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Antioxidant and Antibacterial Activities of Extracts from Cashew Apple, Mango Peel and Kernel, Agricultural by-products Collected in Northern Côte d'Ivoire

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Abstract Cashew (*Anacardium occidentale* L.) and mango (*Mangifera indica* L.) are cash crop products in northern Côte d'Ivoire. However, only cashew nuts and mango pulp are exploited in processing industries. Thus, cashew apple, mango peeling and kernel constitute agricultural waste. The objective of this study is to contribute to their valorization in flours for probable therapeutic use. Therefore, cashew apples, Kent mango peels and kernel collected in Korhogo department (northern Côte d'Ivoire) were processing into flours. Then, aqueous and hydro-ethanolic extracts were prepared using these flours. Antioxidant and antibacterial of these extracts were tested. The antioxidant activity was evaluated by the *2.2-diphenyl-1-picrylhydrazyl* method. The *in vitro* antibacterial activity was tested on *Escherichia coli*, *Staphylococcus aureus* and *Salmonella bongori*, three pathogenic bacteria. Antioxidant tests showed that all aqueous and hydro-ethanolic extracts have an anti-radical power. Their IC50 value varying from 0.106±00 mg/mL to 0.793±0.16 mg/mL compared to that of vitamin C (Reference) which is 0.064±0.68 mg/mL. Aqueous extract of mango kernel has the highest antioxidant power with IC50 of 0.106±00 mg/mL, followed by aqueous extract of mango peel and hydro-ethanolic extract of mango kernel with IC50 of 0.137± 0.90 mg/mL and 0.163±0.21 mg/mL respectively. Antibacterial tests revealed that all extracts were inhibited the *in vitro* growth of the tree bacteria tested with MBC value varying from 0.195 mg/mL to 6.250 mg/mL. Hydro-ethanolic extract of mango kernel is more active with MBC of 0.195 mg/mL, 0.781 mg/mL and 1.562 mg/mL respectively against *S. bongori*, *E. coli* and *S. aureus*. This study reveals that aqueous and hydro-ethanolic extracts of Kent mango kernel have respectively anti-radical and antibacterial properties. Considering these two biological properties of these extracts, mango kernel flour could serve as dietary supplement to improve health.

Keywords: *Cashew apple, mango, peel, kernel, antioxidant, antibacterial, Côte d'Ivoire*

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1. Introduction

Mango (*Mangifera indica* L.), one of the most important tropical fruits traded and consumed worldwide fresh or processed, has an attractive color, distinct taste and aroma [1]. World production of this fruit was estimated at around 48 3613 million tons in 2017, making mango fifth in world fruit production after citrus fruits, grapes, bananas and apples [2]. In Côte d'Ivoire, mango production was 150 000 tons with exports estimated at 32 400 tons or 21.6% in 2017. Mango is the third export fruit of Côte d'Ivoire which is the third country of export after Brazil and Peru [2]. Despite the nutritional importance of the mango and the dietary importance that populations attach to it, only the pulp is the part consumed, which generates enormous post-harvest loss [3]. Post-harvest losses were estimated at around 45% of production in 2017 [2]. Furthermore, mango by-products (peels and kernel) from dried mango producing companies of Korhogo department (Northern Côte d'Ivoire) cause hygiene and safety problems around these factories. However, these by-products contain high levels of various

health-beneficial substances, such as phenolic compounds, carotenoids, vitamin C and dietary fiber [4,5]. Moreover, the production of cashew nuts (*Anacardium occidentale L*) in Côte d'Ivoire has intensified in recent years, increasing from 235.000 tons in 2006 to 738.000 tons in 2018 [6]. Apples represent a ratio of 9 to 10 the weight of the nut, or approximately 7 million tons of cashew apple [7]. They are an invaluable source of nutrients. Indeed, they are very rich in vitamin C, polyphenolic compounds and have a very diverse carotenoid profile [8,9,10]. Unlike other cashew products, almost all of this cashew apple production is abandoned at the harvesting sites as are the residues obtained after extraction of the juice since they are not industrially processed in Côte d'Ivoire [11,12]. However, the cakes contain macromolecules (cellulose, hemicellulose, lignan) which have remarkable functional properties, non-fibrous carbohydrates and proteins [5,13]. Fruits of cashew tree (*Anacardium occidentale* L.) and mango tree (*Mangifera indica* L.) are cash crop products for population in northern Côte d'Ivoire [14]. However, only cashew nuts and mango pulp are exploited in processing industries of Korhogo department (Northern Côte d'Ivoire). Thus, cashew apple, mango peeling and kernel constitute agricultural waste. The objective of this research work is to contribute to these agricultural by-products valorization in flours for their probable therapeutic use. This involves producing flours from cashew apples collected in fields and Kent mango peelings and kernels from processing factories in Korhogo department. Subsequently; antioxydant and antibacterial properties of these flours derived from agricultural by-products will be studied with a view to their therapeutic value.

2. Material and Methods

2.1. Material

2.1.1. Plant Material

The plant material used in this study consists of Kent variety peels and kernel collected at Cooperative Ben n'gnon of Korhogo (COBEKO) and cashew apples from orchards around department of Korhogo (Northern Côte d'Ivoire) in April 2022.

Figure 1. Plant material studied

2.1.2. Bacterial Strains

The strains used for antibacterial test with aqueous and hydro-ethanolic extracts are tree bacteria composed of *Escherichia Coli*, *Salmonella bongori* and *Staphylococcus aureus*. These strains provided by Bacteriology-Virology Laboratory of Pasteur Institute of Côte d'Ivoire.

2.1.3. Bacteria Culture Medium

Bacteria culture medium used for this study is a Mueller-Hinton broth provided by Laboratory Conda S.A (C/ Forja, 9. Torrejón de Adorz 28850, Madrid, Spain).

2.1.4. Chemical Reagents and Solvents

The reagents and chemicals used in this work are of analytical grade. The solvents, consisting of methanol, hexane, ethanol, sodium chloride salt and hydrochloric acid, come from Sharlau. The reagents composed of sulfuric valinine, Dragendorff's reagent, DPPH (2.2-diphenyl-1-picrylhydrazyl), iron trichloride were used.

2.2. Methods

2.2.1. Processing of Producing Flours from Agricultural by-products Flours

Cashew apples collected were washed in tap water then squeezed to remove the juice. The cakes were dried in the sun (32 – 35°C) for 10 days on black tarpaulins at a rate of 10 hours/day. The dry cakes were crushed then sieved (10µm) and finally packaged in plastic pots. Concerning mango peels, they were washed to remove pulp residue and dried in the sun (32 – 35°C) for 14 days on a black tarpaulin at a rate of 10 hours/day. After drying, they were crushed then sieved (10µm) and packaged in plastic pots. As for the kernels, after washing, the almonds were removed from their shells then cut into cubes and finally dried in the sun (32 – 35°C) for 8 days on a black tarpaulin at a rate of 10 hours/day. The dried almonds were crushed, sieved (10µm) and stored in plastic pots.

2.2.2. Extracts Preparation

The aqueous extracts were prepared by macerating in different containers respectively 100 g of flours from by-products (cashew apple, mango peels and kernels) in 1000 mL of distilled water. After filtration, the filtrate is collected then placed in an oven at 50°C until a raw and dry aqueous extract (AE) is obtained. The hydro-ethanolic extracts (HE) were prepared under the same conditions by macerating 100 g of each flour in 1000 mL of ethanol/water mixture (70/30).

2.2.3. Antioxidant Test with Extracts

Antioxidant test with aqueous and hydro-ethanolic extracts of flours from cashew apple, mango peelings and kernel was carried out by the DPPH free radical trapping test according to [16]. In 7 test tubes, 2 mL of stock solution of different extracts is subjected to a dilution range of concentration 1 mg/mL: 2 mL of methanol is introduced into each tube. After homogenizing, 2 mL of solution of the first tube were put in the second tube. This operation is repeated so as to obtain 2 mL in each tested tube. Then 2 mL of ethanolic solution of DPPH previously

prepared at the same concentration were added to obtain 4 mL (final volume). After incubation in the dark for 30 min at room temperature, absorbance of each tube was reading at 517 nm using a visible UV spectrophotometer. A reference standard (ascorbic acid) was also analyzed at the same concentration. The concentration of extracts or vitamin C for inhibition of 50% of DPPH radicals (IC50) was determined by graph (percentage of inhibition of DPPH as a function of concentrations of extracts or vitamin C). The extract with the lowest IC50 value has the highest antioxidant power [16].

2.2.4. Antibacterial Test with Extracts

Antibacterial activities of aqueous and hydro-ethanolic extracts from cashew apple, mango peelings and kernel were evaluated by determination of minimal inhibitory concentration (MIC) and minimal bactericidal concentration (MBC) according to method of [17]. The method consisted of growing young colony of bacterial strains the day before (18 hours before). Then, a dilution range of eight concentrations was prepared in test tubes from a stock solution (2 g of extracts dissolved in 40 mL of Muller-Hinton broth previously prepared) with a concentration of 50 mg/mL. Then they were sterilized for 15 minutes at 120°C. After sterilization, the broth (culture medium) was poured into the previously marked petri dishes and cooled (solidified). After solidification, the different concentrations of culture medium contained in petri dishes were inoculated with inoculum of strains previously prepared. After incubation for 24 hours at 37°C, the MIC and MBC were determinate by observing the growth of colonies in test tubes compared to the control.

2.2.5. Statistical Analysis

The statistical analysis were performed with Graph Pad Prism software version 8.0.2 (263). The variance analysis (ANOVA) was performed to determine differences between the averages according to method of Turkey at the 5% threshold ($p<0.05$ was considered significant). The results were expressed as averages with standard error on mean (mean ± SEM).

3. Results and Discussion

After processing, the flours of cashew apple, Kent mango peeling and kernel obtained were presented in Figure 2.

The Figure 3 represents percentage of inhibition of DPPH radical by the different extracts. Antioxidant tests showed that all aqueous and hydro-ethanolic extracts have an interesting anti-radical power. Their inhibition concentration of 50% of radical (IC50) varying from 0.106±00 mg/mL to to 0.793±0.16 mg/mL compared to that of vitamin C (Reference) which is 0.064±0.68 mg/mL. Aqueous extract of mango kernel has the highest antioxidant power with IC50 of 0.106±00 mg/mL, followed by aqueous extract of mango peel and hydro-ethanolic extract of mango kernel with IC50 of 0.137± 0.90 mg/mL and 0.163±0.21 mg/mL respectively. The lowest anti-radical powers were recorded with aqueous extract of cashew apple (0.625±00 mg/mL) and hydro-ethanolic extracts of mango peel (0.625±00mg/mL) and cashew apple (0.793±0.16 mg/mL). These values highlight the anti-radical potential of these extracts. Comparing our products to controls (Vitamin C), they are less active. However, aqueous extract of mango kernel has the strongest antioxidant power. Our results are in accordance with those obtained by [18], who determined anti-radical activity of peelings and kernel of mango kernel and revealed that the almond was more active than the peel. As for cashew apples, they are less active than mango residues and vitamin C. These results corroborate those of [7] who determined the antioxidant power of cashew apples and revealed that it is not as high compared to other fruits despite its high polyphenol content. The anti-radical activity of these extracts could be attributed to their richness in chemical compounds with antioxidant activity. Particularly, coumarins, total polyphenols, tannins, flavonoids, copper, zinc, vitamin A, vitamin E were compounds detected during phytochemical screening and analysis of nutrient. Indeed, a study carried out by [19] suggested that polar molecules present in plant extracts contribute to the increase in anti-radical activity. Previous studies, which focused on certain fruits and plant extracts, showed a positive and high correlation between total phenolics and free radical scavenging activity [20,21].

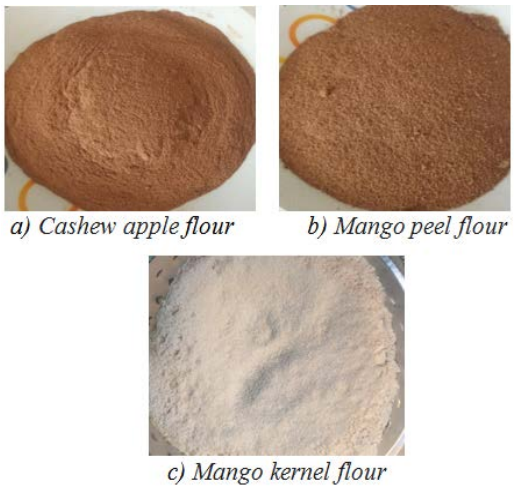
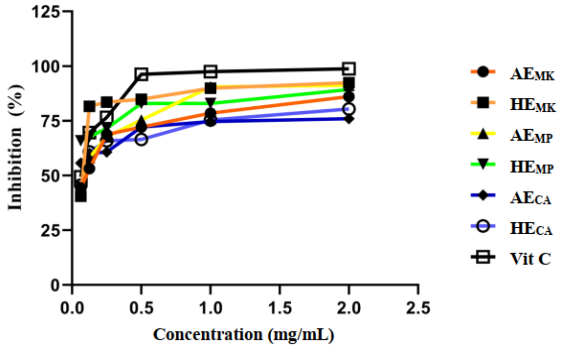


Figure 2. Flours of agricultural by-products studied



AE$_{MK}$: *Aqueous extract of mango kernel;*
HE$_{MK}$: *Hydro-ethanolic extract of mango kernel;*
AE$_{MP}$: *Aqueous extract of mango peel;*
HE$_{MP}$: *Hydro-ethanolic extract of mango peel;*
AE$_{CA}$: *Aqueous extract of cashew apple;*
HE$_{CA}$: *Hydro-ethanolic extract of cashew apple;*
Vit C: *Vitamin C*

Figure 3. Percentage of radical inhibition of aqueous, hydro-ethanolic extracts of agricultural by-product studied and vitamin C according to their concentrations

Antioxidants are involved in treatment and prevention of diseases such as arthritis, asthma, rheumatism, nephritis, cancers, atherosclerosis, diabetes mellitus, inflammatory lesions, immunosuppression diseases, metabolic disorders and Alzheimer's diseases [23]. All these garments then justify the use of these agricultural by-products, in medicine, in cosmetics, in conventional and unconventional food.

Antibacterial parameters of aqueous and hydro-ethanolic of flours from cashew apple, mango peel and kernel against bacteria tested (*S. bongori*, *E. coli* and *S. aureus*) were recorded in Table 1. These parameters revealed that all these extracts were inhibited the *in vitro* growth of the tree bacteria tested with minimal bactericidal concentration (MBC) varying from 0.195 mg/mL to 6.250 mg/mL. For hydro-ethanolic extracts, that of mango kernel flour is more active with MBC of 0.195 mg/mL, 0.781 mg/mL and 1.562 mg/mL respectively against *S. bongori*, *E. coli* and *S. aureus*. Also, aqueous extract from mango kernel flour has moderate antimicrobial activity with MBC of 1.562 mg/mL against *S. bongori* and *E. coli* and 3.125 mg/mL against *S. aureus*. These results are in agreement with those of [23] on the antimicrobial activity of aqueous and alcoholic extracts of mango kernel on *E. coli* and *S. aureus*. Also, several authors have demonstrated that plant extracts with best anti-radical power have good antimicrobial activity [24,25].

Table 1. Antibacterial parameters of extracts from flours of agricultural by-products studied

Bacteria tested	Antibacterial parameters (mg/mL)	Aqueous Extracts		
		AE_{MK}	AE_{MP}	AE_{CA}
Escherichia coli	*MIC*	0.781	3.125	1.562
	MBC	**1.562**	6.250	3.125
Salmonella bongori	*MIC*	0.195	1.562	1.562
	MBC	**1.562**	3.125	3.125
Staphylococcus aureus	*MIC*	1.562	3.125	3.125
	MBC	**3.125**	6.250	6.250

Bacteria tested	Antibacterial parameters (mg/mL)	Hydro-ethanolic Extracts		
		HE_{MK}	HE_{MP}	HE_{CA}
Escherichia coli	*MIC*	0.390	3.125	1.562
	MBC	**0.781**	6.250	3.125
Salmonella bongori	*MIC*	0.097	0.781	3.125
	MBC	**0.195**	1.562	6.250
Staphylococcus aureus	*MIC*	0.781	0.390	3.125
	MBC	**1.562**	**1.562**	6.250

***AE_{MK}:** Aqueous extract of mango kernel; **AE_{MP}:** Aqueous extract of mango peel; **AE_{CA}:** Aqueous extract of cashew apple; **HE_{MK}:**:Hydro-ethanolic extract of mango kernel; **HE_{MP}:** Hydro-ethanolic extract of mango peel; **HE_{CA}:** Hydro-ethanolic extract of cashew apple; **MIC:** Minimal Inhibitory Concentration ; **MBC:** Minimal Bactericidal Concentration*

4. Conclusion

This research work allowed to have scientific knowledge on the antioxidant and antibacterial activity of flour from cashew apple, Kent mango peelings and kernel of Korhogo department in the north of Côte d'Ivoire. The results revealed that the aqueous and hydro-ethanolic extracts of flours from cashew apple, mango peel and kernel have antibacterial and anti-radical properties. However, the aqueous and hydro-ethanolic extracts of flour from mango kernel is most active on bacterial strains tested and has the best anti-radical activity on DPPH radical. Considering these two biological properties of the extracts, these flours could serve as dietary supplement to improve health. For this, a study of subacute toxicity of these extracts on vital organs would be necessary for future investigations.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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