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NUTRITIONAL, ANTINUTRITIONAL AND MINERAL COMPOSITION OF *TRECULIA AFRICANA* SEED AND PULP, A SPONTANEOUS PLANT FOUND IN CÔTE D'IVOIRE

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ABSTRACT

The food use of spontaneous plants remains an alternative to ensure food security and the health of populations. This study was conducted to evaluate the nutritional composition and functional properties of *Treculia africana* seeds and pulp in order to promote their use in food formulations. The results show that the seed and pulp are sources of macronutrients and minerals. The seed is rich in protein (14.23 ± 0.13%), lipids (7.79 ± 0.28%) and carbohydrates (63.97 ± 0.12%) of which 54.03 ± 0.02% is starch. It contains significant amounts of minerals such as phosphorus (259.03 ± 7.52 mg/100g), potassium (702.17±18.18 mg/100g) and magnesium (123.55 ± 7.52 mg/100 g). The pulp is rich in crude fibre (15.93 ± 0.58%), ash (4.40 ± 0.27%), potassium (1422.34 ± 7.44 mg/100g), calcium (108.07 ± 2.26 mg/100g), chlorine (148 ± 8 mg/100g) and iron (12.32 ± 1.76 mg/100g). Rich in nutrients, the pulp and the seed are complementary. Their incorporation into the diets of Ivorians should be encouraged.

KEYWORDS: Nutritional composition, Mineral, antinutrients, *Treculia africana*, spontaneous plant.

1- INTRODUCTION

To live a long and healthy life, it is essential to have a healthy and balanced diet rich in nutrients and meeting the body's nutritional needs. For this reason, rural populations in some developing countries such as Nigeria, Cameroon and Côte d'Ivoire tend to consume indigenous wild plants, generally called spontaneous plants.[1] In the sixties, the entire territory of Côte d'Ivoire was a reservoir of natural resources. More than 12 million hectares of forest have disappeared in less than 40 years in this country, under the effect of anarchic exploitation and shifting agriculture.[2] In rural areas, this deforestation induces both a decrease in cultivable land and a scarcity of spontaneous food plants which represent real sources of nutritional supplements.[1]

Among spontaneous food plants, *Treculia africana* commonly known as African breadfruit is a native wild plant considered endangered. It is native to Africa and is found in tropical areas.[3] The tree reaches 30 to 45 m in height with a trunk circumference of about 4 to 6 m at full maturity.[4] The fruit, referred to as an African legume, is globular, greenish-yellow, and spongy in texture when ripe. It weighs about 10-25 kg with a diameter between 10.5 and 20.5 cm. One fruit can contain around 1,500 seeds. They look like orange pips, are 1.27 cm long, and are embedded at different depths in the fleshy pulp of the fruit.[5] The seeds are valued for their nutritional properties, their richness in carbohydrates, lipids, proteins, and minerals.[6] They are very nutritious and a cheap source of vitamins.

The pulp of fruit is not sufficiently valued, and no article has been found other than the ethno-botanical survey of *Treculia africana* in Côte d'Ivoire [7] as well as the proximal analyzes of the whole fruit.[8] Its consumption is limited to an ethnic group from the Gôh region, in the department of Gagnoa, where the dried pulp is consumed in sauces.[8] Because to this limited interest, several tons of fruit are lost each year across the country. Lack of knowledge of the nutritional properties of the pulp is surely an obstacle to its use. However, the nutritional composition of seeds of *Treculia africana* have been more studied, mainly in Nigeria and Ghana but not in Côte d'Ivoire. The seeds are valued for their nutritional properties, their richness in carbohydrates, lipids, proteins, and minerals.[6] The studies also focus on nutrient and antinutrient composition[9,10] vitamin composition and amino acid profile.[11, 12] These studies also show that the constitution and properties of the plant depend on its state of maturity, the composition of the soil, and the climatic conditions of the location.[14]

Our study aims to assess the nutritional, mineral and anti-nutritional composition of the pulp and seeds of *Treculia africana* fruits harvested in the sub-prefecture of Gueyo, in order to raise awareness of the essential role that this indigenous plant can play in food security and to promote its inclusion in the diet of Ivorians.

2- MATERIAL AND METHODS

2.1- Plant material

The plant material used for this study is mature fruits of *Treculia africana* (Figure 1).

Figure 1: A: mature fruit of *Treculia africana*, B: dried seeds, C: dried pulp.

2.2- Methods

2.2.1- Sampling and preparation of flours

The fruits of *Treculia africana* were harvested in May 2018 from a local farm in the village of Lahouridou, Gueyo sub-prefecture in the Gôh Region, in the Department of Gagnoa (5°40' and 6°10' North latitude and between 5°50' and 6°20' West longitude), west-central Côte d'Ivoire.[7] After harvesting, the fruits were transported to the Biocatalysis and Bioprocesses laboratory of Nangui Abrogoua University (Abidjan, Côte d'Ivoire). The fruits were then washed several times with distilled water, sliced with a stainless-steel knife. The seeds were manually separated from the pulp and both were dried in an oven at 45 °C for 72 hours. The dried samples were crushed with a grinder and sieved with a 250 µm. The resulting flours were placed in fully filled screw-top flasks and stored away from moisture and light.

2.2.2- Determination of the nutritional composition of seeds and pulp of *T. africana*

2.2.2.1-Determination of moisture, ash and crude fiber contents

Moisture, crude fiber, and ash of the seed and pulp flours were determined by the official analytical methods of the Association of Official Analytical Chemists (AOAC).[15]

2.2.2.2.-Determination of lipid content

Lipid content was determined by the method of the French standard AFNOR using Soxhlet as extractor and hexane as solvent for 6 hours.[16]

2.2.2.3- Determination of protein content

Crude protein was determined from the determination of total nitrogen by the method of Kjeldhal.[17] The total protein content is obtained by multiplying the total nitrogen by the factor 6.25 and expressed as a percentage of dry matter.

2.2.2.4- Determination of Metabolizable carbohydrates

Metabolizable carbohydrates were calculated from the contents of the other constituents (moisture, protein, fat, fiber and ash).

Metabolizable carbohydrates = 100 – [% Moisture + % Protein + % Lipids + % Fiber + % Ash]

2.2.2.5- Determination of starch content

Starch content was estimated by the method described by Goñi *et al.*[18] After enzymatic hydrolysis of the starch, the concentration of released glucose was determined and multiplied by 0.9.

2.2.2.6- Calculation of the energy value

The energy value was calculated from the energy value of each macronutrient considering the Atwater coefficients (lipids: 9 Kcal; protein: 4 Kcal; carbohydrates: 4 Kcal).[19]

Energy value (Kcal) = (4 x % protein) + (4 x % carbohydrates) + (9 x % lipids)

2.2.2.7- Determination of mineral composition of flours

The mineral profiles of the flours were determined using a Scanning Electron Microscope (SEM FEG Supra 40 VP Zeiss) equipped with an X-ray detector (OXFORD Instruments) and connected to an energy scattering spectrometry (EDS) platform (Inca Dry Cool, without liquid nitrogen) at the PETROCI laboratory's Analysis and Research Center (CAR) (Abidjan, Côte d'Ivoire). The flours were incinerated at 750 °C for 12 hours in a muffle furnace (ASTM D 482). 10 mg of the ash obtained was spread on the pad (sample holder), which was then attached to the SEM/EDS slide. This assembly was mounted on the SEM chamber stage for X-ray Microanalysis (EDS). Detection of mineral elements was performed by X-ray emission and the data was transferred to a file that could be run in Excel or Word.

2.2.2.8- Determination of anti-nutritional composition (oxalates and phytates)

Oxalates were determined by titration with potassium permanganate ($KMnO_4$) solution, after hydrolysis of flours with H_2SO_4 (3 M).[20]

Phytates were determined by spectrophotometric analysis according to the method of Latta and Eskin.[21] After hydrolysis of the flours in HCl (0.65 N) for 12 h, the filtrates were added to Wade's reagent and incubated for 20 min in the dark and the absorbance was read at 490 nm. A standard curve was prepared with phytic acid up to 10 mg/mL. The result is expressed as mg phytic acid equivalent per 100 g dry matter.

2.3- Statistical analyses

All measurements were performed in triplicate and results are expressed as mean ± standard deviation. An analysis of variance (ANOVA) was performed to compare means using Student's t test with STATISTICA version 7.1 software. Statistical significance was defined at $p \leq 0.05$.

3- RESULTS AND DISCUSSION

3.1- Nutritional composition of seeds and pulp flours

The results of the analyses on the nutritional composition of African breadfruit flours and pulps show that they are rich in macronutrients (proteins, lipids, carbohydrates) but in fiber and ash (Table 1). Significant differences ($p \leq 0.05$) are observed for most constituents, except for moisture.

Table 1: Nutritional composition of seed and pulp flours of *Treculia africana* per 100 g of dry matter (DM).

	Seed	Pulp	
Constituents	**Quantities (% DM)**		**p-value**
Protein	14.23 ± 0.13^b	6.62 ± 0.17^a	0.011
Lipid	7.79 ± 0.28^b	2.59 ± 0.07^a	0.006
Metabolizable carbohydrate	63.98 ± 0.25^b	61.46 ± 0.88^a	0.053
- Starch	54.03 ± 0.02	-	
Fiber	2.01 ± 0.14^a	15.93 ± 0.58^b	0.001
Ash	2.59 ± 0.14^a	4.4 ± 0.58^b	0.005
Moisture	9.40 ± 0.20^a	9.01 ± 0.16^a	0.061
Energy value (kcal)	382.96 ± 1.50^b	295.64 ± 1.41^a	0.018

Values represent the mean ± standard deviation of three measurements (n = 3). Values in the same row with different letters are significantly different (p < 0.05). ***DM:*** *dry matter*

Proteins are essential macronutrients for the body, due to their involvement in several biological functions such as muscle tissue development, enzyme and hormone production. The protein contents are 14.23 ± 0.13% and 6.62 ± 0.17% for seed and pulp respectively (Table 1). The protein content of the seed is higher than 11.06% reported for *T. africana* crude seeds from Nigeria but lower than 17.57% obtained for seeds from Ghana.[22, 9] The protein content of the seed, although lower than that of soybean (40%) and groundnut (30%), is higher than that of most cereals such as maize (10%), sorghum (11%), wheat (8-11%), rice (8%).[23] The pulp content remains weak compared to those cereals. The consumption of 100 to 300g of seed flour could cover the daily protein needs of the body, which depend on several parameters (age, sex, physical activity and body mass). Furthermore, combining *T. africana* seeds and pulp with other protein sources for diet formulation could contribute to the daily protein intake which is recommended at (34-56 g/day) for adults and (13-19 g/day) for children.[10] Seeds could be advantageously used as a substitute for the usual protein sources that have become expensive and inaccessible by rural populations.

Technologically and nutritionally, lipids are essential in diets, as they enhance the taste of foods and preserve their flavours, as well as being essential for the structural and biological functioning of cells and the transport of soluble vitamins.[10] The lipid contents show statistical differences ($p \leq 0.05$), the seed contains 7.79 ± 0.28%, three times more than the pulp (2.59 ± 0.07%). This lipid content of the seed is lower than 9.08% but is higher than 5.27% reported for the Nigerian breadfruit.[9,11] These variations in results are due to geographical distribution and differences in the African breadfruit seed species used in the studies or the processing methods.[14,11] The lipid content of the African breadfruit seed would argue for a high proportion of fat-soluble vitamins. On the other hand, the low lipid content of the pulp would be an advantage for the diet of people suffering from obesity or cardiovascular diseases whose fat intake must be reduced.

Carbohydrates are good sources of energy, rapidly usable by the body and their high concentration is desirable in breakfast and weaning formulations.[9] The carbohydrate content and energy value of the seed (63.98 ± 0.12 g/100 g and 382.96 ± 1.40 Kcal/100 g) are significantly higher ($p \leq 0.05$) than those of the pulp (61.46 ± 0.89 g/100 g and 295.64 ± 1.40 Kcal/100 g) (Table 1). In addition, the carbohydrate fraction of the seed consists of 54.03 ± 0.02% starch, whereas the pulp does not. The carbohydrate content and energy value of the seed in our study corroborate 64.17% carbohydrate and 384.62 Kcal/100 g reported for raw seeds of *Treculia africana*.[22] The high carbohydrate content of the seed and pulp would make them good carbohydrate sources for breakfast and weaning food formulations. The presence of starch in the seed would influence certain properties such as swelling, gelatinization, fluidity, and suitability for use in food processing.[24] Moreover, the low energy value and the absence of starch in the pulp would be an advantage in food formulations for patients with certain metabolic diseases.

The crude fibre contents show a significant difference at $P < 0.05$. The fibre content of the pulp (15.93 ± 0.58%) is seven times higher than that of the seed (2.01 ± 0.14%). The crude fibre content of the pulp in this study is comparable to that of wheat grains, which ranges from 13.4 to 16.6%.[25] It is well documented that high dietary fibre intake has significant health benefits.[26, 27] Dietary fibre intake may protect against cardiovascular disease, diabetes, obesity, colon cancer, constipation, and other diseases.[10, 27] Consumption of the pulp could protect against these diseases. However, the Codex Alimentarius Commission has indicated that the crude fibre content of weaning foods should not exceed 5%.[28] Therefore, the low crude fibre content of the seeds suggests that they may be suitable for weaning diets.

The ash contents show a significant difference ($p \leq 0.05$) with the higher value for the pulp (4.40 ± 0.27). The seed presented an ash content of 2.59 ± 0.14 g/100 g dry matter. The ash content of a food is a true reflection of its mineral content.[10] The high ash content of the pulp reflects its mineral richness compared to the seed. The ash content of the seed corroborates the value (2.64%) for seed harvested in Ghana.[9] However, it is still lower than the 2.92% and 3.04% reported for African breadfruit from Nigeria.[6, 22]

In contrast to the other constituents, the moistures do not show any significant difference. The moisture content is 9.4 ± 0.2% for the seed and 9.00 ± 0.09% for the pulp. These values are within the range of moisture content suitable for flour storage, generally below 10%.[29] Therefore, these low moisture values would allow flours to be stored for long periods and prevent the growth of micro-organisms.

3.1- Anti-nutrient content of seeds and pulp of *Treculia africana*

The levels of antinutrients differed statistically at 5% with higher values in the pulp (Table 2). The pulp contains 1.7 times more oxalate and phytate than the seed. These organic compounds are naturally present in plants and, at high concentrations, are capable of interfering with the absorption of certain nutrients in the body.[22] Therefore, they must be completely removed or partially reduced by applying processing techniques such as boiling, roasting, fermentation, autoclaving, drying, soaking and steaming.[4] The oxalate content of the seeds in this study is higher than the value (85 mg/100 g) reported for seeds harvested in Nigeria.[5] However, it is still lower than the oxalate content of groundnut (140 mg/100 g).[30] Consumption of the pulp or seed does not present any risk as the oxalate content in 1 kg is well below the minimum lethal dose of 4-5 g total oxalates/day.[31] Apart from these negative effects, phytate consumption offers protection against various cancers through its antioxidant properties and increased natural killer cell activity.[32]

Table 2: Oxalate and phytate contents of *Treculia africana* seed and pulp flours per 100 g dry matter (DM).

	Seed	Pulp	
Constituents	**Quantities (mg/100 g DM)**		**p-value**
Oxalates	105.04 ± 7.75^{a}	181.17 ± 13.94^{b}	0.000
Phytates	32.38 ± 1.52^{b}	55.09 ± 1.36^{a}	0.000

Values represent the mean ± standard deviation of three measurements (n = 3). Values in the same row with different letters are significantly different (p < 0.05). ***DM:*** *dry matter*

3.4- Mineral composition of *Treculia africana* pulp and seed flours

Dietary intakes of minerals are necessary because they perform several physiological and metabolic functions in the body. The mineral composition of the seed and the pulp of African breadfruit is shown in Table 3. Contrary to macromolecules, the majority of macro-elements are higher in the pulp than in the seed with 2 times for potassium, 5 times for sodium, 2.5 times for calcium and 4 times for chlorine. Magnesium and Sulphur contents are not significantly different ($p > 0.05$), only phosphorus is 3.5 times higher in the seed. Potassium is the most abundant mineral in pulp and seed as reported in the literature for the seed (587 mg and 534 mg).[14, 9]

The majority of trace elements are also higher in pulp (5 x for iron, 2 x for copper, 7 x for manganese). It should be noted that varying amounts of iron (7.60 and 19.94 mg), copper (1.07 and 4.30 mg) and manganese (0.22 and 29.2 mg) were reported for Nigerian crude seeds [22, 13], and our values remain within these ranges. These results show that the pulp and seed are sources of minerals whose consumption would provide the minerals necessary for the proper functioning of the body. Indeed, these minerals play several essential roles such as the formation of bones, teeth and the nervous system, blood coagulation; regulation of osmotic pressure; cellular energy production; glycogen production and hormone secretion, and are cofactors of many reactions of cellular metabolism.[33 - 35] Mineral ratios such as Ca/P and Na/K are important as they predict bone quality and the risk of developing cardiovascular diseases. The minimum Ca/P ratio required for favourable calcium absorption in the gut for bone formation is 0.5[36] which is achieved for the pulp but not for the seed (< 0.2). Thus, consumption of the seed requires supplementation with other sources of calcium to promote good bone development, e.g. pulp. The Na/K ratio in the body is of great concern for the prevention of high blood pressure and a Na/K ratio of less than 1 reduces high blood pressure.[37] The ratio of the two parts of the fruit agrees with this recommendation with a very low Na/K ratio (Table 3).

Table 3: Composition in macro minerals and trace elements of seed and pulp flours of per 100 g of dry matter (DM).

	Seed	**Pulp**	
Macro minerals (mg/100 g DM)			**p-value**
Sodium (Na)	1.73 ± 0.79^a	9.09 ± 1.78^b	0.001
Magnesium (Mg)	123.55 ± 7.52^a	119 ± 2.08^a	0.062
Phosphorus (P)	259.03 ± 7.3^b	74.2 ± 3.24^a	0.019
Potassium (K)	702.18 ± 18.19^a	1422.34 ± 7.44^b	0.001
Calcium (Ca)	41.9 ± 2.87^a	108.07 ± 2.26^b	0.000
Sulphur (S)	27.39 ± 0.4^a	23.76 ± 3.08^a	0.058
Chlorine (Cl)	35.6 ± 1.05^a	147.5 ± 8.13^b	0.013
Trace elements (mg/100 g DM)			
Iron (Fe)	2.25 ± 0.3^a	12.32 ± 1.76b	0.002
Copper (Cu)	1.64 ± 0.3^a	3.67 ± 0.25^b	0.012
Manganese (Mn)	0.78 ± 0.93^a	5.43 ± 2.26^b	0.000
Ca/P	0.16 ± 0.01^a	1.46 ± 0.09^b	0.021
Na/K	0.002 ± 0.001^a	0.006 ± 0.001^b	0.001

Values represent the mean ± standard deviation of three measurements (n = 3). Values in the same row with different letters are significantly different (p < 0.05). ***DM:*** *dry matter*

4- CONCLUSION

This study highlights the nutritional value of the fruit of *Treculia africana*, particularly the underutilized pulp. The seed and pulp are important sources of macromolecules such as proteins, lipids, carbohydrates and fibres. Their complementarity (high protein content in the seed, fibre in the pulp) is also reflected in their mineral content. Based on their nutritional composition, the consumption of seeds and/or pulp could contribute to the improvement of the nutritional status of populations. Therefore, the conservation, valorisation and promotion of the consumption of seeds and pulp of *Treculia africana* remain a necessity.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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