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CHARACTERIZATION OF THE NUTRITIONAL AND PHYTOCHEMICAL POTENTIAL OF *COLA NITIDA* NUTS CONSUMED IN CÔTE D'IVOIRE

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ABSTRACT

The nutritional value and food safety of certain local products consumed in Côte d'Ivoire remain problematic. The aim of this study was to determine the nutritional and phytochemical potential associated with the consumption of *Cola nitida* nuts. Solvent extraction yielded aqueous and hydro-ethanolic extracts of *Cola nitida* nuts. The nutritional and phytochemical potential of white and red *Cola nitida* nuts was evaluated using standardized chemical methods and qualitative analysis methods, respectively. The nutritional potential of the macronutrients in white *Cola nitida* nuts was 78.19 ± 1.06% (carbohydrates), 8.18 ± 0.02% (proteins), and 0.9 ± 0.1% (lipids), with an energy value of 376.74 ± 1.11 kcal ($p < 0.05$). With 312.62 ± 1.11 kcal, red *Cola nitida* nuts were richer in carbohydrates (84.86 ± 1.05a%) and lower in protein (0.76 ± 0.03%) and lipids (0.9 ± 0.1%) ($p < 0.05$). White and red *Cola nitida* nuts contained lower levels of ash (2.4 ± 0.2; 2.6 ± 0.2), fiber (11 ± 0.5; 11 ± 1), and moisture (10.3 ± 0.1; 10.8 ± 0.2), respectively. Phytochemical screening showed the presence of sterols, polyterpenes, polyphenols, and tannins in both varieties, while flavonoids and alkaloids were detected exclusively in red cola. Overall, this study highlights the nutritional and phytochemical potential linked to the consumption of *Cola nitida* nuts.

Keywords: *Cola Nitida Nut*, Nutritional, Phytochemical, Macronutrients, Aqueous Extracts and Hydro-Ethanolic Extracts.

1 INTRODUCTION

The African continent is renowned for its rich biodiversity, with a large number of plants used for their medicinal properties [1, 2]. Among these medicinal plants with therapeutic virtues are species belonging to the genus Cola [3]. The genus Cola belongs to the Sterculiaceae family and is well known for its medicinal benefits and its numerous uses throughout Africa [2, 4]. It includes several species, but only two are cultivated for their scientific and economic value [5]. These are *Cola acuminata* and *Cola nitida* [5, 6]. The former is native to Central African countries, while the latter is recognized as being native to West Africa [6, 7].

These cola nuts play an important role in several areas, mainly in the pharmaceutical industry (medicine manufacturing) and in traditional medicine (treatment of indigestion, diarrhea and vomiting) [6, 8]. In addition, these nuts are used in the food industry (soft drinks, tonics, wines, liqueurs) and in the chemical industry (dyeing, cosmetics) [9].

In West Africa, and particularly in Côte d'Ivoire, the *Cola nitida* nut is used personally by both rural and urban populations as a chewing gum when fresh [10]. The *Cola nitida* nut is valued for its numerous benefits, notably for curbing hunger and thirst, and is used for its stimulating properties to combat drowsiness due to its high alkaloid content, especially caffeine (2.3%) [11]. Its bitter and astringent taste is characterized by its high content of phytochemicals such as flavonoids and tannins [12]. Furthermore, it holds a central place in Ivorian tradition. Indeed, it is used in various ceremonies and rituals and represents an important symbol of hospitality, integration, unity, and social cohesion [4].

Despite the socio-economic role and nutritional value of the cola nut, many people are unaware of the presence of certain phytochemicals and nutritional values that can improve the well-being of consumers. Despite some work and progress in both production and research in Côte d'Ivoire, data on the dietary, nutritional, and phytochemical potential of cola nuts are scarce or even nonexistent. The overall objective of this study was therefore to determine the nutritional and phytochemical potential of *Cola nitida* nuts sold and consumed in Côte d'Ivoire.

2 MATERIAL AND METHODS

2.1 Biological material

The plant material consisted of red and white *Cola nitida* nuts sold and consumed in Côte d'Ivoire (Figure 1).

Figure 1: *Cola nut nitida* A: *Cola nitida* Red; B: *Cola nitida* White

2.2 Methods

2.2.1 Determination of the nutritional potential of cola nuts

2.2.1.1 Determination of the energy value of cola

The energy value was determined by calculation, according to AFNOR, [13] using the Atwater and Rosa coefficients. The energy was determined according to the following formula:

Energy (calories) = (4 x % protein) + (4 x % total carbohydrates) + (9 x % fat)

2.2.1.2 Determination of Ash Content

For the determination of ash content, the samples were incinerated in a furnace at 550°C for 24 hours. The ash content (Ash content) was determined using the following formula:

$$\textbf{Ash content}\ (\%) = \frac{\textbf{ms}}{\textbf{m}} \textbf{x 100}$$

With, ms: the mass of the ash obtained ; m: the initial mass of the sample.

2.2.1.3 Determination of Fat Content

This determination is based on the fact that fats are soluble in organic solvents such as petroleum ether and hexane. The determination was carried out using the AOAC method [14], which consists of extracting the fats with hexane, which is then evaporated, and the residue is dried and weighed.

2.2.1.4 Determination of Total Lipid Content

Total lipid content (Tlx) was assessed using a conventional Soxhlet extraction with hexane as the solvent [15]. For this purpose, 40 g of the sample were refluxed with 200 mL of hexane for 6 hours. The lipid content was calculated using the following formula:

$$\mathbf{Tlx} = \mathbf{MhMe} \times \mathbf{100}$$

With, Mh: mass of the oil obtained after evaporation of the solvent from the extract ; Me: initial mass of the sample.

2.2.1.5 Determination of Crude Protein

Protein content was determined according to the AOAC method [15], using a Kjeldahl still. This method is based on the determination of total nitrogen, which is then converted into a protein content. One gram of the sample was digested in the presence of a catalyst composed of copper sulfate (CuSO4) and potassium sulfate (K2SO4) in a Buchi 430 digester (Digestor Germany) for 3 hours. Distillation was then carried out in a Buchi 320 distiller (Germany) after the addition of 10 mL of 40% sodium hydroxide (NaOH) solution to the digestate. The distillate was collected in a boric acid buffer solution prepared by dissolving 10 g of boric acid in 1000 mL of distilled water and 11 mL of a color indicator mixture consisting of bromocresol green and methyl red. The distillate was titrated with 0.1 N hydrochloric acid (HCl). Total nitrogen and crude protein levels were obtained using the following formulas:

Total nitrogen content = V(HCl) x N(HCl) x 0.014 x 100 / P

With, V(HCl) = volume of HCl from the burette drop; N(HCl) = normality of HCl; 0.014 = coefficient assigned to the concentration of the normal nitrogen solution (14/1000); P = weight of the sample ; Crude protein content = Total nitrogen content x 6.25

2.2.1.6 Determination of Crude Fiber Content

The fiber content was determined according to the AFNOR method [13]. Two g of *Cola nitida* (me) nut sample were taken and placed in a flask containing 50 mL of 0.25 N sulfuric acid. The resulting mixture was homogenized and boiled for 30 min under reflux. After 30 min, 50 mL of 0.31 N NaOH was added to the contents and the mixture was boiled again under reflux for 30 min. The extract was filtered through Whatman filter paper, and the residue was washed several times with hot water until all alkalis were removed. The residue was dried in an oven at 105 °C for 8 hours. After cooling in a desiccator, the residue was weighed (m1) and then incinerated in a kiln at 550 °C for 3 hours. After cooling, the resulting ash was weighed (m2). The crude fiber content was obtained in grams per 100 g of dry matter according to the formula:

$$\mathbf{Raw\ fibers} = \frac{(\mathbf{m1} - \mathbf{m2})}{\mathbf{me}} \mathbf{x\ 100}$$

2.2.1.7 Determination of Total Carbohydrate Content

The total carbohydrate content was determined according to the formula described by AOAC [15].

Total carbohydrates (%) = 100 - (% fiber + % protein + % fat + % ash*)*

2.2.2 Determination of the phytochemical compounds of cola nuts

2.2.2.1 Obtaining cola nut extracts

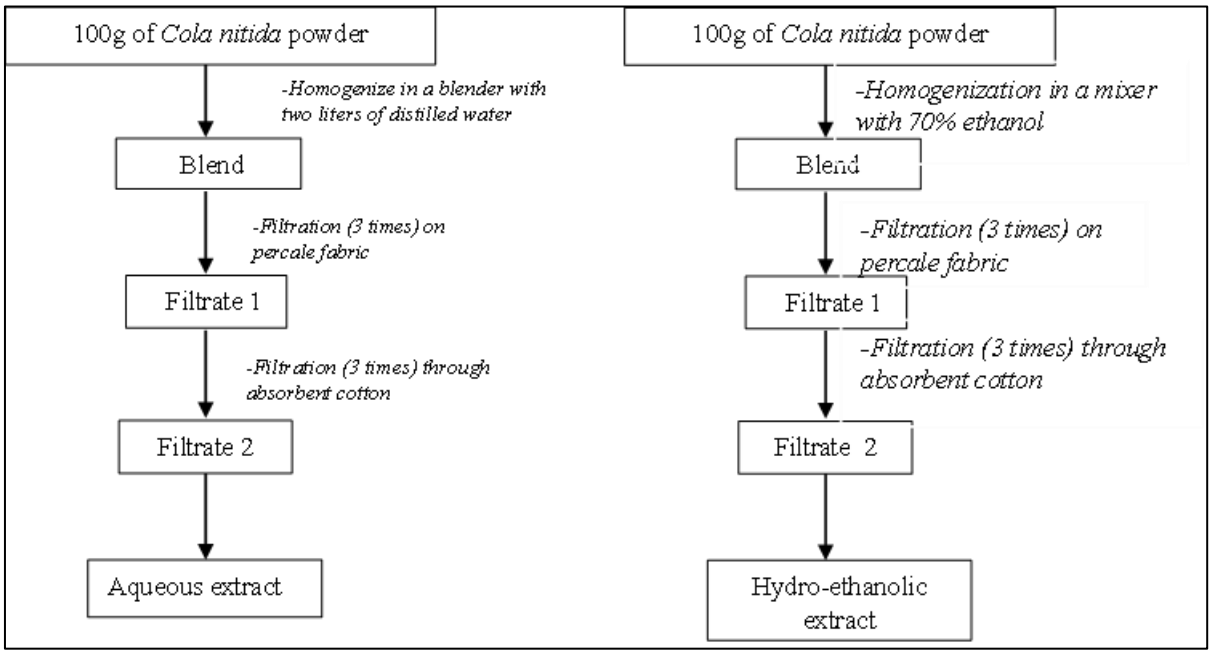
The collected *Cola nitida* nuts were washed, cut into small pieces then dried in the laboratory away from the sun at a temperature of 18°C for three (3) weeks. Once dried, the *Cola nitida* nuts were reduced to a fine powder using a SILVER CREST SC-1589 type blender. Following the method described by Zirihi et al. [16], 70% aqueous and hydro-ethanolic extracts of different cola nut powders were obtained.

For every 100 grams of *Cola nitida* powder, two (2) liters of distilled water were added to each powder, then homogenized in a SILVER CREST SC-1589 blender (Figure 2). The resulting mixture then underwent six (6) successive filtrations: three (3) times through percale cloth, then three (3) times with funnels plugged with absorbent cotton.

The final filtrate obtained from all these operations was frozen and then freeze-dried in a freeze dryer at -60°C for three (3) days. The dry evaporate was collected as a powder, thus constituting the various aqueous extracts. The preparation of the hydro-ethanolic extract followed the same procedure as that of the aqueous extract, except that the *Cola nitida* powder used was homogenized in 70% ethanol (ethanol-distilled water mixture: 70/30, v/v) (Figure 2). The filtrate obtained was dehydrated in an oven at a temperature of 50°C for three (3) days. The dry evaporate recovered from the two types of extracts was in powder form. The extraction steps are summarized in Figure 2. Following the extraction, the different yields of each *Cola nitida* were calculated according to the following formula:

$$r = \frac{m}{M} \times 100$$

- r = yield
- m = mass of dry extract obtained
- M = mass of *Cola nitida* powder used



Source: Zirihi et al. [16]

Figure 2: Diagram of the preparation of the different extracts of *Cola nitida*

2.2.2.2 Qualitative Determination of Phytochemical Compounds

The main active phytochemical compounds contained in *Cola nitida* nuts were qualitatively characterized. The phytochemical groups sought were alkaloids, polyphenols, flavonoids, tannins, saponins, anthraquinones, sterols, and terpenes. For the determination of the different chemical compounds, 2 g of plant extracts were added to 50 mL of distilled water [17].

2.2.2.2.1 Determination of Sterols and Polyterpenes

The presence or absence of sterols and polyterpenes was detected in a test tube. A 2 mL volume of 5% (g/mL) *Cola nitida* nut extract was dissolved in 2 mL of acetic anhydride with 1 mL of sulfuric acid. The appearance of a purple ring at the interphase, turning blue and then green, indicates the presence of sterols and polyterpenes [18].

2.2.2.2.2 Determination of Polyphenols

To detect the presence of polyphenols, a drop of 2% alcoholic ferric chloride (FeCl3) solution was added to 2 mL of 5% (g/mL) *Cola nitida* nut extract. Ferric chloride produces a bluish-black or greenish-black color, indicating the presence of these polyphenolic derivatives. A positive control is performed using an alcohol-based gallic acid solution [18].

2.2.2.2.3 Determination of Flavonoids

Flavonoids were investigated using the method of Kouadio et al. [18] in *Cola nitida* nut extract for their antimicrobial and free radical-scavenging activity. A 5 mL volume of 5% (g/mL) *Cola nitida* nut extract was placed in a test tube. A few drops of HCl and three (3) magnesium shavings were then added. The appearance of a pink or red color indicates the presence of flavonoids.

2.2.2.2.4 Determination of Tannins

Both forms of tannins were detected in the *Cola nitida* extract. The first consists of catechin tannins, which are non-hydrolyzable and composed of condensed catechol polymers. The second form consists of gallic tannins, derived from gallic acid and combined as hydrolyzable glycosides [19].

2.2.2.2.4.1 Determination of Gallic Tannins

A 5 mL volume of the 5% (g/mL) *Cola nitida* nut extract was filtered and saturated with sodium acetate. The addition of three drops of 2% ferric chloride (FeCl3) resulted in a bright blue-black color, indicating the presence of gallic tannins in the medium [20].

2.2.2.2.4.2 Determination of Catechin Tannins

To 5 mL of the 5% (g/mL) *Cola nitida* nut extract, 15 mL of Stiasny's reagent (30% formalin, concentrated HCl) was added. The mixture was maintained in a water bath at 80 °C for 30 min, then cooled [20]. The presence of a large, flake-like precipitate indicates the presence of catechin tannins. Catechin serves as a control.

2.2.2.2.5 Determination of Quinonic Compounds

hese free or combined quinonic compounds were detected using the Borntraeger reaction. A 2 mL volume of 5% (g/mL) *Cola nitida* nut extract was evaporated to dryness in a capsule, and the residue was reconstituted with 5 mL of 1/5 hydrochloric acid. The resulting solution was transferred to a test tube and incubated for 30 minutes in a boiling water bath. After complete cooling, 20 mL of chloroform was added. The chloroform phase, to which 0.5 mL of 1/2 ammonia (Borntraeger reagent) had been added, was then collected. The appearance of a color ranging from red to violet indicates the presence of quinonic compounds [20]. A control was prepared using vitamin E.

2.2.2.2.6 Determination of Saponins

Saponins were investigated in *Cola nitida* nut extract by introducing 15 mL of the 1% (g/mL) *Cola nitida* nut extract solution into a test tube with a diameter of 16 mm and a height of 16 cm. The tube was sealed and then vigorously shaken upright for about 10 seconds, followed by 10 minutes of inactivity. If the foam exceeded 1 cm, this indicated the presence of saponins ([21].

2.2.2.2.7 Determination of Alkaloids

The characterization of alkaloids begins with the dry evaporation of 6 mL of 5% (g/mL) *Cola nitida* nut extract in a capsule. The residue is collected with 6 mL of 60% alcohol. The resulting alcoholic solution is distributed into two graduated cylinders. Two drops of Dragendorff's reagent are then added to the first cylinder. The presence of a reddish-brown precipitate indicates a positive reaction to alkaloids. Two drops of Bouchardat's reagent are added to the second cylinder. The presence of a reddish-brown precipitate indicates a positive reaction to alkaloids. In both experiments, a control test is performed using quinine [21].

2.2.3 Statistical Analysis

All results were processed using GraphPad 5 statistical software (San Diego, CA, USA). These results were analyzed using ANOVA. The Turkey-Kramer multiple comparison test was performed, where a variation above 10% ($p > 0.01$) was considered non-significant and below 10% ($p < 0.01$) was considered significant ($p < 0.01$).

3 RESULTS

3.1 Nutritional Potential of *Cola nitida* Nuts

3.1.1 Nutritional Potential of Macronutrients

The macronutrients in *Cola nitida* nuts exhibited a diversity of nutritional potential (Table 1). In descending order of importance, the nutritional potential of the macronutrients in white *Cola nitida* nuts was 78.19 ± 1.06 b% (Carbohydrates), 8.18 ± 0.02 a% (Protein), and 0.9 ± 0.1 a% (Fat), with an energy value of 376.74 ± 1.11 a kcal ($p < 0.05$) (Table 1). With an energy value of 312.62 ± 1.11 b kcal, red *Cola nitida* nuts were richer in carbohydrates (84.86 ± 1.05

a%) and lower in protein (0.76 ± 0.03 b%) and fat (0.9 ± 0.1 a%) ($p < 0.05$) (Table 1). Significant differences were observed in the proportions of carbohydrates (78.19 ± 1.06a; 84.86 ± 1.05b), protein (8.18 ± 0.02a; 0.76 ± 0.03b), and energy (376.74 ± 1.11a; 312.62 ± 1.11b) in white and red *Cola nitida* nuts (Table 1). No significant difference was noted in the lipid content of the two types of *Cola nitida* (Table 1).

Table 1: Nutritional potential of macronutrients in *Cola nitida* nuts

Type of *Cola nitida*	Macronutrients (%)			Energy value (kcal)
	Carbohydrates (%)	Proteins (%)	Lipides (%)	
White *Cola nitida*	78.19±1.06[a]	8.18±0.02[a]	0.9±0.1[a]	376.74±1.11[a]
Red *Cola nitida*	84.86±1.05[b]	0.76±0.03[b]	0.9±0.1[a]	312.62±1.11[b]

p<0.05

Values with the same letters in the same column are not significantly different at the 5% threshold.

3.1.2 Nutritional Potential of Other Fundamental Parameters

White and red *Cola nitida* nuts contained lower levels of ash (2.4±0.2a; 2.6±0.2b) than of fiber (11±0.5a; 11±1a) and moisture (10.3±0.1a; 10.8±0.2b), respectively. Significant differences were observed in the moisture (10.3±0.1a; 10.8±0.2b) and ash (2.4±0.2a; 2.6±0.2b) content of white and red *Cola nitida* nuts, respectively (Figure 3). No significant difference was noted in the fiber content of the two types of *Cola nitida* (11±0.5a; 11±1a) (Figure 3).

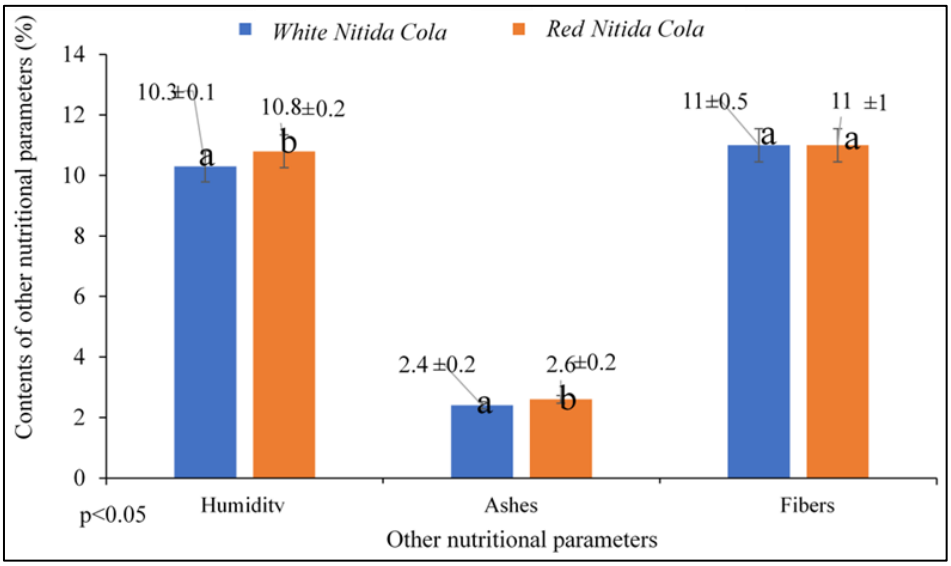


Figure 3: Nutritional potential of other fundamental parameters

On the bar chart, the bands relating to the values of the nutritional potential of the other fundamental parameters of moisture, ash and fiber affected by different letters are significantly different ($p \leq 0.05$).

3.1.3 Macronutrient Distribution in *Cola Nitida* Types

Principal Component Analysis (PCA) results indicate an irrational macronutrient distribution in the different types of white and red *Cola nitida* (Figure 4). These results show that red *Cola nitida* nuts are richer in total carbohydrates compared to white *Cola nitida*, which has a higher protein and energy value. According to the PCA, both types of cola have trace amounts of lipids.

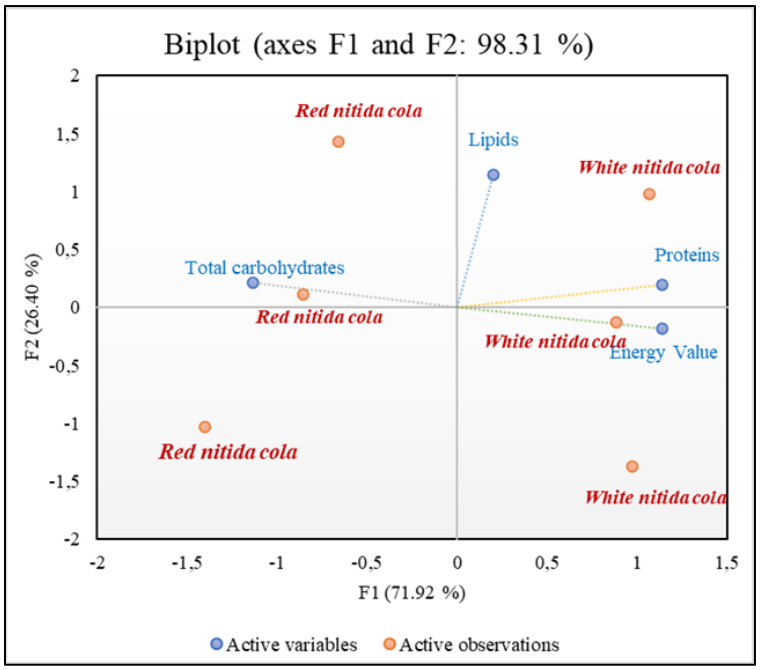


Figure 4: Macronutrient distribution in *Cola nitida* types

3.2 Phytochemical Potential of *Cola nitida* Nuts

3.2.1 Yield of *Cola nitida* Extracts (Red *nitida cola*)

After collection and drying, various powders (Figure 5) and extracts of cola nuts were obtained, and their yields were determined. Analysis of the results revealed that extraction yields varied depending on the type of *Cola nitida* and the solvent used (Table 2). Yields of aqueous extracts obtained by freeze-drying showed significant differences ranging from 0.13 ± 0.01% (red *Cola nitida*) to 0.16 ± 0.01% (white *Cola nitida*), with $p < 0.05$.

Non-significant differences ranging from 0.18 ± 0.00% to 0.18 ± 0.01% were observed in the yields of hydro-ethanolic extracts obtained by hot drying (Table 2). The hydro-ethanolic extracts of white (0.18±0.00) and red (0.18±0.01) *Cola nitida* nuts showed the best extraction yields (Table 2).

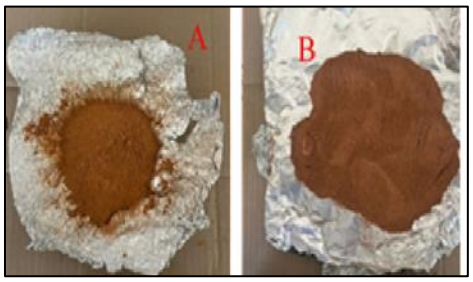


Figure 5: Different powders obtained A: White *Cola nitida* powder; B: Red *Cola nitida* powder

Table 2: Extraction yields

Type of *Cola nitida*	Extract types	Yield (%)
White *Cola nitida*	Aqueous	0.16±0.01[a]
	Hydro-ethanolic	0.18±0.00[b]
Red *Cola nitida*	Aqueous	0.13±0.01[c]
	Hydro-ethanolic	0.18±0.01[b]

$p<0.05$. ; Values with the same letters in the same column are not significantly different at the 5% level.

3.2.2 Phytochemical Potential of *Cola nitida* Nuts

The results showed the presence of sterols and polyterpenes, polyphenols, and catechol and gallic tannins in the aqueous and hydroethanolic extracts of white and red *Cola nitida* (Table 3). Flavonoids and alkaloids were present only in the aqueous and hydroethanolic extracts of red *Cola nitida* nuts (Table 3). No saponoside compounds were detected in the aqueous and hydroethanolic extracts of white and red *Cola nitida* nuts (Table 3).

Table 3: Phytochemical compounds present in *Cola nitida* nuts

Phytochemical compounds sought		Types of *Cola nitida* extracts			
		C. nitida white AE	*C. nitida white HEE*	*C. nitida red AE*	*C. nitida red HEE*
Sterols and polyterpenes		+	+	++	++
Polyphenols		+	+	++	++
Flavonoids		-	-	++	++
Saponosides		-	-	-	-
Quinonic compounds		-	+	-	+
Alkaloids		-	-	+	+
Tannins	Catechism	+	+	++	++
	Gallic	+	+	++	++

(+) : Presence of the phytochemical compound; (-) : Absence of the phytochemical compound; AE: Aqueous Extract; HEE: Hydroethanolic Extract

3.2.3 Distribution of Phytochemicals in *Cola nitida* Types

The results of principal component analysis (PCA) indicate an irrational distribution of phytochemicals in the different types of white and red *Cola nitida* (Figure 6). These results show that red *Cola nitida* nuts are richer in catechins and gallic tannins compared to white *Cola nitida* nuts, which have a higher value in polyphenolic compounds (Figure 6). According to the PCA, neither type of *Cola nitida* has any value in saponin compounds (Figure 6).

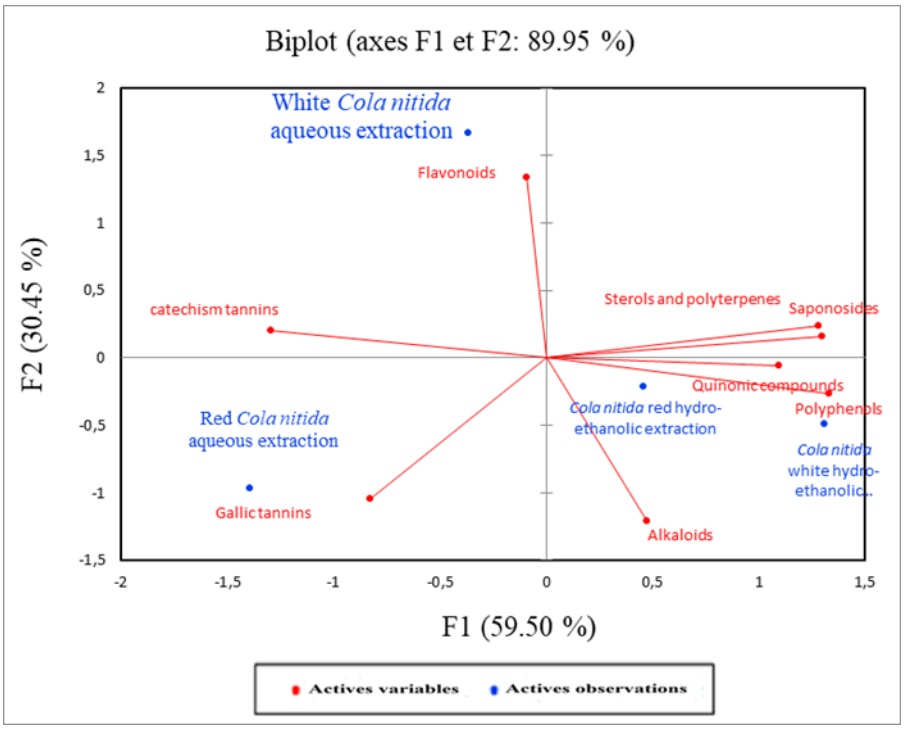


Figure 6: Irrational distribution of phytochemical compounds

4 DISCUSSION

For several decades, medicinal plants have played a significant role in traditional healthcare in Africa, particularly in Côte d'Ivoire, where they are used for the prevention and treatment of numerous diseases [22]. Among them, *Cola nitida* stands out for its cultural, socio-economic, and therapeutic importance, as well as its widespread use in traditional medicine, the pharmaceutical industry, and the food industry [8, 23].

In this study, the nutritional potential showed significant differences between the nuts of white and red *Cola nitida*. The white variety had a higher protein content and a greater energy value, indicating better nutritional potential, while the red variety was richer in carbohydrates, providing a rapid energy boost. This high protein and carbohydrate content of cola nuts could be explained by their botanical origin, chemical composition, and also by the level of maturity of the cola nuts [24, 25].

However, the trace amounts of lipid compounds present in both red and white *Cola nitida* could be explained by the nature of cola nuts, by oxidation reactions, and by enzymatic reactions [26]. Several authors have emphasized the nutritional and functional importance of *Cola nitida*, reporting the richness of species in the genus Cola in energy-rich and bioactive compounds [27, 28].

The results also showed small differences between the white and red varieties of *Cola nitida* in terms of moisture, ash, and fiber content, indicating a relatively homogeneous nutritional composition. The red variety, however, has slightly higher moisture and ash content, suggesting a greater mineral content [6, 17]. The lack of a significant difference in fiber content indicates that both varieties could contribute similarly to digestive health [29]. These observations are consistent with the work of Ojediran and Ojediran [30], who report a significant presence of fiber and minerals in cola nuts. In addition to their nutritional potential, various phytochemical compounds were identified in aqueous and hydroethanolic extracts of white and red *Cola nitida* nuts. Furthermore, the results showed that the hydroethanolic extracts of white and red *Cola nitida* nuts exhibited the highest extraction yields. Indeed, the extraction potential of a solvent is generally explained by its affinity for the phytomolecules present. Moreover, this efficiency can also be attributed to the polarity of the solvent [31].

Furthermore, the observed differences in yields could likely be explained by the chemical composition and maturity of the nuts used, as well as the extraction technique employed [31]. The chemical composition of aqueous and hydro-ethanolic extracts of *Cola nitida* nuts showed a high content of sterols and polyterpenes, polyphenols, and tannins.

This richness confirms the strong bioactive potential of this *Cola nitida* species, particularly its antioxidant and antimicrobial properties reported in several studies [6, 21].

Indeed, the simultaneous presence of catechins and gallic tannins suggests a high capacity for scavenging free radicals and protective activity against oxidative stress [21]. Moreover, the exclusive detection of flavonoids and alkaloids in red *Cola nitida* could explain its more pronounced pharmacological bioactivity, particularly its stimulant and anti-inflammatory activities [6, 32]. Thus, the results support the growing interest in *Cola nitida* as a natural source of valuable therapeutic and nutraceutical compounds in the pharmaceutical and food industries [17].

5 CONCLUSION

This study revealed the diverse nutritional potential of *Cola nitida* nuts. Red *Cola nitida* nuts are richer in total carbohydrates compared to white *Cola nitida* nuts, which have a higher protein and energy value. Both white and red *Cola nitida* nuts contained lower levels of ash, fiber, and moisture. Photochemical screening demonstrated the presence of sterols, polyterpenes, polyphenols, and catechin and gallic tannins in the aqueous and hydroethanolic extracts of red and white *Cola nitida* nuts. Flavonoids and alkaloids were present only in the aqueous and hydroethanolic extracts of red *Cola nitida* nuts. This work represents an important contribution to understanding the nutritional, pharmacological, and microbiological challenges facing the cola sector in Côte d'Ivoire.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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