GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

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Physicochemical and nutritional characterization of flours from cashew apple, Kent mango peelings and kernel almonds collected in Korhogo city (Northern Ivory Coast)

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GSC Biological and Pharmaceutical Sciences, 2023, 22(01), 048–055

Publication history: Received on 20 November 2022; revised on 01 January 2023; accepted on 03 January 2023

Article DOI: https://doi.org/10.30574/gscbps.2023.22.1.0502

Abstract

Present study aims to valorize agricultural by-products which are cashew apple, Kent mango peelings and kernel almonds from Korhogo (Northern Côte d'Ivoire). After sampling, sun-drying and milling of these by-products, the physicochemical and nutritional parameters of flours obtained were determined with focused on food use. For physicochemical properties, moisture contents are respectively 25.33±0.33%, 5.44±0.19% and 14.55±0.19% with dried cashew apple, mango almonds and peelings. pH values are respectively 5.00±0.00, 3.39±0.24 and 3.94±0.00 while ash contents are 2.41±0.14%, 2.41±0.14% and 5.41±0.14%. As for nutritional proprieties of dried cashew apple, mango almonds and peelings contents are respectively 14.86±0.08%, 4.85±0.12% and 3.54±0.02% (protein), 5.18±0.18%, 19.46±0.14% and 3.92±0.06% (lipids), 52.20±0.24%, 67.83±0.44% and 72.38±0.23% (total carbohydrates). These mineral contents are respectively 192±0.00 mg/100g, 361.9±0.04 mg/100g and 203.4±0.02 mg/100g (calcium), 321.5±0.01 mg/100g, 214.5±0.02 mg/100g and 263.4±0.01 mg/100g (magnesium), 7.7±0.00 mg/100g, 3±0.00 mg/100g and 8.8±0.02mg/100g (iron). The respective amino acid and vitamin contents of dried cashew apple, mango almonds and peelings are 4165.25±5.10 mg/100g, 1907.5±2.85 mg/100g and 1561.84±1.52 mg/100g (lysine), 159±0.00 mg/100g, 323.01 mg/100g and 16.63±0.01 mg/100g (arginine), 335.74 mg, 434.52 mg and 310.8 mg (vitamin A), 707.13 mg, 790.88 mg and 299.54 mg (vitamin B2). These interesting physicochemical and nutritional characteristics of flours from cashew apple, mango almonds and peelings give these potentialities use in food and dietary fields.

Keywords: Mango; Cashew apple; By-products; Characterization; Korhogo; Ivory Coast

1. Introduction

Fruits have always been part of the daily human diet and constitute one of the essential elements of the diet. They also contribute to the social well-being and health of populations [1]. Fruit (fresh or processed) is an important source of nutrients. The isolation and characterization of these compounds is a very current research topic. Several studies now suggest the choice of processing them into ingredients that can be incorporated into various food and non-food products

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[2,3]. 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 [4]. Global production was estimated at about 48.3613 million tons in 2017, allowing mango to rank fifth in global fruit production after citrus, grapes, bananas and apples [5]. In Côte d'Ivoire, production was 150.000 tons with an estimated export of 32.400 tons or 21.6% in 2017. This makes mango the third largest export fruit and Côte d'Ivoire the third largest export country after Brazil and Peru [6]. Post-harvest losses were estimated at around 45% of production in 2017 [6]. This constitutes a loss of income for producers and exporters. In addition, mango by-products cause hygiene and sanitation problems in the vicinity of dried mango companies. However, these by-products contain high levels of various health-promoting substances, such as phenolic compounds, carotenoids, vitamin C and food fibers [7,8].

Cashew nut (*Anacardium occidentale*) production in Côte d'Ivoire has intensified in recent years, from 235.000 tons in 2006 to 738.000 tons in 2018 [9]. Apples represent 9 to 10 times the weight of the nut, or about 7 million tons of cashew apples [10]. They are an invaluable source of nutrients. Indeed, they are very rich in vitamin C, polyphenolic compounds and have a very diverse carotenoid profile [11, 12, 13]. In Côte d'Ivoire, almost all of this cashew production is abandoned at the harvest site, as are the residues obtained after juice extraction. However, the cakes contain macromolecules (cellulose, hemicellulose, lignin) that have remarkable functional properties, non-fibrous carbohydrates and proteins [14].

Despite some work carried out by [7] on characterization of some parameters, mango and cashew apple by-products are not valorized in Côte d'Ivoire.

The objective of this study is to valorize these different by-products mango peelings and kernel almonds from dried mango factories and cashew apples orchards around of Korhogo city (northern Côte d'Ivoire) in the food and dietary fields. Therefore, the aim is to evaluate physicochemical and nutritional characteristics of flours produced with these by products.

2. Material and methods

2.1. Materials

2.1.1. Biological material

The biological material used in this study consists of mango peelings and kernel almonds of Kent variety purchased from dried mango factory COBEKO (Cooperative Ben n'gnon of Korhogo) and cashew apples from orchards around the city of Korhogo.

2.1.2. Chemical reagents

The reagents and chemicals used in this work are of analytical grade. Sodium hydroxide, phenolphthalein, methyl red and bromocresol green were obtained from Sigma-Aldrich (France). Amino acid and vitamin standards were purchased from Merck. The solvents, consisting of methanol, hexane, sulphuric acid and hydrochloric acid, were obtained from Sharlau (Spain).

2.2. Methods

2.2.1. Sample processing

Cashew apples were harvested from the orchards during cashew season. They were washed with distilled water and pressed to remove juice. The oilcakes was sun dried at 32 - 35°C for 10 hours a day during 10 days. The dry oilcakes were crushed and sieved (10µm) and finally flour packed in plastic jars. The mango peelings and kernel were collected from the dried mango factory namely COBEKO (Cooperative Ben n'gnon of Korhogo). The peelings were washed to eliminate pulp residues and sun dried at 32 - 35°C for 10 hours a day during 14 days. After drying, they were crushed and sieved (10µm) and the flour packed in plastic jars. As for the mango kernels, after washing, the almonds were removed from their shells, then cut into cubes and finally sun dried at 32 - 35°C for 10 hours a day during 8 days. The dried almonds were crushed, sieved (10µm) and the flour stored in plastic jars.

2.2.2. Determination of physicochemical parameters

The physicochemical parameters of flours from cashew apple, mango peelings and almonds were determined according to [15]. Moisture was determined by placing a capsule containing 10 g of flour in an oven (Memmert, Germany) at 105°C for 24 hours. For pH and acidity, 10 g of flour was homogenized in 100 mL of distilled water. The resulting mixture was filtered through whatman filter paper (No. 4) and the pH was determined by dipping the electrode of the pH meter (Hanna, Spain) into the filtrate. As for the acidity, 10 mL of filtrate was titrated with a 0.1 M NaOH solution in the presence of phenolphthalein. The ash was obtained by incinerating 5 g of flour in a muffle furnace (Pyrolabo, France) at 550°C for 24 hours. After 24 hours and cooling in a desiccator, the ash was weighed.

2.2.3. Determination of nutrient parameters

Protein and lipid of flours from cashew apple, mango peelings and almonds were determinate using method of [**15**]. Proteins were obtained by mineralizing 1 g of flour in the presence of a pinch of mineralization catalyst (Selenium + Potassium Sulphate) and 20 mL of concentrated H_2SO_4 in a digester (Buchi) at 400 °C for 2 hours. After cooling to room temperature, the mineralization was adjusted to 100 mL with distilled water and finally the distillate was recovered in 20 mL boric acid containing the mixed indicator (Methyl Red + Bromocresol Green). The distillate is titrated with a 0.1 N sulphuric acid solution until it turns from green to orange. For the lipids, 10 g of flour was placed in a cellulose extraction cartridge and then placed in the Soxhlet tank. The oil extraction was performed with a solvent reflux system using 300 mL of n-hexane. After 7 h of extraction, the solvent (n-hexane) was recovered using a rotary evaporator (HEIDOLPH, Germany) and the lipid content was determined. Total carbohydrates were determined according to the calculation method recommended by [**16**]. This method takes into account moisture, fat, protein and ash content. Carbohydrates (%) = 100 - (P (%) + L (%) + C (%) + H (%)). The determination of minerals was done according to the method described by CEAEQ (2013) using argon plasma ionizing source mass spectroscopy (ICP-MS). 0.25 g of flour ash was homogenized in 10 mL of a mixture of hydrochloric acid (50%) and nitric acid (50%). The resulting mixture was filtered. The filtrate was made up to 100 mL with distilled water. Qualitative and quantitative determination was performed by spectrometry (ICP-MS) using mineral standard solution. The extraction of amino acids consisted in homogenizing 1 g of flour in 20 mL of 1 N hydrochloric acid is considered significant).

3. Results and discussion

Figure 1 show the fours from cashew apple, mango peelings and kernel almonds obtained after these agricultural by-products processing. Table 1 presents physicochemical parameters of these flours. The results show moisture contents, pH and titratable acidity of these flours are statistically different. Moisture and pH contents ranged from 5.44±0.19 to 25.33±0.33% and from 3.39±0.64 to 5.00±0.00 respectively. Mango almonds flour have the lowest moisture and pH values (5.44±0.19% and 3.39±0.24) followed by those of mango peelings (14.55±0.19% and 3.94±0.00) and cashew apple (25.33±0.33% and 5.00±0.00). These contents are different from those of Touré et *al*. (2020) [7] in mango peelings flour (10.53±0.35% and 3.70 ±0.14) and kernel almonds flour (11.91±0.15% and 4.30 ±0.38). Also, with [17] in cashew apple (9.29±0.07% and 4.23 ±0.01) from Brazil.

a. Flour of cashew apple b. Flour of mango peelings c. Flour of mango kernel almonds

Figure 1 Flours of agricultural by-products processing

This difference in moisture could be due to the drying time. Mango kernel almonds and peelings flours with a moisture content of less than 15% could be preserved for a long time, unlike cashew apple flour. Indeed, the low moisture content of mango kernel almonds and peelings flours and their acidity do not flavor development of microorganisms that generally determine shelf life of products [18]. The microorganisms are then in a metabolic and physiological state where most of the degradation reactions flavored by chemical and enzymatic reactions are slowed down [18]. Regarding ash, content of mango peelings flour (5.41±0.14%) differs statistically from that of mango almonds (2.41±0.14%) and cashew apple (2.41±0.14%). The ash contents of peelings and kernels flours are higher than those of [7] in flour from peeling (3.71±0.43%) and kernels (1.87±0.45%) in Korhogo. On the other hand, the ash content of cashew apple is lower than that of [19] in cashew apple pulp dried in Yamoussoukro. This difference could be due to the low moisture content of our samples resulting in a concentration of some constituents [20].

Table 1 Physicochemical parameters of cashew apple, mango peelings and almonds flours

Parameters	Mango Almonds	Mango peelings	Cashew apple
Humidity (%)	5.44±0.19[c]	14.55±0.19[b]	25.33±0.33[a]
pH	3.39 ±0.24[c]	3.94±0.00[b]	5.00±0.00[a]
Titratable Acidity (meq/100g)	0.36 ±0.02[a]	0.28±0.03[b]	0.07±0.01[c]
Ashes (%)	2.41±0.14[b]	5.41±0.14[a]	2.41±0.14[b]

Values in table are means of three tests, affected by the standard deviations. The statistical differences between these mean values at the 95% level of confidence are indicated on the same line by the different letters a, b and c in superscript.

The nutrient parameters of different flours are presented in Table 2. The contents of protein, fat and total carbohydrates are statistically different. The protein content varies between 3.54±0.02 and 14.86±0.08%. Cashew apples (14.86±0.08%) have the highest content, followed by almonds (4.85±0.12%) and finally peelings (3.54±0.02%). These contents are much lower than those of [7]. Indeed, this author reveals values ranging from 18.45±0.71 to 19.17±0.41%. Dried cashew apple could be considered as a protein source as it has a content higher than 12% [21]. The dried cashew apple could therefore be used as a food supplement in the preparation of infant porridges. With regard to lipid content, the kernel (19.46±0.14%) could be considered as a source of lipids, in contrast to the peelings (3.92±0.06%) and the dried apple (5.18±0.18%). The lipid contents in peelings and dried apple are comparable to maize, whose lipid fraction is between 3 and 5% [22]. Biochemical characterization of these lipid fractions could open up avenues of exploitation in food and cosmetics. Although the total carbohydrate content of our samples is lower than that of starch products with a carbohydrate base of more than 70% [23], they can be considered as significant sources of carbohydrates. Peelings, almonds and cashew apple could provide energy for various activities such as growth, fattening and lactation of ruminants.

Table 2 Nutrient parameters of different flours

	Kent Almond	Kent Peel	Cashew apple
Protein (%)	4.85±0.12[b]	3.54±0.02[c]	14.86±0.08[a]
Lipids (%)	19.46±0.14[a]	3.92±0.06[c]	5.18±0.18[b]
Total carbohydrates (%)	67.83±0.44[b]	72.56±0.23[a]	52.20±0.24[c]

Values in table are means of three tests, affected by the standard deviations. The statistical differences between these mean values at the 95% level of confidence are indicated on the same line by the different letters a, b and c in superscript.

Table 3 shows the mineral composition of cashew apple, mango almonds and peelings flours. The mineral contents of these flours are statistically different. Cashew apple, mango almonds and peelings are significant sources of macro elements. Calcium is major mineral involved in the formation of bones, teeth and muscle contraction. The calcium contents of mango almonds (361.9±0.04 mg/100 g), peelings (203.4±0.02 mg/100 g) and cashew apple (192±0.00 mg/100 g) are much lower than those (1313.76 to 4620 mg/100 g) determined by [24] in Côte d'Ivoire in leaves consumed in the West. The daily calcium and magnesium requirements, which are respectively 800 mg/day and 400 mg/day [25], could be covered to 1/4 for calcium and to 3/4 for magnesium by the different samples studied, which could be recommended as food for children and nursing mothers. Calcium and magnesium are minerals that help regulate blood pressure [26]. The phosphorus contents of the samples studied (1516.7±0.06 to 1841.6±0.07 mg/100 g) are much higher than those (470 and 650 mg/100 g) determined by [27] for 'kplala' and 'dah' leaves consumed in Cameroon. This mineral is essential for bone formation, vitamin D assimilation and cellular energy production [28]. Consumption of these samples would probably reduce the risks of arterial hypertension because the Na/K ratios are lower than 1 [25]. Sodium and potassium are respectively important intracellular and extracellular cations, which are involved in the regulation of plasma volume, acid-base balance, nerve and muscle contraction [29]. Regarding trace elements, the iron content of almonds (3.0±0.00 mg), peelings (8.8±0.02 mg) and cashew apple (7.7±0.00 mg) are higher than the recommended dietary allowance for men (1.37 mg/day) and women (2.94 mg/day) [30]. According to [31], iron plays many biochemical roles in the body, including the synthesis of hemoglobin. Thus, selected samples could be recommended in diets to reduce anaemia, which affects more than one million people worldwide [32]. The presence of zinc, selenium and manganese in the samples could give them added nutritional value as these trace elements are involved in development of brain activity and in the functioning of nervous system [33].

Table 3 Mineral composition of cashew apple, mango almonds and peelings flours

Minerals (mg/100g)		Mango almonds	Mango peelings	Cashew apple
Macro elements	Ca	361.90±0.04[a]	203.40±0.02[b]	192.00±0.00[c]
	Mg	214.50±0.02[c]	263.40±0.01[b]	321.50±0.01[a]
	P	1516.70±0.06[c]	1784.10±0.05[b]	1841.60±0.07[a]
	K	1412.50±0.04[b]	1964.10±0.06[a]	1021.40±0.03[c]
	Na	21.9±0.00[c]	43.4±0.00[b]	48.20±0.01[a]
	Na/K	0.01	0.02	0.04
Trace elements	Fe	3.00±0.00[c]	8.80±0.02[a]	7.70±0.00[b]
	Zn	8.40±0.00[a]	6.90±0.00[b]	5.10±0.00[c]
	Se	0.18±0.00[c]	0.27±0.00[b]	0.41±0.00[a]
	Mn	4.10±0.00[b]	7.10±0.00[a]	1.30±0.00[c]

Values in table are means of three tests, affected by the standard deviations. The statistical differences between these mean values at the 95% level of confidence are indicated on the same line by the different letters a, b and c in superscript.

Table 4 Amino acid profile of almonds, peelings and cashew apple flours

Amino acids (mg/100g)		Flour almonds	Flour peelings	Cashew apple
Non-essentials	Proline	190.12±1.77[b]	313.29±0.84[a]	nd
	Tyrosine	nd	56.99±0.00[a]	nd
	Arginine	323.01±0.00[a]	16.63±0.01[c]	159±0.00[b]
Essentials	Lysine	1907.5±2.85[b]	1561.84±1.52[c]	4165.25±5.10[a]
	Valine	nd	38.94±0.00[a]	nd
	Leucine	nd	78.58±0.50[b]	1187.31±4.05[a]
	Méthionine	nd	0.34±0.00[b]	206.55±1.00[a]
	Histidine	nd	387.98±1.10[a]	nd

Values in table are means of three tests, affected by the standard deviations. The statistical differences between these mean values at the 95% level of confidence are indicated on the same line by the different letters a, b and c in superscript.

The amino acid profile of the studied flours is presented in Table 4. The contents of these flours are statistically different. Concerning non-essential amino acids, proline was identified in mango almonds flour (190.12±1.77mg/100g) and peelings flour (313.29±0.84 mg/100g). Proline contents in almonds and peelings are much lower than those of [34] in baobab leaves (1760 mg). Proline is an amino acid involved in wound healing [35]. Tyrosine was identified in peelings (56.99±0.00 mg/100 g). This content is lower than that of [36] in the leaves of *Moringa oleifera* (1880 mg/100g). This low tyrosine content and its absence in mango almonds and cashew apple flours could be due to its destruction and instability in hydrochloric acid during its hydrolysis [37]. Arginine was identified in the different samples with contents varying from 16.63 to 323.01 mg/100g. It should be remembered that arginine is thought to reduce the risk of arterial hypertension and to protect the intestinal mucosa [38]. Five essential amino acids were detected, namely lysine, valine, leucine, methionine and histidine. Lysine is present in the different samples studied. Cashew apple flour (4165.25±5.10 mg) recorded the highest content, followed by mango almonds flour (1907.5±2.85 mg) and peelings flour (1561.84±1.52 mg). As lysine is the first limiting amino acid in pigs and the second in poultry [39], the samples studied could be used as a feed supplement in pig and poultry farming. In contrast to almonds, valine, leucine, methionine and histidine were identified in the mango peelings. Leucine and methionine are present in mango peelings and in cashew apple. The leucine and methionine contents in mango peelings (78.58±0.50 and 0.34±0.00 mg) and cashew apple (1187.31±4.05 and 206.55±1.00 mg) are lower than those of [40] in *Moringa oleifera* leaves (1950 and 350 mg). The low amounts observed could be due to their destruction in hydrochloric acid during their extraction. The presence of valine in mango peelings (38.94±0.00 mg) could allow a reduction in dietary protein and the achievement of essential amino acid balance [39].

Figure 2 shows the proportions of vitamins in flours studied. Vitamin A is present in all samples. Mango almonds (434.52 mg) contain the highest content followed by cashew apple (335.74 mg) and mango peelings (310.8 mg). These values are higher than those of [41] in leafy vegetables consumed in western Ivory Coast. Vitamin A is implicated in vision, growth and in reducing mortality from respiratory and diarrheal diseases [42]. Mango almonds, peelings and cashew apple could be used in infant porridges to cover the estimated vitamin A requirement of 4.8 mg/day [43]. Vitamin B2 in the samples studied ranged from 299.54 to 790.88 mg. Mango almonds (790.88 mg) had the highest value while peelings (299.54 mg) had the lowest. Cashew apples (707.13 mg) have an intermediate value. The studied samples have higher contents than those of [40] in Moringa leaves. The samples studied could be used as a supplement as vitamins B fight beriberi and are involved in amino acid and nucleic acid metabolism [43]. As for vitamin C, it is almost non-existent in mango almonds and peelings but is in low quantities in cashew apples (12.69 mg). These high losses of vitamin C are thought to be due to sun-drying which exposes the samples to heat, light and oxygen, all of which accelerate the oxidation of vitamin C [44]. As for vitamin E, it was only detected in the mango peelings (236.74 mg). The mango peelings could be used for supplementation of infant foods, which have a daily vitamin E requirement of 6 mg [45].

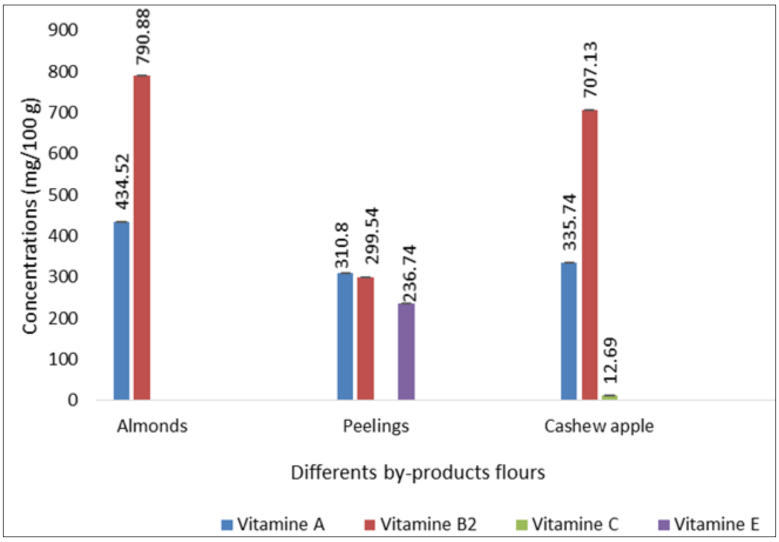

Figure 2 Vitamins contents of flours studied

4. Conclusion

The present study has highlighted the nutritional potential and physicochemical properties of mango almonds, peelings and cashew apple, three agricultural by-products in the city of Korhogo. These by-products contain significant quantities of nutrients. This richness is summarized in vitamins, proteins, lipids and minerals. Therefore cashew apple, mango almonds and peelings contain nutrients capable of covering the energy needs of humans and animals. For a better use of these agricultural residues, it would be desirable to combine them for a better coverage of energy needs.

Compliance with ethical standards

Acknowledgments

The authors are very thankful to COBEKO (Cooperative Ben n'gnon of Korhogo) for the collect of mango almonds and peelings.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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