Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Biochemical profile, nutrients and microbiological quality of mango epicarp and kernels

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ARTICLE INFO

Article History:

Received: 2025/03/27
Accepted: 2025/10/26

Keywords:

Mango,

pericarp,

almonds,

nutritional potential,

antioxidant

DOI: 10.22034/FSCT.22.164.167.

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ABSTRACT

Livestock production is faced with the problem of the high cost of imported concentrates. It is essential to look for alternative feed resources that will ensure the long-term sustainability of the sheep sector or provide solutions to adequately cover feed requirements and guarantee the development and sustainability of the sector. The aim of this study was to characterize mango pericarp and kernel, two mango by-products, with a view to their valorization in animal feed. Mature mangoes were collected in Korogho region. The pericarp and kernel were dried and ground for physico-chemical and microbiological analysis. The kernel and pericarp were rich in lipid and protein, potassium, calcium, phosphorus, iron, magnesium and zinc. The lipid and protein contents of the kernel were higher than those of the pericarp, with respective contents of 3.15 ± 0.01 g/100 g and 4.61 ± 0.05 g/100 g for the kernel, compared with 0.83 ± 0.02 g/100 g and 0.95 ± 0.01 g/100 g. Phenolic compounds were more concentrated in the almond. In addition, all the 100 mg/ml extracts, compared with the vitamin C extract, showed a percentage inhibition of less than 50%. Both samples showed almost similar antioxidant activity at. All the micro-organisms tested were absent from the samples, with the exception of aerobic mesophilic germs and Bacillus. However, the loads of these two micro-organisms were below the EC-2025 standard. Mango by-products could be used as an alternative in the formulation of animal feed.

1. Introduction

The combined effects of urbanization, population growth and new socio-cultural expectations are driving the emergence of a growing demand for animal products in southern countries, especially in cities [1]. Although West African countries account for 25% of the livestock population of sub-Saharan Africa (SSA), livestock production remains low. This results in low animal protein consumption of 8.5 to 9 g per capita per day against a recommendation of 20 g, and a significant increase in imports of milk and dairy products [2].

In developing countries, and particularly in Côte d'Ivoire, the problem of food security remains a concern for our leaders. While the country's success is based on agriculture, this is not the case for animal products. That's why the Ivorian government, through its Ministry of Animal Production and Fisheries, is taking a number of measures to tackle the shortage of animal proteins [3].

One of the main factors limiting livestock production in developing countries is the prohibitive cost of concentrated feed, which is essential if we want to improve the performance of farm animals. Intensifying livestock production in Africa is essential if we want to improve the nutritional status and food security of the population. Usually, the concentrated feed distributed to livestock consists of imported cereals, mainly maize [3]. Feed is the main constraint blamed for low livestock productivity. This is reflected in the low availability of feed, aggravated by competition between humans and livestock over cereals, their high cost and poor feeding practices [4].

However, for some time now, attempts have been made to recycle waste products in order to use them as food supplements or substitutes for animal feed or even human food. In view of its availability, cost and importance in the diets of many sub-Saharan countries, especially Côte d'Ivoire, mango, particularly the epicarp and kernel, could be used as an animal feed ingredient. In Côte d'Ivoire, annual production averages 150,000 tonnes per year [5]. Mango growing is one of the main sources of income in the northern regions of the country. Despite the nutritional and economic importance of mango and the food value placed on it by the population, its use is limited by enormous post-harvest losses. By way of illustration, we might mention the work of Kansci et *al* [6], who put the overall figure for mango post-harvest losses worldwide at around 80%. Huge volumes of mangoes infested by fruit flies are still lost in orchards, at processing plants and in marketing channels (local sales and exports). What's more, mango by-products such as pericarp (mango peel) and mango kernel are not used for human consumption. Adding value to these two by-products in animal feed would create added value for the mango sector and reduce food constraints by increasing the availability of feed for farm animals. The aim of this study was to characterise the pericarps and kernels of mango pits, two mango by-products, with a view to using them in animal feed.

2. MATERIALS ET METHODS

1. Material

The plant material consisted of the pericarp (skin) and kernel of the Palmer mango variety harvested in the town of Korhogo in northern Côte d'Ivoire, 564 km from the city of Abidjan (Figure 1). The Palmer variety was chosen because of its availability. This variety is not exported. It is used for local consumption.

A **B**

Figure 1: Pericarpe et amande du noyaux de mangues

A : pericarpe de mangue ; B :amande du noyaux de mangue

2. Methods

2.1 Sample size

The mangoes were collected in May 2023 in the north of Côte d'Ivoire, in Korhogo to be precise. Mature mangoes were collected by hand using an instrument (a blade mounted on a long handle). The collected mangoes were packaged in labelled and sealed boxes, then transported to the Nangui ABROGOUA University laboratory, where the experiments were carried out. A total of 80 mangoes were collected during one visit. In total, 2 trips were made and 160 mangoes were collected, divided into 2 boxes of 80 mangoes after 8 hours on the road.

2.2 **Flour preparation**

The production of peel and kernel flours was carried out using the method of Ekorong et *al*. [7]. The collected mangoes were washed and then rinsed with distilled water. The mangoes were peeled using a stainless-steel knife and pitted. The peelings were then stripped of their pulp and the kernels of their shells. The peels and kernels were cut into small pieces and dried in an oven (Venticell, Germany) at 50°C for 48 hours. The dried samples were then ground using an electric blender (Moulinex, France) to obtain the flours (Figure 2). The flours obtained were stored in airtight, opaque plastic containers in a freezer at -18°C for analysis.

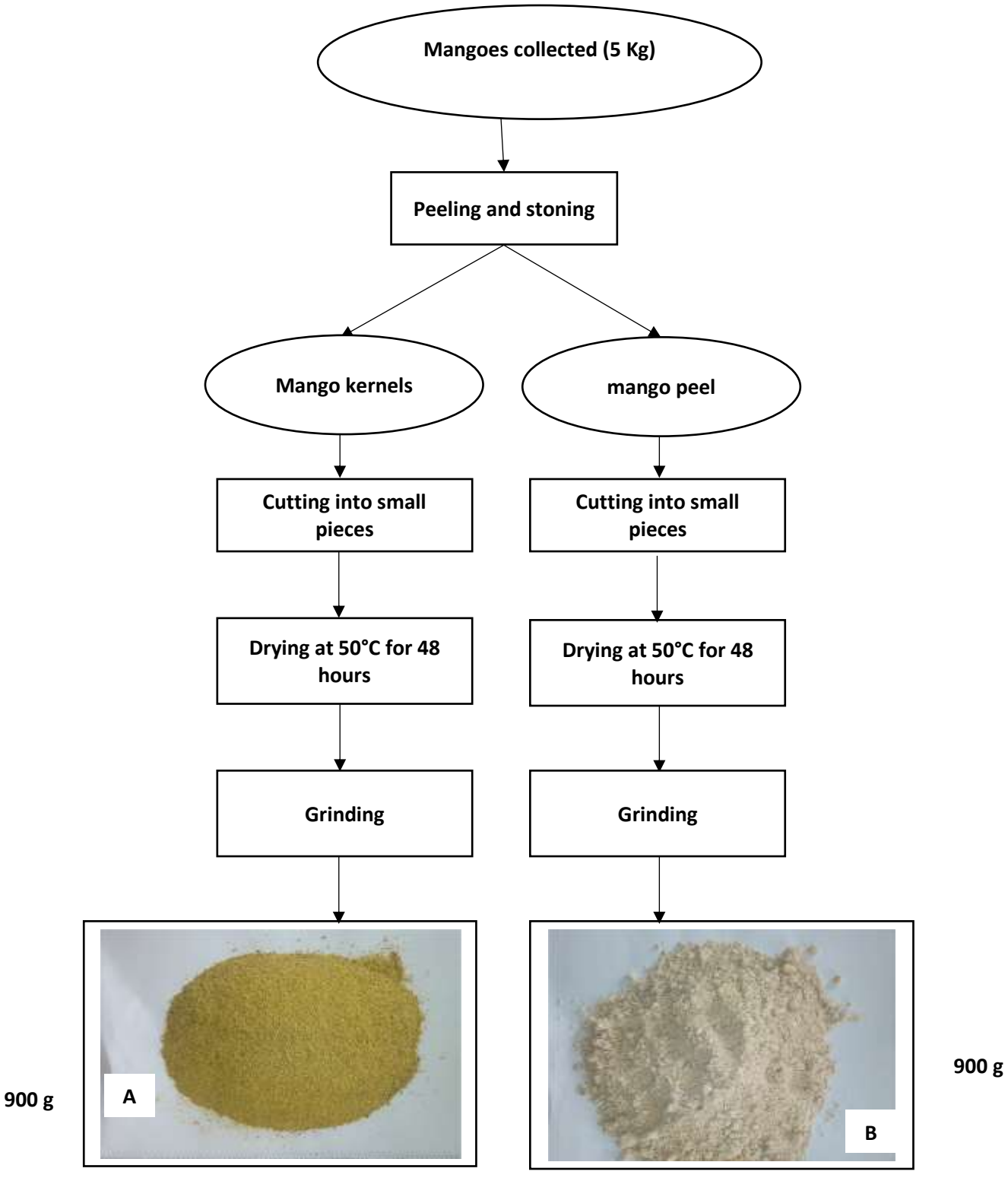

Figure 2: Production diagram for mango kernel pericarp meal and kernels

A: mango kernel flour, B: mango epicarp flour

2.3 Physical and biochemical analysis of mango kernel pericarp and kernel flours

2-3-1-Dry matter, moisture and ash content

The method used to determine dry matter and ash content is that described by AOAC [8]. It is based on dehydration by oven drying at 105°C. In fact, 5 grams of peel or almond meal were decanted into a glass capsule (clean and dry) whose vacuum mass was determined (m0). The capsule containing the sample (total mass m1) was then placed in an oven (Venticell, Germany) set at 105 ± 2°C for 24 hours. Once the capsule had been removed from the oven after 24 h, the entire assembly (sample + capsule) was weighed (m2) after cooling in the desiccator. For ash content, samples are placed in an automatically regulated muffle furnace and then incinerated at 550 ± 15 °C for 12 hours

2-3-2-Determination of reducing sugars

Quantification of reducing sugars is performed using the method of Bernfeld [9]. To 1 ml ethano soluble extract introduced into a test tube, 0.5 ml distilled water and 0.5 ml dinitrosalicylic acid (DNS) are added successively. The mixture was heated in a boiling water bath for 5 minutes and, after cooling, 5 ml distilled water was added. The optical density was read at 540 nm against the blank. A calibration range using a 0.1 mg/ml glucose standard solution was used to quantify reducing sugars. Tests were carried out in triplicate, and the average of the three assays was used.

2-3-3-Protein determination

Total protein was determined by assaying total nitrogen using the AOAC method [8]. The method comprises a mineralization phase, followed by a distillation phase and a sulfuric acid titration phase in the presence of a color indicator. A 5g mass of sample (me) is mineralized in a Kjeldahl matras (Bloc Digest 6, JP Selecta, Spain) at 400 oC for 2 hours with 20 ml of concentrated sulfuric acid in the presence of a pinch of mineralization catalyst (selenite + potassium sulfate). Once the tube has cooled to room temperature, the mineralization mixture is transferred to a 100 ml flask and made up to volume with distilled water. Next, 10 ml of the collected mixture is added to 10 ml of 40% NaOH solution, and placed in the distillation tank. The extension tube of the distillation condenser is then immersed in a beaker containing 20 ml boric acid spiked with a mixed indicator (methyl red + bromocresol green). Distillation was carried out for 10 minutes. The resulting distillate was extracted with a sulfuric acid solution (0.1N) until it turned from green to pink (V1). A blank test (V0) was carried out and the total protein content was determined by the following formula:

$$\textbf{Total protein}\ (\%) = \frac{(V_1 - V_0) \times 14 \times N\ X\ 6\ 25}{m_e}$$

(V1 – V0) × 14 × 6.25 × N Total protein (%) = Ms × 100

V0: Volume (mL) of sulfuric acid solution poured for blank test; V1: Volume (mL) of sulfuric acid solution poured for the test (sample); N : Normality of sulfuric acid solution: 0.1; Me : Mass (g) of sample; 6.25: Nitrogen-to-protein conversion factor

2-3-4-Lipid determination

Lipids are extracted using the SOXHLET method [10]. Total lipids are extracted by hexane (organic solvent) from the sample grind. Ten (10) g of ground sample were placed in a tared extraction cartridge, plugged with absorbent cotton and placed in the Soxhlet extractor. Total lipid extraction was performed using 300 ml hexane for 7 hours at boiling point. The hexane was then evaporated using a rotary evaporator. The tared extraction flask was then dried in an oven at 100°C for 20 min, and the whole (oil - flask) was weighed. Finally, the lipid content was determined using the following mathematical formula:

$$\textbf{Lipids}\ (\%) = \frac{(\mathbf{m} - \mathbf{m_0}) \times \mathbf{100}}{m_e}$$

M0: Mass (g) of empty flask; Me: Mass (g) of sample; M1: Mass (g) of the whole (flask + lipids) after evaporation.

2-3-5-Fiber determination

Fiber content was determined using the AOAC method [8]. Two (2) g of the sample were homogenized in 50 ml of 0.25N sulfuric acid and boiled for 30 min, after which 50 ml of 0.31N sodium hydroxide were added to the boiling mixture for a further 30 min. The extract was then hot-filtered through a funnel fitted with preweighed filter paper, leaving no residue. The residue was washed three times with hot distilled water, then oven-dried at 105°C for 8 hours. The filter paper was cooled in a desiccator and weighed. It was calcined at 550°C for 3 hours in a muffle furnace. The ash was weighed. Fiber content is given by the following formula:

$$\text{Fiber (\%)} = \frac{m - m}{m} \times 100$$

M1: Mass (g) of dried residue; M0: Mass (g) of ash obtained; Me: Mass (g) of sample.

2-3-6-Mineral determination

The macroelements (K, Ca, Mg, P) and microelements (Fe, Zn) were determined by atomic absorption spectrophotometry according to the AOAC digestion method [8]. using strong acids. Thus, a quantity of 0.5 g of ash from the drying of each of the crushed pineapple and cassava peel samples was dissolved in 31 ml of a mixture consisting of perchloric acid (11.80 mol/l), nitric acid (14.44 mol/L) and sulfuric acid (18.01 mol/l). The mixture obtained, well stirred under the hood, was heated on a hot plate until thick white fumes appeared. The reaction medium was then cooled on the bench for 10 min, then diluted in 50 ml of distilled water. It was brought back to the boil for 30 min, then cooled again under the same conditions. The mixture was then filtered on Whatman No. 4 filter paper and the filtrate obtained was made up to the mark of the flask (50 ml) with distilled water. The content of each mineral element was determined using a VARIAN AA.20 flame atomic spectrophotometer at a specific wavelength by comparison with standard solutions. The contents were expressed in mg/100 g of dry matter (DM). As for the mineral macroelement phosphorus (P), its contents in the dry ground materials of the differentsamples were estimated by direct spectrophotometry according to the method[11]. (Taussky and Shorr, 1953). Thus, a quantity of ash from each ground material was mineralized in a mineralizer and the mineralized material obtained was treated with the vanado-molybdic reagent. The optical density of the yellow solution obtained was read by spectrophotometer (PG Instruments, England) at 410 nm. The phosphorus (P) content was determined by comparison with a standard solution (0.136 g of potassium dihydrogen phosphate dissolved in a dilute solution containing 0.1 M nitric acid and 50 mL of distilled water.

2-3-7-Determination of polyphenols

The method of Singleton *et al*. [12]. (1999), using Folin ciocalteu, was used to determine polyphenols. The reagent is a mixture of phosphotungstic acid (H3PW12O40) and phosphomolybdic acid (H3PMo12O40). During oxidation of the polyphenols, it is reduced to a mixture of blue tungsten and molybdenum oxides. The coloration produced is proportional to the quantity of polyphenols present in the samples. One (1) ml of methanoic extract is introduced into a test tube. To the contents of the tube is added 1 ml of Folin ciocalteu reagent. The tube is left to stand for 3 min, then 1 ml of 20% (w/v) sodium carbonate solution is added. The contents of the tube are made up to 10 ml with distilled water. The tube is placed in the dark for 30 min and the OD is read at 725 nm against a blank. A standard range established from a stock solution of gallic acid (1 mg/ml) under the same conditions as the assay was

used to determine the amount of phenols in the sample.

2-3-8-Flavonoid determination

Flavonoids were assayed using the method described by Meda *et al*. [13]. According to the principle, flavonoids react with aluminum chloride in the presence of potassium acetate to give a yellow complex whose intensity is proportional to the quantity of flavonoids present in the medium. A volume of 0.5 ml of methanolic extract is introduced into a test tube. To the contents of the tube are successively added 0.5 ml distilled water, 0.5 ml 10% (w/v) aluminum chloride, 0.5 ml 1 M potassium acetate and 2 ml distilled water. The tube is left to stand for 30 min in the dark, and the optical density (OD) is read at 415 nm against a blank. A standard range established from a stock solution of quercetin (0.1 mg/ml) under the same conditions as the assay was used to determine the amount of flavonoids in the sample.

2-3-9-Determination of antioxidant activity by DPPH

The method used is that of Blois [14] with slight modifications. DPPH was solubilised in absolute ethanol to obtain a solution with a concentration of 0.03 mg/ml. Different concentration ranges of each extract were prepared with the same solvent (100 mg/ml, 50 mg/ml, 25 mg/ml, 12.5 mg/ml, 6.25 mg/ml, 3.125 mg/ml, 1.5625 mg/ml). 1 mL of extract solution to be analysed and 2 mL of DPPH solution were added to dry sterile tubes. After shaking, the tubes were placed in a dark place for 30 minutes. The absorbance of the mixture was measured at 517 nm against a blank consisting of (2 ml DPPH solution + 1 ml absolute EtOH). The positive reference control used was ascorbic acid (vitamin C) prepared under the same conditions as the samples.

The percentage of DPPH inhibition (PR) was calculated using the formula :

$$\mathbf{PR}\ (\%) = \left(\mathbf{1} - \frac{\mathbf{Ae}}{\boldsymbol{Ab}}\right) \times \mathbf{100}$$

Ae: sample absorbances, Ab: blank absorbances

4. Microbiological analysis

Microbiological analysis to prepare the mother suspensions for the samples, 10 g of each sample was mixed with 90 mL of sterile Buffered Peptone Water (BPW). One (1) mL of each stock suspension was aseptically removed and mixed with 9 mL sterile EPT in a test tube. This mixture was homogenized and a 10-1 suspension obtained. Using the same technique, subsequent dilutions were made to 10-5 dilution in accordance with NF EN ISO 6887-V08-010-6 (2013). Aerobic mesophilic germs (AMG) bacteria were counted on PCA agar (Plate count Agar; Oxoïd LTD, Basingstore Hamsphire, England) in accordance with NF V08 051, 1999. The detection and enumeration of Staphylococcus aureus was carried out on Baird Parker agar according to the method of Capita *et al*. [15]. Presumptive colonies of Staphylococcus aureus were either shiny black, whole, convex, surrounded by clear zones extending into the opaque medium, or shiny black, whole, convex, with no well-defined clear zone. The culture medium used for Bacillus enumeration was Mossel agar as described by Mossel *et al.* [16]. Lactose-bile agar with crystal violet and neutral red (VRBL agar) was used for coliform enumeration in accordance with NF ISO 4832 July 1991. RAPID' E. coli agar was used for the detection and enumeration of Escherichia coli in accordance with NF ISO 16140, 2003. Presumptive Escherichia coli colonies are purple to pink. Chloramphenicol Sabouraud agar (Fluka, Bochemica 89579, Sigma-Aldrich 28 Chemie GmbH, India) was used for yeast and mould enumeration in accordance with NF ISO 6611, 1996. Clostridium were enumerated in the mass using tryptone sulfite neomycin agar (TSN, BioMérieux, France) by the method of Harmon *et al*. [17]. Salmonella was detected

using the method described by Hendriken [18].

2-5-Statistical analysis

Means and standard deviations were calculated using Excel 2016. Statistical analyses were carried out using R.3-01 software on the results of physical, biochemical and microbiological of the samples. This software was used to carry out one-factor analyses of variance (ANOVA 1), using Tuckey's test at a significance level of 5% to highlight statistical differences between the means obtained.

3. Results

1. Physicochemical composition of mango pericarp (skin) and kernel flour

Table 1 presents the physico-chemical characteristics of mango peel and kernel. The dry matter content was 89.98 ± 0.02% and 90.07 ± 0.52% for the kernel and skin respectively, while the moisture content was 10.02 ± 0.1% for the kernel and 9.93 ± 0.52% for the mango skin. However, the differences between these parameters were not significant at the 5% level. With regard to ash content, the results showed a significant difference between the samples. The kernel (1.64 ± 0.06%) was richer in ash than the skin (1.58 ± 0.08%).

Table 1: Physicochemical composition of mango pericarp (skin) and kernel flour

Parameters	PAM	PPM
Dry matter (%)	89.98 ± 0.02[a]	90.07 ± 0.52[a]
Moisture content (%)	10.02 ± 0.1[a]	9.93 ± 0.52[a]
Ash content (%)	1.64 ± 0.06[a]	1.58 ± 0.08[b]

The values represent the means and standard deviations of three replicates. For each line of the table, values that do not have the same letter are significantly different ($p < 0.05$). PAM: mango almond flour, PPM: mango pericarp flour.

2. Chemical and nutritional composition of pericarp flour (skin) and mango kernel

The biochemical parameters of mango peel and kernel flours were determined and are presented in Table 2. The results obtained show that the lipid and protein contents of the kernel are higher than those of the skin, with respective contents of 3.15 ± 0.01 g/100 g and 4.61 ± 0.05 g/100 g for the kernel compared with 0.83 ± 0.02 g/100 g and 0.95 ± 0.01 g/100 g for the skin. The carbohydrate content observed in the peel and almond flours varied from 80.45 ± 0.03 to 86.46 ± 0.52 g/100g, giving them energy values ranging from 375.87 ± 0.24 to 357.78 ± 2.05 Kcal/100g DM. The lowest values were recorded for almonds. Fibre content and reducing sugar content were lower in the kernel (0.14 ± 0.00 g/100g and 1.86 ± 0.006g/100g) than in the skin (0.14 ± 0.01 g/100g and 2.89 ± 0.02). The differences observed for the same parameter in the two substrates (peel or almonds) were significant at the 5% threshold.

Table 2: Chemical and nutritional composition of pericarp flour (skin) and mango kernel

Parameters	PAM	PPM
Proteins (g/100 g)	3.15 ± 0.01[a]	0.83 ± 0.02[b]
Lipids (g/100 g)	4.61 ± 0.05[a]	0.95 ± 0.01[b]
Carbohydrate (g/100 g)	80.45 ± 0.03[b]	86.48 ± 0.52[a]
VE (Kcal/100g)	375.87 ± 0.24[b]	357.78 ± 2.05[a]

Reducing sugar (g/100 g)	1.86 ± 0.006^{b}	2.89 ± 0.02^{a}
Fiber (g/100 g)	0.14 ± 0.01^{b}	0.24 ± 0.02^{a}

The values represent the means and standard deviations of three replicates. For each line of the table, values that do not have the same letter are significantly different ($p < 0.05$). PAM: mango almond flour, PPM: mango pericarp flour. Ve: calorific value

3. Mineral content of pericarp flour (skin) and mango kernel

Table 3 shows the mineral contents expressed in mg/100 g of dry matter of the mango samples. The results show that potassium, calcium, phosphorus, iron, magnesium and zinc are more abundant in the mango skin than in the kernel, with respective contents of 45.76 ± 0.7 (mg/100 g), 33.043 ± 0.9 (mg/100 g), 0.78 ± 0.01 (mg/100 g), 2.02 ± 0.02 (mg/100 g), 19.26 ± 0.1 (mg/100 g) and 0.25 ± 0.01 (mg/100 g). The differences observed for the same parameter in the two substrates (peel or almonds) were significant at the 5% threshold, with the exception of Zinc content.

Table 3: Mineral content of pericarp flour (skin) and mango kernel

Parameters	PAM	PPM
K (mg/100 g)	68.67 ± 0.01^{a}	45.76 ± 0.7^{b}
Ca (mg/100 g)	6.487 ± 0.04^{b}	33.043 ± 0.9^{a}
P (mg/100 g)	0^{b}	0.78 ± 0.01^{a}
Fe (mg/100 g)	0.280 ± 0.06^{b}	2.02 ± 0.02^{a}
Mg (mg/100 g)	8.59 ± 0.02^{b}	19.26 ± 0.1^{a}
Zn (mg/100 g)	0.18 ± 0.02^{a}	0.25 ± 0.01^{a}

The values represent the means and standard deviations of three replicates. For each line of the table, values that do not have the same letter are significantly different ($p < 0.05$). PAM: mango almond flour, PPM: mango pericarp flour.

4.Phytochemical content of pericarp flour (skin) and mango kernel

The polyphenol and flavonoid contents of the mango skin and kernel samples are presented in Table 4. The polyphenol content is estimated at 5583.84 ± 0.02 µg/100g and 3038.38 ± 0.03 µg/100g for the mango skin and kernel samples respectively. Flavonoid levels were 2025.49 ± 0.09 µg/100g for the almond samples and 2272.53 ± 0.08 µg/100g for the peel samples. The differences observed for the same parameter in the two substrates (peel or almonds) were significant at the 5% threshold.

Table 4: Phytochemical content of pericarp flour (skin) and mango kernel

Products	Total polyphenols (µg/100g)	Total flavonoids (µg/100g)
PAM	5583.84 ± 0.02^{b}	2025.49 ± 0.09^{a}
PPM	3038.38 ± 0.03^{a}	2272.53 ± 0.08^{b}

The values represent the means and standard deviations of three replicates. For each column in the table, values that do not have the same letter are significantly different ($p < 0.05$). PAM: mango almond flour, PPM: mango pericarp flour.

Antioxidant activity of pericarp flour (skin) and mango kernel

All the extracts at 100 mg/mL, compared with the vitamin C extract, showed a percentage inhibition of less than 50%. The two samples (kernel flour and pericarp) showed almost similar antioxidant activity whatever the concentration, ranging from 100 to 1.56 mg/mL (Figure 3).

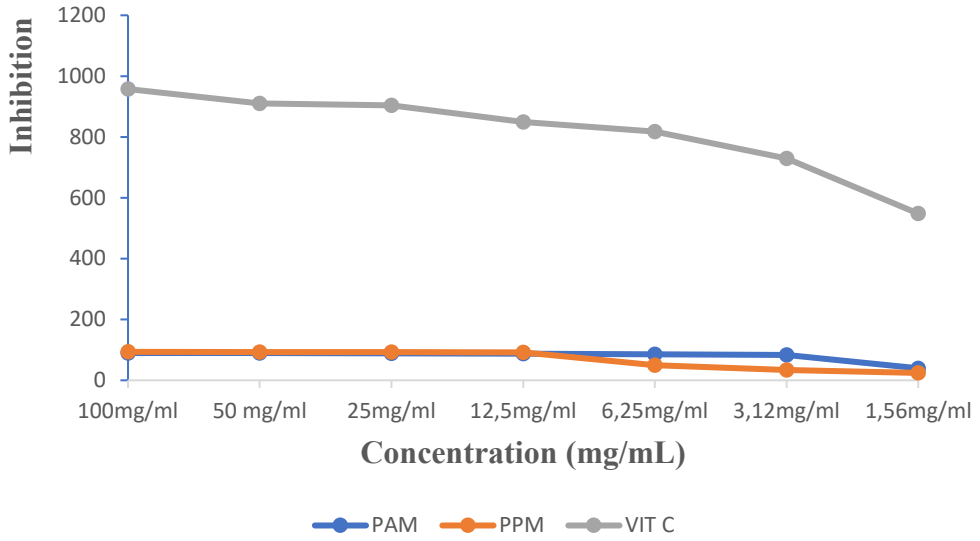

Figure 3: Antioxidant activity of pericarp flour (skin) and mango kernel

PAM: mango almond flour, PPM: mango pericarp flour , Vit C: Vitamin C

6.Loading of microorganisms in mango kernel and pericarp flour

Whatever the product (almond flour, pericarp flour), it was contaminated with mesophilic aerobic bacteria, Bacillus. Mesophilic aerobic germ loads ranged from (1±0.1)102 CFU/g (almond flour) to (2.3±2.1)102 CFU/g (pericarp flour). Bacillus loads ranged from 101a CFU/g in kernel flour to (0.8±0.1)101 CFU/g in pericarp flour). The differences observed in Mesophilic aerobic germ and Bacillus loads were not satisfactory at the 5% threshold. All the samples analysed were not contents coliforms, enterobacteria, E. coli, Clostridium Perfringens and salmonella. The results are presented in Table 5.

Table 5: Loading of microorganisms in mango kernel and pericarp flour

Germs	Kernel flour	Pericarp meal
AMG (CFU/g)	(1±0.1) 10^{2a}	(2.3±2.1)10^{2a}
Total Coliforms (CFU/g)	< 1	< 1
Fecal Coliforms	< 1	< 1
Staphylococcus aureus (CFU/g)	< 1	< 1
Molds (CFU/g).	< 1	< 1
Bacillus(spores) (CFU/g).	10^{1a}	(0.8±0.1) 10^{1a}
Enterobacteria (CFU/g).	< 1	< 1
E. coli (CFU/g).	< 1	< 1
Clostridium Perfringens (CFU/g).	< 1	< 1
Salmonella (CFU/g).	Abs	Abs

The values represent the means and standard deviations of three replicates. For each column in the table, values that do not have the same letter are significantly different ($p < 0.05$).

4. Discussion

The aim of this study was to characterize the pericarps and kernels of mango kernels, two mango by-products, with a view to their use in animal feed. The results showed that, in terms of the physico-chemical characteristics of mango peel and kernel, the moisture content was relatively low for all the samples analyzed. These recorded moisture levels are an important asset for the long-term preservation of these flours, with a reduced risk of microbial growth [19]. According to Aryee *et al.* [20], moisture content is a very important parameter in flour storage, since a moisture content above 12% favors the growth of microorganisms. All the microorganisms we looked for were absent from the samples, except for aerobic mesophilic germs and Bacillus. However, the loads of these two microorganisms were low. This absence could be due to processing during flour production. During flour production, both the kernel and the pericarp are dried at 50°C. At high temperatures, the vegetative forms of microorganisms are destroyed [21]. Ash content was in the order of 1.64 ± 0.00 for the kernel and 1.58 ± 0.00 for the peel. A high ash content is more often attributed to the mineral richness of foods. It could therefore be said that mango kernel is richer in minerals than mango skin. Furthermore, the mineral profile of mango skin and almond showed that potassium, calcium, phosphorus (P), iron, magnesium and zinc are more abundant in mango skin than in almond skin. Minerals play an essential role in animal health. They are involved in many bodily functions such as enzymatic reactions, energy production, transmission of nerve impulses, and multiple biological reactions. Iron is an essential constituent of hemoglobin and is also involved in numerous enzymatic reactions [22]. Iron is involved in the formation of hemoglobin, myoglobin and numerous enzymes. It is also essential for a large number of metabolic reactions. Calcium and phosphorus ensure bone rigidity and promote growth in weaning infants. Zinc, along with iron, is one of the most concentrated minerals in the brain. The concentration of iron and zinc (Zn) obtained in mango peel samples may be sufficient to meet the recommended requirements for livestock. However, the effectiveness of Zn use would depend on its bioavailability and interaction with other mineral elements. As for Magnesium (Mg), its dietary availability for livestock is clearly affected by other dietary components, particularly potassium. High dietary levels of potassium and nitrogen will inhibit rumen uptake of Mg. Calcium (Ca) and soluble carbohydrates can respectively increase and decrease the dietary Mg requirements of cattle, while high dietary P levels appear to lower Ca and Mg requirements [23]. In terms of biochemical composition, the lipid and protein contents of the kernel are higher than those of the skin, with respective contents of 3.15 ± 0.01 g/100 g and 4.61 ± 0.05 g/100 g for the kernel, compared with 0.83 ± 0.00 g/100 g and 0.95 ± 0.00 g/100 g respectively. These results indicate that kernel meals can be used in animal feed as lipid and protein supplements to other sources such as soybean meal and fish meal [24].

The carbohydrate content of pericarp (80.45 ± 0.03 g/100g) and almonds (86.46 ± 0.52 g/100g) gives them energy values of 375.87 ± 0.24 and 357.78 ± 2.05 Kcal/100g DM respectively. Yatnatti *et al* [25] have shown that mango by-products are an alternative energy source to be valorized. In addition, mango by-products can be used as livestock feed [26] due to their higher energy value than corn silage, and could partly replace energy concentrates in animal diets [27].

Total fiber and sugar content are lower in the kernel (0.14 ± 0.00 g/100g and 1.86 ± 0.00

g/100g) than in the pericarp (0.14 ± 0.00 g/100g and 2.89 ± 0.02). Fiber regulates intestinal transit and captures some lipids and carbohydrates, helping to regulate blood sugar levels and prevent excess cholesterol. Thanks to their high degree of saturation, these fibers have a positive effect on overweight and metabolic diseases [28].

Polyphenol contents are estimated at 5583.84 ± 0.00 µg/100g and 3038.38 ± 0.00 µg/100g for almond and mango pericarp samples respectively. Flavonoid levels were 2025.49 ± 0.00 µg/100g for the almond samples and 2272.53 ± 0.00 µg/100g for the pericarp. Polyphenols have anti-inflammatory, urinary antiseptic, hepatic, protective, antithrombotic and anticarcinogenic effects [29]. These compounds are known to inhibit or slow down the oxidation of a substrate, and play an important role in the body. What's more, the polyphenol-rich nature of the samples could help to eradicate the free radicals in the body that are sometimes at the root of many metabolic diseases. For Mbaïhougadobé *et al.*, [30], total phenols and flavonoids are capable of effectively reducing the damage caused by free radicals. All extracts at 100 mg/ml, compared with the vitamin C extract, showed a percentage inhibition of less than 50%. Both mango samples (kernel and pericarp) showed almost similar antioxidant activity at all concentrations, from 100 to 1.56 mg/mL. Traber *et al*. [31] demonstrated that the antioxidant activities of a plant extract are closely associated with its phytochemical makeup and its total amount of phenolic compounds.

5. Conclusion

The aim of this study was to characterize mango pericarps and kernels, two mangoes by- products, with a view to their valorization in animal feed. The results of the analyses showed that the lipid and protein content of the kernel is higher than that of the pericarp. Moreover, potassium, calcium, phosphorus, iron, magnesium and zinc are more abundant in the mango pericarp than in the kernel. The flours contained only aerobic mesophilic germs and Bacillus at reduced loads. Phenolic compounds are more concentrated in the kernel. As a result, mango by-products can be used in the formulation of animal feeds.

6. Acknowledgements

The authors gratefully acknowledge all the mango producers. The authors have not received any direct funding

7. References

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