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Biochemical and phytochemical properties of the pulp of different forms of shea (*Vitellaria paradoxa*) in the northern region of Côte d'Ivoire

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Abstract

Shea (*Vitellaria paradoxa*) fruits were harvested in the departments of Korhogo (Lataha and Nalourgokaha), Sinematiali (Dahouakaha), Dikodougou, Boundiali and Ferké (Houphouekaha) in northern Côte d'Ivoire. The aim of this study is to add value to fresh shea fruit pulp in these departments. The classic biochemical analyses used revealed that fruit pulp is rich in a number of minerals, notably K, P, Mg, Na, Fe, Zn, Mn, Cu and Ca. Potassium was the predominant mineral, with contents ranging from 1108 ±0.2 mg/100g to 1563 ±0.2 mg/100g for rounded pulp and 601.2±0.1 mg/100g to 1342 ±0.3 mg/100g for ovoid pulp. We also note the presence of polyphenols (108.46 ± 0.01 - 146.96 ± 0.01 mgEAG /100g for rounded fruit pulp and 116.60 ± 0.01 - 173.03 ± 0, 01 mgEAG/100g for ovoid fruit pulp) and flavonoids (19.69 ± 0.03 - 61.93 ± 0.01 mgEQ/100g for round fruit pulp and 27.61 ± 0.01 - 94.38 ± 0.01 mgEQ/100g for ovoid fruit pulp). In view of its composition, *Vitellaria paradoxa* pulp can help to prevent certain dietary imbalances and to treat certain pathologies.

Keywords: *Vitellaria paradoxa*; Pulp; Properties; Biochemical; Phytochemical

1. Introduction

In Côte d'Ivoire, many wild fruits are consumed by the rural population for their numerous nutritional and health benefits [1]. These include baobab, néré, tamarind, etc. However, there is another fruit that is richer in nutrients and found in sufficient quantities in the savannahs of Côte d'Ivoire. This is the shea tree (*Vitellaria paradoxa*).

Previous studies on shea fruit pulp have shown that it contains significant quantities of nutrients such as carbohydrates, proteins, fiber, minerals and vitamins [2, 3, 4]. While shea pulp has been the subject of numerous studies in other countries, in Côte d'Ivoire no study has yet been carried out on this vegetative material to our knowledge. It is these observations that have guided this study. This study falls within the context of the development and valorization of local products in Africa. It aims to add value to fresh shea fruit pulp from northern Côte d'Ivoire. The various aspects addressed by this study are the mineral and anti-nutritional composition of *Vitellaria paradoxa* pulp.

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2. Material and methods

2.1. Plant material

The plant material used was fresh shea (*Vitellaria paradoxa*) pulp harvested in the Korhogo (Lataha, Nalourgokaha, Dahouakaha and Dikodougou), Boundiali and Ferké (Houphouekaha) departments. Harvesting was carried out in plantations located in these departments.

2.2. Methods

2.2.1. Sampling

Sampling was carried out in the departments of Korhogo (Lataha and Nalourgokaha), Sinematiali (Dahouakaha), Dikodougou, Boundiali and Ferké (Houphouekaha) between June and July 2022. The departments and shapes of the shea fruit (*Vitéllaria paradoxa*) were selected on the basis of a preliminary survey of shea butter wholesalers in Natio, Korhogo. This direct interview survey revealed the abundance of shea fruits in these departments, and the predominance of ovoid and rounded shapes among the fruits. In these departments, sampling was carried out with the help of two (02) volunteer village guides. Fruits were harvested at maturity from wild shea plants in each of these localities. Two (02) batches of fruit were collected from twenty (20) shea trees in each locality, taking into account the shape of the fruit. Ten (10) trees were used to collect round-shaped fruit and the other ten (10) for egg-shaped fruit. Sixty (60) samples of each fruit shape were collected from the six (06) sites at a rate of 10 samples per site for the first sampling session. Three (03) sampling sessions were carried out for a total of 360 samples (180 samples of the ovoid shape; 180 samples of the rounded shape) (Table 1).The fruit collected was placed in labelled stomacher bags and transported to the laboratory using a cooler containing ice.

Table 1 Sampling summary

		Shea fruit shape		
Localities	**Sampling session**	**Ovoid**	**Rounded**	**Total**
Lataha	3	30	30	60
Nalourgokaha	3	30	30	60
Dahouakaha	3	30	30	60
Dikodougou	3	30	30	60
Boundiali	3	30	30	60
Houphouekaha	3	30	30	60
Total	3	180	180	360

2.2.2. Pulp extraction

Aseptically separated from the kernel, the pulp obtained was ground using a blender for 3 minutes. The ground pulp was packed in jars and stored in the freezer for analysis of the various parameters (figure 1).

Figure 1 Pulp crushed in jars

2.2.3. Dosage of some minerals

Principle

Macroelement content was determined after sample mineralization using the method of [5]. Samples were mineralized by heat treatment with a mixture of concentrated sulfuric acid and salicylic acid. Mineralization was accelerated by the use of a catalyst (selenium) and by increasing the temperature with the addition of hydrogen peroxide (H202).

Mineralization

In a 75-mL mineralization tube, 0.5 g of each ground sample, sieved to 0.5 mm, was weighed. Five (5) mL of extraction solution (sulfuric acid-selenium-salicylic acid, 7.2%) was added to the tube. A blank was prepared with 5 mL of the extraction solution. After standing for 2 hours, the samples were heated at temperatures ranging from 100°C to 340°C. The resulting mineralizate was cooled to room temperature for approximately 12 hours. Fifty (50) mL of distilled water were added to the mineralizate obtained after cooling. The mixture was homogenized and further cooled, and made up to 75 mL with distilled water. The final solution obtained was decanted and 20 mL of each aliquot was used for macro-micronutrient determination. Each solution was stored at 4 °C for the assays.

Dosage

After mineralization, phosphorus was determined by absorption spectrometry at 880 nm using the molybdenum blue method and an auto-analyzer (SKALAR 1000). To this end, 1 mL of perchloric acid, 1 mL of amidol solution and 0.5 mL of ammonium molybdate solution were added successively to the final solution obtained after mineralization. Five (5) mL of 3% lanthanum solution [La(N03)36H20] were added to 10 mL of the final solution for calcium and magnesium determination. Calcium and magnesium were determined at 422.7 nm and 285.2 nm respectively, using an atomic absorption spectrophotometer (PERKIN ELMER 100).

2.2.4. Dosage of trace elements

Principle

Trace elements (Cu, Fe and Zn) were determined in the samples by atomic absorption after acid mineralization using the method described by [5]. The mineralization solution was a mixture of nitric acid (HNO 3, 30%), sulfuric acid (H 2 S04, 96%) and perchloric acid (HCl0 4, 70%).

Mineralization

A quantity of powder from each sample (0.5 g) dried and sieved to 2 mm was collected in mineralization tubes. Five (5) mL each of extraction solution (nitric acid (HNO 3, 30%), sulfuric acid (H2S04, 96%) and perchloric acid (HCl04, 70%)) were added. A blank was prepared with 5 mL of the extraction solution. The mixture (sample and extraction solution) was gradually heated (75°C to 240°C) until white vapors appeared. After cooling, the trace elements were assayed.

Dosage

A volume of 50 mL of distilled water was added to the mineralizate of the samples obtained. After cooling, the resulting mixture was topped up with 75 mL distilled water, stirred again and cooled completely. Cu, Fe and Zn were determined by atomic absorption at 324.8, 248.3 and 219.9 nm respectively.

2.2.5. Determination of total polyphenols

Determination of total polyphenols (in mg A.G eq / g fresh matter) was carried out by adapting the method of [6]. To five (5) g of pulp, 50 mL of distilled water were added. After 5 min homogenization using a magnetic stirrer, the solution was filtered through absorbent cotton. A volume of 2.5 mL of 10% Folin-Ciocalteu reagent was added to 0.5 mL of the filtrate. The resulting mixture was incubated for 2 min at room temperature, protected from light. Two (2) mL of sodium carbonate solution (Na 2 CO 3) at 75 g.L-1 were added and the mixture was placed for 15 min in a water bath at 50°C. After rapidly cooling the mixture in water containing ice, absorbance (Cp) was measured at 760 nm using a UV visible spectrophotometer (JASCO V-530), with distilled water as the blank. Tests were repeated three (3) times for each sample. The total polyphenol (Pt) content was then evaluated according to the following expression:

$$Pt = Cp \times D$$

Pt: total polyphenol content; Cp: absorbance measurement; D: dilution factor.

2.2.6. Determination of total flavonoids

Total flavonoids (mg EQ) were determined using the method of [7]. Fifty (50) mL of distilled water were added to 5 g of pulp. After 5 min homogenization using a magnetic stirrer, the solution was filtered through absorbent cotton. A volume of 0.75 mL of 5% sodium nitrite ($NaNO_2$) was added to 2.5 mL of filtrate. The mixture (0.75 mL) was mixed with 10% aluminum chloride ($AlCl_3$). The resulting solution was kept in the dark for 6 minutes and 5 mL sodium hydroxide (NaOH; 1N) added. The volume was made up to 25 mL with distilled water. After vigorous stirring of the mixture, absorbance (Cf) was measured on a spectrophotometer (JASCO V-530) at a wavelength of 510 nm. For each sample, the tests were repeated three (3) times. The proportion of total flavonoids (Cflav) was evaluated using the expression below:

$$Cflav = Cf \times D$$

Cflav: proportion of total flavonoids; Cf: absorbance measurement; D: dilution factor.

2.2.7. Determination of oxalate content

Extraction and determination of total oxalates were carried out according to the method described by [8]. One gram (1 g) (Me) of ground pulp was homogenized in 37.5 mL H_2SO_4 under magnetic stirring for 1 h. The resulting mixture was filtered through Whatman filter paper, then 25 mL of the filtrate was taken and hot-titrated with a solution of $KMnO_4$ (0.05 M) until the color turned persistent pink (Veq). Oxalate content was determined according to the mathematical expression:

$$\text{Oxalate (mg/100g)} = \frac{2{,}2 \times Veq \times 100}{Me}$$

2.3. Statistical data processing

Results are presented as mean followed by standard deviation. Single-factor analysis of variance (ANOVA) and the Newman Keuls test with a threshold of 5% were used to allocate homogeneous groups for physico-chemical parameters, using STATISTICA version 99 software. The choice of this test was made after verification of the normality and homogeneity of the variances.

3. Results and discussion

3.1. Mineral composition

The mineral composition of the pulp from the various fruits studied is shown in Table 2. Of all these minerals (K, Na, Ca, P, Fe, Mg, Zn, Mn, Cu) analyzed, potassium (K) was the most important mineral ($P<0.05$) with contents ranging from 1108 ±0.2 mg/100g to 1563 ± 0.2 mg/100g for pulps of the rounded form and from 601.2±0.1 mg/100g to 1342 ±0.3 mg/100g for pulps of the ovoid form. The highest content (1563 ± 0.2 mg/100g) was recorded in the rounded form in the Nalourgokaha locality, while the lowest (601.2±0.1 mg/100g) was obtained in the ovoid form pulps in the Dahouakaha locality. These contents are close to those reported by [9] in Chad on the pulp of the same fruit. These authors obtained values of between 1900-2500 mg/100g. Shea pulp is an excellent source of potassium, especially as the daily requirement for an adult is estimated at 380 mg/day [10]. Despite the lower levels of other minerals than potassium in these fruits, their presence remains useful for consumers. Consumption of shea pulp could therefore help to satisfy the human body's need for minerals, thereby contributing to healthy growth and the prevention of certain diseases [11]. Moreover, these minerals are crucial for enzymatic activity and cell protection against free radical attack [12]. According to [13], a healthy diet containing foods high in potassium and low in sodium can reduce the risk of cardiovascular disease. In fact, the sodium content of the pulps sampled was low (18.1±0.2 mg/100 g - 28.3±0.02 mg/100 g for the rounded fruit pulp and 9.4±0.3 mg/100 - 33.1±0.3 mg/100 for the ovoid pulp) and the Sodium/Potassium ratio for the different pulps was less than 1. Consumption of these pulps could therefore be beneficial for hypertensive people [14].

Table 2 Mineral composition (mg/100g) of *Vitellaria paradoxa* shea fruit pulp

Mineral composition (mg/100g)											
Shape	**Pulp**	**Na**	**Mg**	**P**	**K**	**Ca**	**Fe**	**Zn**	**Mn**	**Cu**	**Na/k**
rounded	Boundiali	18,8±0,1^{d}	3,4±0,1^{a}	73,85±0,4^{f}	1108±0,2^{d}	150±0,3^{h}	6,63±0,1^{a}	0,51±0,1^{b}	0,83±0,2^{b}	0,54±0,3^{h}	0,02
	Dahouakaha	26,4±0,1^{g}	3,4±0,2^{a}	75,21±0,2^{f}	1505±0,3^{g}	179,9±0,1^{i}	21,86±0,33^{f}	0,57±0,02^{d}	1,38±0,1^{e}	0,4±0,2^{c}	0,02
	Dikodougou	18,1±0,2^{c}	3,4±0,3^{a}	99,73±0,1^{i}	1387±0,1^{f}	87,18±0,2^{f}	12,51±0,01^{c}	0,68±0,07^{f}	1,19±0,1^{d}	0,51±0,3^{g}	0,01
	Houphouekaha	23±0,1^{f}	3,4±0,1^{a}	22,39±0,2^{b}	1274±0,3^{e}	89,93±0,01^{f}	12,75±0,1^{c}	0,55±0,05^{c}	0,64±0,1^{a}	0,48±0,3^{f}	0,02
	Lataha	24,6±0,4^{f}	3,4±0,2^{a}	70,44±0,3^{e}	1151±0,2^{e}	77,43±0,1^{e}	15,84±0,01^{d}	0,51±0,1^{b}	079±0,5^{b}	0,4±0,1^{c}	0,02
	Nalourgokaha	28,3±0,02^{h}	3,4±0,1^{a}	81,22±0,2^{h}	1563±0,1^{g}	104,8±0,1^{d}	19,19±0,02^{e}	0,64±0,1^{e}	1,01±0,2^{c}	0,3±0,1^{a}	0,02
Ovoid	Boundiali	23,8±0,1^{f}	3,4±0,2^{a}	49,4±0,2^{c}	891,7±0,2^{b}	115,7±0,2^{g}	10,52±0,1^{b}	0,63±0,3^{e}	0,51±0,3^{a}	0,46±0,1^{d}	0,03
	Dahouakaha	12,6±0,2^{b}	3,4±0,1^{a}	17,07±0,1^{a}	601,2±0,1^{a}	49,62±0,1^{b}	15,92±0,2^{d}	0,32±0,2^{a}	0,95±0,5^{b}	0,35±0,2^{b}	0,02
	Dikodougou	9,4±0,3^{a}	3,4±0,3^{a}	78,37±0,2^{g}	1252±0,2^{e}	91,06±0,2^{f}	23,66±0,3^{g}	0,66±0,5^{f}	1,64±0,5^{f}	0,49±0,2^{f}	0,01
	Houphouekaha	21,6±0,1^{e}	3,4±0,2^{a}	62,38±0,2^{d}	1243±0,1^{e}	12,16±0,2^{a}	11,17±0,03^{b}	0,59±0,3^{e}	1,18±0,1^{d}	0,46±0,1^{d}	0,02
	Lataha	21,5±0,1^{e}	3,4±0,3^{a}	45,4±0,1^{c}	1018±0,2^{c}	61,03±0,1^{c}	26,3±0,05^{h}	0,55±0,2^{d}	1,41±0,1^{e}	0,28±0,1^{a}	0,02
	Nalourgokaha	33,1±0,3^{i}	3,4±0,1^{a}	75,51±0,4^{f}	1342±0,3^{f}	92,36±0,1^{f}	14,46±0,02^{d}	0,62±0,1^{e}	1,14±0,2^{d}	0,43±0,1^{e}	0,02

Na: sodium; Mg: magnesium; P: phosphorus; K: potassium; Ca: calcium; Fe: iron; Zn: zinc; Mn: manganese; Cu: copper; Values bearing different letters per parameter in the same column are significantly different at the 5% threshold

3.2. Anti-nutritional composition

Polyphenol, flavonoid and oxalate contents are reported in Table 3. The results show that these contents are significantly different (P <0.05) for both the rounded and ovoid shapes of the different localities.

Total polyphenol levels in *Vitellaria paradoxa* shea pulp of the rounded form ranged from 108.46 ± 0.01 mgEAG/ 100g to 143.33 ± 0.01mgEAG/ 100g, and from 116.60±0.01 to 173.03 ± 0.01 mgEAG/ 100g for the ovoid form. The highest content (173.03 ± 0.01 mgEAG/ 100g) was obtained in the ovoid form in the Dahouakaha locality, while the lowest (108.4 6± 0.01 mgEAG/ 100g) was recorded in the pulps of the rounded form in the Nalourgokaha locality. These contents are lower than those reported by [15] on *Vitex doniana* fruit pulp with a maximum value of 193.33 mg Eq A.G/100g and those of [16]on baobab pulp with average values of 1706 mg/100g for the species *A. za*, 1084 mg/100g for the species *A. digitata* and 1127 for the species *A. madagascariensis*. Differences in content may be due to the type of fruit. They could also be linked to climatic conditions (high temperature, high sun exposure, drought and salinity), which stimulate the biosynthesis of secondary metabolites such as polyphenols [17]. The results show that the pulp of the *Vitellaria paradoxa* shea fruit contains a significant amount of total polyphenols, which could be useful to consumers. According to [18], polyphenols help prevent cardiovascular disease. Consumption of *Vitellaria paradoxa* shea pulp can help prevent oxidative stress-related disorders such as degenerative diseases [19].

The highest flavonoid content was obtained in Lataha and Nalourgokaha respectively, with values of 94.38 ±0.01 mgEQ/100g and 94.60 ± 0.01 mgEQ/100g for the ovoid form. The lowest content was 19.69 ±0.03 mgEQ/100g (rounded form) in Dahouakaha. However, these levels are lower than those reported by [20] on *Vitex doniana* fruit, with a minimum value of 106.67 ± 2.31 mg Eq A.G/100g and a maximum value of 157.33 ± 0.58 mg Eq A.G/100g. This concentration is an asset for health, since flavonoids, by virtue of their function, protect blood vessels from cholesterol-related damage [21].

Oxalate levels in the pulp of the rounded form ranged from 1012±0.05 mg/100g to 9856±0.02 mg/100g. The oxalate contents obtained in the pulp of the shea fruit *Vitéllaria paradoxa* were 9130 ± 0.01 mg/100g, 9240 ±0.02 mg/100g, 9790 ± 0.01 mg/100g, 8030 ±0.02 mg/100g, 8800 ± 0.01 mg/100g and 5808 ± 0.03 mg/100g respectively. The lowest content (1012±0.05 mg/100g) was recorded in the rounded form in the Houphouekaha locality, while the highest contents were 9856±0.02 mg/100g (rounded form) and 9790 ± 0.01 mg/100g (ovoid form) in the Dikodougou and Dahouakaha localities respectively. These levels are higher than those reported by [8] for Néré (25.66 mg/100 g) and Baobab (187.00 mg/100 g) pulps. These values, obtained in the course of our work, would appear to have properties likely to influence the bioavailability of calcium (Ca) and iron (Fe) for the organism [22].

Table 3 Anti-nutritional components of *Vitéllaria paradoxa* shea fruit pulp

Parameters				
Form	**localities**	**Poly totaux (mgEAG/ 100g)**	**FL (mgEQ/100g)**	**Oxalate (mg/100)**
rounded	Lataha	143,33±0,01^{a}	61,93±0,02^{e}	7810±0,01^{d}
	Nalourgokaha	108,46±0,01^{a}	51,92±0,01^{d}	8030±0,01^{d}
	Dahouakaha	146,96±0,01^{a}	19,69±0,03^{a}	7370±0,02^{c}
	Houphouekaha	135,52±0,01^{a}	77,55±0,03^{f}	1012±0,05^{a}
	Dikodougou	125,84±0,03^{a}	59,95±0,01^{e}	9856±0,02^{f}
	Boundiali	138,16±0,01^{a}	43,01±0,02^{c}	7260±0,01^{c}
Ovoid	Lataha	162,58±0,01^{a}	94,38±0,01^{g}	9130±0,01^{e}
	Nalourgokaha	116,60±0,01^{a}	94,60±0,03^{g}	9240±0,02^{e}
	Dahouakaha	173,03±0,01^{a}	27,61±0,01^{b}	9790±0,01^{f}
	Houphouekaha	147,29±0,02^{a}	48,95±0,01^{d}	8030±0,02^{d}
	Dikodougou	118,03±0,01^{a}	38,72±0,03^{c}	8800±0,01^{e}
	Boundiali	120,45±0,01^{a}	92,29±0,01^{g}	5808±0,03^{b}

Poly: Polyphenol; FL: Flavonoids; Means bearing different letters per parameter in the same column are significantly different at the 5% threshold.

4. Conclusion

The aim of this first part was to assess the nutritional quality of shea fruit pulp. The results showed that the pulp is rich in numerous minerals, notably K, P, Mg, Na, Fe, Zn, Mn, Cu and Ca, as well as anti-nutrients (total polyphenols and oxalates) and organic acids, giving it excellent antioxidant properties. This pulp is quantitatively nutritious to meet food safety requirements. Consumption of shea pulp could benefit hypertensives and reduce the risk of cardiovascular disease thanks to the potassium it contains. Consumption of the pulp may also promote brain health thanks to the manganese it contains.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Author's contributions

All authors participated in the redaction of this document.

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