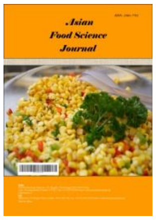

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Mango Peel and Almond Flour (*Mangifera indica* var Amelie,Kent, Keitt, Brooks) harvested, Processed in North of Cote d'Ivoire: Biochemical Parameters and Mineral Content

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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, 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

Mango almond and peel flours are a potential source of nutriment. In this study, the proximate composition and mineral element profile of four varieties of mango flour that are grown and processing in north of Cote d'Ivoire investigated. The data can be used as a reference when these flours are used for further processing in a variety of products. The peels and almonds were harvested fresh, dried in an oven at 50°C for 72 hours, ground and analysed according to standard

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procedures. Results showed carbohydrate, crude protein, total lipid, crude fibre, ash contents and vitamin C of the couple “peel – almond” flours were found to be 83.83-76.16%, 2.48-6.54%, 2.79-13.45%, 9.97-7.67%, 4.25-3.10% and a considerable amount of vitamin C of 307.67–304.85 mg/100g, respectively. They also contained important minerals such as calcium at 1204.45-1064.82 mg/100g, magnesium at 257.46-243.81 mg/100g, and potassium was the major at 1883.65-1617.66 mg/100g, regarding peels and almonds flours, respectively. Mangoes varieties such as Amelie, Kent, Keitt and Brooks have the potential to be a good source of nutrition for humans and animals. Mangoes varieties, peels, almonds, biochemical parameters, minerals.

Keywords: Mangoes varieties; peels; almond; biochemical parameters; minerals.

1. INTRODUCTION

The mango (*Mangifera indica*) is a fruit widely produced in tropical and subtropical regions [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, Ferkessédougou and Odienné) [3]. This country produced several varieties of mango including *Kent*, *Keitt*, *Amélie*, *Tommy Atkins*, *Palmer*, *Brooks*, *Lippens*, *Springfield*. Despite its nutritional and economic importance, mango production in the world is confronted with enormous post-harvest losses (80% of production) [4,5]. 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 [6]. The country's mango industry is therefore faced with a conservation problem. Fruit processing is one of the main ways to overcome this problem. Thus, three new dried mango production units have been opened in the north of the country.

Despite the importance of export, huge part of *mango, Kent, keitt and Brooks* varieties are the most processed while the *Amélie* variety is more destined for export [7]. However, this processing generates by-products (epicarp and seed) that are considered waste and become a source of environmental pollution due to microbial development and unpleasant odors formed by their decomposition [8] and loss of profit. There is therefore a need to treat these wastes. The recovery and valorisation of this food waste, hence, represents a major challenge, both from an economic and ecological point of view. These wastes, composed primarily of pericarp, endocarp and cotyledon, represent 28 to 38% of the total content of the fruit [9].

The valorisation of agricultural co-products / by-products is receiving more attention with many researchers, evaluating the conversion of these into food ingredients and other value-added materials [10,11].

For such a purpose, several studies have been carried out on fruit and vegetable rubbishes. Therefore, mechanical drying of these wastes (mango peel, citrus peel, pineapple peel and tomato processing wastes) gave opportunity to store the substrate all over the year [12]. Several research reports have revealed that food industry by-products can be good sources of potentially valuable bioactive compounds [13,14,15].

Other studies have reported the economic, social, and environmental importance of waste from mango residues (by products). These results have shown the transformation of these residues into biofuel, as a human food supplement, in the formulation of animal feed, etc [10,16,11].

However, the specifications of the parts used are not, or not hardly elaborated. Therefore, a huge knowledge of the characteristics of each rejected part of the mango could better guide its use in a good measure of sustainable development and food interest.

Therefore, this research attempts to highlight the biochemical parameters, mineral content after weighing the proportion of mango almonds and peels of four most processed varieties such as *Amelie*, *Kent*, *Keitt* and *Brooks*, with a view to the marketability of the flour made *via* these by-products.

2. MATERIALS AND METHODS

2.1 Procurement of the Material

Four popular varieties of mango (*Kent*, *Brooks*, *Keitt* and *Amélie*) were selected and harvested at physiological maturity in the plantations of the Korhogo cooperative, located in the Poro region, 635 km from the city of Abidjan and between 9°27 north latitude and 5°38 west longitude. The Amelie variety represents the early *variety, Kent and Keith* represent the full season varieties and Brooks the late variety. 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 Biocatalysis 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 [17].

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 Extraction and Isolation of the Constituent and Proportions

The pulp, peel, kernel, and almond of the four fruit varieties are separated, respectively. Each part is weighed to evaluate their proportion.

2.3 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.

2.4 Oil kernel Extract

20.0 g of each powder almonds and peels were extracted with hexane by Soxhlet at 80 °C (3 x 200 ml, 8 h each). The solvent was dried over anhydrous sodium sulphate. The filtered solvent was evaporated under vacuum to afford a lipid pale yellow semisolid (1.4 g, 6.1% w/w) and a defatted part of the mango used (18.3 g, 91.6% w/w).

2.5 Analytical Methods

Moisture, total protein, ether extract, total ash, crude fiber and minerals were determined according to methods in the A.O.A.C. [18]. Total carbohydrates were calculated by difference. The samples were worked in triplicates and average values were recorded.

2.6 Minerals Analysis

Minerals were determined employing AOAC [18] method. Flour was digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L) and analyzed using an atomic absorption spectrophotometer.

2.7 Statistical Analysis

All analyses were performed in triplicates. Results are expressed as the mean ± standard deviation of several sample with Kyplot (version 2.0 beta 15, ©1997-2001, Koichi Yoshioka) statistical software. The data were statistically analyzed by one way analysis of variance (ANOVA). Means were compared by Turkey's test. Differences were considered statistically significant at $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Parts of Mango Fruit

Variable proportions of peels, pulp, seeds, and almonds fruits was observed. Percent distribution of mango fruit was studied and depicted in Table 1. Peels and seeds ranged from 10 - 25% of the four varieties whole fruits. Mango almond ranking from 1.94 ± 0.26, 4.39 ± 0.37, 3.03 ± 0.25, to 6.38 ± 0.37% whereas mango peel ranged from 4.43 ± 0.20, 3.86 ± 0.16, 6.16 ± 0.41 to 9.07 ± 0.39% of the whole variety fruit *Amelie, Kent, Keitt* and *Brooks*, respectively. The highest ratio was observed for peels of *Keitt* and *Brooks* varieties. However, *Brooks* almond and peel depicted no significant difference ($p > 0.05$) each other compared to the other mangoes collected. Results of this investigation showed the considerable weight (10 – 25%) of the fruit would be throwing away without valorising it. This ratio is agreed with several varieties of mango reported by Variations in pulp, peel, almond and kernel percent of the mango fruits are attributed to the varietal difference [11].

3.2 Biochemical Composition of Flours

Biochemical properties are intrinsic characteristics that affect the behaviour of a food ingredient in a food system during processing, manufacturing, preparation, and storage. The successful utilisation of a by-products flour as a food ingredient depends on the characteristics that it would impart to the product into which it is incorporated. Hence, this study depicted that biochemical parameters and minerals content regarding almond and peel parts of these four mangoes varieties (*Amelie*, *Kent*, *Keitt* and *Brooks*), was remained interesting, and would help to provide information on the utilisation of their flours in the food industry.

The results of the biochemical values of the mango almonds and peels flours from the four varieties was shown in Table 2. It is seen that the moisture contents of these parts fruits ranged from 5.90 ± 0.26% (peel) -7.95% (almond of mango). There was no significant difference between all the parts. However, *Kent* variety humidity content value remained the lowest. The moisture content of the raw material is crucial to determine further processing. These results of peel and almond flour of Amelie, Kent, Keitt and Brooks varieties was shown low moisture content, ranking from 5.90 to 7.95%. This promises a long shelf life for further processing [19]. As shown by this study, values, remain like those related by Irondi et al. [20] for kernel flour (7.31 ± 0.04%). Furthermore, Chew et al. [21] reported that reduced moisture content ensured the inhibition of microbial growth, hence is an important factor in food preservation.

The four mango varieties *Amelie*, *Kent*, *Keitt* and *Brooks* are not significantly different from each other in their peels or almonds flours crude protein content, ranged from 1.81 ± 0.20 - 2.48 ± 0.00% to 4.76 ± 0.18 - 6.54 ± 0.05%, respectively. However, there is a significant difference regarding the parts fruits used, take separately, with high values for *Kent* almond (6.54 ± 0.05%).

Fat contents was statistically different from each other, with the highest value for the *Brook*s variety (13.45 ± 0.60%) regarding almond flour. Although results have shown low content ranking from 1.31 ± 0.20 to 2.79 ± 0.01 for all selected mangoes peels flours.

The results of present investigation are in accordance with the previous findings of Ajila et al. [22]. They carried out proximate profiling of different mango peels and observed protein and fat contents in the range of 1.76-2.05 and 2.16-2.66, respectively. The variations in the proximate composition of different peel samples are due to varietal differences, climatic conditions, topographic locations and agronomic practices [23]. With a maximum at 6.54% for *Amelie*, mango almond studied does not have a protein content comparable to the findings of other authors, for varieties from different African countries [24,25]. The results showed that these almonds are rich in oil and these could be exploited for domestic and industrial purposes.

The mango peels flour had crude fibre values of 8.84 ± 0.00 - 9.97 ± 0.00% and was significantly different compared to those of almonds ranging from 3.63 ± 0.36 - 7.67 ± 0.19% of the four mangoes studied. Furthermore, the lowest and highest values were observed for almond flour (3.63 ± 0.36%) and peel flour (9.97 ± 0.00%) respectively for the *Brooks* and *Keitt* varieties. This result show the importance of the peel as a source of dietary fiber since, according to ANVISA [26], food with a content of 6% can be considered high in fiber.

Total ash content were lower for *Brooks* almonds flour (1.99 ± 0.08%) as well as the carbohydrate content for *Amelie* almonds flour (73.22 ± 0.07%). On the other hand, Total ash content were higher for *Keitt* peels flour (4.25 ± 0.05%) as well as the carbohydrate content for *Amelie* peels flour (83.83 ± 0.03%).

Table 1. Percent distribution of mango fruit parts

	Varieties			
	Amélie	***Kent***	***Keitt***	***Brooks***
Weight (g)				
Whole fruit	499.69 ± 14.92^{b}	580.87 ± 24.45^{a}	353.23 ± 15.66^{c}	295.57 ± 10.52^{c}
Almond	9.83 ± 1.44^{c}	24.88 ± 1.48^{a}	10.63 ± 0.84^{c}	18.80 ± 1.10^{b}
Kernel	30.29 ± 1.62^{dc}	40.51 ± 2.78^{ba}	33.97 ± 2.59^{c}	43.28 ± 2.50^{ab}
Peel	21.99 ± 0.86^{cbd}	22.33 ± 1.06^{bcd}	21.55 ± 1.32^{dc}	26.72 ± 1.18^{a}
Pulp	447.39 ± 13.75^{a}	492.76 ± 22.11^{a}	292.30 ± 14.24^{b}	221.52 ± 7.91^{c}
Ratio (%)				
Almond	1.94 ± 0.26^{dc}	4.39 ± 0.37^{b}	3.03 ± 0.25^{c}	6.38 ± 0.37^{a}
Peel	4.43 ± 0.20^{c}	3.86 ± 0.16^{c}	6.16 ± 0.41^{b}	9.07 ± 0.39^{a}

The means ± standard error on means assigned different letters on the same lines each parameter are significantly different at $p < 0.05$ according to the multiple comparison ANOVA test

Table 2. Biochemical composition (g/100 g of dry weight product) of mango almond and peel flours

		Amelie	***Kent***	***Keitt***	***Brooks***
Moisture (%)	Peel	7.16 ± 0.79^{abc}	5.90 ± 0.26^{c}	7.78 ± 0.26^{ab}	7.83 ± 0.07^{a}
	Almond	7.48 ± 0.28^{abc}	6.09 ± 0.11^{bc}	7.95 ± 0.29^{a}	7.65 ± 0.12abc
Crude protein	Peel	2.48 ± 0.00^{cd}	2.37 ± 0.00^{de}	1.81 ± 0.20^{e}	1.99 ± 0.13^{e}
	Almond	6.54 ± 0.05^{a}	4.92 ± 0.07^{ab}	4.76 ± 0.18^{bc}	4.77 ± 0.05^{bc}
Crude fat	Peel	1.31 ± 0.00^{g}	2.79 ± 0.01^{de}	1.59 ± 0.43^{fg}	2.36 ± 0.08^{ef}
	Almond	9.51 ± 0.09^{cd}	11.87 ± 0.45^{ab}	10.75 ± 0.90^{bc}	13.45 ± 0.60^{a}
Crude fibre	Peel	9.52 ± 0.03 ^{a}	8.84 ± 0.00^{b}	9.97 ± 0.00^{a}	9.05 ± 0.21^{b}
	Almond	7.67 ± 0.19^{c}	6.37 ± 0.01 ^{cd}	5.42 ± 0.34^{de}	3.63 ± 0.36^{e}
Total ash	Peel	2.86 ± 0.00^{de}	4.02 ± 0.27^{ab}	4.25 ± 0.05^{a}	3.90 ± 0.18^{abc}
	Almond	3.05 ± 0.07^{cd}	2.81 ± 0.34^{de}	3.10 ± 0.15^{bcd}	1.99 ± 0.08^{e}
pH	Peel	3.64 ± 0.25^{cd}	3.55 ± 0.44^{d}	4.92 ± 0.02^{bc}	4.94 ± 0.55^{bc}
	Almond	4.85 ± 0.53^{bcd}	5.54 ± 0.03^{ab}	5.76 ± 0.18^{a}	5.63 ± 0.00^{a}
Acidity (meq-g/100g)	Peel	0.48 ± 0.07^{bc}	0.62 ± 0.057^{ab}	0.37 ± 0.06^{cd}	0.31 ± 0.10^{cde}
	Almond	1.10 ± 0.15^{a}	0.25 ± 0.01^{de}	0.21 ± 0.02^{ef}	0.089 ± 0.01^{f}
Vitamin C (mg/100gFM)	Peel	268.65 ± 0.58^{b}	269.04 ± 1.00^{b}	307.67 ± 0.06^{a}	117.54 ± 0.45^{cd}
	Almond	304.85 ± 0.52^{ab}	65.28 ± 0.28^{e}	118.22 ± 0.91^{c}	90.15 ± 0.02^{de}
Reducing sugar (g/l)	Peel	8.70 ± 0.07^{a}	7.26 ± 0.01^{cd}	7.39 ± 0.03^{bc}	7.62 ± 0.02^{ab}
	Almond	2.27 ± 0.07^{g}	2.56 ± 0.02^{fg}	5.15 ± 0.01^{de}	4.76 ± 0.01^{ef}
Total carbohydrates (by difference)	Peel	83.83 ± 0.03^{a}	81.98 ± 0.26^{bc}	82.38 ± 0.64^{b}	82.70 ± 0.17^{ab}
	Almond	73.22 ± 0.07^{e}	74.04 ± 0.23^{de}	75.96 ± 1.22^{cd}	76.16 ± 0.67^{cd}

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

Table 3. Mineral content of varieties mangoes almond and peel flour

		Amélie	*Kent*	*Keitt*	*Brooks*
Micro elements					
Cu (µg/100g DM)	Peel	0.52 ± 0.044^{a}	0.41 ± 0.02^{ab}	0.40 ± 0.01^{ab}	0.59 ± 0.06^{a}
	Almond	0.39 ± 0.01^{ab}	0.37 ± 0.04^{b}	0.37 ± 0.02^{b}	0.38 ± 0.03^{b}
Fe (µg/100g DM)	Peel	1.65 ± 0.02^{cde}	2.08 ± 0.08^{a}	2.21 ± 0.36^{a}	1.94 ± 0.14^{ab}
	Almond	1.32 ± 0.00^{e}	1.89 ± 0.17^{abc}	1.66 ± 0.03^{bcd}	1.47 ± 0.05^{de}
Mn (µg/100g DM)	Peel	0.92 ± 0.01^{a}	0.86 ± 0.02^{a}	0.92 ± 0.04^{a}	0.89 ± 0.08^{a}
	Almond	0.90 ± 0.05^{a}	0.95 ± 0.06^{a}	0.87 ± 0.01^{a}	0.87 ± 0.10^{a}
Zn (µg/100g DM)	Peel	0.51 ± 0.01^{a}	0.32 ± 0.01^{bc}	0.29 ± 0.06^{c}	0.44 ± 0.03^{ab}
	Almond	0.56 ± 0.06^{a}	0.31 ± 0.03^{bc}	0.26 ± 0.00^{c}	0.45 ± 0.05^{ab}
Macro elements					
K (mg/100g DM)	Peel	1549.43 ± 2.00^{ef}	1573.53 ± 0.48^{de}	1883.65 ± 0.23^{a}	1684.85 ± 0.14^{ab}
	Almond	1617.66 ± 1.44^{bc}	1582.59 ± 1.53^{cd}	1502.18 ± 2.52^{g}	1507.21 ± 1.73^{fg}
Ca (mg/100g DM)	Peel	910.93 ± 2.55^{g}	988.76 ± 0.50^{ef}	1127.68 ± 0.08^{bc}	1204.45 ± 0.33^{ab}
	Almond	915.66 ± 0.10^{fg}	1064.82 ± 1.00^{cd}	1034.03 ± 1.91^{de}	897.44 ± 0.51^{a}
Mg (mg/100g DM)	Peel	231.65 ± 1.21^{cd}	195.91 ± 0.54^{fg}	164.87± 0.09^{g}	257.46 ± 0.58^{a}
	Almond	243.81 ± 0.72^{ab}	206.92 ± 1.45^{de}	202.55 ± 2.44^{ef}	235.60 ± 1.19^{bc}
Na (µg/100g DM)	Peel	0.45 ± 0.05^{abc}	0.44 ± 0.01^{abc}	0.45 ± 0.06^{abc}	0.49 ± 0.05^{a}
	Almond	0.40 ± 0.02^{abc}	0.38 ± 0.02^{c}	0.45 ± 0.00^{ab}	0.40 ± 0.01^{bc}
P (µg/100g DM)	Peel	0.011 ± 0.00^{ab}	0.007 ± 0.00^{bc}	0.007 ± 0.00^{bc}	0.006 ± 0.00^{c}
	Almond	0.008 ± 0.00^{ab}	0.013 ± 0.00^{a}	0.013± 0.00^{a}	0.008 ± 0.00^{ab}

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

Results have shown that the peels and almonds of *Kent*, *Amelie*, *Brooks* and *Keit*t mangoes varieties are good sources of carbohydrate.

The pH and acidity index of the flours of the Amélie and Kent varieties are not significantly different. The *Keitt* and *Brooks* results were similar. The lowest pH and acidity index obtained were 3.55 ± 0.44 (flour of *Kent* peels) and 0.08 ± 0.01(flour of *Brooks* almonds), respectively.

Almond flours of the mango varieties studied have shown higher vitamin C ranking from 117.54 ± 0.45 to 307.67 ± 0.06 mg/100g FM than those of the peels (65.28 ± 0.28 - 304.85 ± 0.52 mg/100g FM), with an exception for the *Amelie* variety flours.

It also appeared that total titratable acidity content was lower than that reported for mango almond flours of five varieties (9.33 - 19 meq/100g) [27].

The pH is the sign of the acidity or alkalinity of the flour and affects largely its performances during its use in the food system. Results show that the level of pH for all of mango peel and almond flour remains lower than 6. This report is comparable with that of Okpala et al. [28] and higher than the values reported by Touré et al. [3] regarding the flours of cashew apple (3.80 ± 0.75), mango peel (3.7 ± 0.14) and kernel (4.30 ± 0.38). It was observed in this study that the reducing sugar content of mango peels flour is also higher than value of 1.64 to 4.9% in reports from Diomandé et al. [27].

3.3 Minerals Content of Flours

Mean concentrations of Ca and K present in all varieties (Table 3) tended to build up higher content of these metals. Contrarily, P has been identified to be the only mineral under experimentation that the whole mangoes studied accumulated least.

The concentration of Fe, Zn, Mn, and Cu was found to be lower in mangoes as compared each other. However, no significant difference could be observed for Mn and Zn regardless almond and peel flour of mangoes collected from the whole varieties (Table 3). Furthermore, a maximum concentration of Fe was recorded in mangoes flour whatever the parts studied. Currently, a wide ratio of Ca and P is considered acceptable in dairy cattle ration. However, it is recommended that the Ca: P ratio in the dairy cattle ration should be less than 7 (NRC 2001). In the present study, Ca/P ratio in all varieties was considerably high due a highest amount of Ca (897.44 ± 0.51 - 1204.45 ± 0.33 mg / 100 g) contrasted by significantly lowest P content (0.008 ± 0.00 - 0.013 ± 0.00 µg / 100 g). These results suggest that when these varieties make a significant part of the animal ration, supplementation of P will be required for proper utilisation of Ca and P [22]. Other important resource of these flours is the highest level of potassium (1549.43 ± 2.00 to 1883.65 ± 0.23; 1502.18 ± 2.52 to 1617.66 ± 1.44, peels and almonds respectively). It has known that K is an essential mineral, which plays major roles for the resting membrane potential and the intracellular osmolarity. In addition, for several years, it has been known that potassium also affects endothelial and vascular smooth muscle functions and it has been repeatedly shown that an increase in potassium intake shifts blood pressure to a more preferable level [29].

4. CONCLUSION

Flours contained considerable amounts of carbohydrate, fibre, crude protein, vitamin C. Other than that, it also contained good amounts of calcium, magnesium, and potassium, this being one of those found in the highest proportion. Waste products such as peel and almond of mango fruits, could be used as food by-products, which could help to overcome industrial contamination and food insecurity within the juice and canning industries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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