World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Vitamin and mineral composition of the kernel of shea nuts (*Vitelaria Paradoxa*) from high-growing trees in the Tchôlogo region (Côte d'Ivoire)

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World Journal of Advanced Research and Reviews, 2025, 27(03), 631–638

Publication history: Received on 02 August 2025; revised on 07 September 2025; accepted on 10 September 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.3.2969

Abstract

The study was carried out to determine the vitamin and mineral composition of shea nut kernels from high-producer trees in the Tchôlogo region, with a view to proposing appropriate ways of adding value. Eight composite nut samples were analysed. These were: large ellipsoid tchologo (LELT); large spheroid tchologo (LSPT); large oblong tchologo (LOBT); large ovoid tchologo (LOVT); thin ovoid tchologo (MOVT); thin spheroid tchologo (MSPT); thin ellipsoid tchologo (MELT); thin oblong tchologo (MOBT). The work consisted of determining the content of vitamin B, vitamin C, β-carotene and minerals in shea nut kernels. The results showed that the chromatographic profile of water-soluble vitamins revealed 7 vitamins in shea kernels: vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin B6, vitamin B12 and vitamin C. The LELT sample was the richest in vitamin C, B12 and B2. On the other hand, the MSPT sample had the highest levels of vitamins B1 and B3. Finally, the highest vitamin B5 and B6 contents were recorded in the LOBT and LOVT samples respectively. The chromatographic profile of minerals revealed three main macro-elements in the kernels of the 8 shea samples: magnesium (Mg), phosphorus (P) and potassium (K). This profile also revealed 14 microelements in the shea kernels. The Large Oblong Tchologo (LOBT) and Thin Ovoid Tchologo (MOVT) samples gave the highest P contents. As for the LOBT, LSPT, MOBT and MSPT samples, they gave the highest K content. In view of all these results, almonds from the LOBT and MOVT samples, thanks to their high phosphorus and potassium content, can be an additive in the diet of children suffering from deficiencies in these two minerals.

Keywords: Shea; Almond; Mineral and Vitamin Composition; Chromatographic Profile

1. Introduction

In the Sudanian savannahs of Côte d'Ivoire, the agrarian landscape is dominated by parks of shea (*Vitellaria paradoxa* C.F. Gaertn.) and nere (*Parkia biglobosa* Jacq Benth) [1]. Shea belongs to the Sapotaceae family. It is a plant species endemic to Africa that grows naturally in a wide belt of more than one million km2 between western Senegal and eastern Uganda [2] [3]. V. *paradoxa* is currently divided into two subspecies (V. *paradoxa* subspecies *paradoxa*) found in West and Central Africa and (V. *paradoxa* subspecies nilotica) located in East Africa. Shea is found in between 15 and 21 African countries, from West to East and Central Africa. The 5 largest shea producers are Nigeria, Mali, Burkina Faso, Ghana and Côte d'Ivoire. Annual world shea production is estimated at over 600,000 tonnes, with a production potential of over 1,400,000 tonnes [4] [5].

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In Côte d'Ivoire, shea is a harvested product. The fruit is gathered by women, from which the fat contained in the kernels is extracted to make butter. For this reason, it is known as the 'butter tree' or 'women's gold'.

According to surveys by [6], 639 elite shea trees are preserved in situ on farmers' farms in the Bagoué and Tchologo regions, covering the departments of Boundiali, Kouto, Tengrela, Ferkéssedougou, Kong and Ouangolodougou. These elite shea trees, geo-referenced and chosen by the producers themselves, generally based on criteria such as high fruit yield, sweet taste of the pulp, fruit size and earliness of flowering in the year, now constitute the basic genetic material for shea tree improvement in Côte d'Ivoire [6]. However, the vitamin and mineral composition of the nut kernels of these elite trees has not yet been studied.

The aim of this study is to investigate the vitamin and mineral composition of shea nut kernels from high-producer trees in the Tchôlogo region, with a view to proposing appropriate ways of adding value.

2. Materials and methods

2.1. Vegetal material

The study was carried out on shea nuts extracted from mature fruits (Photograph 1) collected from the crowns of 80 Potentially High Producer Shea (KPHP) trees in the Tchologo region.

Figure 1 Different forms of the shea fruit

2.2. Sampling method

Harvesting was carried out during the fruiting period of the trees (May to July) when the fruit is ripe. Fruits were collected from the underside of each tree. 80 trees were randomly selected, 40 for the thin leaf morphotype and 40 for the broad leaf morphotype. For each leaf shape morphotype, 10 trees were selected by fruit shape (spheroid, ellipsoid, ovoid, oblong). Under each tree per fruit shape, 20 fruits were collected, giving a total of 200 fruits per shape. Thus, for each leaf shape morphotype, 800 fruits for the 4 fruits shape morphotypes were sampled, i.e. 1,600 fruits for the 2 leaf shape morphotypes. The nuts from the 20 fruits per tree in each leaf shape morphotype formed the composite sample

for each tree. So, for the 2 leaf morphotypes, a total of (8) composite nut samples were taken. The kernels from these composite samples were taken and used for the various chemical analyses.

2.3. Determination of vitamin composition in shea kernels

The method described by [7] was used for vitamin C extraction and the method described by [8] using 2,6-dichlorophenol (DCPIP) was used to determine vitamin C contents in shea samples. B-vitamin levels in shea kernels were determined by HPLC using the method of [9]. Finally, β-carotene levels were obtained using the method described by [10].

2.4. Determination of mineral composition in shea kernels

Minerals were determined by atomic absorption spectrophotometry using the strong acid method [11].

2.5. Statistical processing

The data were processed with SPSS version 16.0 using an analysis of variance with 2 classification criteria (fruit shape and leaf shape). The means of the chemical parameters determined by the Newman and Keuls test at the 5 % threshold were used to compare the different samples.

3. Results and discussion

3.1. Mineral content of kernels of different shea varieties

3.1.1. Macro-element content

The chromatographic profile of minerals revealed three main macroelements in shea kernels: Magnesium (Mg), Phosphorus (P) and Potassium (K). Statistical analysis showed no significant difference in Magnesium levels across all samples (Table I).

Magnesium levels ranged from 0.02 mg/kg to 0.04 mg/kg.

In terms of phosphorus, the thin Ovoid Tchologo (MOVT) and Large Oblong Tchologo (LOBT) samples gave the highest levels statistically (0.02 mg/kg). The thin Oblong Tchologo (MOBT), Large Sphéroid Tchologo (LSPT), thin Sphéroid Tchologo (MSPT), Thin Ellipsoid Tchologo (MELT), Large Ovoid Tchologo (LOVT) and Large Ellipsoid Tchologo (LELT) samples recorded the lowest levels statistically.

Finally, in terms of potassium, the thin Spheroid Tchologo (MSPT), Large Oblong Tchologo (LOBT) and thin Oblong Tchologo (MOBT) samples provided the highest levels statistically (0.06 mg/kg). On the other hand, the lowest levels were recorded in the thin Ellipsoid Tchologo (MELT) and Large Ellipsoid Tchologo (LELT) samples. Values were 0.01 mg/kg.

Table 1 Magnesium, phosphorus and potassium contents in shea kernels

Sample	Mg (mg/kg)	P (mg/kg)	K (mg/kg)
LELT	0.02±0.01^{a}	0.01±0.02^{a}	0.01±0.48^{a}
LOBT	0.02±0.01^{a}	0.02±0.24^{b}	0.06±1.50^{d}
LOVT	0.02±0.01^{a}	0.01±0.34^{a}	0.04±2.84^{c}
LSPT	0.02±0.01^{a}	0.01±0.14^{a}	0.06±1.02^{d}
MELT	0.03±0.01^{a}	0.01±0.82^{a}	0.01±0.55^{a}
MOBT	0.03±0.01^{a}	0.01±0.46^{a}	0.06±1.33^{d}
MOVT	0.04±0.01^{a}	0.02±0.05^{b}	0.03±2.25^{b}
MSPT	0.04±0.01^{a}	0.01±0.16^{a}	0.06±0.19^{d}

LELT: large ellipsoid tchologo; LSPT: large spheroid tchologo; LOBT: large oblong tchologo; LOVT: large ovoid tchologo; MOVT: thin ovoid tchologo; MSPT: thin spheroid tchologo, MELT: thin ellipsoid tchologo, MOBT: thin oblong tchologo

Means with different letters in the same column are significantly different at the 5 % threshold according to the Student Neuman Keuls test.

3.1.2. Micro-element content

The chromatographic profile of minerals revealed 14 microelements in shea kernels. These were silver (Ag), cadmium (Cd), tin (Sn), antimony (Sb), barium (Ba), arsenic (As), boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), vanadium (V) and zinc (Zn). Statistical analysis revealed a significant difference in 5 microelements in all samples (Table II).

The lowest boron (B) content (0.05 mg/kg) was found in the Mince Oblongue Tchologo (MOVT) sample. The Large Oblong Tchologo (LOBT) and Large Spheroïde Tchologo (LSPT) samples yielded the highest values statistically (0.09 mg/kg).

The MOVT sample recorded the lowest manganese (Mn) content (0.04 mg/kg), while the LOBT and LSPT samples had the highest statistical values. These values were 0.07 mg/kg.

For arsenic (As), the statistically highest values (0.07 mg/kg) were found in samples MOBT, LSPT and LOBT.

The MOVT, MELT and LOVT samples recorded the lowest cadmium (Cd) content (0.02 mg/kg), while the highest content (0.03 mg/kg) was given by the MOBT, MSPT, LSPT, LELT and LOBT samples.

Finally, the highest selenium (Sn) content (0.03 mg/kg) was observed in samples LELT, LOBT, LOVT, MELT and MOBT. On the other hand, MSPT, MOVT and LSPT yielded the lowest levels (0.03 mg/kg).

Table 2 Microelement content of shea kernels

Sample	B (mg/kg)	V (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
LELT	0.06±1.43^{ab}	0.04±0.48^{a}	0.06±0.73^{bc}	0.03±0.12^{a}	0.03±0.29^{a}	0.05±0.92^{a}	0.06±1.50^{a}
LOBT	0.09±1.06^{c}	0.04±0.25^{a}	0.07±0.42^{c}	0.03±0.04^{a}	0.04±0.08^{a}	0.05±0.05^{a}	0.07±1.52^{a}
LOVT	0.06±1.68^{ab}	0.03±0.31^{a}	0.05±1.36^{b}	0.03±0.08^{a}	0.03±0.11^{a}	0.05±0.70^{a}	0.06±1.04^{a}
LSPT	0.09±1.63^{c}	0.04±0.23^{a}	0.07±0.95^{c}	0.03±0.31^{a}	0.04±0.63^{a}	0.05±0.39^{a}	0.08±1.40^{a}
MELT	0.06±1.43^{ab}	0.04±1.59^{a}	0.06±1.44^{bc}	0.03±0.58^{a}	0.03±1.01^{a}	0.03±0.22^{a}	0.07±1.79^{a}
MOBT	0.09±1.36^{c}	0.03±1.16^{a}	0.06±0.29^{bc}	0.03±0.38^{a}	0.03±0.84^{a}	0.04±0.05^{a}	0.06±1.11^{a}
MOVT	0.05±0.82^{a}	0.03±0.09^{a}	0.04±0.24^{a}	0.03±0.33^{a}	0.03±0.51^{a}	0.03±0.94^{a}	0.05±0.29^{a}
MSPT	0.07±1.02^{b}	0.04±0.25^{a}	0.06±1.34^{bc}	0.03±0.19^{a}	0.04±0.03^{a}	0.04±0.92^{a}	0.07±1.64^{a}

LELT: large ellipsoid tchologo; LSPT: large spheroid tchologo; LOBT: large oblong tchologo; LOVT: large ovoid tchologo; MOVT: thin ovoid tchologo; MSPT: thin spheroid tchologo, MELT: thin ellipsoid tchologo, MOBT: thin oblong tchologo;

Means with different letters in the same column are significantly different at the 5 % threshold according to the Student Neuman Keuls test.

Table 2 (continued): Microelement content of shea kernels

Sample	As (mg/kg)	Mo (mg/kg)	Ag (mg/kg)	Cd (mg/kg)	Sn (mg/kg)	Sb (mg/kg)	Ba (mg/kg)
LELT	0.05±1.35^{a}	0.03±0.29^{a}	0.03±0.014^{a}	0.03±0.20^{b}	0.04±0.93^{b}	0.02±0.96^{a}	0.03±0.58^{a}
LOBT	0.07±0.18^{b}	0.03±0.43^{a}	0.03±0.20^{a}	0.03±0.01^{b}	0.04±1.72^{b}	0.03±0.13^{a}	0.03±1.35^{a}
LOVT	0.05±1.19^{a}	0.03±0.32^{a}	0.02±0.31^{a}	0.02±0.21^{a}	0.04±1.37^{b}	0.02±0.71^{a}	0.03±2.89^{a}
LSPT	0.07±0.63^{b}	0.03±0.11^{a}	0.03±0.71^{a}	0.03±0.09^{b}	0.03±2.06^{a}	0.03±1.35^{a}	0.03±0.19^{a}
MELT	0.05±1.23^{a}	0.02±0.99^{a}	0.02±0.69^{a}	0.02±0.20^{a}	0.04±0.93^{b}	0.02±0.96^{a}	0.03±0.58^{a}
MOBT	0.07±1.23^{b}	0.03±0.43^{a}	0.03±0.91^{a}	0.03±0.72^{b}	0.04±0.30^{b}	0.03±1.28^{a}	0.03±1.35^{a}

MOVT	0.05±0.73[a]	0.03±0.37[a]	0.03±0.07[a]	0.02±0.16[a]	0.03±0.69[a]	0.02±0.32[a]	0.04±1.15[a]
MSPT	0.06±0.72[ab]	0.3±0.43[a]	0.03±0.19[a]	0.03±0.42[b]	0.03±0.69[a]	0.03±0.38[a]	0.03±1.15[a]

LELT: large ellipsoid tchologo; LSPT: large spheroid tchologo; LOBT: large oblong tchologo; LOVT: large ovoid tchologo; MOVT: thin ovoid tchologo; MSPT: thin spheroid tchologo, MELT: thin ellipsoid tchologo, MOBT: thin oblong tchologo

Means with different letters in the same column are significantly different at the 5 % threshold according to the Student Neuman Keuls test.

3.2. vitamin B content of shea kernels

The chromatographic profile of water-soluble vitamins revealed 6 B-group vitamins in shea kernels: vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin B6 and vitamin B12. Statistical analysis showed a highly significant difference in all 6 vitamins in all samples (Table III)

The highest vitamin B1 content (0.72 mg/100g) was obtained in the Mince Spheroide Tchologo (MSPT) sample.

The Large Ellipsoid Tchologo (LELT) sample recorded the highest vitamin B2 content (9.19 mg/100g), and the lowest content (1.60 mg/100g) was given by the Mince Sphéroïde Tchologo (MSPT) sample.

The highest vitamin B3 content (0.36 mg/100g) was provided by the Mince Sphéroïde Tchologo (MSPT) sample, and the statistically lowest contents were given by the Mince Ovoïde Tchologo (MOVT) and Large Ovoïde Tchologo (LOVT) samples.

The Large Oblong Tchologo (LOBT) sample had the highest vitamin B5 content (17.63 mg/100g). However, the MOVT and MELT samples recorded the lowest levels of Vitamin B5.

The highest vitamin B6 content (3.74 mg/100g) was obtained by the Large Ovoid Tchologo (LOVT) sample and the lowest content (2.26 mg/100) by the LELT sample.

The Large Ellipsoid Tchologo (LELT) sample recorded the highest vitamin B12 content (6.75 mg/100g) and the lowest content (2.81 mg/100g) was given by the Thin Ovoid Tchologo (MOVT) sample.

Table 3 Vitamin B content in shea kernels

Sample	Vitamin B_1 (mg/100g)	Vitamin B_2 (mg/100g)	Vitamin B_3 (mg/100g)	Vitamin B_5 (mg/100g)	Vitamin B_6 (mg/100g)	Vitamin B_{12} (mg/100g)
LELT	0.28±0.14[a]	9.19±0.07[f]	0.17±0.03[ab]	12.16±0.07[b]	2.26±0.14[a]	6.75±0.21[g]
LOBT	0.59±0.14[c]	3.08±0.05[b]	0.08±0.02[ab]	17.63±0.21[g]	3.27±0.14[d]	4.76±0.14[d]
LOVT	0.64±0.14[d]	5.46±0.14[d]	0.05±0.03[a]	13.41±0.07[c]	3.74±0.14[f]	4.21±0.07[c]
LSPT	0.63±0.07[d]	4.53±0.21[c]	0.08±0.03[ab]	14.29±0.07[d]	3.23±0.07[c]	4.12±0.07[c]
MELT	0.28±0.14[a]	8.19±0.07[e]	0.22±0.04[b]	11.16±0.07[a]	3.26±0.14[d]	5.75±0.21[f]
MOBT	0.64±0.07[d]	3.16±0.02[b]	0.08±0.02[ab]	16.63±0.21[f]	3.37±0.14[e]	3.76±0.14[b]
MOVT	0.35±0.14[b]	4.31±0.06[c]	0.06±0.05[a]	11.16±0.06[a]	2.41±0.14[b]	2.81±0.14[a]
MSPT	0.72±0.21[e]	1.60±0.14[a]	0.36±0.07[c]	15.47±0.14[e]	3.38±0.07[e]	5.44±0.02[e]

LELT: large ellipsoid tchologo; LSPT: large spheroid tchologo; LOBT: large oblong tchologo; LOVT: large ovoid tchologo; MOVT: thin ovoid tchologo; MSPT: thin spheroid tchologo, MELT: thin ellipsoid tchologo, MOBT: thin oblong tchologo

Means with different letters in the same column are significantly different at the 5 % threshold according to the Student Neuman Keuls test.

3.3. Vitamin C and β-carotene content of kernels from different shea varieties

Statistical analysis showed a significant difference in vitamin C and β-carotene content in all samples (Table IV).

The LELT and MELT samples provided the highest vitamin C content statistically. They were 1.15 mg/100g and 1.29 mg/100g respectively. The other samples recorded the lowest values.

The lowest β-carotene content (2.61 mg/100g) was obtained in the MELT sample. On the other hand, LOBT (3.47 mg/100g) and MOBT (3.67 mg/100g) provided the statistically highest levels.

Table 4 Vitamin C and β-carotene content of the kernels of different shea varieties

Sample	Vitamin C (mg/100g)	β carotene (mg/100g)
LELT	1.15±0.04^{b}	3.29±0.02^{bc}
LOBT	0.22±0.07^{a}	3.47±0.10^{c}
LOVT	0.24±0.07^{a}	2.81±0.15^{ab}
LSPT	0.06±0.04^{a}	3.23±0.02^{bc}
MELT	1.29±0.12^{b}	2.61±0.58^{a}
MOBT	0.27±0.14^{a}	3.67±0.10^{c}
MOVT	0.13±0.07^{a}	2.79±0.17^{ab}
MSPT	0.05±0.06^{a}	3.35±0.10^{bc}

LELT: large ellipsoid tchologo; LSPT: large spheroid tchologo; LOBT: large oblong tchologo; LOVT: large ovoid tchologo; MOVT: thin ovoid tchologo; MSPT: thin spheroid tchologo, MELT: thin ellipsoid tchologo, MOBT: thin oblong tchologo

Means with different letters in the same column are significantly different at the 5 % threshold according to the Student Neuman Keuls test.

4. Discussion

The results of the study showed a great mineral diversity in the different Shea varieties. Thus, the macro-elements obtained in Shea kernels were potassium, magnesium and phosphorus. [12] also observed the same macro-elements in the kernels of different Shea varieties. In their study, the concentrations of these minerals were 2.370; 2.915; 1.99 mg/Kg respectively. It's remarkable how many vital functions minerals such as potassium, calcium, magnesium, iron and copper perform in the body. Each of these minerals plays an essential role in fundamental physiological processes, from the regulation of acid-base balance and osmotic pressure to muscle contraction, energy production, blood coagulation, protein synthesis and even antioxidant protection [13] [14].

Apart from these minerals, the identification of heavy metals in almonds was carried out to ensure their suitability for food use. The results showed low concentrations of heavy metals.

Analyses of shea kernels revealed significant concentrations of vitamins B2, B5, B6 and B12, at 9.19, 16.63, 12.26 and 11.75 mg/100g respectively. It's important to note that these vitamins play an essential role in the proper functioning of various physiological processes in the body. Vitamin B2 (riboflavin) is required for energy production, cell growth and tissue regeneration [15]. Vitamin B5 (pantothenic acid) is essential for hormone production and fatty acid synthesis [16]. Vitamin B6 (pyridoxine) is involved in protein, carbohydrate and fat metabolism, as well as neurotransmitter production [17]. Finally, vitamin B12 (cobalamin) is necessary for the formation of red blood cells and the proper functioning of the nervous system [18].

In addition to these vitamins, shea kernels were found to contain vitamins C and β-carotene. β-carotene (vitamin A) is essential for vision, and is involved in tissue differentiation processes, particularly of epithelial cells [19] [20]. It is required in the skin, mucous membranes, conjunctiva and cornea [19]. The concentration of β-carotene in shea kernels is higher than in cocoa, which has a vitamin A concentration of less than 2 mg/100g [21].

The vitamin C content obtained in our work is close to that recorded in cashew kernels (0.125mg/ 100g) [22]. Indeed, vitamin C's antioxidant properties help the body fight free radicals. It helps prevent certain diseases such as cancer, cardiovascular disease, colds, age-related muscle degeneration and cataracts [23].

5. Conclusion

This study was carried out to determine the vitamin and mineral composition of shea nut kernels from high-producer trees in the Tchôlogo region, with a view to proposing appropriate ways of adding value.

The results showed that the chromatographic profile of water-soluble vitamins revealed 7 vitamins in shea kernels: vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin B6, vitamin B12 and vitamin C.

The LELT sample was the richest in vitamins C, B2 and B12. On the other hand, the MSPT sample was the richest in vitamins B1 and B3. Finally, the LOBT and LOVT samples had the highest levels of vitamin B5 and B6 respectively.

The chromatographic mineral profile revealed three main macro-elements in the kernels of the 8 shea samples: Magnesium (Mg), Phosphorus (P) and Potassium (K).

The profile also revealed 14 microelements in shea kernels. These are silver (Ag), cadmium (Cd), tin (Sn), antimony (Sb), barium (Ba), arsenic (As), boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), vanadium (V) and zinc (Zn). The Large Oblong Tchologo (LOBT) and Thin Ovoid Tchologo (MOVT) samples gave the highest P content. As for the LOBT, LSPT, MOBT and MSPT samples, they provided the highest K content.

In view of all these results, almonds from the LOBT and MOVT samples, thanks to their high phosphorus and potassium content, could be an additive in the diet of children suffering from deficiencies in these two minerals.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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