Journal Pre-proof

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PII: S0023-6438(22)01024-6

DOI: https://doi.org/10.1016/j.lwt.2022.114089

Reference: YFSTL 114089

To appear in: *LWT - Food Science and Technology*

Received Date: 8 May 2022

Revised Date: 4 October 2022

Accepted Date: 13 October 2022

CRediT authorship contribution statement

Rutelene da Cruz Pinheiro: Investigation (equal); Methodology (equal); Formal analysis (equal). Lina Fernanda Ballesteros: Investigation (equal); Methodology (equal); Formal analysis (equal); Conceptualization (equal). Miguel Ângelo Cerqueira: Investigation (equal); Methodology (equal); Formal analysis (equal); Conceptualization (equal). Antonio Manoel da Cruz Rodrigues: Investigation (equal); Methodology (lead). Formal analysis (equal); Conceptualization (equal). José Antônio Couto Teixeira: Investigation (equal); Methodology (lead); Formal analysis (equal). Conceptualization (lead). Luiza Helena Meller da Silva: Funding (lead). Conceptualization (lead); Formal analysis (lead); production of original draft (lead).

Peach palm (*Bactris gasipaes* Kunth) **and mammee apple** (*Mammea americana* L.) **seeds: properties and potential of application in industry**

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ABSTRACT

Peach palm (*Bactris gasipaes* Kunth) and mammee apple (*Mammea americana* L.) are fruits found in Latin America, North of South America (Amazonia) and Western India, traditionally consumed with the disposal of the seeds. These materials presented high caloric value, essential amino acids, phosphorus, magnesium, potassium, calcium, iron, zinc, absence of anti-nutritional compounds, and low concentration of phytates and tannins. The morphological characteristics indicated the presence of starch granules in the mammee apple seeds, which contain 21% of this polysaccharide. The oil from peach palm seeds is rich in lauric acid (49.82%) and myristic acid (21.53%) and the seeds may contain galactomannans in their structure (mannose/glucose 4:1). The mammee apple seed oil showed palmitic acid (30.75%), oleic acid (36.12%), and linoleic acid (25.89%).

The characteristics of these seeds justify their application, converting residues into new materials with possible application in the food industry and other industrial sectors.

Keywords: Chemical composition; Polysaccharides; Seeds; Peach palm; Mammee apple.

1. Introduction

Investigations on fruit processing residues as new materials can modify the economic potential of underexplored raw materials such as peach palm [known in Portuguese as *pupunha*] (*Bactris gasipaes* Kunth) and mammee apple (*Mammea americana* L.) are fruits belonging to the *Palmae* and *Clusiaceae* families, respectively, which can be found at distinct locations in Latin America, North of South America and Western India (Clement et al., 2004; Mourão, & Beltrati, 2000). In Brazil, they are found in the Amazon region and are traditionally consumed by the population, with the disposal of the seeds. The peach palm is a yellow fruit of different sizes with a fibrous pulp, rich in carotenoids, and may or may not have seed. It is marketed in bunches and cooked in water and salt (Bolanho, Danesi, & Beléia, 2014). Mammee apple is a voluminous fruit with a thick gray skin, yellow pulp, rich in sugars and fibers (Mourão, & Beltrati, 2000), and number of seeds varying from one to four, which are rich in coumarins (Yang, Jiang, Reynertson, Basile, & Kennelly, 2006).

The consumption of peach palm and mammee apple pulp is of great economic interest due to its nutritional characteristics and health benefits (Bolanho, Danesi, & Beléia; 2014; Péroumal, Adenet, Rochefort, Fahrasmane, & Aurore, 2017; Lemus, Smith-Ravin, & Marcelin, 2021). As they consist of carbohydrates, lipids, proteins, minerals, and compounds with antioxidant properties, the seeds have been the target of research in several sectors for their use in food, pharmaceutical products and cosmetics (Chiocchetti, Fernandes, Bacchi, Pazim, Sarriés, & Tomé, 2013; Silva, Pinheiro, Paula, Fernandes, &

Rodrigues, 2018). The use of seeds to obtain polysaccharides has been explored with promising results (Peng, Peng, Xu, & Sun, 2012; Bouaziz et al. 2016; Wang, Liu, Wang, Yu, Xu, & Yang, 2017).

Other seeds such as quinoa and amaranth are also known for their nutritional value and functional properties, being rich in proteins, amino acids and minerals; sometimes these fruits are included in the diet (Alvarez-Jubete, Wijngaard, Arendt, & Gallagher, 2010). However, although the seeds have health benefits, they can also cause adverse effects related to the presence of anti-nutritional factors which, depending on the concentration, can prevent the absorption of nutrients and micronutrients (Gemede, & Ratta, 2014). Compounds such as enzyme inhibitors, hemagglutinins, complexing agents with minerals, cyanogenic glycosides, and many others naturally present in vegetables, guide the method of preparation, as well as the indication of raw materials for human and animal consumption (Domodaram, & Parkin, 2007).

Published studies on peach palm plant by-products are focused on residues from heart of palm extraction, with few studies on this fruit seeds. On the other hand, mammee apple seeds are traditionally used as topical agents and in insecticidal preparations in producing regions (Giombelli, Iwassa, Silva, & Barros, 2020; Lemus, Smith-Ravin, & Marcelin, 2021). Although the studies on seed valorization are increasing, the definition of applications and ways of preparation must go beyond the nutritional value, covering the possible presence of anti-nutritional compounds, especially when these materials are not commonly used, such as peach palm and mammee apple seeds. Indications on the chemical and technological properties of Amazonian seeds, such as peach palm and mammee apple, may represent the generation of new opportunities for producing regions in addition to contributing to the reduction of solid waste. This research evaluated these seeds aiming to suggest alternatives for their technological application as a product and/or ingredient, based on characteristics of their composition, considering the indications of preparation and applications and valuing their composition.

2.Materials and methods

2.1. Materials

The peach palm and mammee apple fruits were purchased at the Ver-o-Peso market, located in the city of Belém, Pará, Brazil (latitude 01º27'21" South and longitude 48º30'16" West) during the harvest period (December-March for peach palm (Cymerys, & Clement, 2005), and June-December for mammee apple) (Valois, 2017). The fruits were sanitized with 100 mg L^{-1} sodium hypochlorite solution for 10 min, then peeled and pulped to obtain the seeds, which were separated and packed in plastic bags and stored at -18 °C until the time of analysis.

2.1.2. Flour seed preparation

To carry out the analyses, the seeds were thawed, split in half, and the endosperm was subjected to the drying process at 60 °C in an oven with air circulation (Ethik Tecnologic, 400-2ND) for 24 h, then ground in a mill (Cadence, MDR 302) and the granulometry was standardized in 16 mesh. Both types of flour obtained were placed in high density polyethylene plastic containers and stored at room temperature (25°C) until the time of analysis.

2.1.3.Reagents

All reagents used were of analytical grade. The glucose, arabinose, galactose, xylose, and mannose sugar standards were purchased from Sigma-Aldrich Traning Co Ltd.

2.2. Characterization of peach palm and mammee apple seed flours

The proximate composition of peach palm and mammee apple seed flour was determined according to AOAC (2005). The moisture content was determined in an oven at 105 ± 2°C (Method n. 925.09), lipids by Soxhlet using petroleum ether as solvent (Method n. 945.38), proteins (N x 6.25) by the Kjeldahl method (Method No. 992.23) and ash by incineration at 550°C (Method No. 923.03). Starch was determined in mammee apple seed flour according to AOAC method 12.043 (AOAC, 1975). The reducing sugar in the hydrolysate and non-hydrolyzed samples was determined by the Lane and Eynon method, which uses Fehling's solution A and B (IAL, 2004). Total starch was calculated by the difference between the sugar in the hydrolysate, multiplied by the factor of 0.9 and the sugar content in the sample before hydrolysis. Carbohydrates were obtained by difference and the total energy value was determined by the Atwater conversion factors, described by Osborne and Voogt (1978).

2.2.1 Total phenolic compounds

The concentration of phenolic compounds was determined by the Folin-Ciocalteu method (Xu, & Chang, 2009). Gallic acid was used for the calibration curve and the results were expressed in mg gallic acid equivalent (AGE) g^{-1} of sample.

2.2.2. Minerals

The determination of minerals was carried out according to AOAC methodologies (2005). Copper (Cu), selenium (Se), phosphorus (P), magnesium (Mg), and zinc (Zn) were analyzed by atomic absorption spectrometer (Shimadzu, AA 6300). Sodium (Na) and potassium (K) were determined using a flame photometer (Quimis, Q 398 M2).

2.3. Anti-nutritional factors

2.3.1. Trypsin inhibitors and α-amylase inhibitors

Trypsin and α-amylase inhibitors were determined according to the methodology of Arnon (1970), and Deshpande, and Salunkhe (1982), respectively. The absorbance reading of the trypsin inhibitory activity and α-amylase activity were performed in a spectrophotometer at 280 nm and 550 nm, respectively (Biospectro, BEL SP 2000). The results for α-amylase were expressed in units (U) corresponding to the formation of 1 μmol of reducing sugar per minute, and the results for the trypsin inhibitors were expressed as an increase of one absorbance unit at 280 nm per minute of digestion.

2.3.2. Phytic acid

The phytic acid concentration was determined according to the methodology described by Latta and Eskin (1980) and the DOWEX resin (1x2-200 ion-exchange resin) used according to Ellis and Morris (1986). The absorbance reading was performed at 550 nm and the results were expressed in mg $100g^{-1}$.

2.3.3. Tannins

The tannins were determined according to the AOAC methodology (2012) using tannic acid as a standard; the absorbance reading was performed at 760 nm and the analysis results were expressed in mg 100g-1. Biologically important tannins were evaluated according to the methodology described by Cabral, Peixoto Sobrinho, Amorim, and Alburquerque (2010).

2.3.4. *Hemagglutination capacity*

The hemagglutination capacity was determined according to the methodology described by Moreira and Perrone (1977). The results were analyzed for the presence or absence of agglutination.

2.3.5. Hydrocyanic acid

The presence or absence of hydrocyanic acid was evaluated by the Guignard test by using the plum seed as a standard, which contains cyanogenic glycosidic precursors of hydrocyanic acid in its composition (Araújo, 2011).

2.4. Amino acids

Amino acids were determined according to the methodology described by White, Hart, and Fry (1986) and Hagen, Frost, and Augustin (1989). Quantification was performed by multilevel internal calibration using alpha-aminobutyric acid (AAAB) as an internal standard. The results were expressed in g $100g^{-1}$ of protein.

2.5.Fatty acids

Fatty acids were determined according to the methodology of Rodrigues, Darnet, and Silva, (2010). Methyl esters (FAMEs) were detected in a gas chromatograph (Varian, CP 3380) equipped with a flame ionization detector with a capillary column 88 CP- Sil (60 m, internal diameter 0.25 mm, thickness 0.25 mm, Varian Inc., USA). The operating conditions were as follows: helium as carrier gas at a flow rate of 9 mL min^{-1}, FID detector at 250 °C, injector (split ratio 1: 100) at 245 °C and injection volume of 1 µL. The column temperature was programmed at 80 °C for 4 min, then increasing the rate by 4 $°C.min^{-1}$

until reaching 220 °C. The retention time and peak area were calculated by Varian 3.4.1 software and the results were expressed as total percentage of fatty acids.

2.6. Polysaccharides and lignin

Prior to the analysis of polysaccharides and lignin, the samples were subjected to extractive removal through the Soxhlet extraction system (Tecator, HT2, Netherlands), by using ultrapure water and absolute ethanol as solvents, as described by Sluiter, Ruiz, Scarlata, Sluiter, and Templeton (2008). Extractive-free samples were dried at 60 °C until constant weight and subjected to quantitative acid hydrolysis, following the methodology described by Sluiter, Hames, Ruiz, Scarlata, Sluiter, Templeton, and Crocker (2010). At the end of the hydrolysis, the acid-insoluble residue (Klauson's lignin) was quantified and the solution (liquid) resulting from the quantitative acid hydrolysis was used for the determination of monosaccharides and soluble lignin.

The monosaccharides resulting from the hydrolysis (glucose, arabinose, mannose, galactose, and xylose) were determined by high performance liquid chromatography (HPLC) using LC-10 A equipment (Jasco, Japan) and Meta Carb 87 P column (300 mm × 7.8 mm), as described by Mussatto et al. (2011). Acid-soluble lignin was determined by spectrophotometry at 280 nm (Jasco, V-560) (Mussatto, & Roberto, 2006).

2.7. Scanning electron microscopy

The images were obtained by using a digital scanning electron microscope - SEM (LEO-1430, Zeiss, Germany). The samples were metallized with gold and the coating time was 2.0 minutes. The analysis conditions for the secondary electron images were as follows: electron beam current = 90 μA, constant acceleration voltage = 10 kV, working distance = 15 mm. The images were captured and digitized.

2.8. Polysaccharide extraction process

Two processes of extraction of polysaccharides from seeds were evaluated: aqueous extraction and alkaline extraction. Before starting the extraction process, the whole and degreased samples (Soxhlet lasting 4 h using petroleum ether as solvent), underwent a pre-treatment, as proposed by Cerqueira et al. (2009), for the inactivation of enzymes and elimination of compounds of low molecular weight.

Aqueous extraction was performed according to the methodology of Cerqueira et al. (2009) with some modifications. The ethanol extracts obtained in the pre-treatment were decanted and distilled water was added to the precipitate in a proportion of 1:5 (w/v), which remained at rest for 24 h in a refrigeration chamber (4 ± 2 °C).

After 24 h, the solid fraction resulting from the extracts was kept for 12 h in ethanol (1:3 w/v) at 4 °C, and after centrifugation, ultrapure water (1:5 w/v) was added to the precipitate and kept at rest for 12 h; then, the mixture was stirred (200 rpm h^{-1}) at room temperature. A second wash was performed with the addition of ethanol (1:2 w/v) for 12 h, and distilled water 1:2 (w/v) was added to the precipitate. The extracts were frozen and lyophilized. For a better understanding, the polysaccharides resulting from whole seeds were coded as F1 and the polysaccharides obtained from the defatted seeds were coded as G1 (Fig. 1S).

The alkaline method to obtain polysaccharides was performed according to the methodology of Ballesteros, Cerqueira, Teixeira, and Mussatto (2015) with some modifications. In this procedure, only defatted seed samples were used (Soxhlet equipment lasting 4 h, using petroleum ether as solvent). With the exception of mammee apple seed samples, the same methodology described for the removal of extractives was used to remove lipids, due to the probable presence of starch in a higher proportion than cellulose and hemicellulose.

The samples were suspended in ethanol in a ratio of 1:3 (w/v) and heated at 70°C/15 min for enzyme inactivation. After removing the ethanol, 4 mol L^{-1} NaOH solution and 0.02 mol L^{-1} $NaBH_4$ solution (ratio of 67 mL for 10 g of sample) were added to the precipitate. The mixture was stirred and kept at 25 °C for 120 min, and the pH was adjusted to 5 by adding glacial acetic acid. After centrifugation, distilled water was added to the precipitate, which was lyophilized. This fraction was called Hemicellulose A (Hemi A) (Fig. 1S).

The supernatant resulting from the centrifugation was filtered and dialyzed at 4 °C with an 8000 Da membrane with several wash volumes of distilled water. After dialysis, the material retained in the membrane was frozen and lyophilized and this fraction was named Hemicellulose B (Hemi B). For each fraction obtained, the extraction yields were determined (Fig. 1S).

The polysaccharides obtained by the alkaline and aqueous processes from whole and defatted samples were submitted to quantitative acid hydrolysis, following the methodology described by Sluiter et al. (2010). The monosaccharides of hydrolysates obtained from the aqueous and alkaline extractions were determined by HPLC, LC-10 A equipment (Jasco, Japan), Meta Carb 87 P column (300 mm × 7.8 mm). The freeze-dried samples were analyzed as described by Ballesteros, Cerqueira, Teixeira, and Mussatto (2015), with the exception of the freeze-dried samples obtained from mammee apple seeds (Hemi A and Hemi B) for which, during sample preparation and filtration, the formation of a gel occurred due to the presence of starch, which made it impossible to determine the monosaccharides by HPLC. Therefore, the methodology of Leyva, Quintana, Sánchez, Rodríguez, Cremata, and Sánchez (2008) was used for determination of total sugars.

2.9. Statistical analysis

Peach palm and mammee apple seed flour samples were prepared in triplicate, as well as their analysis and extraction processes. The data were submitted to analysis of variance (ANOVA) and expressed as mean and standard deviation (SD). For all analyses, when a significant difference ($p < 0.05$) was detected in some parameter, Tukey's means test was applied to evaluate the difference between the samples (treatments).

3. Results and discussion

3.1. Composition and properties of mammee apple and peach palm seeds

The mammee apple and peach palm seed flours showed a high percentage of carbohydrates (>50 g $100g^{-1}$), with greater emphasis on the mammee apple seed (Table 1). The peach palm seed flour had a higher lipid content than mammee apple, reaching more than twice the value and being comparable to important oil seeds both from the Amazon and traditional raw materials for the extraction of oils and fats (Costa, Santos, Corrêa, & França, 2016; Almeida, Viana, Costa, Silva, & Feitosa, 2019; Absalome et al., 2020; Mohammed, Samir, Jassim, & Saeed, 2021; Menezes et al., 2022). The protein content of peach palm seed flour also exceeds the mammee apple in about three times and both are below the concentration range of whole wheat flour (Benayad, Taghouti, Benali, Aboussaleh, & Benbrahim, 2021). The starch content in mammee apple seed flour corresponds to less than 1/3 of the starch content of traditional flours, such as corn and wheat (Hoseney, 1994); however, when presenting this starch content, it stands out comparatively to peach palm flour, enabling to establish specific applications due to the lower fat content and the presence of starch.

Minerals, as well as proteins, reflect important differences between the evaluated seeds. Considering the determination of carbohydrates by difference, the carbohydrates stand for mammee apple and were investigated in the present work for both seeds. As for the caloric value, it reflects the composition and is above the range of whole wheat flour (Benayad et al., 2021), characterizing them as high-calorie materials.

Both types of flour showed high concentrations of phenolic compounds with 118.86 ± 0.02 mg GAE g^{-1} for peach palm flour and 2.29 ± 0.01 mg GAE g^{-1} for mammee apple flour, compared to whole wheat flour (0.51 mg GAE g^{-1}) (Benayad et al., 2021), and even to grape seed oil (0.059 to 0.116 mg GAE g^{-1}) (Bail, Stuebiger, Krist, Unterweger, & Buchbauer 2008), with peach palm seeds exceeding the total phenolic compounds of grape skin (20 mg GAE g^{-1}) (Milinčić et al., 2021).

Phosphorus was the predominant mineral in peach palm seeds, with 300 mg 100 g^{-1} (adult RDI – 700 mg). This type of seed also contains magnesium (176 mg.100 g^{-1}) (adult RDI – 260 mg), potassium (137 mg.100 g^{-1}) and calcium (92 mg.100 g^{-1}), in significant amounts. Mammee apple seed flour has proven to be a source of potassium (417 mg.100 g^{-1}) and calcium (124 mg.100 g^{-1}), with lower phosphorus (79 mg.100 g^{-1}) and magnesium (63 mg. 100 g^{-1}) compared to peach palm seed flour, which surpasses whole wheat flour in terms of content of these minerals (Banayad et al., 2021). Mineral intake is important for bone formation and muscle function (FAO/WHO, 2001). As the peach palm and mammee apple seed flours are rich in potassium, phosphorus, magnesium and calcium, they can contribute to the diet as sources of minerals.

Iron and zinc were also found in these types of flour in high concentrations, with 4.40 mg100 g^{-1} and 2.67 mg.100 g^{-1} for peach palm seed flour, and 4.56 mg.100 g^{-1} and 3.97 mg.100 g^{-1} for mammee apple seed flour, respectively. Chiocchetti et al. (2013) evaluated the nutritional quality of agro-industrial by-products and concluded that the concentration of minerals found in peels, bagasse and seeds was higher than in their pulps.

Silva et al. (2018) also reported high mineral concentrations in seeds of Amazonian fruits; these results are similar to those found in the flour types evaluated in this study.

Therefore, nutritionally, both types of flour had similar composition to seeds with high added value, such as quinoa and amaranth, as they have nutritional and antioxidant properties (Alvarez-Jubete, Wijngaard, Arendt, & Gallagher, 2010) and could be indicated to compose foods. However, other properties need to be investigated, such as the presence of anti-nutritional factors.

Trypsin inhibitors, α-amylase inhibitors, hemagglutinating activity and cyanogenic compounds were not detected in any of these types of flour (Table 2). These results are important and demonstrate the viability of flours for consumption, since the presence of anti-nutritional compounds in foods can compromise the absorption of nutrients and micronutrients (Gemede, & Ratta, 2014).

Small concentrations of phytates and tannins were detected in these flours, with 89.96 and 42.60 mg100 g^{-1} for the peach palm seed flour and 46.02 and 70.51 mg100 g^{-1} for the mammee apple seed flour. The phytate content is consistent with phosphorus concentration in peach palm flour; probably, most phosphorus is in the form of phytate. Tannins and phytates become harmful to health when consumed in high concentration, but on the other hand, they can have beneficial effects if ingested in small amounts and are related to a lower risk of cancer (Gemede, & Ratta, 2014). Widely consumed foods, such as cashew nuts, Brazil nuts, macadamia nuts, pistachios, almonds and walnuts, whose phytate concentrations ranged from 150 to 35 mg 100 g^{-1} (Venkatachalam, & Sathe, 2006) and are higher than those found in this study, may indicate that the concentrations of phytate and tannin in mammee apple and peach palm seed flours should not be an obstacle to consumption and studies for the elaboration of products. While the absence of α-amylase inhibitors may be positive, their presence could be of interest for applications in the development of drugs to control diabetes, which cannot be seen according to the results obtained for both studied seeds.

The mammee apple and peach palm seeds showed similar characteristics in relation to the percentage of insoluble lignin, remaining around 5% (Table 2). Seed polysaccharides differed in terms of monosaccharide composition. The mammee apple seed flour hydrolysate stood out for its high concentration of glucose (76%), which is a response to the presence of starch in mammee apple seeds (Mourão, & Beltrati, 2000). In contrast, the concentrations of xylose, galactose and mannose indicate the possible presence of galactomannans in peach palm seeds due to the mannose/galactose ratio around 4:1 (M/G).

Commercial galactomannans such as locust bean gum (*Ceratonia siliqua*), guar gum (*Cyamopsis tetragonolobus*), and *tara* gum (*Caesalpinea spinosa*) have a mannose and galactose ratio (M/G) of 3.5:1, 2:1 and 3:1, respectively (Prajapati et al., 2013). Therefore, peach palm seeds can be used in studies involving the investigation of galactomannans, because they have a M/G ratio similar to commercial gums, which may show their potential for use as a thickener.

This profile in monosaccharides contemplates the presence of a lignocellulosic, a fibrous structure in the peach palm seed meal, as it can be seen in the microstructure (Fig. 2S-A). On the other hand, for mammee apple seed flour the presence of starch, as the main polysaccharide, is confirmed both by the concentration of glucose resulting from hydrolysis of this polysaccharide and by the microstructure (Fig. 2S-B), where the starch granules stand out, opening a perspective for future studies on the properties of mammee apple seed starch.

The flours were evaluated for the amino acid profile of proteins (Table 3). Although the protein content in the flour samples is not high, both the peach palm and mammee apple flour had all the essential amino acids, especially lysine, valine, leucine, and cysteine.

The presence of these constituents enriches the nutritional value of the flours, and therefore, they can be added in the elaboration of food products. There is an emphasis on glutamic acid and arginine in peach palm seed flour. Faccin, Vieira, Miotto, Barreto, and Amante (2009) also found a high amount of glutamic acid in organic rice bran during the preparation of a nutritious rice drink, associating these two amino acids with important protective factors in neurodegenerative processes.

Saturated and monounsaturated fatty acids were found in mammee apple and peach palm seed flours (Table 3). In the oil extracted from peach palm seed, it is possible to observe the predominance of lauric acid (49.82 g $100g^{-1}$), myristic (21.53 g $100g^{-1}$) and oleic acid (12.05 g $100g^{-1}$). The fatty acids that make up the mammee apple seed oil are palmitic acid (30.75 g $100g^{-1}$), oleic (36.16 g $100g^{-1}$), and linoleic acid (25.89 g $100g^{-1}$).

The study of fatty acid composition provides information that serves to direct possible application of oils in different sectors, whether food or not. In this context, the mammee apple seed would be a source of oleic and linoleic acid, which are known for their beneficial health aspects, while the peach palm seed would be indicated for the extraction of lauric acid, which has been used as an antimicrobial agent (Skalicka-Wozniak, Los, Glowniak, & Malm, 2010).

Another fact that can also be observed is the similarity between the fatty acid composition of peach palm seed oil and the fatty acids contained in coconut oil (*Cocos nucifera* L.), mainly in relation to the reported lauric, myristic, oleic, and linoleic acids, according to Manivannan, Bhardwaj, Padmanabhan, Suneja, Hebbar, and Kanade (2018).

3.2. Polysaccharide extraction process

Polysaccharides extracted from mammee apple and peach palm seeds differ according to the previous removal of fat from the samples (Table 5). The analysis of monosaccharides indicated that FI fraction for peach palm seeds retained the highest concentration of mannose (10.39%), which directly reflected in the percentage of total sugars (16.09%). However, it was possible to observe that the removal of lipids from the samples (GI fraction) increased the extraction yield (lyophilized), with Y1 values of 76.81%. The same behavior was observed for the polysaccharides of mammee apple seeds, in which the removal of the lipid fraction from the samples influenced the percentages of glucose (49%) and total sugars (50.88%) for GI fraction. However, as verified in the evaluation of polysaccharides, mammee apple flour has glucose as the main monosaccharide, confirming that starch is the main polysaccharide found in this flour.

In the polysaccharides obtained by alkaline extraction (Table 6), it was possible to observe that Hemi B fraction had better yield of glucose and arabinose for the polysaccharides of peach palm seeds; however, mannose (13.94%) was retained in the Hemi A fraction. Ballesteros et al. (2015) studied the extraction of polysaccharides from spend coffee and concluded that mannose was the most difficult monosaccharide to extract, suggesting more severe treatments.

The alkaline extraction of polysaccharides from mammee apple seeds (Table 6) did not allow the identification of sugars by HPLC, due to gel formation during sample preparation. However, by the analysis of total sugars, it was possible to observe that Hemi A fraction retained the highest concentration of sugars (20,80%).

The yield and composition of the polysaccharides differed according to the seed and the type of extraction used. This behavior was already expected, since polysaccharides identified in seeds and other parts of plant cells may contain soluble and insoluble fractions in water, requiring different extraction methods (Peng, Peng, Xu, & Sun, 2012). Therefore, from the extraction methods suggested in this study, it was possible to observe that both aqueous extraction and alkaline extraction are viable to obtain polysaccharides from peach palm seeds, while the polysaccharides obtained from mammee apple seeds showed better yields through aqueous extraction. Technological applications for these extracted polysaccharides should be studied in future works. Mainly due to the behavior of aqueous and alkaline extraction on the mammee apple seed indicating a potential source of starch.

4. Conclusion

The mammee apple and peach palm seed flours differ in their composition; however, both had a chemical composition that supports future studies for their commercial applications.

As these are not commonly used raw materials and are currently considered waste, the absence of the main anti-nutritional compounds that would limit their consumption was demonstrated, such as: α-amylase and trypsin inhibitors, hemagglutinins, and cyanogenic compounds. The percentages of phytates and tannins are in the same concentration range of commercially valued raw materials.

Both flours had all essential amino acids. Peach palm flour stood out by the non-essential glutamic acid and arginine, which, despite the protein content, may justify its introduction in food formulations.

The peach palm seed flour results in a source of lipids in a higher level than the mammee apple seed flour. In addition, its fatty acids are distinguished with linoleic acid observed in both flours, emphasizing the highest concentration for mammee apple seed flour, which despite having a lower fat content, stands out for the presence of this fatty acid.

Minerals that are important for the diet are present in those flours, with great emphasis on phosphorus in peach palm seed flour and potassium in mammee apple seed flour.

As for the polysaccharides, the peach palm seed flour had glucomannans in addition to cellulose and hemicellulose, while in the mammee apple flour, starch is the main polysaccharide. A response consistent with the composition of the seeds was observed in the extraction processes studied. Also, the removal of fat from the samples is indicated for both alkaline and aqueous extraction. For mammee apple flour, aqueous extraction is more efficient, considering the effects of alkali on starch.

Acknowledgments

The authors would like to thank CAPES foundation for the financial support through the Doctoral Sandwich Abroad Program - PDSE (Process BEX 8229/14-7), CNPq (Process 308021/2015-0 and Process 477013/2013-9), Postgraduate Program - Graduate in Food Science and Technology from the *Universidade Federal do Pará*, University of Minho, Institute of Biological Science II of *Universidade Federal de Goiás*, and PROPESP UFPA (Pro-Dean of Research and Graduate Studies).

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary material

Supplementary data associated with this article can be found in the online version.

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Table 1

Composition of peach palm and mammee apple seed flours (dry basis).

	Seed flour	
	Peach palm fruit	Mammee apple
	Composition (g 100g^{-1})	
Moisture	3.12±0.22	3.79±0.08
Lipids	35.53±0.29	14.52±0.46
Proteins	9.19±0.10	3.62±0.24
Minerals	2.16±0.14	1.63±0.09
Total carbohydrates *	50.00	76.44
ETV (kcal 100 g^{-1})	556.53	450.92
Starch	n.d.	20.11±1.01
	Total phenolic compounds (mg g^{-1})	
	118.86 ±0.02	2.29±0.01
	Minerals (mg100g^{-1})	
Ca	92.00±0.56	124.00±0.98
P	300.00±0.36	79±0.42
K	137.00±0.34	417.00±0.49
Mg	176.00±0.17	63.00±0.14
Na	32.00±0.23	27.00±0.26
Fe	4.40±0.48	4.56±0.55
Cu	1.21±0.16	0.55±0.57
Mn	1.63±0.17	0.29±0.14
Zn	2.67±0.38	3.97±0.17
Se	n.d.	n.d.

Results expressed as mean and standard deviation (M ± S.D.); * Value obtained by the difference in the sum of the other nutrients; n.d.: not determined; d.b. - dry basis.

Table 2

Lignin, monosaccharides, and antinutritional factors in mammee apple and peach palm seeds.

	Peach palm	Mammee apple
	Lignin (g 100g^{-1})	
Insoluble lignin	5.82±0.30	5.04±0.09
Soluble lignin	1.36±0.03	1.81±0.03
	Monosaccharides (g 100g^{-1})	
Glucose	1.01±0.14	76.51±0.55
Xylose	10.05±0.22	7.53±0.22
Galactose	7.60±0.91	n.d.
Arabinose	n.d.	n.d.
Mannose	32.7±	n.d.
Man/Gal	4:1	n.d.
	Antinutritional factors	
Trypsin inhibitor	Absence	Absence
α-amylase inhibitor	Absence	Absence
Phytates (mg 100 g^{-1})	89.96±0.01	46.02 ±0.01
Tannins (mg 100 g^{-1})	42.60±0.01	70.51±0.02
Biologically important tannins	Presence	Presence
Hemagglutinating activity	Absence	Absence
Cyanogenic compounds	Absence	Absence

Results expressed as mean and standard deviation (M ± S.D.); n.d.: not determined.

Table 3

Amino acids in peach palm and mammee apple seeds (dry basis).

Amino acids	Peach palm	Mammee apple
	(mg g^{-1} of proteins)	
Essentials		
Cysteine (Cys)	3.20±0.01	1.70±0.01
Methionine (Met)	2.40±0.07	0.30±0.03
Valine (Val)	5.00±0.07	1.00±0.01
Isoleucine (Ile)	3.50±0.01	0.60±0.02
Leucine (Leu)	5.00±0.02	1.70±0.01
Tyrosine (Tyr)	2.50±0.07	0.40±0.03
Phenylalanine (Phe)	3.80±0.01	0.70±0.02
Histidine (His)	2.60±0.07	0.30±0.01
Lysine (Lys)	5.80±0.14	0.90±0.01
Threonine (Thr)	3.20±0.07	0.60±0.02
Not essentials		
Aspartic acid (Asp)	8.90±0.14	3.80±0.07
Proline (Pro)	3.50±0.07	0.80±0.01
Serine (Ser)	4.80±0.14	0.90±0.02
Glutamic acid (Glu)	17.60±0.42	5.00±0.14
Glycine (Gly)	4.10±0.07	0.90±0.02
Alanine (Ala)	5.40±0.07	1.20±0.01
Arginine (Arg)	20.20±0.28	9.20±0.14

Table 4

Mammey apple and peach palm seeds fatty acids.

Fatty acids	Peach palm	Mammee apple
	Fatty acids (g 100g^{-1})	
Saturated (SAFA)		
Caprylic (C 8:0)	2.08±0.01	0.03±0.01
Capric (C 10:0)	2.06±0.04	0.41±0.03
Lauric (C 12:0)	49.82±0.12	0.25±0.02
Tridecanoic (C 13:0)	0,06±0,05	0
Myristic (C 14:0)	21.53±0.19	0,62±0,04
Pentadecylic (C 15:0)	0	0
Palmitic (C 16:0)	5.84±0.21	30.75±0.09
Margaric (C 17:0)	0	0
Stearic (C 18: 0)	2.88±0.55	2.85±0.09
Monounsaturated (MUFA)		
Palmitoleic (C 16:1)	0	0.88±0.15
Oleic (C 18:1 n-9)	12.05±0.06	36.12±0.84
Polyunsaturated (PUFA)		
Linoleic (C 18:2)	3.56±0.63	25.89±0.14
α- linolenic (C 18:3)	0.10±0.07	0.39±0.02
ω-6/ω-3**	35.6	66.38

** ratio of linoleic (ω-6) and linolenic (ω-3) fatty acids.

Table 5

Monosaccharide composition and extraction yield of polysaccharides from mammee apple and peach palm seeds obtained by aqueous extraction.

Aqueous extraction								
	Monosaccharide composition					Total sugars (%)	Yield***	
Sample**	Glc	Xyl	Gal	Ara	Man		Y1	Y2
Peach palm								
FI	1.12±0.81[a]	0.22±0.28[a]	2.43±0.52[a]	1.93±0.21[a]	10.39±0.84[a]	16.09±0.09[a]	71.90	11.40
GI	0.55±0.21[a]	0.21±0.11[a]	1.55±0.48[a]	1.17±0.36[a]	6.25±0.92[b]	9.74±0.63[b]	76.81	7.48
Mammee apple								
FI	44.0±0.98[b]	n.d.*	0.63±0.11[a]	1.19±0.14[a]	n.d.	45.82±0.95[b]	95.84	43.91
GI	49.0±0.91[a]	n.d.	0.55±0.20[a]	1.17±0.75[a]	n.d.	50.88±0.94[a]	65.93	33.50

Results are mean of three different determinations ± standard deviation; *n.d.: not detectable; Different letters in the same column show a statistical difference ($p<0.05$), **FI: sample containing lipids; GI: defatted sample. ***Y1: total extraction yield, expressed as g lyophilized material per 100 g of the sample; Y2: yield of the amount of sugar extracted, expressed as g total sugar present in the lyophilized material per 100 g of the sample.

Table 6

Monosaccharide composition and extraction yield of polysaccharides obtained by alkaline extraction.

Alkaline extraction								
	Monosaccharide composition					Sugars (%)	Yield**	
Sample	Glc	Xyl	Gal	Ara	Man		Y1	Y2
	Peach palm							
Hemi A	0.11±0.03[b]	0.81±0.29[a]	0.84±0.33	n.d.*	13.94±0.63[a]	15.70±0.30[a]	68.45	10.74
Hemi B	0.85±0.11[a]	0.76±0.09[a]	n.d.	5.49±0.70	0.25±0.12[b]	7.36±0.57[b]	26.78	1.97
	Mammee apple							
Hemi A	n.d.	n.d.	n.d.	n.d.	n.d.	20.80±0.84[a]	85.92	17.87
Hemi B	n.d.	n.d.	n.d.	n.d.	n.d.	10.30±0.41[b]	5.91	0.60

*n.d.: not detectable; results shown as mean ± standard deviation; different letters in the same column show a statistical difference ($p<0.05$), **Y1: total extraction yield, expressed as g lyophilized material per 100 g of the sample; Y2: yield of the amount of sugar extracted, expressed as g of total sugar present in the lyophilized material per 100 g of the sample.

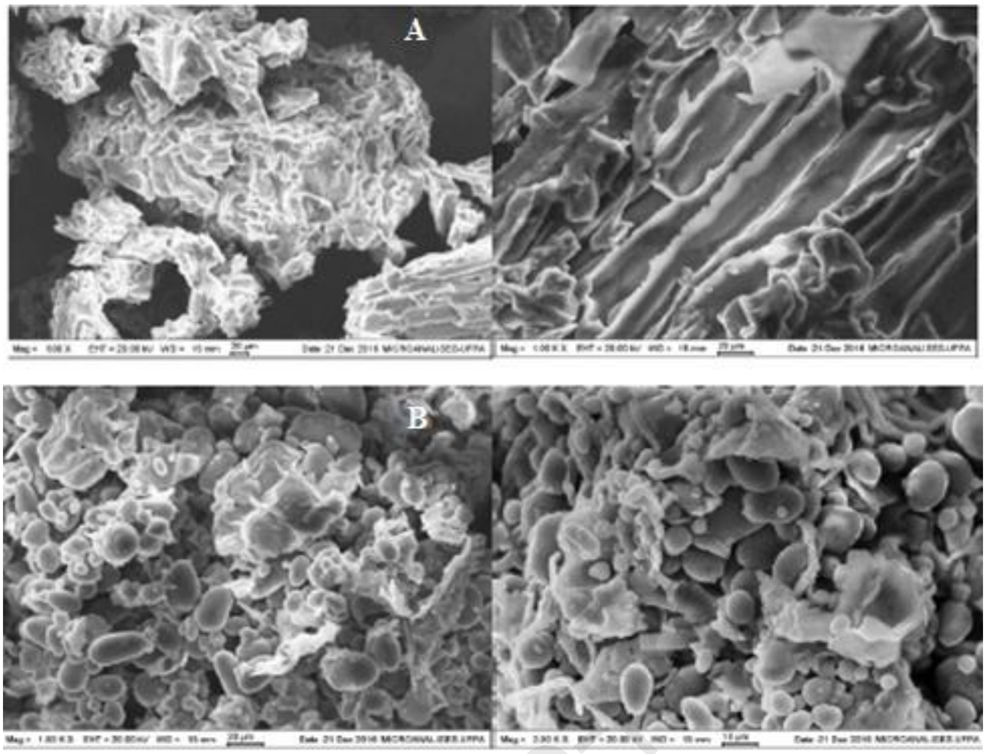

Fig. 1. Micrograph of peach palm seed flour (A) 500 x and 1000 x, and mammee apple seed flour (B) 1000 x e 2000 x.

Highlights

- Properties of *Bactris gasipaes* Kunth and *Mammea americana* L. seeds.
- Peach palm and mammee apple seeds from solid residue to potential raw material.
- Residual seeds from peach palm and mammee apple free of antinutritional compounds.
- Peach palm seed as source of galactomannans and mammee apple seed as source of starch.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: