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Physical, physicochemical, and functional technological properties of flour produced from gueroba fruit pulp

Ana Paula Pereira JORGE[1], Daniel Emanuel Cabral de OLIVEIRA[1*], Weder Nunes FERREIRA JUNIOR[1], Lígia Campos de Moura SILVA[1], Osvaldo RESENDE[1], Viviane Patrícia ROMANI[1]

Abstract

The Cerrado biome has a variety of fruit species less explored, such as gueroba. Flour is obtained by dehydration processes and is an alternative in the food industry for utilizing by-products. The objective of this study was to analyze the physical, physicochemical, and functional technological characteristics of flours from gueroba (*Syagrus oleracea* Becc.) fruit pulp produced by oven drying at different temperatures (40, 50, 60, and 70°C) and by lyophilization. The flour produced by lyophilization of gueroba fruit pulp showed a lighter color. According to the results obtained for the parameter L, it can be suggested that the increase in the temperature used for drying gueroba fruit pulp does not tend to promote browning of the product, the greater amount of soluble solids, higher water absorption index, and lower solubility in milk, lower emulsifying activity, and greater foaming activity. All flours showed pH values between 6.11 and 6.22. Also, the ash contents of the FEG40, FEG50, FEG60, FEG70, and FEGL samples did not differ between treatments, showing mean values of 5.67, 5.39, 5.73, 4.86, and 5.85 g 100 g^{-1}, respectively.

Keywords: *Syagrus oleracea* Becc.; dehydration; fruit; residue.

Practical Application: Production of gueroba flour to increase its consumption.

1 INTRODUCTION

The Cerrado Biome has a variety of fruit species with peculiar sensory characteristics that are less explored scientifically and commercially. The state of Goiás is a major producer of fruits and vegetables, which are largely sent to other consumer centers for fresh consumption. In addition to being a major producer of fruits and vegetables, the state also has a large area of Cerrado that is very rich in native fruits with unknown characteristics in other regions (Aguiar & Camargo, 2004; Gonçalves et al., 2015). Among the species with economic potential, gueroba, gariroba, or guariroba (*Syagrus oleracea*) stands out. For whatever reasons, if food production has not kept pace with the accelerated growth of the population, then there arises the need to find alternative sources and technologies that allow guaranteeing the diversified supply of food, with the maximum of nutritious resources, to these people for the maintenance of good health (Ordóñez, 2005). Within this context, alternative food, a name used to designate the proposal to promote the use of unconventional foods or agro-industrial by-products, accessible to the population, has emerged (Silva et al., 2004).

Flour obtained by dehydration of fruits has received attention from researchers and the food industry and can also be produced from by-products, such as the epicarp with mesocarp of fruits (Alves & Perrone, 2015; Queiroz et al., 2015). Dehydration, drying, or desiccation is one of the oldest processing methods aimed at preserving food in general. It can be carried out by sublimation, removal of water by solvent, the addition of osmotic agents such as salts and sugar, or by a process that usually uses thermal energy to remove part or almost all of the free or surface water from the raw material, that is, evaporation, without removing bonded water (Aguirre & Gasparino Filho, 2002; Almeida et al., 2022). On the contrary, food drying can cause sensory, physical, chemical, and nutritional changes that can affect the quality parameters of the product and its acceptability by consumers (Chen et al., 2016; Jihéne et al., 2013; Puttalingappa et al., 2022).

Lyophilization is a drying method in which the food is first subjected to freezing for subsequent elimination of ice by sublimation, that is, it is transformed directly from the solid state to vapor, under strict conditions of temperature and pressure (high vacuum). Lyophilization, which is also called by other nomenclatures as cryo-dehydration or cryo-drying, is a differentiated process of dehydration of products, as it occurs under special conditions of pressure and temperature, allowing the previously frozen water (solid-state) to pass directly to the gaseous state (without passing through the liquid state), that is, the change of physical state occurs by sublimation (Garcia, 2009). In this context, the objective was to produce flours from the epicarp with mesocarp of gueroba (*S. oleracea*) fruits, which was dried in an oven at temperatures of 40, 50, 60, and 70°C, followed by lyophilization, and then physicochemical and functional technological analyses were performed.

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[1]*Instituto Federal de Educação, Ciência e Tecnologia Goiano, Rio Verde, GO, Brazil.*
*Corresponding author: daniel.oliveira@ifgoiano.edu.br

2 MATERIAL AND METHODS

2.1 Flour preparation

Gueroba fruits were obtained from the region of Piracanjuba, GO, Brazil, with 17° 17' 47" south latitude and 49° 0' 38" west longitude, and in sufficient quantity for the analyses. The experiment was carried out at the Laboratory of Post-Harvest of Plant Products of the Federal Institute of Goiás – Rio Verde Campus. After manual separation and sanitization of gueroba fruits, they were dried.

In the production of the flours, as described by Jorge et al. (2021), four replicates of approximately 500 g of gueroba fruit pulp were separated for each drying temperature, arranged in stainless steel trays without perforations, and subjected to drying at 40, 50, 60, and 70°C in a forced air circulation oven. Drying was carried out until the masses of the samples contained in the trays remained constant. Subsequently, the samples were subjected to lyophilization, and the oven-dried material was spread in stainless steel trays. After being dried, the samples were ground in a Wiley knife mill (Fortinox brand), with a 1-mm mesh sieve, originating the flours from the epicarp (pulp) of gueroba (*S. oleracea*) fruits, which were placed in polypropylene plastic packaging and stored in a biological oxygen demand (BOD) chamber at –4°C until the analyses were performed. To facilitate the identification of treatments, the flours were labeled as shown in Table 1.

2.2 Color determination

The color of the flours from gueroba fruit pulp was determined according to the AACC method 14-22, with direct reading of reflectance of the coordinates L* (defines the lightness), a* (measures the intensity of the color between green and red), and b* (measures the intensity of the color between blue and yellow), using the colorimeter ColorFlex EZ, which evaluates the color attributes by the system of the International Commission on Illumination (CIELAB) (AACC, 2000).

Readings for the different samples were performed in triplicate. Chroma color saturation (Equation 1) and hue angle (Equation 2) were also evaluated as follows:

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

$$^\circ h = \left[\arctan\left(\frac{b}{a} \right) \right] \quad (2)$$

where:

L*: lightness;

a*: red-green chromaticity;

b*: blue-yellow chromaticity;

C*: chroma;

°h: hue angle.

2.3 Hydrogen potential (pH)

The pH was determined using the Association of Official Analytical Chemists (AOAC) method 943.02. For this, 3 g of flour from gueroba fruit pulp was taken 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 min, and the supernatant liquid was transferred to a dry beaker, in which the pH reading was performed using a properly calibrated digital pH meter (AOAC, 2000).

2.4 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 was weighed and transferred to a 125-mL Erlenmeyer flask, diluting with 50 mL of distilled water. Three drops of phenolphthalein were added immediately and titration was performed with 0.1 M sodium hydroxide solution until a rose color was obtained. Titratable acidity was calculated using the Equation 3:

$$\text{Acidity in solution}(\%) = \frac{V \cdot f \cdot 100}{M \cdot c} \quad (3)$$

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, which is 10 for the 0.1 M NaOH solution.

2.5 Total soluble solids

The analysis of soluble solids was performed by diluting 10 g of flour from gueroba fruit pulp in 100 mL of distilled water in an Erlenmeyer flask, stirring the solution with a magnetic

Table 1. Information on the treatments to produce flours from the pulp of gueroba (*Syagrus oleracea*) fruits dehydrated at different temperatures.

Treatment	Flour produced	Abbreviation
40°C	Flour from the epicarp + mesocarp of gueroba dried at 40°C	FEG40
50°C	Flour from the epicarp + mesocarp of gueroba dried at 50°C	FEG50
60°C	Flour from the epicarp + mesocarp of gueroba dried at 60°C	FEG60
70°C	Flour from the epicarp + mesocarp of gueroba dried at 70°C	FEG70
Lyophilization	Flour from the epicarp + mesocarp of gueroba subjected to lyophilization	FEGL

stirrer for 10 min and filtering soon, followed by reading of the filtered material in a digital refractometer at a temperature of 20°C. The result was expressed in °Brix (IAL, 2008).

2.6 Ash (fixed mineral residue)

The fixed mineral residue was determined according to the AOAC method 923.03. For this, 2 g of flour from gueroba fruit pulp was weighed in porcelain crucibles previously dried in a muffle furnace and cooled in a desiccator, with a previously established mass. The samples were placed in the muffle furnace (550 ± 15°C) and kept until complete incineration of organic matter (about 5 h). Then, the samples were taken from the muffle furnace, cooled in a desiccator, and weighed (AOAC, 2000). Incineration residues were calculated using Equation 4:

$$\% \text{ Ash} = \frac{(B - A) \cdot 100}{M} \quad (4)$$

where:

A: mass of empty crucible;

B: mass of crucible with sample after drying;

M: mass of the sample.

2.7 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 for heating at 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 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 was switched off. The distilled solution was titrated with 0.1 N hydrochloric acid until it reached a rose color (AACC, 2000).

After the analysis, calculations were performed using Equations 5 and 6 to determine the protein in the sample:

$$\text{Protein(wet basis)}\,(\%) = \frac{(VL - VB) \cdot (0.014 \cdot 100) \cdot 6.25 \cdot n \cdot Fc}{MS} = y \quad (5)$$

$$\text{Protein(dry basis)}\,(\%) = \frac{y \cdot 100}{(100 - X)} \quad (6)$$

where:

VB: mL of the titrant spent in the blank sample;

VL: mL of the 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 the sample;

X: % moisture content.

2.8 Lipids

Lipid determination was performed according to the AOAC method 925.38. For this, 2 g of each fruit flour was weighed on a filter paper, which was closed and tied with previously defatted wool thread. The samples were transferred to the Soxhlet apparatus, which was connected to a flat-bottomed flask (previously oven-dried at 105°C), and 450 mL of hexane (A.R.) was added to the Soxhlet apparatus. The flask was wrapped with a heating blanket, and the Soxhlet apparatus was connected to the glass Allihn condenser.

The flask was kept under heating for 8 h (4–5 drops per second). After extraction, the tied filter paper was removed, and then the hexane was distilled. The extracted residue was taken to the oven at 105°C, kept for about an hour, and cooled in a desiccator to room temperature. Heating and weighing operations were repeated every 30 min up to a maximum of 2 h, until the masses reached constant (AOAC, 2000). The results were expressed in % of lipids, calculated using Equation 7:

$$\text{Lipids}\,(\%) = 100 \cdot \frac{m}{m'} \quad (7)$$

where:

m: mass of lipids (g);

m': mass of dry matter (g).

2.9 Foaming capacity

Foaming capacity was determined using the method described by Coffmann and Garcia (1977) and adapted. A suspension with 1 g of the sample and 30 mL of distilled water was prepared in a 100-mL beaker, stirred for 5 min with a mechanical stirrer, and later transferred to a graduated beaker. The calculation was made considering the volume before and after foam formation, according to the Equation 8:

$$\text{Foam formation}\,(\%) = \frac{V_F - V_I}{V_I} \cdot 100 \quad (8)$$

where:

V_I: initial volume;

V_F: final volume.

Foam stability was measured while the beaker was kept at room temperature (25°C) and observed at 30-min intervals for 120 min until completion (Coffmann & Garcia, 1977; Pria et al., 2014; Shevkani et al., 2011).

2.10 Emulsion formation

The emulsion formation capacity of the fruit pulp flours was determined according to the methodology described by Yasumatsu et al. (1972). A suspension was prepared with 7 g of sample in 100 mL of distilled water and 100 mL of soybean oil. The suspension was stirred in a mechanical stirrer for 1 min at moderate speed, then divided and placed into graduated tubes, and centrifuged at 3,000 rpm for 5 min. Emulsion formation capacity was determined using the Equation 9:

$$\text{Emulsion formation}(\%) = \frac{\text{VEi}}{\text{Vi}} \cdot 100 \quad (9)$$

where:

VEi: volume of emulsion layer;

Vi: total volume of suspension in the tube.

Emulsion stability (ES) was determined using the same tubes with the emulsions for the determination of emulsifying activity. Initially, the values of the emulsifying layer were recorded, then the tubes were heated in a water bath at 80°C for 30 min and cooled for 20 min in running water, and finally, the tubes with the samples were centrifuged at 3,000 rpm for 5 min. The volume of the final emulsion layer, that is, the emulsifying layer (remaining), was recorded. Equation 10 was used to calculate ES:

$$\text{Emulsified layer}(\%) = \frac{\text{REL}}{\text{IEL}} \cdot 100 \quad (10)$$

where:

REL: remaining emulsified layer, expressed in mL;

IEL: initial emulsified layer, expressed in mL.

2.11 Absorption and solubility indices

Analyses were performed to determine the water, milk, and oil absorption indices and the water and milk solubility indices, according to Anderson et al. (1969), with some adaptations. For this, 1.0 g of fruit pulp flour was placed in a test tube, and then 10 mL of the solvent was added. The tube containing the sample with the solvent was then subjected to centrifugation at 3,000 rpm for 40 min. The supernatant liquid was placed in aluminum crucibles and kept in a water bath at 100°C for 2 h. After that, the crucibles were taken to the oven at 105°C and kept for 3 h for evaporation to occur. The excess gel in the centrifuge tube was weighed. The absorption index was determined from the evaporation residue and the supernatant according to Equation 11:

$$\text{AI} = \frac{\text{MCR}}{\text{M}} \cdot \text{MER} \cdot 100 \quad (11)$$

where:

AI: absorption indices;

MCR: mass of the centrifuge residue (g);

M: mass of the sample (g);

MER: mass of the evaporation residue (g).

Water and milk solubility indices were determined by the ratio between the mass of the evaporation residue and the dry mass of the sample according to Equation 12:

$$\text{SI}\ (\%) = \frac{\text{MER}}{\text{M}} \cdot 100 \quad (12)$$

where:

SI: solubility index (%);

M: mass of the sample (g);

MRE: mass of the evaporation residue (g).

2.12 Statistical analysis

The results were analyzed using the SISVAR® statistical software version 6.0. The results were expressed as mean and standard deviations. The analyses were performed in quadruplicate, and the mean values were evaluated by analysis of variance (ANOVA), followed by the Tukey's means comparison test at a 5% significance level, with a completely randomized design.

3 RESULTS AND DISCUSSION

Table 2 shows the means obtained for the analysis of the coordinates L, a*, b*, hue angle, and chroma. Based on the results obtained for the parameter L, it can be suggested that the increase in the temperature used for drying gueroba fruit pulp does not tend to promote the browning of the product, and the flour produced from the lyophilized product showed a darker color. This result has already been discussed by Aydin and Gocmen (2015), who observed a lower L value in pumpkin flour obtained under conventional drying conditions at 60°C, compared with flour subjected to lyophilization. These results differ from those found in this study, in which the opposite behavior was observed.

Regarding coordinate a* (Table 2), the flours from the epicarp with mesocarp of gueroba fruits dehydrated at the four temperatures (40, 50, 60, and 70°C) showed a greater tendency to green and did not differ from each other, but there was the difference between the flour from gueroba fruit pulp dried at 40°C and the lyophilized one. The coordinate a* represents the tendency of the color ranging from green to red; positive and higher values mean a greater tendency to red, whereas negative and lower values indicate a greater tendency to green (Peixoto, 2016). In the case of flour from gueroba fruit pulp, the ones obtained by conventional drying had lower values for the coordinate a* than the flour obtained by lyophilization.

The coordinate b* indicates the color from yellow to blue; higher values of b* indicate a greater tendency to blue, whereas the lower the value, the greater the tendency to yellow. In this color scale, the values vary from negative to positive (Sergio, 2016). Colorimetric analysis of the flours from the epicarp with mesocarp of gueroba fruits obtained by different drying temperatures and by lyophilization (Table 2) showed that the flour from lyophilized fruit pulp differed from the others and obtained the lowest value, that is, it tended more to yellow. Flours obtained at temperatures of 60 and 70°C did not differ, showing higher values. As shown in Table 2, flours from gueroba fruit pulp subjected to temperatures of 40, 60, and 70°C showed a difference, having the highest values, which suggests that there was greater sharpness and intensity in their color, with greater clarity. The treatment with drying at 50°C was the one with the lowest value and difference in the means comparison test.

The hue angle is the expression of color intensity in degrees, starting at °0, which indicates +a (red), while 90° indicates +b (yellow), 180° indicates –b (green), and 270° indicates –b (blue) (Tibola et al., 2005). Thus, it can be seen in Table 2 that only the treatments with lyophilized flour, flour dried at 40, and flour dried at 50°C showed the difference. Flours produced at temperatures of 60 and 70°C did not differ from each other.

Table 3 describes the values found for the analysis of pH, total titratable acidity, and soluble solids of the gueroba fruit flour. FEG40 and FEG50 showed no difference in pH, differing from the treatments with temperatures of 40 and 70°C. Only the treatment with fruit pulp flour subjected to lyophilization differed from the others, and it had the lowest mean.

Evaluations of gueroba fruit pulp flours showed a pH of around 6, indicating a neutral profile for both conditions of dehydration. Foods with higher acidity have advantages in their preservation because it reduces the conditions for the growth of microorganisms and for enzymatic reactions. However, it is important to consider that, as dry products, flours are stable due to the low moisture content. The acidity parameter of food is directly linked to the preservation of the product, which explains the importance of knowing the acidity level of food, as it can influence the decomposition process, by oxidation, hydrolysis, or fermentation (Brasil, 2005). The values found for titratable acidity ranged between 0.83 and 1.20, and there was no difference between the temperatures at which the flours were dried. It is worth mentioning that the treatment with lyophilization led to the highest mean.

All flours from gueroba fruit pulp produced by drying and also the one produced by lyophilization showed values of soluble solids between 5.00 and 6.90 °Brix, with no statistical difference, which can occur due to the amount of sugars. According to Canuto et al. (2010), soluble solids are directly related to the amount of sugars and organic acids. For Coutinho (2013), one of the factors that influence the water absorption index (WAI) is its form of fragmentation, emphasizing that native plants, due to hydrophilic and hydrophobic aspects, have lower absorption potential when compared with gelatinized starches. This fact may explain the results obtained as the species in question is native. As water is one of the constituents in food, the interactions between these constituents are conditioned to the rheological characteristic and texture, as macromolecules (proteins and polysaccharides) influence the interaction between water and components (Cesario, 2012).

The oil absorption index (OAI) occurs due to the binding between proteins and oil. It indicates the potential application of the flour in food products (Santana et al., 2017). The flours from gueroba fruits obtained by oven drying (FEG40, FEG50, FEG60, and FEG70) did not differ for the WAI, with values between 3.05 and 3.23 g g^{-1}. Regarding the milk absorption index (MAI), none of the treatments showed a difference, with values of 6.04, 7.89, 6.33, 6.41, and 6.49 g g^{-1}, for FEG40, FEG50, FEG60, FEG70, and FEGL flours, respectively (Table 4).

Table 3. pH, total titratable acidity (TTA), and soluble solids (SS) of flours from the pulp of gueroba (*Syagrus oleracea*) fruits*.

Treatment	pH	TTA	SS (°Brix)
FEG40	6.21 ± 0.01a	1.13 ± 0.06a	6.36 ± 0.45a
FEG50	6.17 ± 0.02ab	1.03 ± 0.06a	5.06 ± 1.05a
FEG60	6.14 ± 0.02bc	0.90 ± 0.06a	5.93 ± 1.14a
FEG70	6.16 ± 0.03bc	0.83 ± 0.06a	6.90 ± 0.40a
FEGL	6.12 ± 0.02c	1.20 ± 0.10a	5.00 ± 0.25a

*Means followed by the same letters in the same column did not differ significantly by the Tukey's test at a 5% probability level.

Table 2. Coordinates L, a*, and b*, hue angle, and chroma of flours from the pulp of gueroba (*Syagrus oleracea*) fruits dried at different temperatures*.

Treatments	L	a*	b*	Chroma	°Hue
FEG40	67.05 ± 0.31a	7.02 ± 0.31b	30.43 ± 1.04ab	31.23 ± 0.99abc	1.34 ± 0.01a
FEG50	62.68 ± 2.53b	7.5 ± 0.26ab	27.01 ± 2.54b	28.037 ± 2.40c	1.30 ± 0.03b
FEG60	64.92 ± 2.74ab	8.45 ± 0.45ab	34.07 ± 2.60a	35.10 ± 2.44a	1.33 ± 0.03ab
FEG70	64.97 ± 0.61ab	8.2 ± 0.26ab	31.63 ± 0.65a	32.68 ± 0.70ab	1.32 ± 0.00ab
FEGL	59.03 ± 2.74c	8.68 ± 0.34a	27.21 ± 2.71b	28.56 ± 2.59bc	1.26 ± 0.03c

*Means followed by the same letters in the same column did not differ significantly by the Tukey's test at a 5% probability level.

The OAI of the FEG50, FEG60, and FEG70 flours differed from that of FEG40, and the last one mentioned obtained the highest mean (2.33 g g^{-1}), that is, higher absorption in oil. The food must have an oil absorption capacity to assist in the formulation of other foods (Zhang et al., 2012). The capacity to absorb and retain water in flour influences the texture and flavor retention, besides reducing moisture and oil losses of the products (Massola & Bianchini, 2012).

Even the means comparison test (Tukey's $p < 0.05$) showed no significant differences. Santana et al. (2017) attributed it to the types of hydrophobic groups found in proteins. This occurs because the absorption of fat changes depending on the amount of the existing hydrophobic groups of protein and their interaction with the hydrophobic chains of fat. This statement may justify the difference in MAI, which differed as a function of temperature. The balance of forces that are associated with formation and stability depends on the oil-water relationship (Cesario, 2012).

The concentrations of proteins, as well as their characteristics and composition, are factors related to foaming activity, the capacity to form hydrophobic bonds for the air-liquid interface to occur. The better the quality of the protein, about its capacity to form cohesive, elastic, and continuous films impermeable to air, the better the stability of the foam. Foaming activity is closely related to the concentration of proteins, and proteins of flexible chains and poor in secondary and tertiary structures that adapt quickly at the air-liquid interface are needed. In addition, these proteins need to be able to form hydrophobic bonds on their surface. Foam stability is related to the quality of the protein, and cohesive, elastic, continuous, and air-impermeable films need to be formed (Santana et al., 2017).

Foaming capacity (Table 5) did not differ between the flours produced by oven drying and lyophilization, with values of 2.22 for most of them. FEG40 had the highest foaming capacity (4.52). The main importance of foam in foods is related to the texture of the final product. The aeration of the product alters its rheology, contributing to those that were initially fluid to be molded (Campbell & Mougeot, 1999). None of the gueroba fruit pulp flours produced showed stability of the foam formed, and there was no more foam at the end of 30 min. The means comparison test showed differences for all treatments with drying at different temperatures. However, the same was not observed for protein and ash.

Table 4. Water, oil, and milk absorption indices of flours from the pulp of gueroba (*Syagrus oleracea*) fruits*.

Treatments	Absorption index (g/g)		
	Water	Oil	Milk
FEG40	3.05 ± 0.45a	2.33 ± 0.07a	6.04 ± 0.30a
FEG50	3.22 ± 0.25a	2.15 ± 0.02a	7.89 ± 0.15b
FEG60	3.23 ± 0.22a	1.93 ± 0.02a	6.33 ± 0.19a
FEG70	3.11 ± 0.14a	1.89 ± 0.02a	6.41 ± 0.30a
FEGL	3.05 ± 0.21a	1.94 ± 0.03a	6.49 ± 0.23a

*Means followed by the same letters in the same column did not differ significantly by the Tukey's test at a 5% probability level.

Table 6 shows that there was no difference for the variables as a function of the method used (temperature variation) and lyophilization, with a low standard deviation. This can be explained by maturity, storage time, and action of microorganisms, which are the main factors altering the indices of these variables when it comes to the drying process and temperature variation. Studies conducted by Dionello et al. (2000) and Menezes et al. (2012) can confirm these assumptions.

Regarding the lipid levels of gueroba fruit flours, Table 6 shows that drying did not cause significant increments in the FEG40, FEG50, FEG60, FEG70, and FEGL samples. The protein contents of FEG40, FEG50, and FEG60 differed from that of the lyophilized sample (FEGL), with variations among the treatments. The protein contents of the samples were close to those reported by Santana et al. (2017), who found protein values between 9.79 and 6.40 g 100 g^{-1} for fruit flours. Also, the ash contents of the FEG40, FEG50, FEG60, FEG70, and FEGL samples did not differ between treatments, showing mean values of 5.67, 5.39, 5.73, 4.86, and 5.85, respectively.

4 CONCLUSION

Oven drying and lyophilization allowed the production of flours from gueroba fruits with satisfactory characteristics, promoting reduction of initial water content, pH and acidity, lipids, and soluble solids. No difference was observed for variables that can affect quality, such as texture, color, and flavor. The only variable that showed a difference in the physicochemical analysis was pH, in the lyophilization treatment, compared with those with drying at different temperatures. Regarding the absorption indices, there was a significant difference in the MAI for the flour from gueroba fruit pulp dried at a temperature of 50°C. The means comparison test showed differences for lipids in the treatments with different temperatures. However, the same was not observed for protein and ash.

Table 5. Emulsion, emulsion stability, and foaming capacity of flours from the pulp of gueroba (*Syagrus oleracea*) fruits*.

Treatments	Emulsion	Emulsion stability	Foaming capacity
FEG40	0.87 ± 0.59ab	1.77 ± 2.31a	4.52 ± 0.14a
FEG50	0.37 ± 0.64b	0.29 ± 2.38a	2.22 ± 1.36a
FEG60	0.29 ± 0.59b	0.22 ± 0.13a	2.22 ± 1.28a
FEG70	0.22 ± 0.13b	0.22 ± 0.13a	2.22 ± 0.00a
FEGL	1.40 ± 0.13a	1.04 ± 0.13a	2.22 ± 0.00a

*Means followed by the same letters in the same column did not differ significantly by the Tukey's test at a 5% probability level.

Table 6. Lipids, ash, and proteins of flours from the pulp of gueroba (*Syagrus oleracea*) fruits expressed in g 100 g^{-1}*.

Treatment	Lipids	Ash	Proteins
FEG40	4.50 ± 0.06ab	5.67 ± 0.71a	9.79 ± 0.10a
FEG50	4.66 ± 0.05a	5.39 ± 0.39ab	8.90 ± 0.18ab
FEG60	4.54 ± 0.20a	5.73 ± 0.31a	8.80 ± 0.27ab
FEG70	4.61 ± 0.26a	4.86 ± 0.45b	7.44 ± 0.19bc
FEGL	4.32 ± 0.24b	5.85 ± 0 .37a	6.40 ± 0.18c

*Means followed by the same letters in the same column did not differ significantly by the Tukey's test at a 5% probability level.

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