Original article

Nutritional composition of shea (*Vitellaria paradoxa*) fruit pulp across its major distribution zones in Nigeria

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Nutritional composition of shea (*Vitellaria paradoxa*) fruit pulp across its major distribution zones in Nigeria.

Abstract — Introduction. The widely recognised dietary and socio-economic value of the shea nut and its butter extract seems to have diminished the usefulness attached to the shea fruit pulp, which is also very important. This is evident from the dearth of scientific information on the nutritional content of the pulp. **Materials and methods**. We determined the nutritional composition of shea fruit pulp of fruits collected in seven locations spread in the southern Guinea savanna, northern Guinea savanna and the Sudan savanna of Nigeria. **Results**. Analysis of variance revealed a significant effect of agro-ecological zones on carbohydrate, protein, fibre and energy. The southern Guinea savanna zone recorded comparatively more carbohydrate and energy content than the other two zones, while maintaining lower values for protein and fibre. Conversely, all nutritional traits varied significantly across the fruit pulps for fruits collected in the individual locations surveyed in the three zones. Values for carbohydrate, protein and fat ranged from 29.3–45.3%, 2.6–7.0% and 0.7–1.7%, respectively. Correlation analysis established a positive significant relationship between carbohydrate and energy, but its relationship with fibre and protein was negative and significant. Fibre content maintained a negative relationship with energy while being positively correlated with protein. Principal component analysis identified fibre, energy, ash, protein and moisture as nutritional traits that could be used in classifying shea fruit pulp. **Discussion**. Our study showed that the Nigerian *Vitellaria* fruit pulp has adequate nutritional content that is comparable with that of other species. The strong statistical linkage between fibre and protein in shea fruits presents an attractive combination, particularly for children of the rural zones with restricted access to the more conventional and expensive food sources.

Nigeria / *Vitellaria paradoxa* / fruit pulps / proximate composition

Valeur nutritionnelle de la pulpe de karité (*Vitellaria paradoxa*) selon les principales zones d'extension de la plante au Nigéria.

Résumé — Introduction. La valeur diététique et socio-économique largement reconnue de la noix de karité et du beurre qui en est extrait semble avoir dissimulé l'importance de la consommation de la pulpe du fruit qui est également très importante. Cela apparaît évident lorsqu'on considère la pénurie d'informations scientifiques sur la valeur nutritionnelle de cette pulpe. **Matériel et méthodes**. Nous avons déterminé la composition nutritionnelle de la pulpe de karité pour des fruits collectés dans sept localités du Nigéria, réparties dans des zones de savane guinéenne méridionale, savane guinéenne du Nord et savane soudanienne. **Résultats**. L'analyse de variance a révélé un impact significatif des zones agro écologiques sur les taux en hydrates de carbone, protéines, fibres et sur la valeur énergétique. La zone de savane guinéenne méridionale a induit comparativement des teneurs plus élevées en hydrates de carbone et en énergie que les deux autres zones, tout en présentant des valeurs plus basses pour les taux en protéines et en fibres. Réciproquement, tous les paramètres nutritionnels de la pulpe ont varié de manière significative pour les lots de fruits provenant de chacune des localités considérées dans les trois zones agro écologiques étudiées. Les taux en hydrates de carbone, protéines et matières grasses ont été de 29,3–45,3 %, 2,6–7,0 % et 0,7–1,7 %, respectivement. Une corrélation significativement positive a été trouvée entre le taux en hydrates de carbone et la valeur énergétique, alors qu'une corrélation négative est apparue entre les teneurs en fibres et en protéines. Par ailleurs, la teneur en fibres a présenté une corrélation significativement négative avec la valeur énergétique, tout en étant franchement corrélée avec le taux en protéines. L'analyse en composantes principales a déterminé la teneur en fibres, la valeur énergétique, le taux en cendres, la teneur en protéines et la teneur en eau comme caractères nutritionnels pouvant être utilisés pour classifier la pulpe des fruits de karité. **Discussion**. Notre étude a prouvé que la pulpe des fruits nigérians de *V. paradoxa* a une valeur nutritionnelle comparable à celle d'autres espèces fruitières. La forte liaison statistique entre les teneurs en fibres et en protéines des fruits de karité présente un intérêt réel, en particulier pour les enfants des zones rurales ayant un accès limité à des ressources alimentaires plus conventionnelles et plus coûteuses.

Nigéria / *Vitellaria paradoxa* / pulpe de fruits / composition globale

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1. Introduction

The shea butter tree, *Vitellaria paradoxa*, belongs to the family Sapotaceae. In Nigeria, it is found scattered through much of the savanna belt [1]. *Vitellaria* is both a fruit tree and an oilseed crop [2, 3]. It is, however, better known for its fat, commonly called shea butter, that is extracted from the kernels of its nuts [4]. Shea butter is still considered second to palm oil as the most important source of cooking fat, particularly by West African rural dwellers [5]. Its importance in this regard becomes magnified in areas that are climatically unsuitable for the cultivation of the oil palm [6].

Apart from the above use, the butter is used locally in soap and pomade production [7] and in the treatment of cough and minor bone dislocation [8]. In Europe and other parts of the developed world, shea nuts, imported from Africa, are used mainly in the food and cosmetic industries [9]. The export of shea nuts is said to exert a positive impact on the economies of the exporting countries [10].

The shea tree also produces a fruit whose pulp is sweet and edible when ripe. The fruit pulp, made up of the epicarp and mesocarp, constitutes up to 50–80% of total fruit weight and could be fed to livestock [6]. The fruit is widely consumed among African peoples among whom the species occurs, and it is even sold in local markets [4]. Shea fruit ripen at a very critical time of the year – the early part of the rainy season – when labour-intensive farming operations need to be carried out [11], and yet there is prevailing hunger due to depletion of stored food reserves [4]. The importance of the fruit among both children and adults at this critical period is therefore considerable.

However, the widely recognised dietary and socio-economic value of the shea nut and its butter extract seem to have diminished the usefulness attached to the shea fruit pulp, which is also very important. This is evident from the dearth of scientific information on the nutritional content of the pulp. Two reports available [4, 5] focused more on the elemental nutrient composition and sugar content, while neglecting its proximate qualities. Hoe and Sing [12] analysed the fruit pulp of 16 indigenous Malaysian fruits and found their nutritional content to be comparable, if not superior in some cases, to that of commonly cultivated species such as guava and papaya. We decided to undertake this work to capture the nutritional content of shea fruit pulp and its possible variation across the Nigerian savanna. This represents an effort towards highlighting the nutritional importance of shea fruit, particularly now that the species is globally gaining increasing commercial and scientific attention.

2. Materials and methods

2.1. Collection and preparation of samples

Fallen fruits of the shea tree were collected from seven locations (Akwanga, Jalingo, Kachia, Kano, Lokoja, Makurdi and Yola) across the Guinea and Sudan savanna zones of Nigeria in July 2006 (*table I*). Fruits were collected from 25 trees in each site and were pooled together, then samples were taken from each bulk for analysis. Fresh whole fruits were depulped and the fruit pulp, comprising the epicarp and mesocarp, was oven-dried at 65 °C [4] to a constant weight. Dry samples were finely milled for laboratory analysis.

2.2. Laboratory analysis

Nutritional composition of milled samples was determined following procedures outlined by the Association of Official Analytical Chemists [13] at the Crop Science laboratory of the University of Nigeria, Nsukka. Three samples (replications) from the bulked fruits from each site were analysed. The constituents determined were moisture, ash, crude fat, crude fibre, crude protein, carbohydrate and energy (cal·100 g^{-1}). Ash was estimated by incinerating 2 g of sample in a muffle furnace at 600 °C until ash was obtained. Determination of fat was done by extracting 2 g of sample with petroleum

Table I.
Geographic description of accession collection sites surveyed in Nigeria for studying the nutritional composition of shea fruit pulp.

Agro-ecology	Collection site	Altitude (m)	Latitude	Longitude	Annual rainfall (mm)
Southern Guinea savanna	Akwanga	308	8° 55'	8° 24'	1300
	Lokoja	97	7° 47'	6° 43'	1300
	Makurdi	97	7° 41'	8° 37'	1150
Northern Guinea savanna	Jalingo	350[1]	9° 11'	11° 15'	1050
	Kachia	682	9° 56'	8° 00'	1300
Sudan savanna	Kano	488	12° 00'	8° 31'	850
	Yola	174	9° 14'	12° 23'	950

[1] Value is mean of the general range of 200–500 m, based on Ologe [13].

ether in a Soxhlet apparatus. The micro-Kjedahl method was employed for estimation of crude protein. The value for carbohydrate was obtained by subtracting from 100 the summation of values of moisture, ash, crude protein, crude fat and crude fibre. Energy content was calculated by multiplying the values for crude protein, fat and carbohydrate by the Atwater factors of 4, 9 and 4, respectively [14].

Fibre was determined using the Weende method which involves hydrolysing the protein, starch and other digestible carbohydrates and fat out of the sample (1.5 g) before proceeding with the test.

2.3. Statistical analysis

Analysis of variance was carried out separately on the agro-ecological zones and on the individual accessions. Principal component analysis was performed to identify traits' contribution to observed variability in shea fruit pulp composition. The statistical software employed for the analysis was GENSTAT Discovery, edition 2 [15]. In addition, SPSS was used to estimate correlations among nutritional traits. Furthermore, accession by traits' interaction analysis to identify which traits of a specific accession are most prominent was accessed by GGE biplot analysis [16]. The significance of treatment means was detected by least significant difference (LSD) at the 5% probability level.

3. Results

Agro-ecological zones significantly ($P < 0.05$) affected carbohydrate, protein and fibre contents, and energy, of the shea fruit pulp studied (*table II*). Whereas carbohydrate decreased at higher latitude, the reverse was the case with protein: for example, fruits collected from the Sudan savanna contained 5.7% protein as against 3.8% for fruits collected from the southern Guinea savanna. Shea fruits from the southern Guinea savanna zone had less fibre than those from other zones, even though they had comparatively higher energy content. Conversely, the levels of moisture, fat and ash were statistically the same across agro-ecologies.

The specific locations (accessions) of fruit collection significantly ($P < 0.05$) influenced all nutritional qualities investigated (*table III, figure 1*). Makurdi and Yola fruits had high moisture contents; in contrast, fruits from Akwanga had very low moisture levels. It was observed that, even among accessions from a particular agro-ecology, moisture content varied remarkably; for example, Lokoja and Makurdi, though both belong to the southern Guinea savanna agro-ecology, varied significantly in moisture content. The Lokoja accession had the highest value for percent carbohydrate, while Kachia and Kano had the lowest. Protein content also varied widely from a low value of 2.6% for

Table II.
Nutritional composition of Nigerian shea fruit pulp based on agro-ecological zones. Fruits were collected from at least 50 trees in each agro-ecological zone, pooled together in each zone. After the fruit pulp was oven-dried, at least six samples from the lots were analysed per zone.

Agro-ecological zone	Moisture	Carbohydrate	Protein	Fat	Fibre	Ash	Energy (cal·100 g^{-1})
	(%)						
Southern Guinea savanna	9.1	42.7	3.8	1.4	37.8	5.2	198.5
Northern Guinea savanna	9.5	33.7	4.8	1.4	44.5	6.2	166.4
Sudan savanna	9.5	35.2	5.7	1.1	44.3	4.9	173.5
Least significant difference (0.05)	Not significant	5.0	1.5	Not significant	4.2	Not significant	16.1

Table III.
Nutritional composition of the Nigerian shea fruit pulp based on accessions. Fruits were collected from 25 trees per site and pooled together. After the fruit pulp was oven-dried, three samples from the lots were analysed per site.

Zone	Accession	Moisture	Carbohydrate	Protein	Fat	Fibre	Ash	Energy (cal·100 g^{-1})
		(%)						
Southern Guinea savanna	Akwanga	8.8	42.5	3.5	1.7	39.0	4.6	198.8
	Lokoja	8.5	45.3	4.4	1.2	35.5	5.2	209.2
	Makurdi	10.1	40.4	3.5	1.4	38.9	5.9	187.6
Northern Guinea savanna	Kachia	9.2	29.3	7.0	1.5	48.6	4.5	158.3
	Jalingo	9.7	38.1	2.6	1.3	40.4	8.0	174.5
Sudan savanna	Kano	9.0	29.3	5.3	1.6	48.8	6.2	152.2
	Yola	10.0	41.1	6.1	0.7	39.8	3.6	194.7
Least significant difference (0.05)		0.3	0.8	0.2	0.2	1.6	0.2	2.0

the Jalingo accession to a high value of 7.0% for the Kachia accession. All accessions had fat content above 1%, except Yola with a fat content of 0.7%. Values for crude fibre were high, ranging between 35.5% for Lokoja fruits and 48.8% for Kano fruits. Ash content was highest (8.0%) for the Jalingo accession and lowest (3.6%) for the Yola accession even though the two locations belong to the same ecological zone (Sudan savanna). The energy value of shea fruit pulp from Lokoja was higher than those of the other locations. Kano fruits had the lowest energy content. The biplot analysis (*figure 1*) clearly revealed that Lokoja fruits were highest in energy and carbohydrate content; Kachia and Kano fruits combined high contents of protein, fibre and fat, while Jalingo fruits were most prominent for the ash content. Fruits collected at Akwanga and Makurdi were the most similar in nutritional qualities.

Correlation analysis among nutritional traits revealed that moisture content did not show a significant relationship with any of the other traits (*table IV*). However, carbohydrate and energy were significant and positively correlated. The relationships of carbohydrate with fibre and protein were significant but negative. Protein content had a highly significant negative relationship with ash but its correlation with fibre was positive and significant. There was a high negative but significant relationship

between fibre and energy. It was noteworthy that, of all traits considered, only carbohydrate maintained a positive significant relationship with energy. Other traits were negatively correlated with it, although only fibre was significantly so.

The relative importance of the nutritional quality traits of shea fruit pulp as discriminant variables for characterising Nigerian shea fruit accessions was examined with Principal Component Analysis (PCA) (*table V*). PCA revealed that carbohydrate, fibre and energy explained up to 48% of the existing variability in the fruits collected from seven locations in Nigeria. Also, it was notable that the quantity of protein and ash in the fruit pulp accounted for about 27% of the total variance, while moisture explained 18%. It was notable that the fat content of the accessions evaluated was not distinct enough to serve as a discriminant variable; however, energy, protein and fibre contents revealed high potentials for nutritional classification of shea fruits from Nigeria.

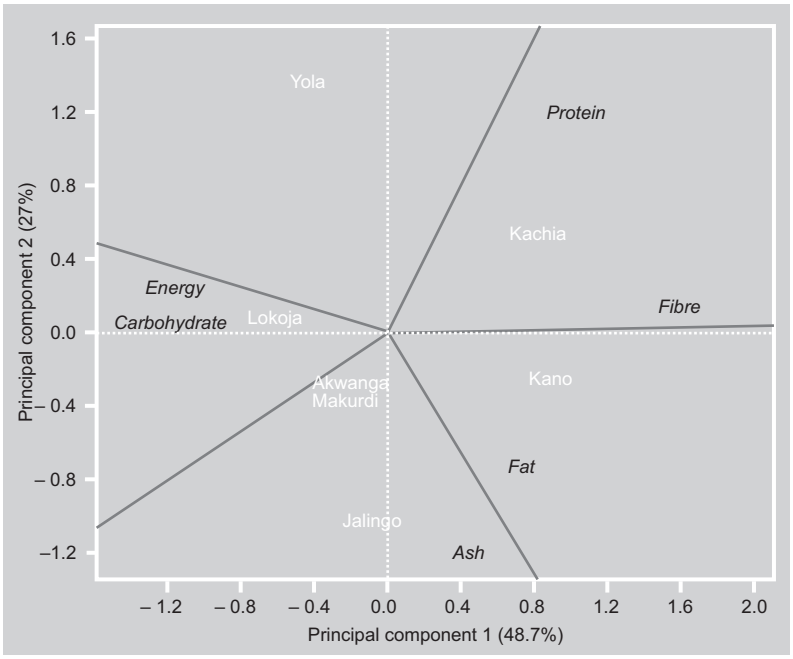

Figure 1.
Presentation of the plan of the first two axes for a principal component analysis studying nutritional qualities of shea fruit pulp of seven accessions of *Vitellaria paradoxa* fruits across their major distribution zone in Nigeria.

4. Discussion

The higher amount of carbohydrate in the southern Guinea savanna fruits may be attributed to more adequate water supply that is necessary for optimum rates of photosynthesis [17]. Generally, the amount of rainfall decreases as one moves from the southern Guinea savanna further North [18]. Since soil nitrate nitrogen is highly mobile and easily leached [20], it is likely that the wetter southern Guinea savanna zone afforded greater opportunities for leaching losses, hence the disparity in observed fruit protein content across ecologies. The higher protein values among northern Guinea savanna and Sudan savanna fruits agrees with Maranz *et al.* [4] ,who reported a pattern of higher protein content. The higher protein value of the drier ecologies was evident among individual accessions, except for Jalingo with a protein value of 2.6%. In our context, Kachia, though with a higher

Table IV.
Correlations among nutrional traits of shea fruit pulp sourced from seven locations of collections surveyed in Nigeria.

Components	Energy	Ash	Fibre	Fat	Protein	Carbohydrate	Moisture
Moisture	– 0.102	0.111	– 0.042	0.359	– 0.056	– 0.022	–
Carbohydrate	0.976**	– 0.153	– 0.980**	– 0.376	– 0.524*	–	
Protein	– 0.366	– 0.669**	0.581**	– 0.214	–		
Fat	– 0.377	0.298	0.359	–			
Fibre	– 0.936**	0.033	–				
Ash	– 0.330	–					
Energy	–						

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

Table V.
Eigen vector values for principal components of nutritional composition of shea fruit pulp sourced from seven locations in Nigeria.

Principal components	Moisture	Carbohydrate	Protein	Fat	Fibre	Ash	Energy	Latent roots	% of total variation explained
Axis 1	– 0.02629	– 0.54104	0.29311	0.23518	0.53698	0.06045	– 0.52283	3.379	48.27
Axis 2	0.06597	0.00473	0.60029	– 0.43600	0.06060	– 0.65374	0.11886	1.860	26.57
Axis 3	0.81853	– 0.07632	– 0.08487	– 0.45690	0.00602	0.27719	– 0.17706	1.294	18.48

rainfall amount than in other locations in the Southern Guinea Savanna (*table I*), may still be considered a drier zone since the rainfall is distributed over a relatively shorter period [18].

The comparatively higher fibre content among the northern Guinea savanna and Sudan savanna fruits points towards a higher accumulation of non-digestible carbohydrate owing to reduced rates of photosynthesis prevalent under conditions of low moisture availability. In general terms, the fibre content range of 35.5–48.8% seems rather high when compared with other agroforestry species such as African star apple (*Chrysophyllum albidum*) and African pear (*Dacryodes edulis*), with values of 4% and 17.9%, respectively [21, 22]. On health grounds, however, high fibre content of foods could be desirable since it prevents obesity, lowers blood cholesterol and reduces the risk of heart disease by binding bile salts and cholesterol secreted in the bile, which are subsequently excreted out of the body. Besides, it is credited with cancer prevention as it binds potentially carcinogenic compounds from diets and thereby precludes their absorption into the body and thus their interaction with intestinal walls [23].

The percentage of ash in a food material is an indication of its inorganic content [23]. In the context of this study, the exceptionally high ash values of the Jalingo fruits could be explained based on soil type, identified as a source of variability in shea nut tree characters. Jalingo soils, described as tropical ferruginous soils, are noted for their high productivity compared with other soil types [19]. Apart from Lokoja, soils of the sites where other accessions were collected were either lithosols (Akwanga, Yola, Kano and Kachia) or ferralsols (Makurdi), and are noted to be lower in fertility compared with the tropical ferruginous soils [19].

The energy value of 152.2–209.2 cal·100 g^{-1} seems high enough for a fruit. This is interesting when considering that the time of shea fruit drop coincides with the season of tasking and energy-sapping farm operations [4] with corresponding low food reserves in the barns [11]. *Vitellaria* fruits thus serve as a fresh food source, providing part of the energy needed for the laborious farm operations at this time.

The energy-related traits of shea fruit pulp as obtained in this study are comparable with those reported for plantains and bananas, which are commonly consumed as staple tropical fruits [24]. The only exception is in terms of carbohydrate content, in which the shea fruit values were lower than those of plantains and bananas. In societies with critical protein needs such as Nigeria, the nutritional rating of shea fruit pulp may be higher than ordinarily recognised when its protein content (2.6–7.0%) is rated against the zero protein content of mango fruit [25], one of the commonest tropical fruits. Maranz *et al*. [4], analysing shea fruit pulp from six African countries (excluding Nigeria), found the protein content varied between 2.4% and 10.3% with a mean of 5.6%. Our values range from 2.6% to 7.0% with a mean of 4.6%, indicating that protein value of the Nigerian shea fruit is in close proximity to what may be regarded as the African average.

The highly significant relationship between carbohydrate and energy suggests that fruits high in carbohydrate would expectedly

yield a greater amount of energy. The negative significant relationship between fibre and carbohydrate as well as energy is understandable since a high proportion of fibre in a food substance will reduce the amount of digestible carbohydrate, invariably leading to low energy generation. However, the significant positive relationship between protein and fibre suggests joint inheritance. The nutritional implication is that it is possible to consume a high-fibre product that is rich in protein, an essential combination for children of the poor rural dwellers.

The eigen values for the nutritional traits as revealed by the PCA indicated the relative importance of the traits for classifying Nigerian shea fruit germplasm; however, energy, protein and fibre contents revealed high potentials as discriminate variables for nutritional classification of shea fruits from Nigeria. The above traits could therefore form the basis for classifying shea fruit pulp in terms of nutritional composition across the major shea distribution zone in Nigeria.

The results of this study indicate variation in shea fruit pulp across the Nigerian savanna. Besides, the fruit pulp is nutritious enough, especially given its high protein, fibre, carbohydrate and energy content. The comparable nutritional levels of shea fruit pulp with those of some common tropical fruits reinforce its usefulness in alleviation of hunger among rural dwellers. Besides, it has nutritional potentials to suggest its inclusion in complementary food production for children and the need to bring the species to regular cultivation culture and for genetic improvement.

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Valor alimenticio de la pulpa de karite (*Vitellaria paradoxa*) según las principales zonas de extensión de la planta en Nigeria.

Resumen — Introducción. El valor dietético y socio-económico ampliamente reconocido de la nuez de karite así como el de la manteca que se extrae de ella parecen haber disimulado la importancia del consumo de la pulpa del fruto que es también muy importante. Esto parece evidente cuando uno considera la penuria de informaciones científicas sobre el valor nutritivo de esta pulpa. **Material y métodos**. Determinamos la composición nutritiva de la pulpa de karite para los frutos cosechados en siete localidades de Nigeria, repartidas en zonas de sabana guineana meridional, sabana guineana del norte y sabana de Sudán. **Resultados**. El análisis de varianza mostró un impacto significante de las zonas agro-ecológicas tanto sobre los índices de hidratos de carbono, proteínas, fibras como sobre el valor energético. La zona de sabana guineana meridional indujo comparativamente unos contenidos más elevados en hidratos de carbono y en energía que las otras dos zonas, y presentó, no obstante, unos valores más bajos para los índices de proteínas y de fibras. Recíprocamente, todos los parámetros nutricionales de la pulpa variaron de manera significativa para los lotes de frutas procedentes de cada una de las localidades consideradas en las tres zonas agro-ecológicas estudiadas. Los índices de hidratos de carbono, proteínas y de materias grasas fueron de 29,3–45,3 %, 2,6–7,0 % y 0,7–1,7 %, respectivamente. Se encontró una correlación significativamente positiva entre el índice de hidratos de carbono y el valor energético, mientras que apareció una correlación negativa entre los contenidos en fibras y en proteínas. Por otro lado, el contenido en fibras presentó una correlación significativamente negativa con el valor energético, a la vez que estaba francamente correlacionado con el índice de proteínas. El análisis de composiciones principales determinó el contenido en fibras, el valor energético, el índice de cenizas, el contenido en proteínas así como el contenido en agua como caracteres nutricionales que pueden emplearse para clasificar la pulpa de los frutos de karite. **Discusión**. Nuestro estudio demostró que la pulpa de los frutos nigerianos de *V. paradoxa* tiene un valor nutricional comparable al de otras especies fruteras. La fuerte relación estadística entre los contenidos en fibras y en proteínas de los frutos de karité presenta un interés real, en particular para los niños de las zonas rurales cuyo acceso a los recursos alimentarios más convencionales y más costosos, es limitado.

Nigeria / *Vitellaria paradoxa* / pulpa de frutas / composición aproximada