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Nutritional properties of yellow mombin (*Spondias mombin* L.) epicarp flours by conventional drying and lyophilization

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Abstract

Yellow mombin (*Spondias mombin* L.) has an unusual aroma and slightly acidic flavor, which leads to the interest in its fresh consumption or industrial use, causing its epicarp (peel) to be discarded, which generates industrial residue. The nutritional value of fruit epicarp is almost always high and, in some cases, may be even higher than the that of the fruit itself. The objective of this study was to evaluate the flours produced from the epicarp of yellow mombin (*Spondias mombin* L.), through conventional drying and lyophilization. Contents of water, ash, lipids, proteins and minerals were analyzed and carbohydrate content and energy value were determined. Moisture content was below 8.87%, being within the acceptable limit. The flours showed high contents of ash, lipids and proteins, with values above 5.61, 7.76 and 11.90%, respectively. Fe, Zn and Mn contents were above the daily intake recommendation. The temperatures used to dehydrate yellow mombin epicarp did not cause nutritional alteration in the flours compared with the flour from the lyophilized epicarp.

Keywords: fruit, residue, nutritional value; industrial residue; drying.
Abbreviations: K_potassium; Ca_calcium; P_phosphorus; Mg_magnesium; Fe_iron; Zn_zinc; Cu_copper; Mn_manganese; FEPL_Flour from lyophilized yellow mombin epicarp; FEP40_Flour from yellow mombin epicarp dried at 40 ºC; FEP50_Flour from yellow mombin epicarp dried at 50 ºC; FEP60_Flour from yellow mombin epicarp dried at 60 ºC; FEP70_Flour from yellow mombin epicarp dried at 70 ºC.

Introduction

Yellow mombin (*Spondias mombin* L.) is a plant native to tropical America and, in Brazil, it occurs in several states. Yellow mombin has a slightly acidic aroma and flavor, which leads to interest in its fresh consumption or use to produce juices, jams, liqueurs, ice cream and nectars (Souza et al., 2010). The potential of yellow mombin pulp for industrialization causes its epicarp (peel) to be discarded, generating industrial residue.

The removal of the epicarp from fruits causes a major loss of nutrients, mainly fibers and minerals. Therefore, by developing products from these residues it is possible to include them in the daily diet of humans, enabling the nutritional enrichment of other products, and flour is a good alternative to facilitate this inclusion (Lima et al., 2015).

Fruit residues such as epicarp and seeds may have higher nutritional value than the pulps. Processing fruit residues in the form of flour reduces the volume, due to the removal of free water by the process of drying or lyophilization, and reduces chemical and microbiological reactions, thus producing a safe food for human consumption (Soquetta et al., 2016).

Industrially, dehydrated and powdered fruits can be used as additives in beverages, performing the functions of flavoring, natural dye and functional additive, causing the final product to have higher nutritional value (Karam et al., 2016).

For the production of flours, it is necessary to dehydrate the raw material, and different methods can be used. Food drying is effective in the conservation; however, if performed improperly, it can cause physical, chemical and sensory changes that may affect the nutritional value and acceptability of the final product by the consumer (Chen et al., 2016; Jihéne et al., 2013), consequently its marketing.

The lyophilization process enables stability of the product, avoiding the chemical and biological reactions that degrade it, because the matter is frozen and then the water present is reduced, promoting sublimation and then desorption (Marques, 2008). Lyophilization is mainly used in foods with high quality and mainly for Cerrado fruits (Terroni et al., 2013).

Thus, the objective of this study was to evaluate the flours produced from the epicarp of yellow mombin (*Spondias mombin* L.) through conventional drying and lyophilization.

Results and discussion

Proximal composition

There was no difference between FEPL and FEP40, which had the highest values of moisture content and differed from the other treatments (Table 1). The FEP50, FEP60 and FEP70 flours differed from one another, and FEP70 showed the lowest moisture content. The drying temperature directly interfered in the moisture content of the flours produced from drying in the oven, being reduced with the increase in temperature.

All flours had safe levels for consumption and storage, with moisture content below 8.87%, and the Brazilian legislation recommends that flours have the maximum moisture content of 15% (BRASIL, 2005). To prevent the growth of micro-organisms, the moisture content of food should be kept at low levels (Reis et al., 2017).

Regarding the ash content, there was no difference between the flours, with values ranging from 5.61 to 5.91 g $100g^{-1}$ (Table 1). The values found corroborate those reported by Storck et al. (2015), who worked with apple residue flour and observed ash contents between 4.38 and 16.86%.

Santiago et al. (2016), evaluating passion fruit peel flour, found 7.21% of moisture content, 4.32% of ash, 0.98% of proteins and 0.93% of lipids. For moisture content and ashes, the values were close to those found in the study, but the lipid contents of passion fruit rind were much lower than those of yellow mombin epicarp (peel).

Table 1 also shows that the flours from lyophilized yellow mombin epicarp (FEPL) showed no difference for lipid content compared to flours produced by oven drying at different temperatures (FEP40, FEP50, FEP60 and FEP70).

The lipid contents found in yellow mombin epicarp flours were between 7.76 and 14.69 g $100g^{-1}$, values close to that found by Martínez-Girón et al. (2017), who studied pupunha residue flour obtained by convective drying and observed 13% of lipids. The high lipid content may be related to a high content of polyunsaturated fatty acids. Martínez et al. (2015), studying mango and orange epicarp flours, found values of 1.84 and 1.73%, respectively, which are lower than those found in the present study.

Other authors also found high lipid contents in fruit residue flours. For instance, Storck et al. (2015) found lipid contents between 2.53 and 9.35 g $100g^{-1}$ for orange residue flour and between 5.6 and 17.3 g $100g^{-1}$ for grape residue flour, and these values corroborate those found in the present study.

For protein analysis, contents of 11.90 (FEPL), 12.21 (FEP40), 12.09 (FEP50), 12.48 (FEP60) and 12.70 (FEP70) g $100g^{-1}$ were found in the yellow mombin epicarp flours, which showed no significant difference.

The values obtained for carbohydrates were 62.31, 66.45, 63.42, 64.87 and 59.19 g $100g^{-1}$, for FEP40, FEP50, FEP60, FEP70 and FEPL flours, respectively, and there was no difference between the flours. Similar values were found by Storck et al. (2015) for flours from orange and apple industrial residues obtained by drying in an oven with temperature between 50 and 55 °C, which had contents between 63.4 and 73.4% and between 67.4 and 74.9%, respectively.

Leonel et al. (2014) evaluated peel flour of pineapple at two maturity stages, dried in an oven with a temperature of 45 °C and found carbohydrate contents of 43.36 and 47.34 g $100g^{-1}$ and proteins contents of 4.45 and 4.15 g $100g^{-1}$; these values are lower than those found for the yellow mombin epicarp flours.

For blueberry residue flour produced by drying in an oven at 60 °C for 36 hours, Goldmeyer et al. (2014) obtained higher values than those found in the present study for carbohydrates (85.15%) proteins (5.27%).

Also, it can be observed that there was no difference for the energy value of the different flours of the yellow mombin epicarp, with values of 397.01, 384.09, 406.76, 404.00 and 416.62 kcal $100g^{-1}$ for FEP40, FEP50, FEP60, FEP70 and FEPL, respectively. Bampi et al. (2010) found an energy value of 216.09 kcal for Japanese raisin flour dried in an oven at 60 °C, which is relatively lower than those found in the present study.

Silvino et al. (2017) evaluated the nutritional quality and morphological parameters of yellow mombin (*Spondias mombin* L.) and found an energy value of 49.15 kcal, moisture content of 86.78%, ash content of 2.62%, lipid content of 1.35%, protein content of 2.93% and carbohydrate content of 6.32%. It was verified that the values were higher for all properties, except moisture content, found in the yellow mombin epicarp flour. Evaluating the nutritional properties of yellow mombin, Tiburski et al. (2011) found 83.66% moisture, 0.62% lipids, 1.06% protein, 0.76% ash, 13% carbohydrate and energy value of 65.42 kcal, which are also different from those found here.

Mineral analysis

It can be observed that the flours FEP40, FEP50, FEP60, FEP70 and FEPL showed no difference for the contents of any of the macrominerals analyzed, indicating that there was no relation of drying temperature with the contents of K (potassium), Ca (calcium), P (phosphorus) and Mg (magnesium). The same was verified by Granito et al. (2003) when analyzing the effect of bean cooking for flour production, compared with a control sample without cooking.

The exposure of food to high temperatures, as in cooking processes, causes significant losses of minerals. Albrecht et al. (1987) found reductions of 56% for Ca and 18.6% for K. The temperatures of 40, 50, 60 and 70 °C used for oven drying of yellow mombin (*Spondias mombin* L.) epicarp were not enough to cause losses of these minerals. Contents between 2937.50 and 3541.66 mg $100g^{-1}$ of K were found for yellow mombin epicarp. Oliveira et al. (2013) found potassium content of 2433 mg $100g^{-1}$ for beet flour

The contents found were between 218.41 and 532.50 mg $100g^{-1}$ for Ca, between 170.12 and 215.76 mg $100g^{-1}$ for P and between 80.14 and 102.33 mg $100g^{-1}$ for Mg. RDC No. 269 of September 22, 2005, recommends daily intake (RDI) for adult individuals of 1000 mg of Ca, 260 mg of Mg and 700 mg of P, indicating that the consumption of 100 grams of epicarp flour daily would meet a significant part of this need (ANVISA, 2005).

Sabino et al. (2017) evaluated the contents of macrominerals in flours produced from fruit peel and obtained for pineapple peel flour contents of 427.0, 43.55 and 22.80 mg $100g^{-1}$ for K, Ca and Mg, respectively.

Table 1. Mean values of moisture content, ashes and lipids of yellow mombin (*Spondias mombin* L.) epicarp flour, expressed in g 100g^{-1}.

Treatments	Moisture content	Ashes	Lipids
FEP40	8.87±0.13^{d}	5.61±0.04^{a}	10.93±2.92^{a}
FEP50	7.77±0.09^{c}	5.91±0.12^{a}	7.76±4.46^{a}
FEP60	6.76±0.05^{b}	5.87±0.11^{a}	11.9±1.71^{a}
FEP70	6.30±0.29^{a}	5.70±0.17^{a}	11.46±3.98^{a}
FEPL	8.50±0.11^{d}	5.87±0.31^{a}	14.69±6.19^{a}

Means followed by equal letters in the column do not differ significantly by Tukey test at 5% probability level.

Table 2. Mean values for the contents (microminerals), on dry basis, of iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) of yellow mombin (*Spondias mombin* L.) epicarp flours.

Treatments	Cu (mg 100g^{-1})	Zn (mg 100g^{-1})	Mn (mg 100g^{-1})	Fe (mg 100g^{-1})
FEP40	19.11±1.80^{a}	11.56±0.14^{a}	18.54±0.24^{a}	18.09±1.41^{a}
FEP50	20.31±1.42^{a}	12.06±0.16^{a}	17.64±0.27^{a}	15.42±2.47^{a}
FEP60	25.15±02.48^{b}	12.57±0.28^{a}	18.41±1.37^{a}	15.26±1.09^{a}
FEP70	26.83±0.81^{bc}	12.93±0.85^{a}	22.57±1.33^{b}	17.88±1.45^{a}
FEPL	29.65±0.63^{c}	11.90±1.74^{a}	21.51±0.98^{b}	19.12±9.17^{a}

Means followed by equal letters in the same column do not differ significantly by Tukey test at 5% probability level.

Table 3. Information on the treatments for the production of flours of the epicarp of yellow mombin dehydrated under different conditions.

Treatment	Produced flour	Abbreviation
Drying at 40 °C	Flour from yellow mombin epicarp dried at 40 °C	FEP40
Drying at 50 °C	Flour from yellow mombin epicarp dried at 50 °C	FEP50
Drying at 60 °C	Flour from yellow mombin epicarp dried at 60 °C	FEP60
Drying at 70 °C	Flour from yellow mombin epicarp dried at 70 °C	FEP70
Lyophilization	Flour from lyophilized yellow mombin epicarp	FEPL

The same authors found for papaya peel flour contents of 485.00, 86.80 and 29.60 mg 100g^{-1} for K, Ca and Mg, respectively. It can be observed that, in both flours mentioned, only the K content was higher than that found in the present study.

Copper (Cu) contents showed no difference between FEP40 (19.11 mg 100g^{-1}) and FEP50 (20.31 mg 100g^{-1}) (Table 2). FEP70 (26.83 mg 100g^{-1}) was similar to both FEP60 and FEPL. However, FEPL had the highest content of this macromineral (29.65 mg 100g^{-1}), differing from FEP60 (25.15 mg 100g^{-1}).

Regarding the zinc (Zn) and iron (Fe) contents, there was no difference between the different flours, indicating that the drying temperature of yellow mombin epicarp was not related to the amount of these minerals present in the different flours (Table 2). Bergman et al. (1996) reported losses of 40% for Fe and 14% for Zn with the food cooking process.

Boen et al. (2017) found values between 4.1 and 10 mg 100g^{-1} of iron and between 0.6 to 1.5 mg 100g^{-1} of zinc in wheat and corn flours, and these values were lower than those found in yellow mombin epicarp flours.

FEP40 (18.54 mg 100g^{-1}), FEP50 (17.64 mg 100g^{-1}) and FEP60 (18.41 mg 100g^{-1}) showed similarity in Mn contents and, likewise, there was no difference between FEP70 (22.57 mg 100g^{-1}) and FEPL (21.51 mg 100g^{-1}), with FEP70 and FEPL having the highest levels (Table 2).

It was not possible to establish a relationship between the drying temperature of the yellow mombin epicarp and the differences in Cu and Mn contents, since for both microminerals there was similarity between the contents found in FEP70 and FEPL.

Freitas et al. (2016) evaluated the amount of zinc and manganese present in strawberry flour and found contents between 3.88 and 6.48 mg 100g^{-1} for zinc and 0.4 and 0.66 mg 100g^{-1} for manganese, values lower than those found in the present study.

Sabino et al. (2017) also evaluated macrominerals in fruit peel flour and found in melon peel flour contents of 6.62, 8.43, 0.23 and 1.46 mg 100g^{-1} for Fe, Zn, Cu, Mn, respectively. For mango peel flour, the values found were 1.08, 6.80, 0.19 and 0.34 for Fe, Zn, Cu and Mn, respectively.

Contents between 11.56 and 12.93 mg 100g^{-1} for zinc (Zn) and between 15.26 and 19.12 mg 100g^{-1} for iron (Fe) were found in yellow mombin epicarp. These values are higher than those recommended for daily intake (RDI) for adults, according to RDC No. 269 of September 22, 2005, which recommends the consumption of 14 and 7 mg per day of iron and zinc, respectively. For manganese (Mn), the contents found in yellow mombin epicarp flours were between 17.64 and 22.57 mg $100g^{-1}$, also higher than the daily intake recommendation, according to the same legislation, which is 2.3 mg. Only for the macromineral copper (Cu), the content obtained was not sufficient based on the daily recommendation, as it necessary to ingest 900 mg of copper daily (ANVISA, 2005).

It was found that the yellow mombin (*Spondias mombin* L.) epicarp flours dehydrated under different conditions are excellent sources of the microminerals Fe (iron), Zn (zinc) and Mn (manganese).

Materials and methods

Plant material

Yellow mombin fruits were collected in the municipality of Montes Claros de Goiás, Brazil, located at 16º 06’ 20” S and 51º 17’ 11” W, at an altitude of 464 meters. At each collection point, geographic coordinates were collected with a GPS (Global Position System) device. The fruits were harvested manually, by shaking the branches to cause ripe fruits to fall and collecting them on a tarpaulin stretched on the soil, preventing them from injuries and degradation.

Conduction of the research

After collection, the fruits were separated according to the degree of maturity and were taken to the Fruit and Vegetable Laboratory of the Federal Institute of Goiás - Campus of Rio Verde.

As the fruits reached adequate maturity, the peduncles were removed, washed under running water, sanitized by immersion in 150 ppm L^{-1} sodium hypochlorite for ten minutes, rinsed to remove residual chlorine and dried on paper towels. The fruits were subjected to the pulping process in an electrical pulper (Tortugan/Processor ker Mod 1.5) for separating the endocarp, pulp and epicarp.

To produce the flours, portions of approximately 700 g of yellow mombin epicarp were separated for each drying temperature, arranged on stainless-steel trays without perforations and dried at 40, 50, 60 and 70 ºC in a forced air circulation oven. Drying was performed until the masses of the samples contained in the trays remained constant. Another 700-g portion of yellow mombin epicarp was subjected to lyophilization, and the material was first frozen and then arranged in the drying chamber of the lyophilizer, where it remained for a period of 24 h.

After being dried, the samples were subjected to grinding in a Wiley-type knife mill (Fortinox brand), with 1-mm-mesh sieve, giving rise to yellow mombin epicarp flours (Table 3). The flours were placed in plastic polypropylene packages and stored in B.O.D. chamber at -4 °C, where they remained until the analysis.

Moisture content

Moisture content was determined by the oven drying method (130 ± 1 °C) according to the AACC method (44-15 A). Aluminum containers previously dried at 130 °C received 3 g of yellow mombin peel flour. The containers with the samples were kept in an oven until reaching constant mass. They were then cooled in desiccator (AACC, 2000).

Ash (fixed mineral residue)

Ash contents were determined using the method described by AOAC 923.03. Porcelain crucibles previously dried and cooled in a desiccator were weighed and then received 2 g of yellow mombin peel flour. The crucibles were kept in a muffle furnace at temperature of 500 ± 15 °C for approximately 5 h, to promote complete incineration of organic matter, and then they were placed in a desiccator to be cooled (AOAC, 2000).

Only the ashes remain at the end of this procedure, being called fixed mineral residue, and the following equation was used for its calculation.

$$\text{Ashes}(\%) = \frac{(\text{B - A}) \cdot 100}{\text{MS}} \quad (1)$$

Where,

A - mass of empty crucible;

B - mass of crucible with sample after drying;

MS - mass of sample.

Crude protein

Crude protein was determined by the Kjeldahl method, in which the total organic nitrogen content was evaluated according to the 46-12 AACC method.

For this, 0.25 g of the sample was added to a test tube, followed by 1.0 g of the catalyst and 6.0 mL of sulfuric acid (A.R.). The tubes were placed on the rack and taken to the digester block with heating of 400 °C until the sample showed a light green color, which indicated full digestion.

At the end of digestion, the tubes were removed from the digester block and cooled. After that, the boiler heating was switched on and then switched off when the water boiled. Subsequently, the reservoir received 50% sodium hydroxide and a 250-mL Erlenmeyer flask containing 10 mL of 2% boric acid and 5 drops of indicator solution was connected to the condenser outlet.

The tube containing the sample was connected to the distiller, and the valve of the sodium hydroxide reservoir was closed. With the boiler switched off, the valve was opened to slowly release the sodium hydroxide (25 mL) into the tube containing the sample until it turned black. The boiler was heated to start drag distillation of ammonia (NH_3) and, when the volume of the solution reached 75 mL, the boiler heating was switched off. The distilled solution was titrated with 0.1 N hydrochloric acid until reaching a rosy color (AACC, 2000).

After the analysis, calculations were performed using equations 2 and 3 to determine protein in the sample.

$$\text{Protein (wet basis) (\%)} = \frac{(\text{VL- VB}) \cdot (0.014 \cdot 100) \cdot 6.25 \cdot \text{n} \cdot \text{Fc}}{\text{MS}} = \text{y}$$

$$\text{Protein (dry basis) (\%)} = \frac{\text{y} \cdot 100}{(100 - \text{X})}$$

where,

VB - mL of titrant spent in blank sample;

VL - mL of titrant spent;

0.014 - meq Nitrogen;

6.25 - Factor of conversion from N content to protein;

n - Titrant normality;

Fc - Correction factor for the titrant normality;

MS - Mass of sample;

X - % moisture content.

Lipids

Lipid determination was performed according to the AOAC 925.38 method, using the Soxhlet method. After distillation, the flaks were taken to the oven at 105 °C for evaporation of the residual solvent until reaching constant weight, cooled in desiccator and their masses were recorded (AOAC, 2000).

The results were expressed as % lipids, calculated using Equation 4.

$$\text{Lipids (\%)} = 100 \cdot \frac{m}{m'} \quad (4)$$

where,

m - mass of lipids, g;

m' - mass of dry matter.

Carbohydrates

Carbohydrate content was determined using the method of calculation by difference described by Sniffen and Perez (1992), according to Equation 5, which considered the whole matter, and the result was expressed in g 100 g^{-1}.

$$CH = 100 - (X + L + CP + A) \quad (5)$$

where,

X - moisture content;

L - lipids;

CP - crude protein;

A - ashes.

Energy value

Energy value was determined by Equation 6, using the following Atwater conversion factors: proteins, 4 kcal g^{-1}; carbohydrates, 4 kcal g^{-1}; lipids, 9 kcal g^{-1} (Merril and Watt, 1973; Angelis, 1977).

$$\text{Energy value (kcal/100g)} = (\text{protein} \cdot 4) + (\text{carbohydrates} \cdot 4) + (\text{lipids} \cdot 9) \quad (6)$$

Minerals

Minerals were determined by digestion of organic matter with nitric acid and quantified according to the AOAC 985.01 method.

After cooling the samples to room temperature, the ashes were moistened with demineralized water and 1 mL of nitric acid was added. The ashes were moistened and heated in a heating plate up to constant mass. Then, the samples were placed back into the muffle furnace (400-450 ºC), and nitric acid was repeatedly added until the complete mineralization of the sample.

The ashes were dissolved with nitric acid and quantitatively transferred with distilled and deionized water to 25-mL volumetric flask. The samples were prepared in triplicate and a blank of the reagents was prepared simultaneously.

For the quantification of minerals in inductively coupled argon plasma emission spectrometer, a standard curve was prepared, considering the sensitivity of the device and the linear working range for each element. The solutions were prepared in hydrochloric acid medium at 10% v/v (IAL, 2008; AOAC, 1995). The concentration of the elements, in mg L^{-1}, in the sample was determined by equation 7.

$$C' = \frac{L' \cdot b' \cdot d'}{v} \quad (7)$$

where,

C' - concentration of the elements;

L' - Sample reading, mg L^{-1};

b' - volume of flask to which the sample ash was transferred, mL;

d' - sample dilution factor;

v' - sample volume, mL.

Statistical analysis

The results were analyzed using the statistical program Sisvar® version 6.0. The results were expressed as mean ± standard deviations in tables. The analyses were performed in triplicate and the mean values were evaluated by analysis of variance (ANOVA) followed by Tukey test at 5% significance level, with a completely randomized design (CRD).

Conclusions

Yellow mombin (*Spondias mombin* L.) epicarp flours dehydrated under different drying conditions and by lyophilization showed moisture contents within the recommended margin. Temperature increase was inversely proportional to moisture content. All flours (FEP40, FEP50, FEP60, FEP70 and FEPL) had high lipid contents. For the macrominerals Fe, Zn and Mn, the contents found met the need according to the recommended daily intake per 100 g of flour. There was no relationship of the temperature used for epicarp dehydration to produce the flours with their nutritional quality.

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