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Chemical characterization and nutritional potential of the pulp, kernel and shell of the wild fruit of *Dialium guineense* from Côte d'Ivoire

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***Abstract*:**

Dialium guineense is a tree whose fruits are widely consumed by the Ivorian population. However, contrary to the species of the countries of the sub-region, the fruits of *D. guineense* of Côte d'Ivoire remain little served in terms of scientific data. This work was devoted to the chemical, mineral nutritional and anti-nutritional analyses of the different parts of the fruit of *D. guineense* (shell, pulp and kernel) according to the procedures described in the collections of international standards (AOAC, AFNOR, etc.) and those resulting from the literature.
Nutritional parameters, such as fat, crude protein, moisture, total fiber, total carbohydrates, total sugars, reducing sugars, siliceous constituents and energy value of the pulp, core and hull, were measured. The acidic character of the fruit was demonstrated by determining the pH and acidity of the pulp, core and shell. The presence of macro and trace elements, such as calcium Ca, chlorine (Cl), magnesium (Mg), potassium (K), sodium (Na), phosphorus (P), sulfur (S), aluminium (Al), copper (Cu), iron (Fe), manganese (Mn), silicon (Si) and zinc (Zn) were measured in different parts of the *Dialium guineense* fruit. In summary, *Dialium guineense* fruits can indeed be considered as a valuable source of nutrients for human and animal consumption.

***Keywords*:** *Dialium guineense*; Nutritional parameters; Chemical properties; Mineral composition.

1 Introduction

Dialium guineense is a specie of plant in the Fabaceae family. Its various organs (leaves, roots, fruits, etc.) are widely used in various fields by people of Sub-Saharan Africa. This plant belongs to the Dialioideae subfamily, which comprises 85 species, including 24 species in sub-Saharan Africa and 17 genera [1, 2].

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Dialium guineense is used in traditional medicine to treat various pathologies such as dental caries, cough, diarrhea, fever, jaundice, dysmenorrhea, ulcers, hemorrhoids, anemia, diabetes, stomach pain and palpitations [3-5]. From a nutritional perspective, the fruits are particularly popular because they are a source of minerals [6]. They are used as a food supplement for the population [7] and have been found to improve lactation in some women [8]. In Côte d'Ivoire, *D. guineense* fruits are among the most consumed wild fruits by the local population [9]. In urban areas, they are known as "black cat" due to their velvety black shell. Researchers have conducted several studies on these fruits in different countries within the sub-region. For instance, studies in Benin focused on the nutritional and mineral content of the fruit pulp [10]. Similar work has been carried out on the pulp of the Senegalese specie [11]. Phytochemical, nutritional, biological and mineral studies were conducted on the pulp and seeds of *D. guineense* from Nigeria [4, 12]. Additionally, mineral composition studies were performed on the different parts of the fruit of the Ghanaian specie, including the pulp, shell and kernel [13]. All the information contributes to an important and reliable database for effectively evaluating this plant specie in these countries.

However, in contrast to these, there is still a lack of scientific data on the Côte d'Ivoire specie. To fill this information gap, the present study aimed to determine the chemical, nutritional, antinutritional and mineral characteristics of the shell, kernel and pulp of *Dialium guineense* harvested in Côte d'Ivoire.

2 Material and methods

2.1 Plant material

The fruits of *Dialium guineense* were collected in March 2020 in Dimbokro (6°39′ north, 4°42′ west), a town in the center of Côte d'Ivoire located in the N'Zi region. The collected samples were identified by an ethnobotanist from the University of Nangui Abrogoua and then certified at the National Floristic Center of Abidjan (Côte d'Ivoire) according to with the existing herbarium (N°UCJ009331). The fruits were cleaned and then peeled. The different parts (pulp, stones, and shells) were separated and dried in an air-conditioned room at 18 °C for 21 days and then ground into powder using an electric grinder.

2.2 Determination of chemical characteristics

The pH of the different parts of this fruit was measured using a PHS-550 pH meter in a solution containing a mixture of extract and 10% (w/v) distilled water [14]. The free acidity of *D. guineense* fruit organs was determined by titration with NaOH (0.1 N) in the presence of phenolphthalein [14].

2.3 Determination of nutritional characteristics

The moisture content of *Dialium guineense* fruit organs was determined using to the methods described in the international standard books [15, 16].

Nitrogen content estimation was performed using the Kjeldahl method [17]. Crude protein content was calculated from the

nitrogen amount using a factor of 6.25 [17, 18].

The fat content of the fruit parts was extracted by Soxhlet extraction with hexane [19].

Total sugars content was determined colorimetrically by measuring the optical density at 490 nm. The solution used for measurement contained a mixture of phenol (C_6H_6O, 5%), sulfuric acid (H_2SO_4, 97%) and carbohydrate extract [20-23]. The proportion of reducing sugars was determined by measuring the absorbance at 540 nm of a mixture of the carbohydrate extract and 3.5-dinitrosalycilic acid ($C_7H_4N_2O_7$) [24, 25].

The total fiber content was determined following methods described by the AOAC [14].

Total ash content was determined gravimetrically according to the methods described by the French Association for Standardization [15].

The siliceous constituents were determined gravimetrically from total centers after heat treatment with a 10% dilute HCl solution [12].

Energy values were assessed using the methods described by the AOAC [14].

2.4 Determination of anti-nutritional composition

Oxalate content was estimated through titration in potassium permanganate solution, following the method described by Day and Underwood [26].

The number of phytates was determined using a colorimetric method based on optical density measurements. A mixture of an acidified solution (HCl, 0.65 N) and a Rose Wade reagent was analysed at 490 nm [27]. Finally, the ratios of oxalate to calcium and phytate to iron were determined [28-30].

2.5 Determination of mineral characteristics

After incineration at 550 °C for three hours, the mineral composition of the pulp, kernel and shell of *Dialium guineense* fruit was determined using a Scanning Electron Microscope (SEM, FEG Supra 40 VP Zeiss) equipped with an X-ray detector (Oxford Instruments), which is connected to an EDS microanalyzer (Inca Dry Cool, without liquid nitrogen).

2.6 Statistical analysis

All measurements were performed in triplicate and results are expressed as mean ± standard deviation (Mean ± SD). Statistical processing of the data (one-way ANOVA) was performed using the STATISTICA 7.1 software.

3 Results and discussion

3.1 Chemical and nutritional composition

Chemical and nutritional compositions of the pulp, shell and kernel of *Dialium guineense* are given in table 1. The moisture content recorded is 11.52 ± 0.07% for the kernel; 11.56 ± 0.07% for the shell and 22.72 ± 0.05% for the pulp. Interestingly, both the kernel and shell exhibit similar moisture levels, as confirmed by Tukey's test. However, these values differ from those reported in other studies conducted on *D. guineense* in different parts of West Africa. In fact, studies analyzing the pulp of *D. guineense* specie from Senegal (12.45 ± 0.23%) [11] and

Benin (9.36 ± 1.36%) [10] revealed low values. Similarly, the pulp (4.9 – 19.61%) and kernel (5.9 – 10.05%) of the Nigerian matrix exhibited similar finding [6, 12]. This discrepancy may be attributed to the different drying methods employed. While *D. guineense* organs from Senegal were sun-dried, those from Nigeria and Benin underwent dehydration in an oven at 55°C and at room temperature in a ventilated room, respectively. In general, *D. guineense* cannot be considered an oilseed due to the low-fat content in various parts of the fruit (2.45 – 4.77%) (Table 1). These values are comparable to those reported for the Nigerian (pulp: 2.6%; kernel: 5.4%) [12] and Senegalese (pulp: 3.09 ± 0.79%) specie [11], but lower than that the Beninese species' pulp (9.21 ± 0.50%) [10]. However, the *D. guineense* kernel (23.58 ± 1.18%) has the highest proportion of crude protein compared to the pulp (3.23 ± 0.16%) and shell (2.15 ± 0.14%). Thus, it can serve as a protein source for both humans and animals. These finding align with data from Nigerian studies, which show higher crude protein in the kernel (14.88 – 17.44%) than in the pulp (3.94 – 8.3%) [6, 12, 31, 32]. The estimated total carbohydrate content for the kernel, pulp and shell is 56.79 ± 1.22%; 70.15 ± 0.97% and 79.44 ± 0.71%, respectively. Therefore, the different parts of *Dialium guineense* fruit can be considered carbohydrate sources, supported by research in Senegal [11], Benin [10] and Nigeria [12].

Notably, the shell of *D. guineense* (30.14 ± 0.02%) contains more total fiber than the kernel (12.24 ± 0.1%) and pulp (0.43 ± 0.05%). While these values differ from Nigerian reports 0.6 - 1.21% for the pulp and 13.52 ± 0.36% for the seeds [31]. Climatic and geographical factors may explain the variation [32]. Overall, the shell (351.02 ± 0.32 kcal/100 g), kernel (364.47 ± 0.35 kcal/100 g), and pulp (317.01 ± 0.14 kcal/100 g) of *D. guineense* fruit offer significant energy potential.

Table 1
Chemical and nutritional parameters of the different parts of the fruit of *Dialium guineense*.

Parameters	Pulp	Kernel	Shell
pH	2.89 ± 0.02^{c}	5.53 ± 0.01^{a}	3.67 ± 0.01^{b}
Free acidity (mEq/100 g)	19.20 ± 0.2^{a}	1.69 ± 0.37^{c}	5.80 ± 0.2^{b}
Moisture (%)	22.72 ± 0.05^{a}	11.52 ± 0.07^{b}	11.56 ± 0.07^{b}
Crude Protein (%)	3.23 ± 0.16^{b}	23.58 ± 1.18^{a}	2.15 ± 0.14^{c}
Fat content (%)	2.57 ± 0.006^{b}	4.77 ± 1.015^{a}	2.45 ± 0.043^{c}
Total carbohydrates (%)	70.23 ± 0.06^{b}	56.81 ± 0.12^{c}	79.49 ± 0.10^{a}
Total sugars (%)	0.50 ± 0.004^{c}	0.77 ± 0.004^{a}	0.59 ± 0.003^{b}
Reducing sugars (%)	0.40 ± 0.001^{a}	0.16 ± 0.001^{c}	0.23 ± 0.003^{b}
Total fiber (%)	0.43 ± 0.05^{a}	12.24 ± 0.1^{b}	30.14 ± 0.02^{c}
Total ash (%)	1.33 ± 0.13^{c}	3.34 ± 0.14^{b}	3.78 ± 0.29^{a}
Siliceous constituents (%)	0.24 ± 0.004^{a}	0.77 ± 0.003^{b}	1.14 ± 0.02^{c}
Energy values (kcal/100 g)	317.01 ± 0.14^{c}	364.47 ± 0.35^{a}	351.02 ± 0.32^{b}

Values in the same row with different superscripts are statistically different at $p < 0.05$.

Interestingly, although the shell and core of this fruit, constituting approximately 40% and 28% of the fruit mass, respectively [11, 33], they are not included in our regular diet. However, the kernels contained in the almond are rich in protein (23.58 ± 1.018%), and the shells contain abundant assimilable carbohydrates (79.49 ± 0.10). The use of these components can really be useful in the fight against protein-energy malnutrition. The shell is the richest in mineral components, followed by the kernel (3.34 ± 0.14%) and the pulp. Overall, the ash proportion in the pulp is lower than that in specie from Senegal (1.63 ± 0.05%) [7], Nigeria (1.80 – 3.2%) [7, 12, 32] and Benin (1.70 ± 0.05%) [10]. However, the Côte d'Ivoire fruit kernel contains more mineral matter than the Nigerian specie (2.5%) [12, 31]. The variation in results can be attributed to differences in fruit ripeness and harvesting locations. In terms of siliceous constituents, the shell contains the highest abundance (1.14 ± 0.02%), followed by the kernel (0.770 ± 0.003%) and the pulp (0.240 ± 0.004%) (Table 1). Notably, the siliceous constituents in the pulp (0.24 ± 0.004%) closely resemble those found in the Malian specie (0.27%) [34]. The physical properties of different parts of the *Dialium guineense* fruit were evaluated by analyzing their pH and free acidity. *D. guineense* fruits are generally acidic, as indicated by pH measurements in the pulp (2.89 ± 0.02), kernel (5.53 ± 0.01) and shell (3.67 ± 0.01) (Table 1). Titratable acidity values (Table 1) provide insights into the content of mineral and organic acids in these parts of the fruit. The high acidity observed in the pulp (19.20 ± 0.2 mEq/100 g DM) can be attributed to the presence of significant acids, including ascorbic acid (with content ranging from 4.5 to 35.7 mg/100g) [7, 10, 12]. Interestingly, the pH values for the Ivorian specie align with those of the Nigerian specie (pulp: 3.25 and kernel: 5.47) [6].

3.2 Antinutritional composition

An analysis of the antinutritional composition of the fruit parts of *Dialium guineense* revealed significant differences (Table 2). Phytates were detected only in the stone (seed) of the fruit, with an estimated content of 14.83 ± 0.07 mg/100 g DM. Phytates are known for their ability to chelate minerals (such as calcium, iron and zinc), which can reduce their bioavailability. However, they also have antioxidant properties and may offer health benefits. The presence of phytates in the stone suggests that it plays a protective role for the seed during germination. As for oxalates, they were detected in all parts of the fruit with proportions of 44.55 ± 1.26; 55.90 ± 1.09 and 50.03 ± 1.26 mg/100 g DM for the pulp, kernel and shell, respectively.

Table 2
Antinutritional composition of the different parts of the fruit of *Dialium guineense*.

Parameters	Pulp	Kernel	Shell
Total Oxalates (mg/100 g DM)	44.55 ± 1.26^{c}	55.90 ± 1.09^{a}	50.03 ± 1.26^{b}
Phytates (mg/100 g DM)	-	14.83 ± 0.07^{a}	-
Oxalates/Calcium	0.45 ± 0.01^{a}	0.12 ± 0.002^{b}	0.07 ± 0.002^{c}
Phytates/Iron	-	1.21 ± 0.006^{a}	-

Values in the same row with different superscripts are statistically different at $p < 0.05$.

The oxalates contents observed in the Ivorian specie was significantly higher than that reported by Adepoju for the Nigeria specie (0.90 ± 0.04 mg/100 g DM) [32]. He also mentioned the presence of phytates in the pulp (1.30 ± 0.03 mg/100 g DM) [32], which contradicts the information obtained for the Ivorian specie. The variation in results between studies arises from differences in the methods used for analysis [27, 31]. Additionally, soil composition, climate, and geographical location can impact the chemical composition of plants [35]. Furthermore, the existence of an antagonistic effect between oxalic acid and calcium [36] as well as phytic acid and iron [37], prompted the investigation of the phytate/iron and oxalate/calcium molar ratios in different parts of *D. guineense* (Table 2). The phytate/iron molar ratio for the kernel was determined to be 1.210 ± 0.006, which falls well below the recommended range of 10 to 15 for enhancing iron bioavailability [30, 38]. As for the molar ratio of oxalate to calcium, the values obtained were 0.45 ± 0.01 for the pulp, 0.12 ± 0.002 for the kernel and 0.07± 0.02 for the shell. These values are below the threshold of 2.25 for improving calcium bioavailability [29]. Overall, consuming various parts of *D. guineense* is unlikely to impact on the body's absorption and utilization of iron and calcium, so there are no concerns.

3. 3 Mineral composition

The mineral analysis carried out on the different parts of the *Dialium guineense* fruit revealed the presence of macroelements (Ca, Cl, K, Mg, Na, P and S) and microelements (Fe, Mn, Cu Al, Si and Zn) in variable proportions (Table 3).

Statistical treatment of the data showed a significant difference ($p < 0.05$) in the mineral contents obtained: calcium (Ca) (98.88 ± 2.98 – 742.60 ± 35.57 mg/100 g DM), potassium (K) (945.34 ± 33.3 – 1709.87 ± 46.89 mg/100 g DM), phosphorus (P) (11.73 ± 3.03 – 458.38 ± 6.12 mg/100 g DM) and magnesium (Mg) (48.59 ± 5.88 – 585.28 ± 7.78 mg/100 g DM) (Table 3). *Dialium guineense* offers a significant amount of macroelements essential for bone health. Consuming 100 g of this fruit can meet daily calcium and magnesium requirements for both infants (Ca: 400 mg; Mg: 40 mg) and adults (Ca: 900 mg; Mg: 480 mg) [39]. Additionally, trace elements like iron and manganese are present in significant quantities, particularly in different parts of the fruit (with higher concentrations in the shell). Copper was exclusively found in the pulp (4.73 ± 0.72 mg/100 g DM) and kernel (8.47 ± 1.87 mg/100 g DM). While the absence of aluminium was observed in the same parts of the fruit. As for zinc, it was only observed in the kernel (3.01 ± 0.53 mg/100 g DM).

The high siliceous constituents' content in the shell (see Table 1) could be attributed to the significant presence of silicon (Si) (688.8 ± 21.52 mg/100 g DM) in this organ. Compared to the pulp of the Benin (14.75 ± 0.25 mg/100 g) [9] and Senegal (6.47 ± 1.80 mg/100 g) [11] specie, the pulp of the Ivorian matrix contains little iron (4.85 ± 0.55 mg/100 g). The iron in *Dialium guineense* from Côte d'Ivoire falls below the recommended daily intake (8 mg for infants; 18 mg for adults) [39]. Notably, this iron content in Côte d'Ivoire's *Dialium guineense* exceeds that reported by Nigerian researchers (1.4 – 4.1 mg/100 g) [7, 32].

Table 3
Mineral element contents of different parts of the *Dialium guineense* fruit in mg/100g dry matter (DM).

Minerals	Pulp	Kernel	Shell
Ca	98.88 ± 2.98^{c}	452.02 ± 15.59^{b}	742.60 ± 35.57^{a}
Cl	11.88 ± 1.11^{c}	14.83 ± 1.22^{b}	25.92 ± 0.84^{a}
K	945.34 ± 33.3^{c}	1507.92 ± 35.38^{b}	1709.87 ± 46.89^{a}
Mg	48.59 ± 5.88^{c}	585.28 ± 7.78^{a}	193.18 ± 20.7^{b}
Na	13.33 ± 1.11^{a}	8 ± 0.82^{c}	12.82 ± 2.69^{b}
P	115.73 ± 3.03^{c}	458.38 ± 6.12^{a}	285.72 ± 25.29^{b}
S	26.78 ± 3.30^{c}	232.60 ± 4.02^{a}	30.66 ± 6.16^{b}
Al	-	-	9.20 ± 2.90^{a}
Cu	4.73 ± 0.72^{b}	8.47 ± 1.87^{a}	-
Fe	4.85 ± 0.55^{c}	12.24 ± 3.89^{b}	14.22 ± 0.84^{a}
Mn	13.81 ± 1.45^{c}	18.33 ± 2.27^{b}	68.29 ± 2.94^{a}
Si	46.17 ± 6.55^{b}	30.37 ± 1.41^{c}	688.8 ± 21.52^{a}
Zn	-	3.01 ± 0.53^{a}	-

Values in the same row with different superscripts are statistically different at $p < 0.05$.

Aluminum is found only in the shell of the Côte d'Ivoire fruit (9.20 ± 2.90 mg/100 g) while it is found in various parts of the Ghanaian fruit [13].

Additionally, sodium and potassium are present in all organs of the fruit, contrary to Ghanaian specie where the shell and kernel lack these elements [13]. Overall, the amount of minerals observed in the different parts of the fruit of *D. guineense* from Côte d'Ivoire exceeds that reported for specie from Senegal [11], Benin [10], Ghana [13] and Nigeria [7, 12, 32]. This variation may be attributed to specific climatic and environmental conditions, geographical diversity and variations in analytical methods. In terms of mineral content, consuming *D. guineense* fruits from Côte d'Ivoire could potentially help address mineral deficiencies in humans and enhance livestock nutrition.

4 Conclusion

This study has highlighted the chemical, nutritional, antinutritional and mineral properties of the different parts of the fruit of *Dialium guineense* from Côte d'Ivoire. The results demonstrate that, similar to the pulp which is the commonly consumed part, the shell and the kernel (often neglected) serve as an undeniable source of nutrients beneficial for the body. Efficient valorization of these different parts can contribute to addressing mineral deficiencies in humans and improving the quality of animal feed.

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