Nutrient and Anti–Nutrient Composition of Shea (*Vitellaria paradoxa* C. F. Gaertn) Kernel and Pulp in the North East Nigeria

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Abstract: This study determines the proximate, mineral, amino acid and anti-nutritional compositions of shea (*Vitellaria paradoxa*) kernel and pulp using standard analytical methods. The result showed that the contents of crude fat and protein in the kernel are higher than that of the pulp. The only minerals whose values ranged between 40.0 to 200 mg/100 g were P, Ca and Na for the kernel and pulp samples but values of other minerals (Mn, Fe, Zn, K, Cu and Mg) were below 10.00 mg/100 g on wet weight basis. Amino acid analysis of kernel and pulp showed concentrations of TAA (57.92 and 57.48 g/100 g crude protein), TEAA (27.10 and 19.04 g/100 g cp) and TNEAA (30.82 and 38.44 g/100 g cp). Arginine was the most concentrated EAA in both the kernel and pulp samples. Except for the alkaloid, the kernel sample contained higher concentrations of anti-nutritional factors than the pulp. Generally, *Vitellaria paradoxa* kernel and pulp contained nutritive minerals and sufficient proportions of EAAs however, supplementation of all the EAAs will be required in order to meet up with FAO/WHO dietary requirements. Also the high contents of some of their anti–nutrients may pose a nutritional problem in their consumption.

Keyword: *Vitellaria paradoxa*, Kernel, Pulp, Proximate, Minerals, Amino Acids, Anti-Nutrients

Introduction

Shea butter is an extract from the seed of shea nuts tree (*Vitellaria paradoxa* formerly known as *Butryspermum paradoxum, B. parkii* and *B. paradoxa*) belonging to *Sapotaceae* family – has been used for a wide range of cosmetics products. It has also been used for ethno–pharmacological purposes. For instance, local healers have used shea butter for the treatment of nostril inflammation, nasal congestion, minor bone dislocation, cough, leprosy and rheumatism [1, 2]. Shea butter has been used in addition, to massage newly born babies, protect against *Simulium* infection as insect repellent and prevent stretch marks among African pregnant women [2]. Furthermore, shea butter has served in African kitchen as edible oil due to its price affordability and highly nutritional value [3, 4]. For example, shea butter is used in northern Nigeria as the base of soup and condiments.

Diets in developing economies like Nigeria are predominantly based on poorly digestible proteins from less refined cereals and grain legumes, which contain high levels of less-digestible protein fractions, high levels of insoluble fibre and high concentrations of anti–nutritional factors [5]. Anti–nutritional factors may occur endogenously or may be formed during heat/alkaline processing of proteins. The examples of major naturally occurring anti–nutritional factors include trypsin inhibitors and haemagglutinins in legumes; tannins in legumes and cereals; phytates in cereals and oilseeds; glucosinolates in canola and mustard protein products; gossypol in cottonseed protein products;

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and uricogenic nucleic acid bases in yeast protein products [5, 6, 7].

In Nigeria, the shea-butter tree occurs mainly across the wide expanse of Guinea and Sudan savanna zones otherwise known as savanna belt [8, 9]. Hence, this wide distribution and high concentration of the trees presumably accounts for Nigeria's position as the leading producer of shea nuts in Africa [10]. Unfortunately, very little information exists on amino acids composition of shea-butter fruit (both kernel and pulp) found in the savanna/shea belt of Nigeria. Therefore, in order to find means of enriching diets of rural communities within the shea belt and to raise the nutritional potential of shea-butter fruit, we deemed it is important to assess the chemical composition of the shea-butter fruit (kernel and pulp) grown in north–east, Nigeria so as to provide the much needed information on the nutritive values (proximate, minerals and amino acids) and anti–nutritional factors (saponin, tannin, alkaloid, oxalate, cyanide and phytate).

Materials and Methods
Collection and preparation of samples
Fresh shea-butter fruits were collected from a small farm at Wukari, Taraba State (Northern guinean savanna), Nigeria. The fruits were de-pulped and the fruit pulp, comprising the epicarp and mesocarp, were oven-dried (between 40 °C and 50 °C) to a constant weight for five days. The de-pulped seeds of the shea-butter fruit were cracked to remove the kernel which was also oven–dried at the same temperature range for 4 days. Dried samples were finely milled for laboratory analysis.

Proximate analysis
The moisture, ash, crude fat, crude protein (N x 6.25), crude fibre and carbohydrate (by difference) were determined in accordance with the standard methods of AOAC [11]. All proximate analyses of the sample flours were carried out in triplicate and reported in percentage. All chemicals were of Analar grade.

Mineral analysis
The standards of K, Na, Ca, Mg, Mn, Fe, Cu and Zn solutions of 0.2, 0.4, 0.6, 0.8 and 1.0 mgL^{-1} were prepared from each of the metal solutions of 1000 mgL^{-1} stock solutions. The filtrates of the digested

samples were analysed by atomic absorption spectrophotometer (AAS). The detection limit of the metals in the sample was 0.000 mgL^{-1} by means of the UNICAM 929, London, atomic absorption spectrophotometer powered by the solar software. The optimal analytical range was 0.1 to 0.5 absorbance units with coefficient of variation from 0.9% to 2.21%. Phosphorus was determined colorimetrically [12] using a Spectronic 20 (Gallenkamp, London, UK) instrument, with KH_2PO_4.

Amino acid analysis
The amino acid analysis was by Ion Exchange Chromatography (IEC) [13] using the Technico Sequential Multisample (TSM) Amino Acid Analyzer (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 $mLmin^{-1}$ at 60°C with reproducibility consistent within ± 3%. The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. Amino acid values reported were the averages of two determinations. Nor–leucine was the internal standard. Tryptophan was determined after alkali (NaOH) hydrolysis by the colorimetric method [14].

Determination of isoelectric point (pI), quality of dietary protein and predicted protein efficiency ratio (P–PER)
The predicted isoelectric point was evaluated according to Olaofe & Akintayo [15]:

$$plm = \sum_{i=1}^{n=1} pliXi \quad ----(1)$$

Where:
pIm = the isoelectric point of the mixture of amino acids;
pIi = the isoelectric point of the ith amino acids in the mixture;
Xi = the mass or mole fraction of the amino acids in the mixture.

The quality of dietary protein was measured by finding the ratio of available amino acids in the sample protein compared with the needs expressed as a ratio. Amino acid score (AAS) was then estimated by applying the FAO/WHO [13] formula:

$$AAS = \frac{mg\ of\ amino\ acid\ in\ 1g\ of\ test\ protein}{mg\ of\ amino\ acid\ in\ reference\ protein} \times \frac{100}{1} \quad -----(2)$$

The predicted protein efficiency ratio (P–PER) of the seed sample was calculated from their amino acid composition based on the equation developed by Alsmeyer *et al.* [16] as stated thus;
P–PER = –0.468 + 0.454(Leu) – 0.105(Tyr) - - - - - - - - - - - - - - - - - - (3)

Anti–nutritional Factors Determination

The contents of saponin, tannin, alkaloid, phytate, oxalate and cyanide were determined on each of the sample flours by methods described by some workers [17, 18].

Statistical analysis of the samples

The fatty acid values were obtained by multiplying crude fat value of each sample with a factor of 0.8 (i.e. crude fat x 0.8 = corresponding to fatty acids value [19]. The energy values were calculated by adding up the carbohydrate x 17 kJ, crude protein x 17 kJ and crude fat x 37 kJ for each of the samples [20]. Errors of three determinations were computed as standard deviation (SD) for the proximate composition. The grand mean, SD and coefficient variation (RSD) were also determined.

Results and Discussion

Proximate composition is important in determining the quality of food materials and often the basis for establishing their overall nutritional value. Table 1 depicts the proximate compositions of kernel and pulp of *Vitellaria paradoxa*. The kernel and pulp sample values were: 4.41% and 9.72%, 3.17% and 4.78%, 45.62% and 10.95%, 9.30% and 5.23%, 4.73% and 6.57% and 32.77% and 62.77% for moisture, ash, crude fat, crude protein, crude fibre and carbohydrate, respectively. The calculated fatty acids and metabolizable energy were 36.50 and 8.76%; 2403.13 and 1560.88 kJ/100 g, respectively.

Table 1: Proximate composition (%)[a] of kernel and pulp of *Vitellaria paradoxa*

Parameter	Kernel	Pulp	Mean	SD	RSD
Moisture	4.41 ± 0.19	9.72 ± 0.22	7.07	2.66	37.62
Ash	3.17 ± 0.08	4.78 ± 0.23	3.98	0.81	20.35
Crude fat	45.62 ± 0.29	10.95 ± 0.56	28.29	17.34	61.29
Crude protein	9.30 ± 0.11	5.23 ± 0.27	7.27	2.04	28.06
Crude fibre	4.73 ± 0.29	6.57 ± 0.11	5.65	0.92	16.28
Carbohydrate[b]	32.77 ± 0.15	62.77 ± 0.91	47.77	15.00	31.4
Fatty acid[c]	36.50 ± 0.24	8.76 ± 0.45	22.63	13.87	61.29
Energy[d]	2403.13 ± 15.15	1560.88 ± 9.57	1982.01	421.13	21.25

[a]Mean values ± standard deviations of triplicate determinations; [b]Carbohydrate percent calculated as the (100 – total of other components); [c]Calculated fatty acid (0.8 x crude fat)
[d]Calculated metabolizable energy (kJ/100 g) (protein x 17 + fat x 37 + carbohydrate x 17)
SD = Standard deviation; RSD = Relative standard deviation.

The moisture contents obtained for the kernel and pulp of *Vitellaria paradoxa* varied significantly with those obtained for soursop (10.97%), *Pterygota macrocarpa* (10.38%), *Hexalobus crispiflorus* (7.11%), *Bracystegia eurycoma* harm (10.60%), *Clitandra togolana* (10.81%) and *Adansonia digitata* pulp (10.90%) as reported by many researchers [21 – 26]. The results however, are higher when compared to the seed of *Maesobotry barteri* fruit (3.85%) [27], leaves of *Moringa oleifera* (3.21%) [28], *Haematostaphis barteri* seed (2.75%) and pulp (3.56%) [29], *Adansonia digitata* seed (3.50 %) [26] and kersting's groundnut (1.7%) [30]. Moisture content in foods has an important relationship between conservation and the physical, chemical and microbiological changes during the storage [31]. Moderate moisture content of $\leq 12\%$ is preferred for shelf stability of food on long storage [32].

Fiber intake is largely important due to its physiological effects that have benefit health implications [33]. Strong correlations exist between the moisture contents and crude fiber which could be of interest to human health as the fibrous are easily digested and disintegrate. Crude fibers in the diet are necessary for digestion and for effective elimination of wastes. It can lower the serum cholesterol, the risk of coronary heart disease, hypertension, constipation, varicose veins, diabetes, phlebitis, obesity, cancer of breast, rectum and colon cancer and even threat of gastrointestinal disorders [34 – 35]. The fibre content values obtained in the kernel (4.73%) and pulp (6.57%) samples of *Vitellaria paradoxa* exceed that of *P. guineense* schum and thonn (4.20%) [24], *T. triangulare* (2.40%), *T. occidentalis* (1.7%) and *C. argentea* (1.8%) [36] and cowpea (3.60%) [37].

Ash contains mineral materials of the food/plant because ashing destroys all the organic material present in the sample. Ash is also an indicative of high digestibility of the plant [38]. Findings of present study indicate that there are more minerals in the pulp (4.78%) than the kernel (3.17%), the values of ash content are comparable favourably to those

reported for *Lophira lanceolata* (1.45%) [38], pulp of *Haematostaphis barteri* (2.97%) [29], seed of *Adansonia digitata* (2.80%) [26] and some leafy vegetable such as *Solanium nodiflorum* (ogumo) (2.67%) [39]. Protein is viewed as the most expensive component of any diet, and is an essential ingredient forming part of a healthy balanced diet. It plays an important role in nutrition through catalyzing, regulating, protecting and providing energy [40]. The observed crude protein content for both the kernel (9.30%) and pulp (5.23%) of *Vitellaria paradoxa* are lower than the reported values for *Momordica balsamina* (11.29%), *Moringa oleifera* (20.72%), *Lesianthera africiana* leaves (13.10 – 14.90%) and *Leptadenia hastate* (19.10%) [41], cowpea (24.13%) [42], pigeon pea (21.53%) [43], bambara groundnut (24.44%) [44], and kersting's groundnut (12.90%) [30]. Ene-Obong [45] reported that diet is nutritionally satisfactory if it contains high calorie value and a sufficient amount of protein. Some scholars also stated that any plant food that provide about 12% of their caloric value from protein are considered good sources of protein [46, 47]. Thus, neither the seed nor the pulp is a good source of protein.

Fat provides very good sources of energy and aids in transport of fat soluble vitamins, insulates and protects internal tissues and contributes to important cell processes [48]. The crude fat content of kernel and pulp of *Vitellaria paradoxa* were 45.62 and 10.95 %, respectively. This qualifies *Vitellaria paradoxa* kernel (45.62%) as an oil-rich food, since it is comparable with soybean (22.8 – 23.5%) [49, 50]. The crude fat percentage of *Vitellaria paradoxa* kernel appears good when rated against the 20 – 50 reported by Maranz and Wiesman [51]. According to these authors, crude lipid between 20 and 30% are low, those above 30.5% are intermediate and values above 40% are good. Such classification would place shea - kernel crude lipid/fat from the northern guinean savanna of Nigeria (Wukari, Taraba State) under good lipid content group.

The carbohydrate contents of 32.77 % in the kernel and 62.77 % in the pulp showed that shea-butter kernel and pulp can be categorized as carbohydrate rich food. The carbohydrate content of the pulp is higher than 47.00 % and 44.60 % reported for *A. muricata* [52] and *Adansonia digitata L.* [53]. Relatively high energy value of 2403.13 and 1560.88 kJ/100 g for *Vitellaria paradoxa* kernel and pulp, respectively indicates that the fruit is a concentrated source of energy and within the recommended energy dietary allowances for children [54]. It equally implies that promoting consumption of shea-butter fruit is of great benefit to the human diet. The high fatty acid value obtained for the kernel (36.50) is an indication that the oil from the kernel of *Vitellaria paradoxa* may not be suitable for use in cooking (edibility), but however, be useful for industrial purposes [55]. The RSD is highly varied in some parameters: Moisture (37.62), crude fat (61.29) and calculated fatty acids (61.29) while the parameter with least RSD was crude fibre (16.28) (Table 1).

Table 2: Mineral composition (mg/100 g) of kernel and pulp of *Vitellaria paradoxa* on wet weight basis

Mineral	Kernel	Pulp	Mean	SD	RSD
Na	118.31	174.93	146.62	28.31	19.31
Ca	59.41	62.46	60.94	1.53	0.03
K	2.75	0.17	1.46	1.29	88.36
Mn	0.34	0.38	0.36	0.02	5.56
Mg	6.29	4.83	5.56	0.73	13.13
Cu	3.92	3.26	3.59	0.33	9.19
Zn	2.68	2.02	2.35	0.33	14.04
Fe	0.91	1.11	1.01	0.1	9.90
P	58.22	41.67	49.95	8.28	16.57
Ca/P	1.02	1.50	1.26	0.24	19.05
Na/K	43.02	1029.0	536.01	492.99	91.97
Na/Mg	18.81	36.22	27.52	8.71	31.63

Ca/P = Calcium to phosphorous ratio; Na/K = Sodium to potassium ratio; Na/Mg = Sodium to magnesium ratio; SD = Standard deviation; RSD = Relative standard deviation.

The most abundant mineral in seed and pulp samples was sodium (118.31 and 174. 93 mg/100 g, respectively) while the least was Fe (0.91 and 1.11 mg/100 g). The values (mg/100 g) of other essential minerals in the kernel and pulp were Ca (59.41 and 62.46), K (2.75 and 0.17), Mg (6.29 and 4.83) and P

(58.22 and 41.67). Calcium in conjunction with phosphorous, magnesium, vitamin A, C and D, calorie and protein are all in involved in bone formation [56]. Calcium is also important for blood clotting, muscle contraction and in certain enzymes in metabolic processes [57]. Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves [57]. Phosphorous assists calcium in many body reactions, although it also has independent functions. It has been reported that modern diets that are rich in phosphorus and animal proteins may promote the loss of calcium in the urine [58]. This has lead to the concept of calcium to phosphorous ratio. If the ratio is low (low Ca high P intake) more than the normal amount of Ca may be lost in the urine. Food is considered 'good' if Ca/P ratio is above '1' and 'poor' if the ratio is less than '0.5' while a Ca/P ratio above '2' helps to increase the absorption of Ca in the small intestine. The result of Ca/P ratio in the two samples was good: kernel (1.02), pulp (1.50). The ratio of Na/K in the body is of great concern for the prevention of high blood pressure. A Na/K ratio less than '1' is recommended; however the kernel and pulp of *Vitellaria paradoxa* may not be able to prevent blood pressure because the Na/K ratio is far greater than '1'. The ratio of Na/Mg is higher than the normal range (4.00). The adrenal glands play an essential role in regulating sodium retention and excretion. Studies have also shown that Mg will affect adrenal cortical activity and results in increased Mg retention [59]. The Na–Mg profile is indicative of reduced adrenal cortical function. Zinc and copper are intricately related to the hormones, progesterone and estrogens, respectively; and their tissue levels may be indirectly reflective of the status of these hormones within the body [59]. The values recorded for Zn and Cu in the present study were 2.68 and 2.02, 3.92 and 3.26 mg/100 g for the kernel and pulp, respectively. The RSD varied with a range of 0.03–91.97 (Table 2).

The results of amino acid composition of kernel and pulp samples of *Vitellaria paradoxa* are shown in Table 3. Glu and Arg were the most concentrated in kernel sample with the respective value (g/100 g crude protein) of 10.14 and 7.14, while Pro and Glu were the most concentrated in pulp sample with 15.23 g/100 g and 6.97 g/100 g cp, respectively. Arg was the most concentrated essential amino acid in both samples with 7.14 g/100 g and 3.01 g/100 g cp for the kernel and pulp sample, respectively. The least was Try (0.75 and 0.50 g/100 g cp) in kernel and pulp. Arginine is an essential amino acid which has direct antioxidant activity [60] and is also necessary for children growth [61]. The Arg is only considerably high in the kernel sample. The Lys

content in the kernel sample (3.05 g/100 g cp) is found to be higher than that of *L. cylindrica* kernel (2.9 g/100 g cp) [62], while the Met content (1.55 g/100 g cp) for the kernel sample is higher than that reported by Olubunmi *et al.* [63] for *A. cruenthus* (0.93 g/100 g cp), *C. olitorius* (0.75 g/100 g cp), *C. chayamansa* (0.80 g/100 g cp) and *B. alba* (0.67 g/100 g cp). The concentrations of Val (3.04 g/100 g cp kernel and 2.89 g/100 g cp pulp) and Ile (1.83 g/100 g cp kernel and 1.34 g/100 g cp pulp) were found not to meet the FAO/WHO/UNU [64] requirement for these two EAA (3.50 g/100 g cp and 2.80 g/100 g cp, respectively) for pre-school children aged 2-5 years.

Ile is an essential amino acid for both young and old. Met is needed for the synthesis of choline which in turn forms lecithin and other phospholipids in the body. When the diet is low in protein, for instance in alcoholism and kwashiorkor, insufficient choline may be formed; this may cause accumulation of fat in the liver [65]. Other EAAs with appreciable contents obtained in the analyzed samples include Phe (3.02 g/100 g cp), Leu (4.12 g/100 g cp) and Try (0.75 g/100 g cp), all in the kernel sample. Phe is the precursor of some hormones and the pigment melanin in hair, eyes and tanned skin [63]. It has been explained by Gold [66] that Phe is needed in treating brain disorder, normal functioning of the central nervous system, control of symptoms of depression and chronic pain, while Try is important in the manufacture of neurotransmitter serotonin, which regulates mood and sleep pattern, treatment of jet lag, depression and binge eating. Try is also required for the treatment of vascular migraines, panic attacks, rheumatoid arthritis, and normal functioning of the central nervous system [67]. Leu, Ile and Val (branched-chain amino acids) work together to repair muscles, regulate blood sugar and provide body with energy.

The predicted protein efficiency ratio (P – PER) is one of the quality parameters used for protein evaluation [13]. P – PER value in this report for kernel sample (1.17) is higher than the reported P – PER values of *Adansonia digitata* pulp (1.10) [26] and *Lathynis sativus L.* (1.03) [50], but lower than those reported by Audu and Aremu [68] (2.5), Oyetayo and Ojo [69] (1.89) and Aremu *et al.* [70] (2.77) for red kidney bean, *L. cylindrica* and tiger nut, respectively. The calculated isoelectric point (pI) is of significance in protein purification. The *Vitellaria paradoxa* kernel had the highest calculated pI of 6.03 which is the point at which the protein should accumulate during purification. The Lys/Arg ratio has been reported to play a role in the artherogenocity of a protein. Kritchevsky [71]

reported that a Lys/Arg ratio as high as 2.0, increases the artherogenic potential of a diet. However, the Lys/Arg ratios of both the kernel (0.43) and pulp (0.73) of *Vitellaria paradoxa* were very low. Thus the shea-butter kernel and pulp may possess a low artherogenic potential.

Some studies suggested that the Leu/Ile balance is more important than dietary excess of Leu alone [72, 73]. As excessively high intake of Leu has been linked to the development of pellagra, a deficiency

of the vitamin niacin that cause diarrhea, mental disorder and dermatitis. Too much Leu in the diet can also disrupt kidney and liver function and increase the amount of ammonia in the body. The Leu/Ile ratios in the samples (2.10 and 2.25) were relatively not high. Generally, the above mentioned amino acids were low in both samples but comparatively higher in the kernel. The RSD varied with a range of 1.00 in calculated pI to 74.46 in Pro (Table 3).

Table 3: Amino acid composition (g/100 g cp) of kernel and pulp of *Vitellaria paradoxa*

Amino acid	Kernel	Pulp	Mean	SD	RSD
Lysine (Lys)[e]	3.05	2.20	2.63	0.43	16.19
Histidine (His)[e]	0.77	0.89	0.83	0.06	7.23
Arginine (Arg)[e]	7.14	3.01	5.08	2.07	40.69
Aspartic acid (Asp)	4.57	3.60	4.09	0.49	11.87
Threonine (Thr)[e]	1.83	2.55	2.19	0.36	16.44
Serine (Ser)	3.32	2.22	2.77	0.55	19.86
Glutamic acid (Glu)	10.14	6.97	8.56	1.59	18.53
Proline (Pro)	2.23	15.23	8.73	6.50	74.46
Glycine (Gly)	3.82	3.37	3.60	0.23	6.26
Alanine (Ala)	3.41	3.19	3.30	0.11	3.33
Cystine (Cys)	1.09	1.45	1.27	0.18	14.17
Valine (Val)[e]	3.04	2.89	2.97	0.08	2.53
Methionine (Met)[e]	1.55	0.67	1.11	0.44	39.64
Isoleucine (Ile)[e]	1.83	1.34	1.59	0.25	15.46
Leucine (Leu)[e]	4.12	2.86	3.49	0.63	18.05
Tyrosine (Tyr)	2.24	2.41	2.33	0.09	3.66
Tryptophan (Try)[e]	0.75	0.50	0.63	0.13	20.00
Phenylalanine (Phe)[e]	3.02	2.13	2.58	0.45	17.28
Isoelectric point (pI)	6.03	5.92	5.98	0.01	1.00
P–PER	1.17	0.56	0.87	0.31	35.63
Leu/Ile	2.25	2.10	2.18	0.08	3.67
Lys/Arg	0.43	0.73	0.58	0.15	25.86

[e]Essential amino acid; **P–PER =** Predicted protein efficiency ratio; SD = Standard deviation; RSD = Relative standard deviation.

The quality of a protein depends primarily on its capacity to satisfy the needs for nitrogen and essential amino acids [74]. Table 4 depicts the essential, non – essential, acidic, neutral and sulphur containing amino acids. The total amino acid (TAA) was 57.92 and 57.48 g/100 g cp for kernel and pulp samples, respectively. These values are higher than the 42.48 g/100 g cp (*B. eurycoma*) and 48.13 g/100 g cp (*B. sapida*) reported by many researchers [24, 75]. But the values are lower to those reported for the seeds of *Mucana puriens var pruriens* (92.43 g/100 g) [76], *Lophira lanceolata* seeds (355.01 g/100 g) [77] and fermented cocoa nibs (70.8 g/100 g). The EArAA ranged from 2.63 - 3.77 g/100 g cp which is averagely lower than the ideal range suggested for infant protein (6.8 – 11.8 g/100 g cp) [64]. The aromatic amino acids are precursors of epinephrine and thyroxin [61]. Though the

concentrations of total sulphur amino acids (TSAA) which ranged from 1.21 – 2.59 g/100 g cp are lower than the 5.8 g/100 g cp recommended for infants FAO/WHO [78]; the % Cys in TSAA found in the pulp sample is greater than the reported value for *Parkia biglobossa* seeds (44.4%) and *O. gratissimum* (46.67%) [79]. It has also been reported that most animal proteins are low in Cys and hence in Cys/TSAA ratio, for instance, 21.0%, 38.8% and 35.5% were reported for *Limicolaria sp*, *A. archantina* and *A. marginata,* respectively [80]. Cys is known to pair with Met in improving protein quality and it also has positive effects on mineral absorption, particularly Zn [24, 81].

The %TNEAA was 53.21 % while %TEAA (with His) and %TEAA (without His) were 46.79 % and 45.46 %, respectively for the kernel sample. This is

an indication that the kernel protein is of high quality. It can also be observed that the %TEAA for the kernel sample in this report is well above the 39% considered to be adequate for ideal protein food for infants, 26% for children and 11% for adults [64]. The % of TNAA is 55.68% (kernel) and 71.00% (pulp) meaning that the bulk of the amino acids in both samples are neutral. Percentage total acidic amino acids (TAAA) were 25.40 (kernel) and 18.39 (pulp) which are lower than % TNAA, whilst that of total basic amino acids (TBAA) were 18.92 (kernel) and 10.61 (pulp) which made them the third largest group among the parameters.

Table 4: Concentrations of essential, non–essential, acidic, basic, neutral, sulphur, aromatic, etc. (g/100 g cp) amino acid of kernel and pulp of *Vitellaria paradoxa*

Amino acid description	Kernel	Pulp
Total amino acid (TAA)	57.92	57.48
Total non–essential amino acid (TNEAA)	30.82	38.44
% TNEAA	53.21	66.88
Total essential amino acid (TEAA)		
With histidine	27.10	19.04
Without histidine	26.33	18.15
% TEAA		
With histidine	46.79	33.12
Without histidine	45.46	31.58
Essential alphatic amino acid (EAAA)	10.82	9.64
Essential aromatic amino acid (EArAA)	3.77	2.63
Total neutral amino acid (TNAA)	32.25	40.81
% TNAA	55.68	71.00
Total acidic amino acid (TAAA)	14.71	10.57
% TAAA	25.40	18.39
Total basic amino acid (TBAA)	10.96	6.10
% TBAA	18.92	10.61
Total sulphur amino acid (TSAA)	2.64	2.12
% cystine in TSAA	41.29	68.40

Table 5: Amino acid scores of kernel and pulp of *Vitellaria paradoxa* based on FAO/WHO standards

EAA	PAAESP g/100g protein	Kernel		Pulp	
		EAAC	AAS	EAAC	AAS
Ile	4.0	1.83	0.46	1.34	0.34
Leu	7.0	4.12	0.59	2.86	0.41
Lys	5.5	3.05	0.55	2.20	0.40
Met + Cys (TSAA)	3.5	2.64	0.75	2.12	0.61
Phe + Tyr	6.0	5.26	0.88	4.54	0.76
Thr	4.0	1.83	0.46	2.55	0.64
Try	1.0	0.75	0.75	0.50	0.50
Val	5.0	3.04	0.61	2.89	0.58
Total	**36.0**	**22.52**	**5.05**	**19.00**	**4.24**

EAA = Essential Amino Acid; **PAAESP** = Provisional Amino Acid (Egg) Scoring Pattern; **EAAC** = Essential Amino Acid Composition; **AAS** = Amino Acid Score.

Results of essential amino acid scores based on the provisional amino acid scoring pattern [13] standards are shown in Table 5. The essential amino acid contents in this report are lower than the FAO/WHO [13] recommended pattern. Thus by implication, dietary formula based on the kernel and pulp samples of *Vitellaria paradoxa* will require essential amino acids supplementation. Generally, the EAAs that most often act in a limiting capacity are Met (and Cys), Lys and Try [64]. In this study, Ile (0.46 and 0.34) and Lys (0.55 and 0.40) are the first and second limiting amino acids (LAA) for both the kernel and pulp samples, respectively.

Dietary anti-nutritional factors such as tannin, phytate, cyanide, alkaloid, oxalate and saponin have been reported to adversely affect the digestibility of protein, bioavailability of amino acids and protein quality of foods [82]. Table 6 presents the anti-nutritional properties of *Vitellaria paradoxa*. The tannin contents (5.46 and 14.03 mg/100 g) are

considered high when compared with the value (0.017 – 0.103%) for cucurbita fruits, 2.56% reported for cuban boa (*Epicrates anquifer*) [83], and 3.8 and 4.56% for two medicinal plants *Senna alata* and *Cajanus cajan* [84]. But the contents are lower than the 21.19% observed for *Moringa oleifera* leaves [28]. Another study shows that tannin usually forms insoluble complexes with proteins, thereby interfering with their bioavailability [85]. This will result in reducing the protein and amino acid digestibility. The poor palatability of food is generally attributed to high content of tannins (Mehansho *et al.,* 1987). Tannins are also capable of lowering the available protein by antagonistic competition and therefore eliciting protein deficiency syndrome Kwashiorkor.

Table 6: Anti-nutritional properties of kernel and pulp of *Vitellaria paradoxa*

Parameter	Kernel	Pulp	Mean	SD	RSD
Oxalate (mg/100 g)	649.00	221.50	435.25	213.75	49.11
Saponin (%)	8.15	0.24	4.2	3.96	94.29
Alkaloids (%)	0.38	1.13	0.76	0.38	50.00
Tannins (mg/100 g)	14.03	5.46	9.75	4.29	44.00
Cyanide (mg/100 g)	14.85	4.17	9.51	5.34	56.15
Phytate (mg/100 g)	350.07	88.91	219.49	130.58	59.49

SD = Standard deviation; RSD = Relative standard deviation.

Alkaloid concentrations were 0.38% in kernel and 1.13% in pulp samples. These values are very low compared to the reported 9.6% (lima bean) and 8.6% (scarlet runner bean) [87] and 5.0% (black turtle bean) [82]. High level of alkaloids exerts toxicity and adverse effects to humans, especially in physiological and neurological activities. For instance, consumption of high tropane alkaloids will cause rapid heartbeat, paralysis and in fatal case, lead to death. However, lower dose of alkaloids mediate important pharmacological activities, such as analgesic, reducing blood pressure, killing tumour cells, stimulating circulation and respiration. Though dietary saponins exert various biological benefits, such as anti-inflammatory, anti diabetic, anti-atherosclerotic and serve as protective functions like gastro-protective, hepatoprotective and hypolipidemic [88], they were found to affect protein digestibility by inhibiting various digestive enzymes such as trypsin and chymotrypsin [89], as well as reduce nutrient utilization and conversion efficiency [90]. The value of saponin for the kernel (8.15%) is higher than the reported values of *Vigna subterranea* (4.6%), *Phaseolus coccineus* (4.1%) and *Phaseolus lunatus* (3.2%) as reported by Aremu *et al.* [87].

The oxalate levels found in this work were 649.00 (kernel) and 221.50(pulp) mg/100 g of *Vitellaria paradoxa*. Oxalate serves as chelating agents and may chelate many toxic metals such as mercury and lead, but one major concern is its ability to trap heavy metals in the tissues of living organism thereby making elimination of them very difficult. In human body, oxalate in the form of oxalic acid combines with divalent metallic cations such as iron II (Fe^{+2}) and calcium (Ca^{2+}) to form crystals of the corresponding oxalates which are then excreted in urine as minute crystals. Oxalate crystals are razor sharp and may cause damage to various tissues. The sharp crystals cause damage due to their physical structure, but any contact with the crystals also increases inflammation. Iron oxalate crystals cause significant oxidative damage and diminish iron stores needed for red blood cell formation whereas many kidney stones result from calcium crystals. These oxalates can form larger kidney stones that can obstruct the kidney tubules. An estimated 80% of kidney stones are formed from calcium oxalate [91]. The kernel sample has oxalate value higher than the observed value of 254 mg/100 g in soybean and 286 mg/100 g for pigeon pea [92]; 495.0 mg/100 g for scarlet runner bean, 490.6 mg/100 g for bambara groundnut [87], but the value is lower than 225740 and 166890 mg/100 g as found in red kidney bean and black turtle bean, respectively [82]. Phytate (a salt form of phytic acid) content were 350.07 mg/100 g in the seed and 88.91 mg/100 g in pulp sample (Table 6). The kernel sample value is comparable with 353.9 mg/100 g (bambara groundnut) and 365.5 mg/100 g (lima bean) [87], but it is lower than the values reported for soybean (4050 mg/100 g), pigeon pea (1170 mg/100 g) and cowpea (2040 mg/100 g) [92], black turtle bean (11250 mg/100 g) [82]. Phytic acid was reported to reduce blood glucose and possesses health benefits to diabetic patients. This is because the anti-nutrients concentration of phytic acid reduces the rate of starch digestion and slows down the gastric emptying which in turn, lowers blood glucose. However, excessive amounts of phytic acid in the diet will form insoluble complexes with multi-charged metals [93], such as copper (II), zinc (II),

calcium (II) and iron (III). This results in a deficit of the absorption of some dietary minerals and leads to mineral deficiencies. Cyanide is the chemical substance responsible for tissue hypoxia, and chronic exposure to it particularly hydrogen cyanide may cause neurological, respiratory, cardiovascular and thyroid defects [94]. The cyanide levels found in this work were 14.85 and 4.17 mg/100 g for kernel and pulp samples, respectively. The observed kernel value is higher than the early findings of Owolabi *et al.* [95] on cowpea seed (3.7 mg/100 g) and Zafar *et al.* [96] on *Achnatherum hymenoides*, but lower than 40.78 mg/100 g of *Dioclea reflexa* seed reported by Bolanle and Adedayo [97].

Conclusion

Compositional evaluation of kernel and pulp of shea-butter (*Vitellaria paradoxa*) fruit was presented in this study, which showed that kernel sample has high fat and energy contents with nutritionally valuable minerals comparable with known fat–rich plant based foods, such as groundnut and soybean. The result also revealed that essential amino acids were present in appreciable amount for both the kernel and pulp however supplementation of all the essential amino acids may be required in order to meet FAO/WHO diet requirement. Some anti-nutritive factors such as oxalate, saponin, alkaloids, tannins, cyanide and phytate were detected and were present in relatively high quantities particularly oxalate and phytate; these factors may pose a nutritional problem in its consumption. Reduction of these anti-nutrients during the processing of *Vitellaria paradoxa* kernel such as boiling is therefore of great importance for the safety of this fruit.

Conflict of Interest

Authors declare that there are no conflicts of interest in the study.

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