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Determination of the Content of Polyphenols, Flavonoids, Tannins, Mineral Elements and Antioxidant Activity of Almonds Obtained from Cashew Nuts (*Anacardium occidentale*, Anacardiaceae) from Center Côte d'ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: *Anacardium occidentale* from the Anacardiaceae family, is a plant whose almonds have been widely consumed in Côte d'Ivoire in recent years. In addition, almonds are a matrix containing approximately 22-24% fat; which gives it great interest in terms of valorizing its nutritional properties.
Study Design: This is how the nuts were harvested at the beginning of 2023 in Sessenouan, a village in Bouaké, in central Côte d'Ivoire. Cashew nuts were obtained from ripe fruits of the *Anacardium occientale*. After recovering the almonds, they were dried and then well preserved for the various analyses; which analyses were carried out at the Chemistry laboratory of the Felix Houphouët-Boigny Polytechnic Institute in Yamoussoukro, a city located 95 kilometers from Bouaké.
Place and Duration of Studies: After the harvest in April 2023 and the recovery of the almonds, the analyses were carried out from June to September 2023.
Methodology: The quantification of total polyphenols, total flavonoids, condensed tannins and mineral elements was done by classical dosage methods; As for the antioxidant activity of the almond extract, it was evaluated with respect to DPPH using vitamin C as a control.
Results: This study showed that the almonds of *Anacardium occidentale* (Anacardiaceae) from central Côte d'Ivoire contain appreciable levels of total polyphenols (21000 ± 1,330 µg EAG/g), total flavonoids (36000 ± 2,660 µg EQ/g), condensed tannins (19.813 ± 0.02 µg EAT/g) and minerals: K (458.61 ± 1.01 mg/100g), Mg (300.72 ± 0.57 mg/100g), P (142.51 ± 0.15 mg/100g), Ca (31.73 ± 0.32 mg/100g).
Conclusion: The analysis of these results indicates that the almonds of *Anacardium occidentale* from Côte d'Ivoire are a source of micronutrients and can therefore be used in both herbal medicine and human nutrition in our developing countries. Future work will focus on the chemical and physical properties of the fat extracted from the almonds.

Keywords: Anacardium occidentale; almond; micronutrients; mineral elements; Côte d'Ivoire.

ABBREVIATIONS

G : Gram
mL : Milliliter
MS : Dry Matter
DPPH : 1,1-diphenyl-2-picrylhydrazine
NaOH : Sodium Hydroxide
CI : Côte d'Ivoire

1. INTRODUCTION

At all times and in all latitudes, agricultural practices have been the most important factor in spatial dynamics in rural areas (Adou et al.2015). The development of agro-industrial plantations coupled with its processing units consume space; which is not the case for the Western cashew tree. The cashew tree, *Anacardium Occidentale*, belongs to the Anacardiaceae family. It is native to the tropical regions of Brazil. The name cashew is said to be derived from the Tupi-Guarani (Indian tribe of Northeast Brazil) "acâ-yu" which means yellow apple (Lautié et al.2001). Its cultivation has developed in West Africa because of its great hardiness and its multiple products. The cashew tree was introduced in Côte d'Ivoire in response to the very advanced degradation of land due to deforestation (Adouko et al. 2016). Since 2008, the country has become the leading African exporter of raw cashew nuts (Djaha et al. 2010) And exports of raw cashew nuts represent 33.4%

of total exports in 2012 (Anonymous 2013). In addition to the multiple uses of the fruits that are the cashew nut and apple, the plant provides a range of secondary products. Thus, the leaves are used as condiments and have certain therapeutic properties (fight against burns). The bark rich in tannin is used in tanning; it is used to prepare indelible inks and black powder. The wood, yellow to red in color, is used in cabinetmaking and the manufacture of boxes (Lautié et al.2001).

However, we note very little research work on *Anacardium occidentale* from Côte d'Ivoire, especially on the almonds of the plant. The objective of this work is part of the growing interest given to non-timber forest products by scientific research in recent years, with a view to their valorization. This study of almonds obtained from the nuts of *Anacardium occidentale* (or cashew nuts) from the center of Côte d'Ivoire highlights its richness in micronutrients, mineral elements and its antioxidant activity.

2. MATERIALS AND METHODS

2.1 Plant Materials

Cashew nuts were collected from fruits harvested in Bouaké, in central Côte d'Ivoire, precisely in the village of Sessenouan. After the nuts were collected in April 2023, they were then shelled and the almonds dried in an air-conditioned room (18°C) for 21 days, then stored in an oven (50°C) for 7 days in the laboratory of the Water and Natural Substances Chemistry Unit, Houphouët-Boigny National Polytechnic Institute (INPHB) in Yamoussoukro (Côte d'Ivoire).

2.2 Analytical methods

2.2.1 Determination of mineral elements

2.2.1.1 Ash content

Seeds (mass m = 0.4 g) were incinerated for 8 h in an oven at 600°C until a constant mass (m') of white ash was obtained (AFNOR, 1981-1982). The ash content is calculated according to the equation.

$$\text{Teneur cendre} = \frac{\text{m}'}{\text{m}} \times 100$$

2.2.1.2 Mineral determination

The determination of mineral elements was carried out according to the IITA method (IIAT, 1981 and Severin et al. 2018). To the plant ash obtained (0.4 g), 2 mL of concentrated hydrochloric acid (HCl) diluted by half were added. The whole was heated on a hot plate until dry, then placed in an oven (60°C) for 1 h. The dry residue was taken up in 2 mL of the same solvent, then filtered into a graduated flask (100 mL). Distilled water was added to the filtrate up to the gauge mark to constitute the standard solution. In a graduated flask (50 mL), to this solution (5 mL), 2 mL of lanthanum chloride ($LaCl_3$) were added, and the whole was made up to the gauge mark with distilled water. Minerals were assayed using an atomic absorption spectrophotometer (AAS 20, VARIAN type), at different wavelengths: 285.2 nm for K (Potassium); 213.9 nm for Ca (Calcium); 279.5 nm for Mg (Magnesium); 327.4 nm for P (Phosphorus); 248.3 nm for Fe (Iron).

2.2.2 Determination of total phenols

The amount of total phenols in the extracts is determined by the Folin-Ciocalteu colorimetric method. It is based on the oxidation of phenolic compounds by the Folin-Ciocalteu reagent in a basic medium (Singleton et al. 1999 and Konan, 2010). The reduced blue products absorb at 760 nm, the intensity of which is proportional to the amount of total phenols present in the sample. To 1 mL of hydromethanolic extract diluted 1/10 with distilled water, 1.5 mL of NA2CO3 (17%, m/V) and 0.5 mL of Folin-Ciocalteu reagent (0.5N) are added. The whole is incubated at 37°C for 30 minutes. The absorbance is read at 720 nm against a blank without extract taken as a reference (Alloka-Kouamé et al. 2022). Quantification of total phenols is performed based on the calibration line of gallic acid at different concentrations (0 to 1000 µg/mL) prepared under the same conditions. The results are expressed in microgram equivalent of gallic acid dry matter (µg EAG/g DM). The total phenol content (Q) is calculated according to the formula:

$$Q = \frac{(\text{V} \times \text{C} \times \text{d})}{m} \text{ (en µg EAG/g MS)}$$

V: final volume of extract; C: concentration of extract (µg/mL); d: dilution; m: mass of dry hydrolyzed plant material (g).

Fig. 1. Nuts (A) and dried almonds (B) of *Anacardium occidentale* (Cashew nuts) from Bouaké (Côte d'Ivoire) *[Photos taken by Katou in 2023]*

2.2.3 Total flavonoids determination

The quantification of flavonoids was carried out according to the aluminum trichloride ($AlCl_3$) method described by Marinova et al., (2005). The principle of the method is based on the formation of a brownish complex between flavonoids and $AlCl_3$; this complex absorbs at 510 nm. Comparison of the observed absorbance with that of quercetin (standard) allows the total flavonoid content to be assessed. 1500 µL of distilled water and 150 µL of 5% $NaNO_3$ were added to 150 µL of hydro-ethanolic extract. After 5 min of rest in the dark, 150 µL of 10% $AlCl_3$ were added. The mixture was kept in the dark again for 11 min, then 500 µL of NaOH (1 M) was added. After stirring, the absorbance was read by UV-Visible spectrophotometer at 510 nm. A calibration line made from solutions of different concentrations of quercetin (0 to 50 µg/L) and carried out under the same operating conditions was used to quantify flavonoids. The results are expressed in micrograms of quercetin equivalent per gram of extract (µg EQ/g).

2.2.4 Determination of condensed tannins

The determination of condensed tannins was carried out according to the method described by Julkunen-Titto (1985) and Heilmer et al. (2006) slightly modified. To 400 µL of each sample, 3 mL of vanillin solution (4% in methanol) and 1.5 mL of concentrated HCl were added. The mixture was incubated for 15 min and the absorbance was read at 500 nm. The concentrations of condensed tannins were deduced from the calibration ranges established with catechin (0 – 300 µg/mL), and were expressed in micrograms of catechin equivalent per gram (µg CE/g) of extract.

2.2.5 Evaluation of antioxidant activity against DPPH

The method used is that described by Wood et al., (2002) and Kadja (2011) which was modified in terms of concentrations for the determination of the antioxidant activity of plant extracts against DPPH (1,1-Diphenyl-2-picrylhydrazyl). DPPH is solubilized in absolute ethanol at 0.3 mg/mL, and the extracts are prepared in ethanol (EtOH) at concentrations 8; 4; 2; 1; 0.5; 0.25; 0.125 mg/mL Katou et al. (2021). The reaction mixture used for the test, consisting of the extract (1 mL) and the DPPH dilution (2 mL) after shaking, is placed away from light for 30 min. The reaction mixture introduced into the tank of the UV-Visible spectrophotometer, the absorbance of which is read at 517 nm against a blank (prepared under the same conditions without DPPH). Vitamin C served as a reference. The percentage reduction of the DPPH radical is calculated according to the formula:

$$\%\ Réd = \frac{Ab - Ae}{Ab}\ x\ 100$$

% Red: percentage reduction; Ab: absorbance of the blank; Ae: absorbance of the sample.

3. RESULTS AND DISCUSSION

3.1 Mineral Content

Table 1 presents the mineral composition of almonds obtained from cashew nuts in the city of Bouaké, in central Côte d'Ivoire. Mineral elements are not synthesized by the body, so they must be provided regularly through our diet. They are irreplaceable micronutrients; in fact, their insufficient presence or excess leads to the appearance of specific pathologies Pasteur J-L., (2018).

The values obtained in Table 1 clearly indicate the presence of essential minerals in the almonds obtained from cashew nuts in the city of Bouaké, in central Côte d'Ivoire.

Table 1. Mineral content

Mineral elements	Almonds (Concentration in mg/100g)
Na	2,45 ± 0,12
K	458,61 ± 1,05
P	142,51 ± 0,15
Ca	31,73 ± 0,32
Mg	300,72 ± 0,57
Cu	1,83 ± 0,08
Fe	1,94 ± 0,09
Mn	0,51 ± 0,02
Zn	4,85 ± 0,26

Mean ± S.E.M = Mean values ± Standard error of means of three experiments

Table 2. Mineral composition of some oilseeds

	Mineral composition in mg/100g								
Seeds	**Na**	**Ca**	**K**	**Mg**	**P**	**Zn**	**Fe**	**Mn**	**Cu**
Anacardium occidentale Bouaké (CI)	2,45±0,12	31,73±0,32	458,61±1,05	300,72±0,57	142,51±0,15	4,85±0,26	1,94±0,09	0,51±0,02	1,83±0,08
Anacardium occidentale Togo (Abalokoka E-Y et al. 2018)	3,39-7,56	44,34-80,43	145,47-182,15	103,81– 249,80	139,61-164,00	4,39– 6,99	7,05-7,76	1,23-1,67	2,46-3,27
Parkia biglobosa (Cissé et al. 2021)	4,47	1,545	6,24	3,285	-	0,003	0,022	0,031	0,02
Griffonia simplicifolia (Novidzro et al. 2019)	1,26	1,63	25,02	1,15	13,80	0,005	0,06	0,003	0,02

	Mineral composition in mg/100g								
Seeds	**Na**	**Ca**	**K**	**Mg**	**P**	**Zn**	**Fe**	**Mn**	**Cu**
Myrianthus arboreus (Severin et al.2018)	-	412-520	900-1031	287-350	290-430	0,72-1,03	1,73-2,9	0,55-1,3	-

At the same time, analyzing Table 2, which presents the comparative mineral composition of some oilseeds, it should be noted that the results with *Anacardium occidentale* from the center of Côte d'Ivoire are an excellent source of potassium (458,61 ± 1,05 mg/100g); magnesium (300,72 ± 0,57 mg/100g) and phosphorus (142.51 ± 0.15 mg/100g). However, they are an average source of sodium (2,45 ± 0,12 mg/100g) and calcium (31,73 ± 0,32 mg/100g).

3.2 Total Phenol Content

The polyphenol content of *Anacardium occidentale* from central Côte d'Ivoire is given in Table 3; its value is 21000 ± 1330 µg EAG/g of DM. The total polyphenol content of the seeds is (960 µg EAG/g of DM). Note that this family of secondary metabolites, widely distributed in the plant kingdom (Psotova et al. 2003) provides the seeds with antioxidant power (Mbaye et al. 2013). This rate could explain the anti-inflammatory and antioxidant power of the seeds. By comparing this value with that obtained for certain plants or plant organs recognized for their richness in phenolic compounds, including dates (5660 µg EAG/g) (Bessas, 2008) and grape seeds (7500 µg EAG/g) (Cristina et al. 2009) it is possible to affirm that *Anacardium occidentale* almonds from the center of Ivory Coast are very rich in phenolic compounds.

Table 3. Total polyphenol content

	Value
Experiment 1	0,19
Experiment 2	0,22
Experiment 3	0,22
Mean	0,21 ± 0,0133
Total polyphenols (g EAG/g)	0,021 ± 0,00133
Total polyphenols (µg EAG/g)	21000 ± 1330

3.3 Total Flavonoid Content

Flavonoids occupy a prominent place in the group of phenols; they are secondary metabolites present in almost all organs of the plant (leaves, flowers, seeds, roots, etc.). And until recently, more than 4000 natural flavonoids have been described (Harborne and William,2000). The average value of total flavonoids obtained after tests, presented in Table 4 is 36000 ± 2660 µg EQ/g of dry matter.

3.4 Condensed Tannin Content

The condensed tannin content is 19,83166 ± 0,02444 µg EAT/g DM (Table 5). It is good to know that tannins exhibit the properties of vitamin P. They strengthen blood vessels and contribute to the accumulation of vitamin C in the body. They are also anti-infectious (Latte and Kolodziej 2000 & Leitao et al. 2005) prevent cardiovascular risks and are anticancer (Cheruvanky 2004 and Gosse et al. 2005).

Table 4. Total flavonoid content

	Value
Experiment 1	0,35
Experiment 2	0,4
Experiment 3	0,33
Mean	0,36 ± 0,0266
Total flavonoids (g EQ/g)	0,036 ± 0,00266
Total flavonoids (µg EQ/g)	36000 ± 2660

Table 5. Total tannin content

	Valeur
Experiment 1	19,812
Experiment 2	19,814
Experiment 3	19,869
Mean	19,83166 ± 0,02444
Total tannins (µg EAT/g)	19,83166 ± 0,02444

3.5 Antioxidant Activity

The anti-radical capacity of the extracts of *Anacardium occidentale* almonds is indicated in Table 6. The studied extract presents an antioxidant profile; this antioxidant potential could be justified by the presence of several secondary metabolites in the almonds of *Anacardium occidentale* from Ivory Coast, because Silviya et al., (2010) showed that the richer an extract is in polyphenols, its antioxidant power is hig.

Table 6. Value of antioxidant activity

	Value
Experiment 1	0,5409
Experiment 2	0,5394
Experiment 3	0,5393
Mean	0,539866667
Inhibition (%)	21,96203142
Antioxidant Concentrations or Activity (µM éqTrolox)	2,20060435

However, the antioxidant activity of the almond extract which is 2.2 µM eqTrolox is low compared to the activity of the vitamin C control which is Ao = 0.6918 µM eqTrolox.

4. CONCLUSION

This study showed that almonds obtained from *Anacardium occidentale* nuts from central Côte d'Ivoire are an excellent source of micronutrients, particularly in view of the data obtained in polyphenols, flavonoids, tannins, macroelements and trace elements. In view of the mineral composition and antioxidant activity, almonds could be exploited both in therapeutics and in human nutrition.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby declare that no generative artificial intelligence technology was used in the writing or editing of the manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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