PHYSICAL-CHEMICAL CHARACTERIZATION OF POWDER SOURSOP OBTAINED BY FOAM-MAT DRYING

CARACTERIZAÇÃO FÍSICO-QUÍMICA DE PÓ DE GRAVIOLA OBTIDO POR SECAGEM EM LEITO DE ESPUMA

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ABSTRACT: The development and improvement of fruit processing technologies in powder form is a alternative to add value to the product and increase the income of the producers, being required the knowledge of physical-chemical properties of the product. The aim of this study was to determine the physical-chemical properties of soursop powder obtained by foam-mat drying. To the foam formation, albumin was added to the pulp at concentration of 7.43% in mass and subjected in mixer for 15 min; then, it was spread onto trays forming a thin layer about 5.0 mm thick, and the drying conditions were: 40, 50, 60, 70 and 80 °C, 5.6 m s^{-1} and 60%. Moisture content, water activity, titratable total acidity and hydrogenic potential of soursop powder indicate good stability of the product obtained by foam-mat drying, without the need of addition of preservatives for its conservation. Reducing sugars increased with increasing drying temperature due to the concentration of the compounds caused by moisture content reduction. In addition, the color was the physical-chemical property that presented greater sensitivity to drying, mainly by darkening index. Temperatures lower than 60 °C indicate higher preservation of initial characteristics for soursop powder. Besides that, bulk density, true density, porosity and repose angle increased subtly with drying temperature.

KEYWORDS: *Annona muricata* L. Moisture content. Bulk density. Color. Repose angle.

INTRODUCTION

Soursop (*Annona muricata* L.) is a fruit belonging to Anonaceous family originating from lowlands of Tropical America (BAPTESTINI et al., 2015). In Brazil, it is specially grown in northeastern states and the production is destined to agroindustry, where it is used in manufacture of juice, ice cream, jams and crystallized sweets (FIGUEIRÊDO et al., 2013). The regionalization of production, combined with the difficulty in reconciling the supply and the perishability of the fruit, contribute to the development and improvement of conservation processes, such as drying and refrigeration (BAPTESTINI, 2015).

The development and improvement of the technology of processing of fruit powder facilitates the consumption of the same in any time of the year (OLIVEIRA et al., 2010). In the foam-mat drying method, the food is transformed in a stable foam by means of foaming agents and air incorporation, nitrogen or other gases, in blenders or other foam generating equipment (FELLOWS, 2006). The foam is spread over a perforated or non-perforated surface, generally using layer with thickness around 2 to 5 mm. Drying results in a porous and brittle product, of easy milling and powder transformation with good rehydration properties (BASTOS et al., 2005).

Physical-chemical parameters of some powdered foods can be found in literature: *Cuminum cyminum* (BRITO et al., 2012), cocoa substitutes (MEDEIROS; LANNES, 2010) and ground roasted coffee (OLIVEIRA, et al., 2014) but, related to soursop are few (GURGEL, 2014; MACHADO, 2015). According to Wilhelm et al. (2004), the study of physical properties enables the prediction of agricultural products behavior relative to responses of physical and chemical treatments, in order to allow the maintenance of quality and safety of processed foods. Already Canuto et al. (2010) affirm that the physical-chemical characterizations of fruits are important for the knowledge of nutritional value, and from the commercial point of view, to add value and quality to the final product.

This study aimed to determine and evaluate the physical-chemical properties of powder soursop obtained by foam-mat drying.

MATERIAL AND METHODS

Soursop fruits (*Annona muricata* L.) were used, in which the pulp was obtained with the aid of industrial pulper, then it was packed in PET bottles

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sanitizes with water and chlorine, and stored in a freezer at -18 °C for later use.

To the foam formation, was added the albumin pulp at concentration of 7.43% in mass and submitted to stirring in a domestic shaker for 15 min.

Formed foam was scattered on trays forming a thin layer of about 5.0 mm thickness. Then, the trays were taken to drying in an oven with forced air circulation, in which the temperatures, velocity and average relative humidity of input air were 40, 50, 60, 70 e 80 °C, 5.6 m s^{-1} and 60% (BAPTESTINI et al., 2015).

Following analyzes were made to characterize the physical-chemical properties of soursop powder:

Moisture content.

Was obtained by gravimetry using oven at 105 ºC for 24 h. For weighing, an analytical balance was used.

Water activity (a_w).

Was determined by Aqualab 4TE apparatus at 25 °C of temperature.

Titratable total acidity (TTA).

Was determine in percentage of citric acid by titration of 10 mL of sample in 90 mL of distilled water with solution 0.1 N of NaOH, in presence of phenolphthalein.

Hydrogen potential (pH).

Was determined directly in the samples by potentiometry, using a pHmeter.

Total soluble solids content (TSS).

Was determined by a refractometer, being expressed in °Brix.

Total soluble sugar content (TSS) and reducing (SR).

Was made according to method of Somogyi-Nelson (MALDONADE et al., 2013).

Color.

Samples were submitted to reading in a tristimulus colorimeter, for direct determination of reflectance of L^*, a^* and b^* coordinates, using the Hunter Lab scale and the illuminant 10°/D65.

By L^*, a^* e b^*values, colorimetric indexes were calculated: chroma (C^*) (Equation 1), and hue angle (h^*) (Equation 2).

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

$$h^* = \tan^{-1} \frac{b^*}{a^*} \quad (2)$$

True density (ρ_u).

Was determined with a helium pycnometer, followed by use of 3 and 4 equations:

$$V_s = V_e - V_a\left(\frac{P_1}{P_2} - 1\right) \quad (3)$$

$$\rho_u = \frac{m_s}{V_s} \quad (4)$$

In wich:

P_1: initial pressure, (psi); P_2: final pressure, (psi); V_a: sample chambre volume, (cm^3); V_s: solid volume, (cm^3); V_e: expansion chambre volume, (cm^3); ρ_u: true density, (kg m^{-3}); m_s: solids mass, (g).

Bulk density (ρ_{ap}).

Was determine using a hectoliter balance.

Porosity (Ɛ).

Was calculated indirectly according to Equation 5 (MOHSENIN, 1986).

$$\varepsilon = 100\left(1 - \frac{\rho_{ap}}{\rho_u}\right) \quad (5)$$

In wich:

ε: porosity, (%); ρ_{ap}: bulk density, (kg m^{-3}).

Repose angle (α).

To determine the repose angle was used a cylinder provided of an opening on the bottom on which a circular platform of known diameter rises. The cylinder, with the bottom opening closed, was filled with the powder. Then, the powder was removed by the opening in the bottom, remaining a cone of dust on the circular platform. Repose angle was calculated by the following equation:

$$\alpha = arctag\left(\frac{2h}{D}\right) \quad (6)$$

In wich:

α: repose angle, (degrees); D: diameter of circular platform, (mm); h: height of dust cone, (mm).

Statistical analysis.

The experiment was set up according to completely randomized design with five replicates, and data were analyzed by regression analysis. Models were chosen based in the coefficient of determination and the significance of regression coefficients; using test "t" and adopting level of 5% of probability.

RESULTS AND DISCUSSION

It is observed the reduction of moisture content and water activity with the increase of drying temperature (Figure 1) and good adjustment of linear and quadratic model for moisture content and water activity, respectively (Table 1). The use of higher temperatures implies a greater temperature difference between the product and the drying air, resulting in greater heat transfer and, consequently, greater evaporation of water in the product, resulting in lowers moisture content and water activity.

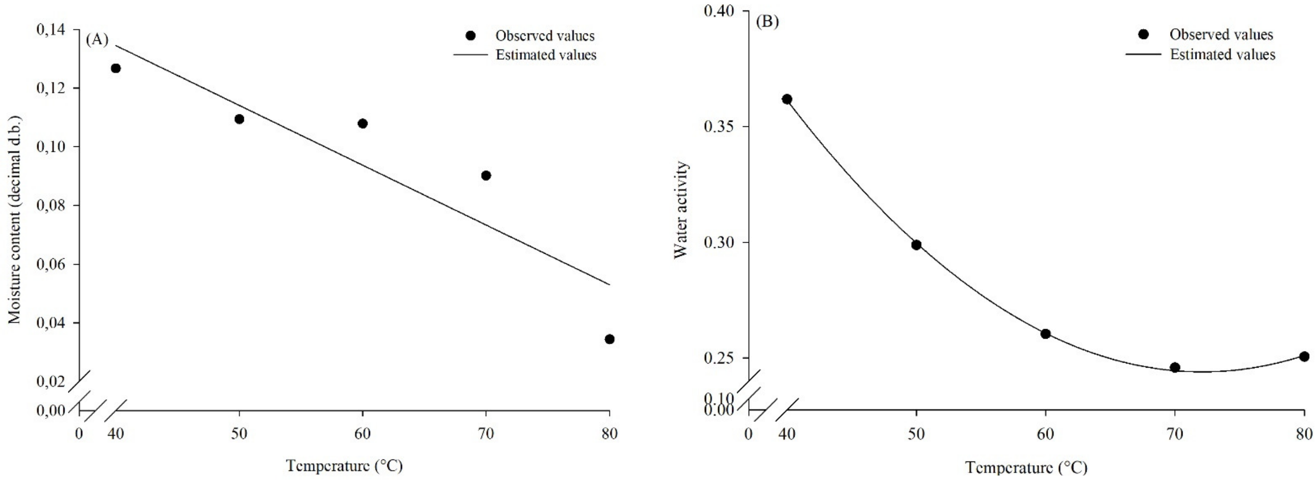

Figure 1. Effect of drying temperature on moisture content (A) and water activity (B) of soursop powder.

Table 1. Regression equations as a function of temperature (T) and coefficients of determination.

Identification	Equation	R^2 (%)
Moisture content	$MC = -0.002 \times T + 0.216$	81.98
Water activity	$A_w = 0.0001 \times T^2 - 0.016 \times T + 0.836$	99.97
Titratable total acidity	$TTA = 0.001 \times T + 0.21$	99.99
Hydrogen potential	$pH = 4.69$	-
Total soluble solids	$TSS = -0.01 \times T + 4.07$	62.50
Total soluble sugar	$TSS = -0.009 \times T^2 + 1.453 \times T - 18.346$	99.63
Reducing sugars	$RS = -0.002 \times T^2 + 0.336 \times T - 0.404$	91.72
L^* coordinate	$L^* = -0.01 \times T^2 + 1.34 \times T + 30.50$	98.10
a^* coordinate	$a^* = -0.07 \times T + 11.83$	85.32
b^* coordinate	$b^* = 0.003 \times T^2 - 0.37 \times T + 31.67$	97.93
Hue angle	$h^* = 0.21 \times T + 59.97$	93.32
Chroma	$C^* = 0.004 \times T^2 - 0.43 \times T + 35.43$	91.66
True density	$\rho_u = 0.218 \times T + 1380.553$	98.11
Bulk density	$\rho_{ap} = -0.025 \times T^2 + 3.551 \times T + 293.716$	86.42
Porosity	$\varepsilon = 0.005 \times T^2 - 0.566 \times T + 85.60$	88.60
Repose angle	$\alpha = -0.001 \times T^2 + 0.17 \times T + 7.83$	81.76

Moisture content of soursop powder remained within the standards established by the National Sanitary Surveillance Agency (ANVISA) for dehydrated products. The RDC resolution nº 272 of September 22, 2005 of ANVISA recommends that dried or dehydrated fruit products must have a maximum moisture content of 25% (BRASIL, 2005). Osório et al. (2011) report moisture content of 5.37±1.63 e 2.75±1.72 (g/100g) in powdered guava pulps obtained by drying with hot air and by lyophilization, respectively.

Low values of physical-chemical characteristics of soursop powder contribute to its conservation, because according to Jay (2006) values of water activity between 0.44 and 0.54 present reduced enzymatic activity and there is no growth of filamentous fungi, yeasts and bacteria.

Titratable total acidity increased with the elevation of drying temperature (Figure 2A), as expected, due to concentration of compounds provided by the reduction of moisture content. In addition, good fit of linear model is observed (Table 1).

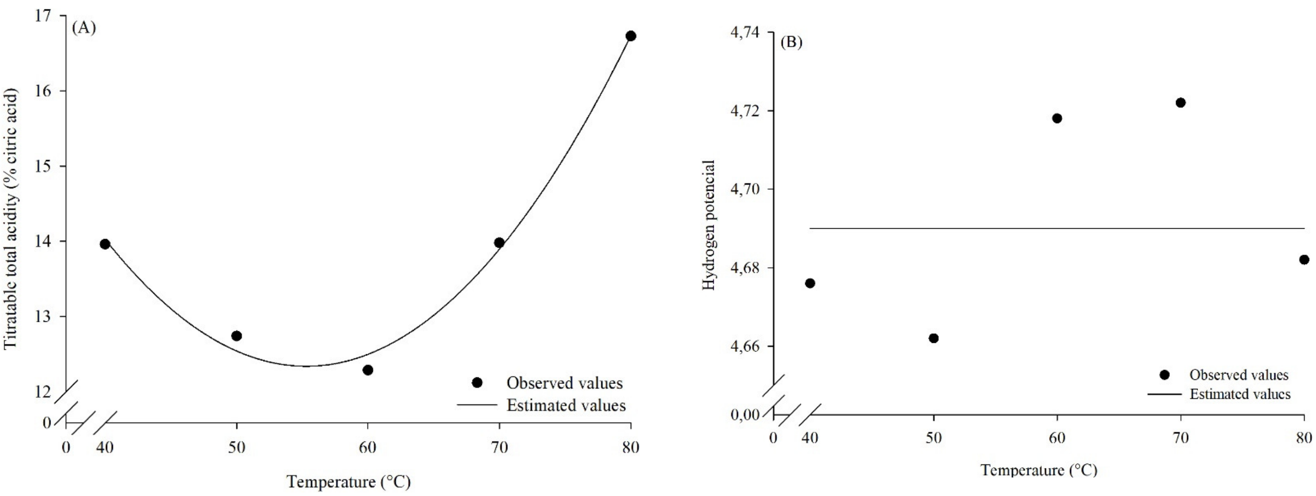

Figure 2. Effect of drying temperature on titratable total acidity (A) and hydrogen potential (B) of soursop powder.

To the experimental data of hydrogen potential (Figure 2B) it was not possible to adjust regression curve, being the average represented by the line. Moreover, it was observed that the hydrogen potential presented low values, as well as titratable total acidity. These parameters, along with moisture content and water activity, indicate that soursop powder probably does not require the addition of preservatives to prevent the development of fungi and bacteria.

Total soluble solids correspond to all solids dissolved in water, such as sugars, salts, proteins and acids, which are important compounds responsible for the taste and consequent acceptance by consumers (MORAES, 2006). These reduced with increasing drying temperature, which was not expected (Figure 3A).

Carbohydrates are the most abundant macronutrients in fruits and vegetables, being classified in mono, oligo and polysaccharides. Monosaccharides are simple non-hydrolysable sugars, while oligosaccharides and polysaccharides are formed by monosaccharide molecules bound by hemiacetal bonds (MALDONADE et al., 2013). Monosaccharides are reducing sugars because they have a free carbonyl or ketone group, which can be oxidized in presence of oxidizing agents in alkaline solutions. Oligo and polysaccharides, which do not have this characteristic without suffering hydrolysis of glycosidic bond, are denominated non-reducing sugars (SILVA et al., 2003). The total soluble sugar and reducing sugars content increased with increasing drying temperature, due to compounds concentration coming from moisture content reduction (Figure 3B and 3C). A good fit of quadratic model is observed (Table 1).

The luminosity increase with drying temperature elevation (Figure 4A), until 60 °C of temperature. From this point, the value decreases because the compounds concentration occurs due to more pronounced reduction in moisture content. Ramallo and Mascheroni (2012) did not have significant variations in the L* coordinate of dehydrated pineapple slices, with 69.26±2.92 of average value. With respect to a* coordinate (Figure 4B), it was observed decrease of coordinate with increase of drying temperature, but this remained positive, indicating the color as little red.

The b^* coordinate (Figure 4C) increased with increase of drying temperature, indicating greater intensity of yellow color, and presented lower values when compared to mean values (29.11±1.58) reported by Ramallo and Mascheroni (2012) when studying pineapple slices.

The models fitted to experimental data of L^*, a^* and b^* coordinates as a function of temperature, presented good adjustments with determination coefficient of 98.10, 85.32 and 97.93%, respectively and significance of regression coefficients (Table 1).

Color is an attribute fundamental in judgment of food quality, once the visual appreciation is the first sense to be used and therefore, a decisive characteristic in the choice and the product acceptance (LIMA et al., 2007). The visual impact generated by color may overlap with that caused by other attributes of appearance and odor, and can also exhibit effect on own intensity where the taste is perceived (SILVA, 2012).

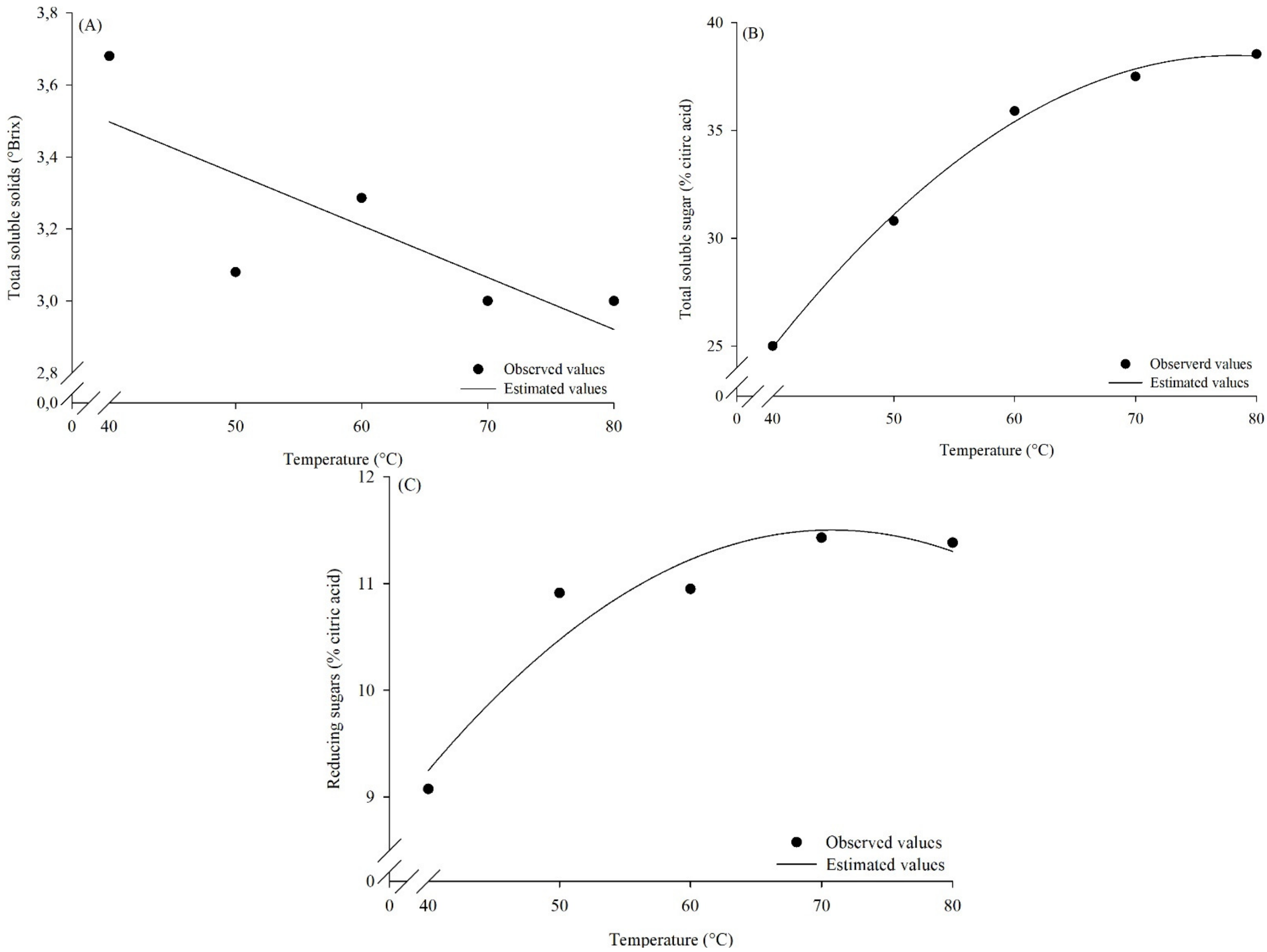

Figura 3. Effect of drying temperature on total soluble solids (A), total soluble sugar (B) and reducing sugars (C) of soursop powder.

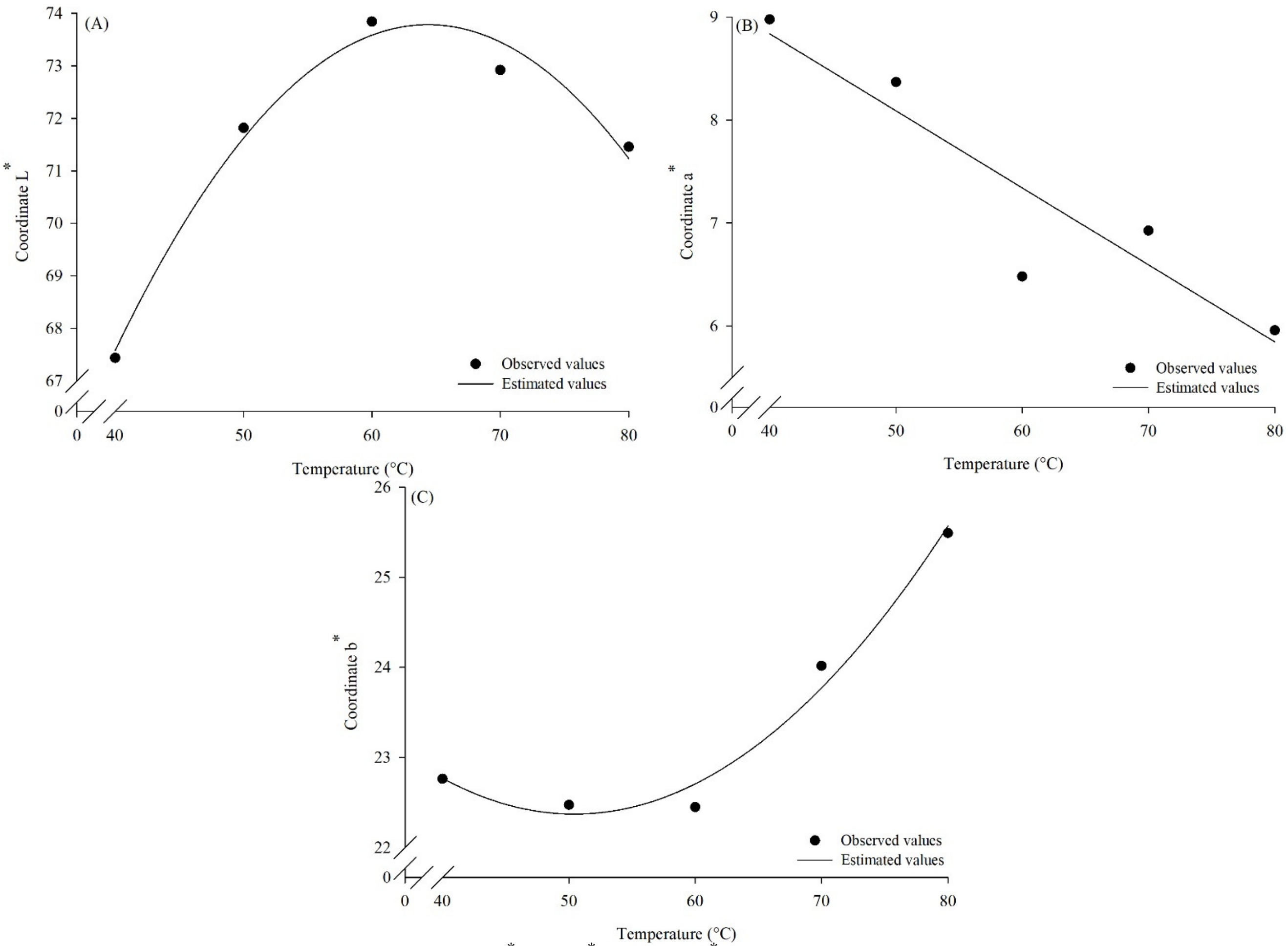

Figure 4. Effect of drying temperature on L^* (A), a^* (B) and b^* coordinates (C) of soursop powder.

The general appearance of a product is a combination of luminosity, hue angle and chroma, whose combination of these three attributes that produces a visual impact on human eyes (LIMA et al., 2007).

Chromatic tonality or hue (Figure 5A) was the parameter that presented the most significant changes with drying. It was verified increase of hue with elevation of drying temperature from 68.51 to 76.83, indicating a tendency of yellow-orange for the soursop powder.

Saturation (Figure 5B) had a quadratic behavior with drying temperature (Table 1). Their values were 24.48 to 26.18, with little increase, showing the color stability. These values were similar to those found by Ramallo and Mascheroni (2012) in drying of pineapple.

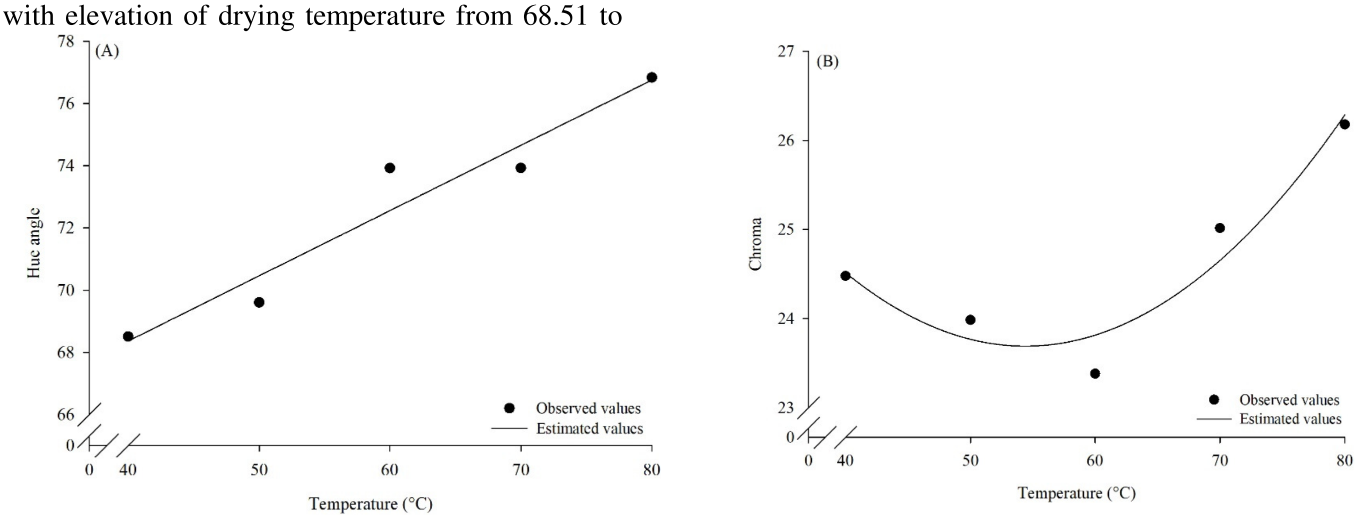

Figure 5. Effect of drying temperature on hue angle (A) and chroma (B) of soursop powder.

True density (Figure 6A) represents the ratio between solid mass and volume occupied by the product, excluding open and closed pores, as well as other empty spaces (BRITO et al., 2012). True density ranged from 1389.29 to 1398.22 kg m^{-3}; presented a linear relation with drying temperature and determination coefficient of 98.11% (Table 1).

The influence of drying temperature on bulk density is shown in Figure 6B. Bulk density is the ratio between solid mass and solid volume containing pores (OLIVEIRA et al., 2014). It is observed increase of bulk density with increase of drying temperature and good adjustment of quadratic model (Table 1). This trendy was not expected, once at higher temperatures, the moisture content was lower, resulting in higher bulk density values. However, it was observed visually that the particle size decreased with increasing drying temperature. In a given volume, finer particles agglomerate more intensely, resulting in a larger mass for that volume, whereas for larger particles there is less agglomeration, culminating in a lower mass and, consequently, lower bulk density values. This research corroborates with Carvalho (2014), what studied the production of pumpkin pulp powder by the foam bed drying process. Bulk density ranged from 392.93 to 418.88 kg m^{-3}; presented a linear relation with drying temperature and determination coefficient of 86.42% (Table 1).

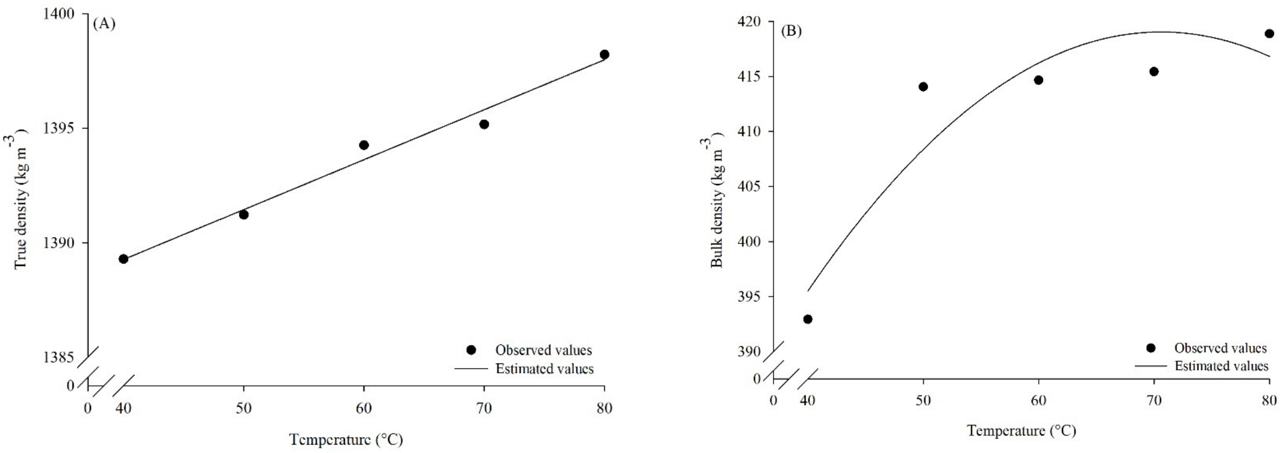

Figure 6. Effect of drying temperature on true density (A) and bulk density (B) of soursop powder.

Porosity of soursop powder (Figure 7A) had minimal influence of drying temperature and presented values between 69.53 and 72.97%. At higher drying temperatures, the porosity had a small increase, possibly by the fine granulometry of the powder. Schubert (1987) reports that porosity increases with decreasing particle size due to adhesion between particles allows a loose structure of the mass.

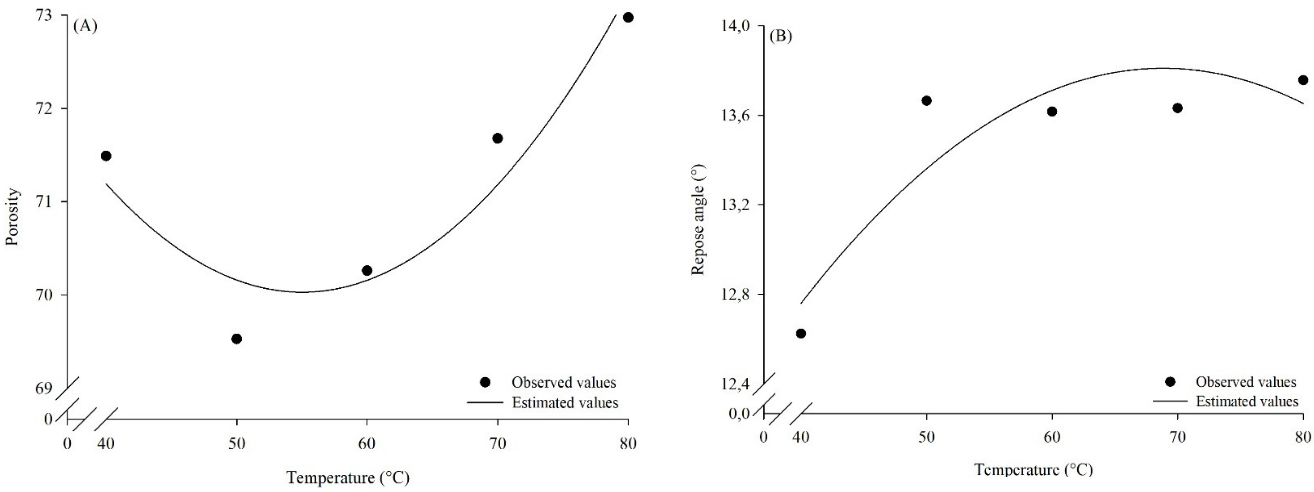

Figure 7. Effect of drying temperature on porosity (A) and repose angle (B) of soursop powder.

Repose angle value of soursop powder (Figure 7B) increased with elevation of drying temperature. At higher temperatures, the powder had finer grain size. Geldart et al. (2009) emphasize that smaller particles allow increase of total number of these particles in the product mass, increasing the cohesion forces product/product. This favors better stability to product mass, culminating in formation of larger slopes.

CONCLUSIONS

Moisture content, water activity, titratable total acidity and hygrogenic potential of soursop powder indicate good stability of the product obtained by foam-mat drying, without the need of addition of preservatives for its conservation.

Reducing sugars increased with increasing drying temperature due to the concentration of the compounds caused by moisture content reduction. In addition, the color was the physical-chemical property that presented greater sensitivity to drying, mainly by darkening index.

Temperatures lower than 60 °C indicate higher preservation of initial characteristics for soursop powder. Besides that, bulk density, true density, porosity and repose angle increased subtly with drying temperature.

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RESUMO: O desenvolvimento e aperfeiçoamento de tecnologias de processamentos de frutos na forma de pó é uma alternativa para agregar valor ao produto e aumentar a renda dos produtores, sendo necessário para isso o conhecimento das propriedades físico-químicas do produto. Assim objetivou-se determinar as propriedades físico-químicas do pó de graviola obtido pelo método de secagem em leito de espuma. Para a formação da espuma foi adicionada, à polpa, albumina, na concentração de 7,43% em massa e submetida à agitação em batedeira doméstica, durante 15 min; em seguida, esta foi espalhada sobre bandejas formando uma camada fina de cerca de 5,0 mm de espessura cujas condições de secagem foram: de 40, 50, 60, 70 e 80 °C, 5,6 m s^{-1} e 60%. O teor de água, atividade de água, acidez total titulável e o potencial hidrogeniônico do pó de graviola indicam boa estabilidade do produto obtido pelo método de secagem em leito de espuma, não necessitando portanto, da adição de conservantes para sua conservação. Os açúcares aumentaram com o incremento da temperatura de secagem devido a concentração dos compostos provocada pela redução do teor de água. Adicionalmente, a cor foi a propriedade físico-química que apresentou maior sensibilidade à secagem, principalmente pelo índice de escurecimento. Temperaturas menores que 60 °C indicam maior preservação das características iniciais para o pó de graviola. Além disso, a massa específica aparente e unitária, a porosidade e o ângulo de repouso aumentaram sutilmente com a temperatura de secagem.

PALAVRAS-CHAVE: *Annona muricata* L. Teor de água. Massa específica aparente. Cor. Ângulo de repouso.

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