



## **Bioactives and Antimicrobial Potential of Processing by Products of Four Mango Varieties (*Mangifera indica* Varieties Amelie, Kent, Keitt and Brooks) from the Poro Region (Ivory Coast)**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors KHK and YTM designed the study, wrote the protocol. Authors MD, JOG, KHK and KAK anchored the field study, gathered the initial data and performed preliminary data analysis. While authors KHK, JBF, EJPK and LPK managed the literature searches, interpreted the data and produced the initial draft. All authors read and approved the final manuscript.*

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### **ABSTRACT**

**Aims:** During the industrial processing of mango, considerable quantities of peel and seeds are rejected, which results in a significant economic loss for the manufacturer, as well as an impact on the environment. However, mango almond and peel flours present enormous nutritional and especially therapeutic potentialities. Thus, the objective of this work is to contribute to the valorization of the waste of 4 varieties of mango (Amelie, Kent, Keitt, Brooks) from north in Ivory

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Coast by the determination of their bioactive compounds in, order to be used in the pharmaceutical industry.

**Place and Duration of Study:** Laboratory of Biochemistry and Food Technology, Nangui Abrogoua University, Abidjan 02, Ivory Coast. Between March 2019 to July 2021.

**Methodology:** Phenolic compounds of the Mango almond and peel flours were extracted with ethanol. UV-VIS spectrophotometry was employed to further quantify the total phenolic, tannin and total flavonoid content. DPPH radical scavenging assay, 2,2-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid (ABTS) scavenging test and ferric reducing antioxidant power (FRAP) were used to determine antioxidant activity. As for phenolic acids, they were analysed by HPLC. Well diffusion method was used to determine antibacterial activity.

**Results:** The analysis of the bioactive compounds of these mango discards revealed that they are characterised by high contents of total polyphenols  $39.67 \pm 0.04$  to  $85.18 \pm 0.01$  mg/g in the peel and  $22.86 \pm 0.03$  to  $58.43 \pm 0.00$  mg/g in the almond, flavonoids  $4.36 \pm 0.03$  to  $20.43 \pm 0.02$  mg/g in peel and from  $6.59 \pm 0.01$  to  $26.72 \pm 0.02$  mg/g in almonds, tannins  $5.04 \pm 1.13$  to  $8.64 \pm 0.76$  mg/g in peel and from  $6.58 \pm 0.06$  to  $12.46 \pm 0.11$  in almonds. Antioxidant activity varies in peel and almond from  $64.49 \pm 2.56$  to  $96.40 \pm 0.32$  % and  $89.16 \pm 1.45$  to  $97.96 \pm 0.25$  % respectively for ABTS, from  $59.51 \pm 0.26$  to  $86$ ,  $27 \pm 0.56\%$  and  $80.39 \pm 0.56$  to  $87.21 \pm 0.39\%$  for DPPH inhibition and from  $0.59 \pm 0.0$  to  $0.72 \pm 0.01$  mg/g and from  $0.81\%$  to  $0.92\%$  mg/g for iron reduction by the FRAP method. As for the antimicrobial activity, very marked inhibition diameters were observed both with the peel extracts and in the almonds for different bacteria (*B. ceurus*, *E. coli*, *ST. aureus*, *S. typhi*, *P. aeruginosa*).

**Conclusion:** These results demonstrate that the antimicrobial and antioxidant activities of the by-products of the four mango varieties are potential sources of bioactive compounds. These by-products could therefore be used in the pharmaceutical industry and diet.

**Keywords:** Mango peel and almond; phytochemical; antioxidant activity; antimicrobial activity.

## 1. INTRODUCTION

The mango (*Mangifera indica* Linn) is a fruit widely produced in tropical and subtropical regions [1]. In the year 2018, the annual global production of mangoes was approximately 52 million tons as per the Food and Agriculture Organization, and production exhibits an increasing trend each year [1]. Its global production is estimated at forty-five million tons in 2014 and is about 1,374,000 tons in 2010 in West Africa [2]. In Côte d'Ivoire, the orchard is concentrated in the northern zone, in the savannah regions (Korhogo, Sinématiali, Ferkessedougou and Odienné) [3]. Mango also represents a very important economic source for producing countries, particularly for Côte d'Ivoire, where it contributes to about 4 % of the Ivorian GDP. Côte d'Ivoire produces several varieties of mango including Kent, Keitt, Amelie, Tommy Atkins, Palmer, Brooks, Lippens, Springfield [4].

However, mango production in the world is confronted with enormous post-harvest losses (80 % of production) [5,6]. In Côte d'Ivoire, these losses are estimated at 30 to 40 % of national production and are observed at several levels of the mango cycle [7,8]. They are often due to the

unfairness of mango distribution systems across the country, attacks by fruit insects [9,10], pests and the lack of adequate post-harvest technologies for stabilising and preserving the fruit either in its fresh or processed state [6].

Fruit processing belongs one of the main ways to overcome this problem. Therefore, three new dried mango production units have been opened in the north of the country. Despite the importance of export, some of the mango, Kent (this mango has a widened ovoid shaped fruit and has a rich, sweet flavour. It will usually turn a greenish-yellow colour with some red blush as it matures), Keitt (The fruit is comparatively large, they are of ovoid shape with a rounded apex lacking a beak and the skin colour is typically green with some light red blush), Brooks (The fruit is oblong in shape and lacks a beak. The skins turn a green-yellow colour when ripe. The flesh is yellow in colour with medium fiber and has a mild, sweet flavour) and Amelie (the fruit is a green or pale yellow-skinned mango, sometimes with a red blush. It is a medium sized roundish fruit with a slightly prominent 'nose') varieties are increasingly processed [11].

Mango products are well demanded by consumers for their flavour, convenience and bioactive compounds; however, during

processing considerable generation of by-products can be an issue [12]. Depending on the mango variety, the peel and seed contribute about 15-20 % and 10-25 % of the whole fruit weight, respectively [13,14]. After industrial processing of mango, considerable amounts of peel and seeds are discarded, resulting in high economic loss to the manufacturer, as well as an impact to the environment such as water pollution, unpleasant odours, asphyxiation, vegetation damage, and greenhouse gas emissions [15,16]. In addition, waste disposal is costly and adds to the total cost of production. Therefore, it is necessary to consider alternative uses for these mango by-products, in order to avoid environmental problems and to create new revenue sources, providing greater economic returns to the agribusiness [17].

Several Studies have shown that it is possible to recover compounds with antioxidant, antimicrobial and antifungal properties from mango kernel and peel. [18-22], which generates high hopes for the continued search for new drugs and bioactive components in the food, cosmetic and pharmaceutical industry [23,24].

In this context, the analysis of natural compounds with antioxidant and antimicrobial potential is getting attention. Therefore, the main goal of this research is to highlight the agro-industrial bioactive and antimicrobial potential of mango by-products (almonds and peels) of four most processed varieties such as Amelie, Kent, Keitt and Brooks, from the Poro Region (Côte d'Ivoire), with a view to the marketability of the flour made via these by-products.

## 2. MATERIALS AND METHODS

### 2.1 Procurement of the Materials

Four varieties of mango (Kent, Brooks, Keitt and Amelie) were selected and harvested at physiological maturity in the plantations of the Korhogo (North of Côte d'Ivoire). The harvest was done during the 2019 and 2020 fruiting seasons in March to April for the Amelie variety; April to July for the Kent variety; June to August for the Keith variety and July to August for the Brooks variety.

The samples were brought to the Bio catalysis and Bioprocessing Laboratory of Nangui Abrogoua University. The fruits were thoroughly washed with double distilled deionized water to remove any pollutant, pesticide residues, dirt,

and dust on the surface. They were then kept for ripening at room temperature within three (3) days for the Amelie variety and seven (7) days for the other three varieties [25].

All solvents and reagents used were of analytical grade (E. Merck, Darmstadt, Germany), unless otherwise stated and the solutions were prepared with distilled water.

### 2.2 Preparation of Mango Peels and Almonds Flours

The mangoes were sorted, washed, wrung, and peeled with a stainless-steel knife. Almonds are then manually extracted after pitting the fruits with the same knife. The respective weighed samples of almonds and peels were oven dried at 50°C for 72 hours and then crushed in a blender to obtain flours, used as material.

### 2.3 Polyphenol, Flavonoid, and Tannin

#### 2.3.1 Extraction of phenolic compounds

Extraction of phenolic compounds were determined employing Singleton et al. [26] method. A sample (10 g) of fine dried mango by-product samples' flour was extracted by stirring with 50 ml of ethanol 80 % (v/v) at 25 °C for 24 hours and filtered through Whatman n°4 paper. The residue was then extracted with two additional 50 ml portions of ethanol. The combined ethanolic extracts were evaporated at 35 °C (rotary evaporator HEILDOLPH Laborata 4003 Control, Schwabach, Germany) until 25 ml, prior to phenolic compound contents determination.

#### 2.3.2 Determination of total phenolic compounds content

Contents of total phenolic compounds were estimated according Folin-Ciocalteu method [26]. A volume of 1 ml of ethanoic extract of each sample was added to 1 ml of Folin-Ciocalteu's solution in a test tube. After 3 minutes, 1 ml of 20% sodium carbonate solution was added to the mixture and adjusted to 10 ml with distilled water. The mixture could stand at room temperature in a dark environment for 30 min. Absorbance was measured against the blank reagent at 725 nm. Gallic acid was used for the calibration curve with a concentration range of 50 - 1000 µg/ml.

Results were expressed as mg gallic acid equivalent (GAE)/100g DW (Dry Weight).

### 2.3.3 Determination of tannin

Tannin content was determined using the method described by Bainbridge et al. [27]. A volume of 1 ml of each ethanoic extract was collected and mixed with 5 ml of reaction solution [vanillin 0.1mg/ml in sulphuric acid 70 % (v/v)]. The mixture could stand at room temperature in a dark environment for 20 min. The absorbance was measured at 500 nm against a blank (without extract).

Tannic acid was used for the calibration curve with a concentration range of 0 - 100 µg/ml.

The results were expressed as mg of tannic acid equivalents (TAE)/100 g DW.

### 2.3.4 Determination of total flavonoid content

The total flavonoids content was determined using the Dowd method [28]. 5 ml of 2 % aluminium trichloride (AlCl<sub>3</sub>) in ethanol was mixed with the same volume of the ethanoic extract solution (0.4 mg/ml). After ten minutes the absorbance was measured at 415 nm using PerkinElmer UV-VIS Lambda. Blank sample consisting of a 5 ml extract solution with 5 ml ethanol without AlCl<sub>3</sub>. The total flavonoid content was determined using a standard curve with catechin (0 – 100 mg/l) as the standard.

Total flavonoids content is expressed as mg of catechin equivalents (CE)/100 g DW.

## 2.4 Phenolic Compounds Content (HPLC Analysis of Phenolic Acids and Flavonols)

The ethanoic extracts of phenolic compounds from the different mango discard samples prepared earlier (50 mL) were diluted in 100 mL of distilled water and 20 µL of each sample was analysed using an analytical HPLC unit (Shimadzu Corporation, Japan) equipped with a binary pump (LC-6A) coupled to a UV-VIS detector (SPD-6A). Phenolic compounds were separated on an ICsep ICE ORH- 801 column (length 25 cm) at a fixed temperature of 30 °C. The mobile phase consisted of a 50 mM NaH<sub>4</sub>H<sub>2</sub>PO<sub>4</sub> solution at pH 2.6 (eluent A), an acetonitrile/NaH<sub>4</sub>H<sub>2</sub>PO<sub>4</sub> solution (80:20, v/v) (eluent B) and 200 mM o-phosphoric acid, pH 1.5 (eluent C). The running time was 70 min with a flow rate of 1 mL/min. The detection wavelength was set at 280 nm. The phenolic compounds in the ethanoic extract of the mango discard samples were identified by comparing their

retention times with those obtained by injecting the standard solution containing the standard phenolic compounds under the same conditions. The standard or reference phenolic compounds used were Gallic acid, Tannin H<sub>2</sub>O, Na Cinamate, Caffeine, Coumarin acid and Quercetin.

The individual phenolic compounds of the different mango discard samples were quantified by estimating their concentrations expressed in mg/kg dry matter from the average of the peak areas of each of the standard phenolic compounds. Thus, the EC<sub>x</sub> concentration of an individual phenolic compound x identified in a sample was calculated using the following equation:

EC<sub>x</sub>: concentration of phenolic compound x identified in the sample

T area: average of the peak areas of the standard phenolic compounds

Ex area: peak area of phenolic compound x identified in the sample

CT<sub>x</sub>: concentration of the standard phenolic compound corresponding to phenolic compound x

## 2.5 Antioxidant Activities

### 2.5.1 DPPH assay

The antioxidant activity of the extracts was evaluated by DPPH radical scavenging assay which was described by Tlili et al. [29].

The free radical scavenging activity of the plant extracts was measured by 1.1-diphenyl-2-picrylhydrazil (DPPH), with some modifications. Briefly, 0.3 mM solution of DPPH in ethanol was prepared and 1 ml of this solution was added to 2.5 ml of mango extract and was allowed to stand at room temperature for 30 min, and then absorbance was read at 517 nm against blank samples. Lower absorbance of the reaction mixture indicated higher free radical scavenging activity. IC<sub>50</sub> value was determined from the plotted graph of scavenging activity against the different concentrations of the 4 mango varieties almond and peel extracts, which is defined as the total antioxidant necessary to decrease the initial DPPH radical concentration by 50 %. Ascorbic acid (Vitamin C) was used as reference compound.

### 2.5.2 ABTS assay

The Trolox Equivalent Antioxidant Capacity (TEAC) test described in Tlili et al. [29] was used

to assay the antioxidant activities. The ABTS + radical cation was produced by mixing a solution of ABTS (8 mM) and a solution of K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> (3 mM) (1 / 0.5, v / v). The mixture was then incubated for 16 h in the dark at room temperature (25 °C). Then, 0.1 ml (standard or extract) diluted in ethanol (1/10, v / v), was added to 3.9 ml of the diluted ABTS solution. The mixture was vigorously vortexed for 2 min following by incubation for 6 min in the dark at room temperature (25 °C). The absorbance of the mixture was read in the Jasco V-530 UV-visible spectrophotometer at 734 nm. The results were expressed in  $\mu\text{mol. g}^{-1}$  TE (Trolox Equivalents). The percent degradation of ABTS by Trolox was compared to that of the sample. Percentage degradation A (%) of ABTS was expressed by using following mathematical formula,

$$A (\%) = \frac{A(\text{blank}) - A(\text{extract})}{100} \times A(\text{blank})$$

A(blank) = blank absorbance after incubation.

A(extract) = extract absorbance at 734 nm after incubation

The amount of sample necessary to decrease the absorbance of DPPH by 50% (IC<sub>50</sub>) was calculated graphically.

### 2.5.3 Reducing power determination: FRAP assay

The ferric reducing capacity of extracts was investigated by using the potassium ferricyanide-ferric chloride method [29]. Briefly, 0.2 mL of each of the extracts at different concentrations, 2.5 mL of phosphate buffer (0.2 M, pH 6.6), and 2.5 mL of potassium ferricyanide K<sub>3</sub>Fe (CN)<sub>6</sub> (1 %) were mixed and incubated at 50 °C for 20 min, to reduce ferricyanide into ferrocyanide. The reaction was stopped by adding 2.5 mL of 10 % (w/v) trichloroacetic acid followed by centrifugation at 1000 rpm for 10 min. Finally, 2.5 mL of the upper layer was mixed with 2.5 mL of distilled water and 0.5 mL of FeCl<sub>3</sub> (0.1 %) and the absorbance was measured at 700 nm. The reducing power of the extracts was represented as ascorbic acid equivalent (mg AAE/ g of extract).

### 2.6 Determination of Antibacterial Activity

The antibacterial activity of the ethanolic extracts was evaluated against strains of pathogenic

bacteria (*Staphylococcus aureus*, *Bacillus cereus*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Escherichia coli*,) using the well diffusion method as described by Aricia et al. [30] and Toty et al. [31].

### 2.7 Statistical Analysis

All chemical analyses and assays were performed in triplicate, unless otherwise indicated. Results were expressed as mean values  $\pm$  standard deviation (SD).

Analysis of variance (ANOVA) followed by Duncan's test was performed to test for differences between means by employing Kyplot (version 2.0 beta 15, c1997-2001, Koichi Yoshioka) statistical software. For each parameter, identical script indicates no significant difference at  $p < 0.05$  according to the Kruskal-Wallis test between mean values.

## 3. RESULTS AND DISCUSSION

### 3.1 Phenolic Compounds, Flavonoids, Tannins and Anthocyanins Contents

Table 1 shows the contents of estimated polyphenols, flavonoids, tannins and anthocyanins from the by-products (peels and almonds) of four mango processed varieties harvested at maturity stage.

#### 3.1.1 Polyphenols

The results revealed that the phenolic compounds of the peels and almonds of the mango varieties studied (Amelie, Kent, Keitt and Brooks) were significantly different ( $P \leq 0.05$ ), with values ranging from  $39.67 \pm 0.04$  to  $85.18 \pm 0.01$  mg/g for the peels and from  $22.86 \pm 0.03$  to  $58.43 \pm 0.00$  mg/g for the almonds, regardless of the mango variety. These differences in polyphenol content between the varieties can be explained by the intrinsic botanical difference of these mangoes. These results showed the mangoes peels were constitutes a good source of polyphenols. they can be used in food, cosmetics, and pharmacology. Indeed, according to Sabu and Kattan [32], polyphenols have beneficial effects on human health in relation to their antioxidant actions. Moreover, these compounds prevent neurodegenerative diseases, cardiovascular diseases, and cancer [33,34].

### 3.1.2 Flavonoids

The results revealed that the flavonoids compounds of the peels and almonds of the mango varieties studied (Amelie, Kent, Keitt and Brooks) were significantly different ( $P \leq 0.05$ ), with values ranging from  $4.36 \pm 0.03$  to  $26.72 \pm 0.02$  mg/g. A high level of flavonoids was determined for the couple Amelie and Keitt accounting for ( $26.72 \pm 0.02$ ;  $26.46 \pm 0.01$  mg/g) followed by ( $20.47 \pm 0.04$ ;  $20.43 \pm 0.02$  mg/g) in the almond and the peel, respectively.

### 3.1.3 Tannin

The condensed tannin amount determined was significantly different besides the investigated parts from our four varieties mango fruits. High level was observed for Amelie and Keitt in almonds ( $12.46 \pm 0.11$ ;  $12.40 \pm 0.11$  mg/g) and peels ( $8.64 \pm 0.76$ ;  $8.35 \pm 1.10$  mg/g), respectively with no significant difference at the level  $p < 0.05$ . Whereas Brooks has lower tannin levels with  $5.04 \pm 1.13$  and  $6.58 \pm 0.06$  mg/g in peel and almond, respectively.

### 3.1.4 Anthocyanins

The results showed that the four mango varieties almond contained higher concentrations of anthocyanins ( $3.07 - 6.82$  mg/g) than peel ( $0.96 - 6.15$  mg/g). on the other hand, the highest contents were observed in the peel ( $6.15 \pm 0.01$ ) and kernel ( $6.82 \pm 0.08$ ) of Kent variety. They constituted a good source of Anthocyanin. Indeed, Anthocyanins, as natural colorants, have value-added properties. These antioxidants properties, as nutraceutical and many health benefits, such as an antimicrobial effect and prevention of chronic diseases [35].

### 3.2 Phenolic Compounds Contents

In this study, four phenolic compounds have been separated and identified from peels and almonds of these four varieties of mango. the data were showed in Table 2. Thus, the analysed results revealed highest values of tannic acids in almonds and peels of the Amelie variety.

**Table 1. Polyphenol, flavonoid, tannin and Anthocyanins compounds of mango almond and peel flours**

Parameters (mg/g)		Amelie	Kent	Keitt	Brooks
Polyphenols	Peel	$85.18 \pm 0.01^a$	$50.09 \pm 0.01^e$	$63.13 \pm 0.03^b$	$39.67 \pm 0.04^f$
	Almond	$58.43 \pm 0.00^c$	$25.36 \pm 0.03^g$	$57.16 \pm 0.04^d$	$22.86 \pm 0.03^h$
Flavonoids	Peel	$20.43 \pm 0.02^{cd}$	$4.36 \pm 0.03^g$	$20.47 \pm 0.04^{bc}$	$7.66 \pm 0.02^{ef}$
	Almond	$26.72 \pm 0.02^a$	$6.59 \pm 0.01^{fg}$	$26.46 \pm 0.01^{ab}$	$12.06 \pm 0.02^{de}$
Tannins	Peel	$8.64 \pm 0.76^{cd}$	$6.70 \pm 1.05^{de}$	$8.35 \pm 1.10^{cd}$	$5.04 \pm 1.13^e$
	Almond	$12.46 \pm 0.11^a$	$11.54 \pm 1.26^{abc}$	$12.40 \pm 0.11^{ab}$	$6.58 \pm 0.06^{de}$
Anthocyanins	Peel	$0.96 \pm 0.32^g$	$6.15 \pm 0.01^{ab}$	$1.44 \pm 0.17^{fg}$	$1.63 \pm 0.05^{ef}$
	Almond	$3.07 \pm 0.04^{de}$	$6.82 \pm 0.08^a$	$5.47 \pm 0.33^{bc}$	$4.46 \pm 1.13^{cd}$

Values are mean  $\pm$  standard deviation of three measurements ( $n = 3$ ). For each parameter, identical script indicates no significant difference at  $p < 0.05$  according to the Kruskal-Wallis test between mean values

**Table 2. Phenolic compounds contents (mg/g DW) of mango almond and peel flours.**

Phenolic compounds (mg/g)	Extracts	Amélie	Kent	Keitt	Brooks
Tannic acid	Peel	$3621.33 \pm 0.51^{ab}$	$408.33 \pm 0.03^{bc}$	nd	$0.12 \pm 0.00^e$
	Almond	$4761.13 \pm 0.67^a$	$45.77 \pm 0.05^{cd}$	nd	$14.87 \pm 0.00^{de}$
Gallic acid	Peel	$100.77 \pm 0.06^{de}$	Nd	$390.63 \pm 0.06^a$	$286.97 \pm 0.04^{ab}$
	Almond	$180.37 \pm 0.03^{bcd}$	$252.8 \pm 0.07^{abc}$	$158.29 \pm 0.08^{cd}$	Nd
Sodium cinnamate	Peel	$86.13 \pm 0.05^f$	$296.90 \pm 0.04^{de}$	$251.43 \pm 0.06^e$	$87.30 \pm 0.05^f$
	Almond	$1026.27 \pm 0.21^a$	$682.67 \pm 0.06^{ab}$	$640.30 \pm 0.00^{bc}$	$497.73 \pm 0.05^{cd}$
Coumarin	Peel	nd	Nd	$098.93 \pm 0.04^a$	Nd
	Almond	nd	Nd	nd	Nd

Values are mean  $\pm$  standard deviation of three measurements ( $n = 3$ ). For each parameter, identical script indicates no significant difference at  $p < 0.05$  according to the Kruskal-Wallis test between mean values. nd. not detected

Therefore, as mentioned by Yener et al. [36], these by-products remain interesting, because tannic acid is used as a flavoring agent in food and beverage industry. Additionally, it has very important applications in wine industry as natural clarifying agent, color stabilizer and taste enhancer. Unfortunately, peels and almonds of Keitt variety are not a tannic acid source.

Gallic acid is one of the major compounds in our different samples. In Fact, gallic acid is a compound with cytotoxic activity against cancer cells. The high levels of gallic acid in peel and almond make these discards an excellent source of antioxidant molecules [37]. Gallic acid also has antiviral activity, so these by-products could find several applications in pharmaceutical industries [38,39].

### 3.3 Antioxidant Activities

In this study, the antioxidant activity of almond and peel (by-products) from 4 mango varieties (Amelie, Kent, Keitt and Brooks) were determined by DPPH radical scavenging, ABTS radical decolorization and Ferric reducing antioxidant power (FRAP) assays. The corresponding increase or decrease of the absorbance at a given wavelength is related to the concentration of antioxidant in these discards

of mango. The results are summarized in Table 3.

In this study, the antioxidant activity of almond and peel (by-products) from 4 mango varieties (Amelie, Kent, Keitt and Brooks) by DPPH radical scavenging, ABTS radical decolorization and Ferric reducing antioxidant power (FRAP) assays, revealed the almond extracts exhibited potential to combat the free radicals generated as a result of oxidative stress compared to peel extracts. The strongest antioxidant activity in almonds suggests that this potentiality is not necessarily related to the amount of polyphenolic compounds, but rather to the specificity of these molecules [40]. In addition, some varieties such as Brooks and Keitt clearly be obvious from other varieties, suggesting the strong antiradical power of their peel and almond. The use of the almond of these varieties would therefore be indicated for the preparation of products (food, cosmetics, pharmaceuticals) with strong antioxidant power that could guarantee the reduction of radicals and lengthen cell life. These results are matched with those of Rymbai et al. [41] and Villanueva et al. [42] in their studies on the determination of the antioxidant activity of several mango varieties by scavenging DPPH and ABTS and FRAP radicals. The inhibition power observed at the

**Table 3. Antioxidant activity (IC50 mg/mL) of mango almond and peel flours**

Test		Amelie	Kent	Keitt	Brooks	Vitamin C
DPPH	Peel	0.163±0.03 <sup>c</sup>	0.164±0.00 <sup>c</sup>	0.026±0.01 <sup>b</sup>	0.017± 0.00 <sup>a</sup>	0.016 ±0,00 <sup>a</sup>
	Almond	0.45± 0.00 <sup>c</sup>	0.45± 0.04 <sup>c</sup>	0.017±0.00 <sup>a</sup>	0.032±0.00 <sup>b</sup>	
FRAP	Peel	0.032±0.02 <sup>b</sup>	0.033± 0.00 <sup>b</sup>	0.126±0.01 <sup>c</sup>	0.125± 0.00 <sup>c</sup>	0.006±0.00 <sup>a</sup>
	Almond	0.034±0.01 <sup>b</sup>	0.033±0.00 <sup>b</sup>	0.012±0.00 <sup>a</sup>	0.007± 0.00 <sup>a</sup>	
ABTS	Peel	0.165±0.03 <sup>b</sup>	0.275±0.04 <sup>c</sup>	0.051±0.01 <sup>a</sup>	0.165± 0.00 <sup>b</sup>	0.014±0.01 <sup>a</sup>
	Almond	0.063±0.02 <sup>a</sup>	0.155±0.03 <sup>b</sup>	0.029±0.01 <sup>a</sup>	0.092±0.01 <sup>a</sup>	

Values are mean ± standard deviation of three measurements (n = 3). For each test, identical script indicates no significant difference at p < 0.05 according to the Kruskal-Wallis test between mean values.

**Table 4. Diameters of inhibition of mango almond and peel flours (mm)**

Bacteria		Amelie	Kent	Keitt	Brooks
<i>B. ceurus</i>	Peel	18.00 ± 1.41 <sup>c</sup>	17.00 ± 1.41 <sup>b</sup>	20.00 ± 1.41 <sup>c</sup>	17.00 ± 1.24 <sup>b</sup>
	Almond	24.50 ± 0.71 <sup>e</sup>	22.00 ± 2.83 <sup>d</sup>	20.50 ± 2.12 <sup>c</sup>	15.00 ± 0,00 <sup>a</sup>
<i>E. coli</i>	Peel	17.50 ± 0.71 <sup>a</sup>	16.00 ± 0.00 <sup>a</sup>	19.00 ± 1,41 <sup>b</sup>	19.00 ± 0.00 <sup>b</sup>
	Almond	19.00 ± 1.41 <sup>b</sup>	17.50 ± 0.71 <sup>a</sup>	19.50 ± 0.71 <sup>b</sup>	20.50 ± 0.71 <sup>c</sup>
<i>ST. aureus</i>	Peel	20.50 ± 0.71 <sup>a</sup>	20.00 ± 1.41 <sup>a</sup>	25.50 ± 2.12 <sup>c</sup>	31.50 ± 3.53 <sup>e</sup>
	Almond	20.50 ± 2.12 <sup>a</sup>	23.00 ± 1.41 <sup>b</sup>	28.50 ± 0.70 <sup>d</sup>	22.50 ± 2.12 <sup>b</sup>
<i>P. aeruginosa</i>	Peel	19.00 ± 0.00 <sup>b</sup>	15.50 ± 0.71 <sup>a</sup>	20.00 ± 0.00 <sup>b</sup>	16.50 ± 3.53 <sup>a</sup>
	Almond	23.00 ± 1.41 <sup>c</sup>	19.50 ± 3.53 <sup>b</sup>	20.00 ± 1.41 <sup>b</sup>	20.00 ± 0,00 <sup>b</sup>
<i>S. typhi</i>	Peel	19.00 ±0.00 <sup>b</sup>	18.50 ±0.71 <sup>b</sup>	20.50 ±0.71 <sup>c</sup>	25.00 ± 2.83 <sup>d</sup>
	Almond	21.00 ± 2.82 <sup>c</sup>	18.00 ± 0.00 <sup>b</sup>	20.00 ± 1.41 <sup>a</sup>	10.50 ± 0.70 <sup>a</sup>

Values are mean ± standard deviation of three measurements (n = 3). For each parameter, identical script indicates no significant difference at p < 0.05 according to the Kruskal-Wallis test between mean values.

level of DPPH, FRAP and ABTS confirmed that the peel and almond extracts presented an antiradical potential that would allow them to play a beneficial role in terms of preventive action on human health [32].

### 3.4 Determination of Antibacterial Activity

The antimicrobial potential of the mango peel and almond extracts based on the inhibition zones against the specific microbes are presented in Table 4. The four mango varieties peel and almond extracts had some zones of inhibition when introduced to some specific microorganisms, such as *Bacillus cereus*, *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Salmonella typhi*. The results showed an important antimicrobial potent in almond as well as in peel. Similar findings were demonstrated in various studies wherein leaf extracts and seed kernel of mango exhibited antimicrobial potential against *S. aureus* and *E. coli* [43,44]. The potent antimicrobial activity demonstrated by the mango almond extracts could be attributed to the presence of specific phytochemicals such as flavonoids, terpenes, tannins, and coumarins [45].

### 4. CONCLUSION

The phytochemical characterisation of this study clearly demonstrates that mango fruit by-products contain a rich potential source of valuable components, such as tannin, phenolic compound and carotenoid. Moreover, this study also revealed that the extract of mango peel and almond showed good antioxidant and antimicrobial activity. These by-products could therefore be used in the pharmaceutical industry and diet.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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