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Physical, physicochemical and functional technological properties of flours produced from yellow mombin (*Spondias mombin* L.) epicarp

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Abstract

Yellow mombin (*Spondias mombin* L.) is a plant native to tropical America and occurs in several states in Brazil. Yellow mombin fruit has desirable characteristics for industrialization, but its epicarp (peel) having good nutritional characteristics is discarded. Flour obtained by dehydration processes is an alternative in the food industry for the utilization of by-products. Thus, the objective of this study was to develop a product from an industrial residue and analyze the physical, physicochemical and functional technological characteristics of the yellow mombin epicarp flours produced by drying in an oven, subjected to different temperatures (40, 50, 60 and 70 ºC) and by lyophilization. To reach these final moisture contents, the required times were 11.5, 9.0, 7.0 and 4.5 h, respectively, for the temperatures of 40, 50, 60 and 70 °C. For lyophilization, 24 hours were required. After the samples were dried, they were processed to obtain the flour and evaluated for color, pH, titratable acidity, total soluble solids, bulk density and granulometry. Flour produced by lyophilized epicarp of yellow mombin showed a lighter color and a higher tendency to yellow, greater amount of soluble solids and lower density. FEPL particles were smaller, i.e., finer flour. All flours had low pH values, between 2.65 and 2.83.

Keywords: *Spondias mombin* L.; dehydration; processing; fruit; residue.
Abbreviations: FEP40_ Drying at 40 ºC; FEP50_Drying at 50 ºC; FEP60_Drying at 60 ºC; FEP70_Drying at 70 ºC; FEPL_Lyophilization.

Introduction

Yellow mombin (*Spondias mombin* L.) is a plant native to tropical America and is found in several states in Brazil. Its fruit is known by several names depending on the locality, such as ‘taperebá’ in the Amazon region, ‘cajá pequeno’ in São Paulo and Minas Gerais, ‘cajá mirim’ in the Southern states, and ‘cajá’ in the Northeast region (Bosco et al., 2000). For the juice industry, fruits with high yield, good consistency and high sugar content and acidity are preferable. However, there are still no reports of yellow mombin production technologies for industrial and commercial exploitation (Pinto et al., 2003).

Yellow mombin fruits have a highly appreciated aroma and flavor and are mainly used in the production of jellies, sweets, popsicles, ice creams, pulps, juices and nectars. Different authors describe the good quality of yellow mombin in industrial utilization, for instance, Gomes (1985) reports that the fruit has pleasant flavor and refreshment, showing to be an ideal raw material for the production of ice cream, jellies, jams and juices, from which brandy and liquor can be produced.

The epicarp (peel) of fruits is considered industrial residue, but researchers have emphasized the importance of including these by-products as ingredients in human food (Fava et al., 2013). There has been a considerable increase in fruit consumption in recent years, which is related to the search for improvement in quality of life, and consumers are seeking to consume fresh or processed fruits with higher nutritional value. Thus, given the importance of the development of processed products from fruits, flour becomes an alternative and can be easily included in the human diet due to its benefit-cost ratio, since it is a source of mainly nutrients and fibers (Brito et al., 2017).

Flour obtained from the dehydration of fruits has received attention from researchers and the food industry, and it can also be produced from by-products, such as their epicarp (Alves and Perrone, 2015; Queiroz et al., 2015). In this context, dehydration aims to reduce the amount of water in food to safe levels to minimize or even prevent the reactions that cause food deterioration, and the drying process is one of the main ones used for the conservation of fruits and vegetables (Jihéne et al., 2013).

On the other hand, food drying can cause sensory, physical, chemical and nutritional changes that may affect quality parameters of the product and consumer acceptability (Chen et al., 2016; Jihéne et al., 2013).

Another alternative for food dehydration is lyophilization, which allows greater maintenance of food quality, but is more expensive and requires skilled labor, which limits the use of this method by part of the industry (Corrêa et al., 2011). In the lyophilization process, the food is first subjected to freezing and water is removed by sublimation, with the aim of reducing and/or preventing the growth of microorganisms (Ramírez-Navas, 2006).

It is important to know the changes in the chemical composition, nutrients and application characteristics of food, which can be caused by dehydration processes, so it is possible to choose the best method for certain products (Michalska et al., 2017).

In view of the above, the objective was to produce flours from the epicarp of yellow mombin (*Spondias mombin* L.), as a way of utilizing the industrial by-product through conventional drying in an oven at temperatures of 40, 50, 60 and 70 ºC, as well as through lyophilization, and to perform the physicochemical and functional technological analyses of the flours produced.

Results and discussion

Color

The flour of yellow mombin epicarp produced by lyophilization showed higher lightness (L), that is, tending more to white, while the flour produced by drying at 70 ºC showed a greater darkening compared to the other drying temperatures (Table 1). Based on the results obtained for the analysis of parameter *L**, it was observed that the increase in drying temperature of the yellow mombin epicarp promoted darkening of the product, and the flour produced from the lyophilized product obtained a lighter color. Aydin and Gocmen (2015) report that pumpkin flour produced by conventional drying at 60 ºC had lower *L** value compared to the flour produced by lyophilization. The fact that the flours subjected to conventional drying showed darker color may be related to the occurrence of the Maillard reaction, which causes the appearance of dark pigments when the food is subjected to high temperatures (Batista et al., 2014).

In relation to the *a** coordinate, it is observed that the flours of yellow mombin epicarp dehydrated at the four temperatures (40, 50, 60 and 70 ºC) showed a higher tendency to green and did not differ from each other, differing from the flour of the lyophilized yellow mombin epicarp (Table 1). The *a** coordinate represents the color from green to red, and positive and higher values mean greater tendency to red, whereas negative and smaller values indicate greater tendency to green. In the case of the flours of yellow mombin epicarp, it was possible to verify that the flours obtained by conventional drying showed lower values for *a** coordinate than for the flour obtained by lyophilization, indicating that the flour from the lyophilized product had higher tendency to red.

Freitas et al. (2018), working with foam-mat drying of the pulp of yellow mombin (*Spondias mombin* L.) at different temperatures, reported that the increase in temperature caused darkening of the product and there was a tendency to red.

The *b** coordinate indicates the color from yellow to blue; higher values indicate a greater tendency to blue and the lower the value, the greater the tendency to yellow. This color scale has values from negative to positive. It was verified that the flour of the lyophilized epicarp differed from the others and obtained higher value, that is, it tended more to the yellow color (Table 1). The flours at temperatures of 40, 50 and 60 ºC showed no difference from one another, and the flour at 70 ºC was similar to that produced at 50 ºC. Figure 1 shows the images of the flours produced by drying at different temperatures and by lyophilization.

The flours FEP40, FEP50 and FEP60 showed no difference for chroma, with values of 23.25, 23.67 and 23.09, respectively (Table 1). For FEP70 (24.44), there was an increase in this value, differing from the others, and FEPL had the highest value (28.59) for chroma, also differing from other flours. Thus, FEPL showed a greater sharpness and intensity in the color, with greater clarity. According to Martinazzo (2006), chroma (Chr) is the representation of expressiveness, sharpness and intensity of the color of the product analyzed, or also defined as the amount of color that differentiates the strongest color from the weakest color.

In a study with acerola flour obtained at temperatures of 60, 70 and 80 ºC, Reis et al. (2017) found that the flour with seed obtained at 60 ºC had lower value of lightness (L). The authors also report that storage caused a reduction in the value of chroma for all acerola flours without seeds produced at different drying temperatures.

Hue angle is the expression in degrees of color intensity, starting at º0, which indicates +a (red), 90º indicates +b (yellow), 180º indicates –a (green) and 270º indicates -b (blue) (Tibola et al., 2005). The hue angles found for the color of the yellow mombin epicarp flours were relatively low, indicating that they are close to the axis (Table 1). FEP70 had the lowest value, differing from the others, and FEPL had the highest value, also differing from all others. Oliveira et al. (2016) studied the effect of drying on the color of baru (*Dipteryx alata* Vogel) fruits and reported that there was no effect of drying temperature and moisture content of the product on the hue angle (ºh).

For the total color difference (ΔE), FEP70 had the lowest value (60.24), differing from the others (Table 1). FEP50 and FEP60 showed no difference for this value, and FEP40 had a slight increase in this value (62.19). FEPL had the largest total color difference, with a value of 62.19, differing from the others.

The browning index (BI) is used to measure the tendency to brown color, which is caused by enzymatic and non-enzymatic reactions that occur during food processing (Mohapatra et al., 2010; Maskan, 2001). The BI values found for the flours FEPL (22.68) and FEP50 (21.65) showed no difference, and the BI determined for FEP70 was the highest one (25.82) and differed from the others (Table 1). However, it was not possible to directly relate the temperature increase with the browning index. Wang et al. (2018), working with lemon slices obtained BI values from 3.88 to 27.14 with the increase in drying temperature.

Color is a sensory analysis attribute of easy perception and directly influences the decision of purchase by the consumer, and the quality of the flour is associated with a lighter color, which will allow a final product with the desired aspect. Lighter flours are generally preferred by the consumer, but do not always have the best quality (Miranda et al., 2009).

Table 1. Means of the values found for the coordinates of *L**, *a** and *b**, hue angle (ºh), chroma, total color difference (ΔE) and browning index (BI) of flours from the epicarp of yellow mombin (*Spondias mombin* L.).

Treatments	*L**	*a**	*b**	ºh	Chroma	ΔE	BI
FEP40	57.68±0.25^{b}	5.34±0.24^{a}	22.63±0.34^{a}	1.34±0.01^{b}	23.25±0.38^{a}	62.19±0.17^{c}	19.84±1.14^{a}
FEP50	56.78±0.61^{c}	5.45±0.29^{a}	23.040.70^{ab}	1.34±0.01^{b}	23.67±0.75^{a}	61.53±0.28^{b}	21.65±2.39^{b}
FEP60	57.30±0.23^{bc}	5.44±0.07^{a}	22.44±0.18^{a}	1.33±0.01^{b}	23.09±0.19^{a}	61.78±0.22^{b}	19.92±0.50^{a}
FEP70	55.05±0.80^{d}	5.46±0.24^{a}	23.58±0.37^{b}	1.30±0.00^{a}	24.44±0.43^{b}	60.24±0.56^{a}	25.82±2.01^{c}
FEPL	66.36±0.80^{a}	6.44±0.38^{b}	28.06±1.10^{c}	1.37±0.01^{c}	28.59±1.16^{c}	72.27±0.35^{d}	22.68±3.16^{b}

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

Figure 1. Image of the flours of yellow mombin (*Spondias mombin* L.) epicarp produced by drying at different temperatures (40, 50, 60 and 70 ºC) and by lyophilization.

Table 2. Hydrogen potential (pH), total titratable acidity (TTA), soluble solids (SS) and apparent specific mass (ASM) of flours of yellow mombin (*Spondias mombin* L.) epicarp

Treatments	pH	TTA	SS (ºBrix)	ASM (g mL^{-1})
FEP40	2.83±0.09^{b}	0.73±0.05^{a}	2.56±0.01^{a}	0.69±0.01^{b}
FEP50	2.68±0.08^{ab}	0.59±0.01^{a}	2.60±0.1^{ab}	0.61±0.01^{b}
FEP60	2.68±0.02^{ab}	0.55±0.04^{a}	2.65±0.0^{ab}	0.69±0.04^{b}
FEP70	2.65±0.06ª	0.60±0.15^{a}	2.70±0.5^{ab}	0.69±0.03^{b}
FEPL	2.71±0.01^{ab}	0.76±0.08^{a}	2.73±0.3^{b}	0.60±0.02^{a}

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

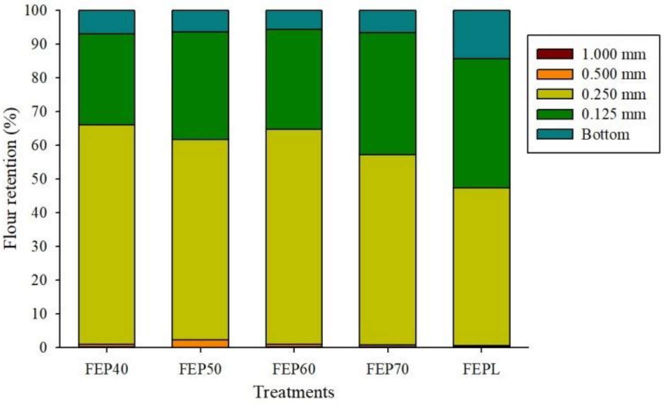

Figure 2. Mean values of the granulometric distribution of the flours of yellow mombin (*Spondias mombin* L.) epicarp for different mesh openings (mm).

Table 3. Information on the treatments for the production of flours from the epicarp of yellow mombin (*Spondias mombin* L.) dehydrated under different conditions.

Treatment	Flour produced	Abbreviation
Drying at 40 ºC	Flour from yellow mombin epicarp dried at 40 ºC	FEP40
Drying at 50 ºC	Flour from yellow mombin epicarp dried at 50 ºC	FEP50
Drying at 60 ºC	Flour from yellow mombin epicarp dried at 60 ºC	FEP60
Drying at 70 ºC	Flour from yellow mombin epicarp dried at 70 ºC	FEP70
Lyophilization	Flour from lyophilized yellow mombin epicarp	FEPL

pH, Titratable acidity, Total soluble solids, Apparent specific mass

FEP50, FEP60 and FEPL flours showed no difference for pH and the treatments of 40 and 70 ºC differed from each other, with FEP40 showing the highest mean (2.83) and FEP70 showing the lowest mean (2.71) (Table 2). The evaluations of yellow mombin epicarp flours showed low means of pH, indicating acidity under both dehydration conditions, with values between 2.65 and 2.83.

Foods with higher acidity have advantages in their conservation, because they reduce the conditions for the growth of microorganisms and also for enzymatic reactions. The results found for pH corroborate those reported by Freitas et al. (2018), who worked with yellow mombin (*Spondias mombin* L.) pulp powder, obtained by foam-mat drying at different temperatures, and obtained pH values between 2.65 and 2.8. Silvino et al. (2017) in their study with yellow mombin pulp found pH value of 1.45, which is below the values found in the present study for flours under different dehydration conditions.

The acidity parameter of a food is directly linked to the conservation of the product, which explains the importance of knowing the acidity content of the food, and acidity may have influence on the process of decomposition, either by oxidation, hydrolysis or fermentation (Brasil, 2005).

The values found for titratable acidity were between 0.55 and 0.76, and there was no difference between the flours analyzed (Table 2). The values of titratable acidity of the yellow mombin epicarp flours obtained by drying at different temperatures and by lyophilization were close to those found by Freitas et al. (2018), who observed values between 0.6 and 1.2 for yellow mombin pulp powder.

All flours, both those produced by drying and the one produced by lyophilization, showed reduced values of soluble solids, indicating low amount of sugars, but this characteristic may be due to the fact that the fruit does not have a sweet taste. According to Canuto et al. (2010), soluble solids are directly related to the amount of sugars and organic acids.

It can be observed in Table 2 that FEP40 and FEPL differed from one another, and FEPL had the highest value of soluble solids, so it is possible to affirm that there was greater water removal by the lyophilization process. FEP40 had the lowest value, showing a higher amount of water in the product, which does not corroborate with Freitas et al. (2018), who report that the lowest drying temperature promoted greater removal of water from the yellow mombin powder. FEP50, FEP60 and FEP70 flours had intermediate values and did not differ from each other.

Carvalho et al. (2017) studied the physicochemical characterization of the pulp of yellow mombin (*Spondias mombin* L.) and found pH values of 2.26 and 2.93, with titratable acidity between 1.08 and 1.78 and soluble solids between 7.77 and 13.03. The values of the present study show that the pH results corroborate those found for the yellow mombin epicarp, while the values of titratable acidity and soluble solids found for the epicarp differ from those of the aforementioned study.

In relation to the apparent specific mass, only the flour produced by lyophilization (FEPL) differed from the others, showing the lowest mean, that is, this flour proved to be lighter than the others (Table 2). The difference in the specific mass of FEPL may be related to lower moisture content in this flour and greater amount of air in its molecules. The advantage of products with higher specific mass is that they require smaller packaging (Santhalakshmy et al. 2015).

Granulometry

The flours obtained by conventional drying in an oven had the highest percentage retained on a 0.25-mm-mesh sieve, with values of 63.87, 63.36, 59.11 and 58.09% for FEP40, FEP50, FEP60 and FEP70, respectively (Figure 2). Coelho and Wosiacki (2009) found that 59.26% of the apple flours had granulometry lower than 0.5 mm. The 0.125-mm-mesh sieve retained the second highest proportion, with values of 27.53, 28.25, 32.43 and 32.92% for FEP40, FEP50, FEP60 and FEP70, respectively.

There was a linear trend of granulometry as a function of the drying temperature of the epicarp for flour production, and the increase in temperature causes a reduction in the proportion of material retained on the 0.250-mm-mesh sieve. Opposite effect was observed with the 0.125-mm-mesh sieve, in which the increase in temperature promoted greater retention of material of this particle size. It can be affirmed that the increase in drying temperature promotes the production of flours with smaller granulometry, that is, finer granulometry.

Storck et al. (2015) in their study with flour from juice production residue, found that the flour of acerola residue showed granulometry ≤ 0.250 mm, while flours from orange, grape and apple residue showed granulometry ≥ 0.600 mm.

Regarding the flour of lyophilized yellow mombin epicarp (FEPL), a different trend was observed for its granulometry, with 39.54% retained on the 0.25-mm-mesh sieve and 40.83% retained on the 0.125-mm-mesh sieve (Figure 2). FEPL showed lower granulometry, that is, the lyophilization process led to the production of flour with smaller particles. To reinforce this statement, the sieve without perforation (bottom) retained the proportions of 7.36, 4.98, 6.45, 7.67 and 18.32% for FEP40, FEP50, FEP60, FEP70 and FEPL. It should be noted that a large proportion of FEPL passed through the 0.125-mm-mesh sieve, while the flours obtained by drying in the oven had a lower percentage.

According to the Brazilian legislation (Brasil, 2005), for the commercialization of wheat flour, 95% of the sample needs to pass through the 250-µm-mesh sieve. The same occurred for the flours obtained in the present study, in which the flours of the yellow mombin epicarp showed granulometry close to that established for wheat flour.

Granulometry is directly related to the quality of the final product to be prepared, and the size of the particles influences the water absorption capacity, mixing time and sensory characteristics (Borges et al., 2003).

Materials and methods

Plant materials

Yellow mombin fruits from natural vegetation were collected in the region of Montes Claros de Goiás (16º 06’ 20” S and 51º 17’ 11” W). At each collection point, geographic coordinates were recorded by a GPS (Global Positioning System) device. Harvest was carried out manually, and the fruits were collected by shaking the branches to cause ripe fruits to fall and collecting them on a tarpaulin stretched on the soil to avoid injuries. After collection, the fruits were separated according to the degree of maturity and sent to the Fruit and Vegetable Laboratory of the Federal Institute of Goiás - Campus of Rio Verde.

As the fruits reached the appropriate degree of maturity, the peduncles were removed, washed in 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) to separate the endocarp, pulp and epicarp.

Flour making and Conduction of the drying

For the production of flours, portions of approximately 700 g of yellow mombin epicarp were separated for each drying temperature, arranged in stainless-steel trays without perforations and dried at 40, 50, 60 and 70 ºC in an air circulation oven. Drying was conducted until the masses of the samples contained in the trays remained constant for three consecutive weighing procedures. To reach these final moisture contents, the required times were 11.5, 9.0, 7.0 and 4.5 h, respectively, for the temperatures of 40, 50, 60 and 70 °C. The other 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 hours.

After being dried, the samples were subjected to the grinding process in a Wiley-type knife mill (Fortinox brand), with a 1-mm-mesh sieve, originating the flours of the epicarp of yellow mombin (*Spondias mombin* L.). The flours were placed in polypropylene packages and stored in B.O.D. chamber at -4 ºC until the analysis was performed. To facilitate the identification of treatments, the flours were named according to Table 3.

Color determination

The color of the yellow mombin epicarp flours was determined according to the AACC 14-22 method, using the ColorFlex EZ colorimeter, which evaluates the color attributes by the system of the International Lighting Commission (CIELAB) (AACC, 2000). Readings for the different samples were performed in triplicate.

$$\text{Chroma} = \left[\left(a*^2 + b*^2 \right)^{\frac{1}{2}} \right] \quad (1)$$

$$°\text{h} = \left[\text{arctang} \left(\frac{b*}{a*} \right) \right] \quad (2)$$

$$\Delta\text{E} = \sqrt{\Delta L*^2 + \Delta a*^2 + \Delta b*^2} \quad (3)$$

$$\text{BI} = 100 \left(\frac{\text{X} - 0.31}{0.17} \right) \quad (4)$$

$$\text{X} = \frac{(a* + 1.75L*)}{(6.645L* + a* - 3.012\, b*)} \quad (5)$$

Where,

*L**: lightness; *a**: green-red chromaticity; *b**: blue-yellow chromaticity; ºh: hue angle; ΔE: Total color variation; BI: browning index;

pH

The AOAC 943.02 method was used to determine the pH. 3 g of yellow mombin peel flour were added in a 250-mL Erlenmeyer flask and diluted with 30 mL of distilled water. The mixture was stirred until the particles became homogeneous. The solution remained at rest for 10 minutes and the supernatant liquid was transferred to a dry beaker where the pH was read using a properly calibrated digital pH meter (AOAC, 2000).

Titratable acidity

The analysis of titratable acidity present in the sample was performed using the methodology described by the Adolfo Lutz Institute (IAL, 2008), in which 2 g of sample were weighed and transferred to a 125-mL Erlenmeyer flask, diluting with 50 mL of distilled water. Immediately after, 3 drops of phenolphthalein were added and titration was performed with 0.1 M sodium hydroxide solution, until a rosy color was obtained. Titratable acidity was calculated using the following equation:

$$\text{Acidity in Solution (\%)} = \frac{\text{V} \cdot \text{f} \cdot 100}{\text{M} \cdot \text{c}} \quad (6)$$

Where,

V = Quantity of the 0.1 M sodium hydroxide solution spent in the titration (mL); f = factor of the 0.1 M sodium hydroxide solution; M = mass of sample used in the titration (g); c = correction for the NaOH solution, 10 for the 0.1 M NaOH solution.

Total soluble solids

The analysis of soluble solids was performed by diluting 10 g of flour from yellow mombin peel in 100 mL of distilled water in an Erlenmeyer flask, stirring the solution with a magnetic stirrer for 10 min, filtering soon after, followed by reading of the filtered material in digital refractometer at temperature of 20 ºC. The result was expressed in ºBrix (IAL, 2008).

Apparent specific mass

Apparent specific mass was determined based on the relationship between the mass of yellow mombin epicarp flour and the direct reading of the volume occupied by the sample, with graduated cylinder, with results expressed in g mL^{-1} (AACC, 2000).

Granulometry

Granulometry was determined using a sieve shaker and a set of sieves corresponding to the following mesh openings: 1 mm; 0.5 mm, 0.25 mm, 0.125 mm and bottom without perforation. The set of sieves was overlaid in ascending order of mesh opening on the shaking device, then 100 g of the flour sample were placed on top of the sieve set and the shaker was turned on. The samples of each treatment were subjected to vibration for 15 min. Then, the sieves that had retained sample were weighed to determine the retained fractions (Perry and Chilton, 1973). The retained fraction was expressed in percentage according to Equation 7.

$$\text{PR (\%)} = \frac{(\text{M}_1 - \text{M}_2)}{\text{MS}} 100 \quad (7)$$

Where,

PR % = percentage retained on each sieve; M_1 = mass of sieve plus retained fraction; M_2 = mass of sieve; MS = mass of sample.

Statistical analysis

The results were analyzed using the statistical program SISVAR® version 6.0. The results were expressed as mean ± standard deviation 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

Flours produced by lyophilization were lighter in color and with a higher tendency to yellow, higher amount of soluble solids, lower density and smaller particles.

In general, FEPL showed better characteristics for physical, physicochemical and technological functional analyses.

Drying in the oven and lyophilization enabled the production of flours from yellow mombin epicarp with satisfactory characteristics.

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