METHODS

Nut collection: Seeds were obtained from fruits collected from the following nine locations: Ilorin, Lokoja, Makurdi, Akwanga, Minna (Southern Guinea Savanna), Kachia, Jalingo (Northern Guinea Savanna), Yola and Kano (Sudan Savanna) in July, 2006. The geographic information of these sites has been given in previous reports (Ugese *et al*., 2008 & 2010). In each location, 15-25 trees were selected, with each tree contributing 45 seeds (nuts) that were subsequently analysed (Ugese *et al*., 2010). The seeds were sun dried for 3-4 hours each day for ten days until they rattled, indicating sufficient level of dryness. They were thereafter decorticated, sliced into smaller pieces and finely milled for laboratory analysis. Since seeds of the Ilorin provenance were too few to be included, only 8 locations were analysed.

Laboratory analyses: Laboratory procedures adopted were as outlined by the Association of Official Analytical Chemists (AOAC, 1980). A 2g sample of the kernel was extracted with petroleum ether using a soxhlet apparatus. The extracted fat was oven dried at 100⁰C after which it was weighed. The percentage fat content was estimated as follows:

$$\% \text{ Fat} = \frac{C - A}{B} \times 100$$

Where A = weight of empty flask

B = weight of the sample

C = weight of flask + oil after drying.

The micro- Kjedahl method was adopted for estimation of crude protein. This method estimate Nitrogen content which is multiplied by a factor of 6.25 to obtain crude protein. To determine ash content, 2g of sample was incinerated in a muffle furnace at 600^{0}C until ash was obtained. Fibre was determined using the Weende method which involved hydrolysing the protein, fat, starch and other digestible carbohydrates out of the sample before completing the test. Carbohydrate was obtained by subtracting values of other proximate traits analyzed from 100. To calculate energy content, crude protein, fat and carbohydrate values were multiplied by the Atwater factors of 4, 9 and 4, respectively (Joslyn, 1970). The above process was applied on the shea kernel cake to determine its proximate qualities.

Data analysis: Data collected was subjected to analysis of variance (ANOVA). Means were separated using F-LSD. Principal component analysis (PCA) was used to identify traits capable of being used for shea kernel and kernel cake classification in Nigeria. The statistical software used for the analyses (ANOVA and PCA) was GENSTAT Discovery Edition 3, Release 7.2DE (GENSTAT, 2007). In addition, correlations among traits were assessed by use of SPSS version 10.

RESULTS

Proximate qualities of kernel (table 1) indicate variation in all the proximate traits except ash content across agro ecologies. Kernels from the northern guinea savanna had the least moisture, carbohydrate and protein content but were higher in fat, fibre and energy.

Table 1: Proximate composition of shea kernel based on agro-ecological zone in Nigeria.

Agro ecological zone	Moisture %	Carbohydrate %	Protein %	Fat %	Fibre %	Ash %	Energy Cal/100g
Southern guinea savanna	3.2	47.8	8.1	30.2	5.8	4.9	495.4
Northern guinea savanna	2.7	44.1	7.1	34.8	6.8	4.5	518.1
Sudan savanna	3.0	48.1	8.1	30.1	6.1	4.6	495.6
$LSD_{(0.05)}$	0.4	1.7	0.7	1.0	0.3	NS	10.8

NS – No significant difference

All proximate traits varied with individual accession (Table 2). Moisture content varied from 2.2 (Jalingo) to 3.4 % (Lokoja and Akwanga); the least carbohydrate value (43.4%) was from Kachia while Akwanga, Kano and Makurdi had the highest values. Protein content varied from 6.3 to 8.9% while fat content was from 28.6 to 34.9%. Jalingo kernels had the highest fibre content (7.2%) while those of Makurdi had the lowest (4.6%). Ash content ranged from a high of 5.4% for kernels obtained from Akwanga to a low of 4.3% for kernels from Jalingo. The highest energy content was from the Jalingo kernels followed by those from Kachia and Makurdi, in that order. Kernels from Akwanga yielded the least energy.

Table 2: Proximate composition of shea kernel based on accession.

Accession	Moisture %	Carbohydrate %	Protein %	Fat %	Fibre %	Ash %	Energy Cal/100g
Lokoja	3.4	47.2	7.6	30.8	6.0	5.0	496.4
Makurdi	3.0	48.7	8.4	30.8	4.6	4.6	505.6
Akwanga	3.4	48.3	7.4	28.6	6.9	5.4	480.2
Minna	2.9	47.2	8.9	30.6	5.8	4.6	499.7
Kachia	3.1	43.4	7.9	34.6	6.4	4.6	516.6
Jalingo	2.2	45.1	6.3	34.9	7.2	4.3	519.7
Yola	3.2	47.6	8.5	30.4	5.9	4.4	498.0
Kano	2.8	48.9	7.6	29.7	6.2	4.8	493.3
$LSD_{(0.05)}$	0.2	0.9	0.5	1.0	0.4	0.4	14.8

Principal component analysis results for shea kernel are summarized in Table 3. The 3 principal axes retained explained 87.9% of the total variation in shea kernel proximate attributes. It appeared to suggest that fat, protein, fibre and carbohydrate are more promising traits that could more adequately classify shea kernel in Nigeria according to proximate qualities. Correlation analysis showed that energy was positively correlated to fat but negatively correlated to carbohydrate and ash. Similarly, protein maintained significant negative relationship with fibre. A significant negative correlation was observed between fat and carbohydrate (Table 4). In terms of shea kernel cake, only moisture and fibre showed significant variation across the three ecologies (Table 5). Northern guinea savanna samples had the least moisture and fibre, the latter being statistically the same as that of the southern guinea savanna zone. It is noteworthy that even in terms of protein, fat and ash content, values of the samples from the northern guinea savanna zone manifested a tendency to be comparatively inferior.

However, as with shea kernel, all proximate attributes of the kernel cake were remarkably influenced by accession (Table 6). Moisture content of the Jalingo kernel cake was the lowest while that of Akwanga was the highest. The energy related traits of carbohydrate, protein and fat varied from 58.4 – 71.9, 7.6-10.1 and 2.8-4.0%, respectively. Shea cake from Akwanga and

Kano was more fibrous than the rest while that of Akwanga had higher ash content. Energy generation was highest for shea cake obtained from Jalingo, though this was statistically the same as that from Minna, and lowest for those from Akwanga and Kano.

Table 3: Eigen vector values for principal components of shea kernel content sourced from 8 locations in Nigeria.

Proximate trait	PRIN. 1	PRIN. 2	PRIN. 3
Moisture	-0.42775	0.03934	-0.47649
Carbohydrate	-0.21948	-0.07746	**0.77522**
Protein	-0.27961	**0.58243**	-0.18462
Fat	**0.51106**	0.01717	-0.23902
Fibre	0.19549	**-0.64757**	-0.16073
Ash	-0.39568	-0.42328	-0.22970
Energy	0.48448	0.23328	-0.04666
Latent roots	3.124	1.700	1.330
Percent of total variation explained	44.62	24.28	19.00

Table 4: Correlations between proximate traits of kernels of *Vitellaria paradoxa* sourced from 8 locations in Nigeria.

	Moisture	Carbohydrate	Protein	Fat	Fibre	Ash	Energy
Energy	-0.657	-0.759*	-0.242	0.953**	0.026	-0.815*	-
Ash	0.663	0.415	-0.009	-0.672	0.140	-	
Fibre	-0.303	-0.451	-0.790*	0.293	-		
Fat	-0.611	-0.903**	-0.415	-			
Protein	0.631	0.334	-				
Carbohydrate	0.292	-					
Moisture	-						

*, ** - Correlation is significant at the 5% and 1% levels of probability respectively.

Table 5: Proximate composition of shea kernel cake based on agro-ecological zone.

Agro ecological zone	Moisture %	Carbohydrate %	Protein %	Fat %	Fibre %	Ash %	Energy Cal/100g
Southern guinea savanna	3.1	66.2	9.2	3.4	12.6	5.5	332.2
Northern guinea savanna	2.4	68.0	8.8	3.2	12.3	5.3	336.0
Sudan savanna	2.5	64.0	9.3	3.4	15.4	5.4	323.8
LSD $_{(0.05)}$	0.4	NS	NS	NS	1.9	NS	NS

NS – No significant difference

Table 6: Proximate composition of shea kernel cake based on accession.

Accession	Moisture %	Carbohydrate %	Protein %	Fat %	Fibre %	Ash %	Energy Cal/100g
Lokoja	3.2	68.9	8.6	3.0	10.5	5.8	337.0
Makurdi	3.0	69.1	9.3	3.1	10.6	4.9	341.5
Akwanga	3.3	58.4	8.9	4.0	19.3	6.1	305.2
Minna	2.8	68.4	10.1	3.6	9.9	5.2	346.4
Kachia	3.0	64.4	9.9	2.9	14.4	5.4	323.3
Jalingo	1.8	71.9	7.6	3.4	10.1	5.2	348.6
Yola	2.2	68.6	9.8	2.8	11.5	5.1	338.8
Kano	2.8	59.6	8.8	3.9	19.3	5.6	308.7
LSD $_{(0.05)}$	0.3	1.1	0.6	0.3	0.6	0.3	5.6

Three principal axes were retained when principal components analysis was used on kernel cake proximate qualities. The three axes explained 89.0% of the total variation (Table 7). Here, it seemed that carbohydrate, fibre, energy, protein, moisture and ash were marked out as discriminate traits for shea cake classification based on proximate qualities.

Similar patterns of correlations as observed among the kernel traits were observed among the kernel cake traits except for the higher number of significant correlations (Table 8). Thus, energy had significant positive statistical linkage with fat but maintained negative statistical linkages with ash and moisture. Ash was positively related with moisture ($P<0.05$) but negatively correlated to fat ($P<0.01$). Protein content correlated negatively to fibre but positively to moisture. On the other hand, fat content had negative significant relationship to both moisture and carbohydrate.

Table 7: Eigen vector values for principal components of shea kernel cake sourced from 8 locations in Nigeria.

Proximate trait	PRIN. 1	PRIN. 2	PRIN. 3
Moisture	-0.27763	-0.48229	**0.58653**
Carbohydrate	**0.46914**	0.09614	0.25569
Protein	0.02037	**-0.78089**	-0.37839
Fat	-0.33263	0.35216	-0.30465
Fibre	**-0.46698**	0.03413	-0.26361
Ash	-0.38819	0.14251	**0.52971**
Energy	**0.47224**	0.05359	0.06731
Latent roots	4.138	1.353	0.738
Percent of total variation explained	59.11	19.32	10.54

Table 8: Correlations between proximate traits of kernel cake of *Vitellaria paradoxa* sourced from 8 locations in Nigeria.

Parameter	Moisture	Carbohydrate	Protein	Fat	Fibre	Ash	Energy
Energy	-0.652**	-0.245	-0.231	0.774**	0.033	-0.690**	-
Ash	0.621**	0.119	-0.064	-0.521**	0.203	-	
Fibre	-0.245	-0.231	-0.459*	0.273	-		
Fat	-0.523**	-0.570**	-0.196	-			
Protein	0.438*	-0.404	-				
Carbohydrate	-0.160	-					
Moisture	-						

*, ** - Correlation is significant at the 5% and 1% levels of probability respectively.

DISCUSSION

Variation in fat content of shea kernels across agro ecologies agrees with findings by Maranz and Wiesman (2003) who found fat content to vary across four climatic zones of several African countries. In their case, the sahelian zone, representing the most dry and hot zone of the four had trees with significantly higher fat content. In this study, the northern guinea savanna, which seems to represent an intermediate zone with respect to climatic variables of temperature and moisture among the three zones, recorded the highest fat percentage in shea nuts. This may be suggestive that fat content is not simply a response to climatic variables but may reflect genetic constitution.

Fat concentration across accessions varied from 28.6 to 34.9%. Other reports have given fat ranges of 32 – 38% (Kar & Mital, 1981); 31 – 62% (Umali & Nikiema, 2002) and 40 – 60% (Vickery & Vickery, 1979). Maranz *et al.* (2004) in their broad based African study reported a range of 20 – 50% with fat percentages as low as 12.4%. The authors however considered values from less than 20% as being from immature kernels whose nuts are normally identified by a white or piebald testa instead of the characteristic shiny brown seed coat. Such could arise if immature fruits are blown down by strong winds.

It was observed in the period of fruit collection that insect attack on immature fruit could predispose them to premature fall. Most of such fruits as well as other unripe ones fall with the stalk still attached and may appear lighter than healthy or ripe fruit. When pinched, the fruit pulp which may still be very firm to the touch appears whitish on the inside and readily exudes a milky substance. Those attacked by insects may have holes that go right into the immature kernel. During the present study care was taken to avoid such fruits so as not to introduce any confounding factors.

Traditional African methods of fat extraction are tasking. As such, fat yield of shea kernel is a key consideration since higher fat content implies higher return on the same amount of energy invested. The fat percentage range in this study (28.6-34.9) appears impressive when rated against the 20-50% reported by Maranz *et al.* (2004). According to these authors fat percentages between 20 and 30 are low, those in the mid 30's are intermediate and values above 40 are good. Such classification would place Kachia and Jalingo shea accessions under the intermediate fat category while the rest would be in the low or poor fat content group. All considered, fat percentages obtained in Nigeria (this study) are higher than those reported for North and West Cameroon as well as Western Mali and Senegal.

Although, kernel fat values of up to 60% or more have been reported (Adu Ampomah *et al.* 1995; Umali & Nikiema, 2002), Maranz *et al*., (2004) have expressed strong reservation on the accuracy of such values, attributing it rather to insufficient expulsion of water in the extracted fat. However, given the considerable variation in shea traits across the distribution range due to genetic and environmental factors, shea fat values of about 60% are possible.

The protein value of 6.3-8.9% reported here approximately compares to the range of 7 – 9% by Umali and Nikiema (2000). However, their carbohydrate values (31-38%) appear appreciably lower than what was obtained in our case (43.4 – 48.9), the difference being up to 10%. This could likely be a compensatory response of carbohydrate to the comparatively low fat content.

The high energy content of shea kernel (480.2 – 519.7cal/100g) may partly explain the reason shea butter tree seedlings are able to withstand or survive the long dry period prevalent in the savanna region. The significant positive correlation between fat and energy and corresponding negative relationship between energy and carbohydrate apparently signifies the relative contribution of these two traits to energy generation. Thus fat is evidently more important in energy production than carbohydrate.

Umali and Nikiema (2002) have given the following ranges of proximate traits of shea seed cake: 48 – 67.5% carbohydrate, 8 – 25% protein, 2 – 20% fat, 5 – 12% fibre and 5 – 7% ash. Corresponding ranges in this study were 58.4 – 71.9, 7.6 – 10.1, 2.9 – 4.0, 9.9 – 19.3 and 4.9 – 6.1%, respectively. With respect to carbohydrate and fibre, the ranges in our study were higher. However, for the other traits the ranges are lower especially the upper limit values. Shea kernel cake appears to be higher in fibre content compared to cashew nut meal but comparable to that of cottonseed meal. Similarly, shea fat content is higher than that of cashew nut meal but comparable to that of soybean meal (Aduku, 1993).

These proximate qualities including the high energy content has qualified shea seed cake at least as a potential source of feed for livestock. According to ICRAF (2000), shea nut cake is already being used as a livestock and poultry feed. One advantage shea cake may have is its reported low aflatoxin content even when mouldy, although the presence of anti-nutritional factors and low digestibility (Umali & Nikiema, 2002) appear to be setbacks that need to be overcome. According to the above authors, shea seed cake is utilized in Europe as a non-nutritional bulk for compound cakes. The significant positive correlation between fat and energy is an indication that even in the seed cake, the fat component is contributing more to energy than carbohydrate. In Nigeria, conventional oilseed resources such as groundnut cake, soybean cake, cotton seed cake and palm kernel meal have made remarkable contributions to the livestock feed industry (RMRDC, 2003).

Results of this study show the excellent proximate qualities of the Nigerian shea seed and seed cake and points to their potential significance in the Nigerian animal feed industry. Their use would help to reduce pressure on conventional food items that are normally used in the feed industry thereby releasing more food for direct human consumption.

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