Hindawi
Journal of Food Quality
Volume 2022, Article ID 7107107, 8 pages
https://doi.org/10.1155/2022/7107107

Research Article

Impact of Different Drying Methods on the Acerola-Ceriguela Mixed Pulp: Physicochemical Characteristics, Bioactive Compounds, and Sensory Attributes

Marcony Silva Júnior,[1] **Nathalia Silva**,[1] **Christine Ribeiro**,[1] **Caio Veríssimo**,[2] **Ana Paula Rocha**,[3] **Carlos Grosso**,[1] **and Maria Inês Maciel**[1]

[1]*Food Science and Technology, Federal Rural University of Pernambuco (UFRPE), Recife, PE, Brazil*
[2]*Department of Rural Technology, UFRPE, Recife, PE, Brazil*
[3]*Agroindustry Laboratory, Federal University of Campina Grande, Campina Grande, PB, Brazil*

Correspondence should be addressed to Maria Inês Maciel; m.inesdcd@gmail.com

Received 8 February 2022; Accepted 15 June 2022; Published 6 July 2022

Academic Editor: Encarna Aguayo

Fruit mixed pulp has the objective of improving the nutritional and sensorial characteristics, as well as the development of new flavours and aromas. Different methods of drying (e.g., spray-drying, spouted bed drying, and freeze-drying) can influence the quality of the final product. The objective of this study was to select the drying method that enables the production of acerola-ceriguela mixed pulp (ACMP) with higher quality. For this selection, the powder pulps were evaluated for their physicochemical characteristics (water activity, moisture, soluble solids (SS), titratable acidity (TA), SS/TA, and instrumental colour), retention of the bioactive compounds (ascorbic acid, total carotenoids, and phenolic compounds), and sensory evaluation (acceptance, check-all-that-apply (CATA), and intent to purchase). The physicochemical characteristics of the freeze-dried and spray-dried ACMP were nonsignificant ($p > 0.05$) but differed significantly ($p > 0.05$) from spouted bed powder. ACMP freeze-drying powder resulted in higher retention of ascorbic acid, total carotenoids, and phenolic compounds. The powder obtained by spray-drying showed higher retention of bioactive compounds compared to the spouted bed drying. Therefore, this study suggests that powder obtained by freeze-drying resulted in greater sensorial acceptance.

1. Introduction

Brazil has the highest biodiversity of fruit, particularly tropical ones with exotic flavours and aromas that are greatly appreciated by consumers, including acerola (*Malpighia emarginata* D.C.) and ceriguela (*Spondias purpurea* L.) [1, 2]. Acerola is one of the richest natural sources of ascorbic acid and contains a plethora of phytonutrients like carotenoids, phenolics, anthocyanins, and flavonoids [3]. Fruit consumption is associated not only with the maintenance of various metabolic activities of the organism but also with a reduction in the risk of degenerative diseases [4]. Health benefits can be attributed to the antioxidant capacity of the fruit depending on the type of phytochemicals, such as vitamins, carotenoids, and polyphenols [5]. Fruit has a high moisture content (80%) that results in its classification as perishable. To increase the shelf life of the fruit and avoid the degradation of vitamins and other nutrients, different methods of preservation can be utilized. Dehydration of fruits is a widely popular preservation technique to extend their shelf life and make seasonal produce available throughout the year [6]. Among them, drying that enables the production of powders with low moisture prolongs the shelf life of food. In addition, drying offers a convenient consumer product and/or ingredient that are handled more easily by food processors [7].

There are various drying techniques used to produce powdered foods, such as spouted bed drying, spray-drying, and freeze-drying. These techniques prevent significant losses of food products [8]. Spray-drying has been widely used for commercial purposes, primarily to produce fruit juice powder and powdered milk [9]. The spouted bed drying is a promising alternative to dry fruit pulps that produce a high-quality powder and has the potential to conduct granulation or agglomeration at a low cost [10]. Freeze-drying is a technique based on water removal by sublimation developed to overcome the losses of the compounds responsible for the aroma of foods [5].

Physicochemical, sensory attribute, and bioactive compound determinations are necessary to develop new products before their commercialization. The desire of the food industries to have access to fast sensorial methods triggered the development of the check-all-that-apply (CATA) method. The CATA test is a descriptive test that has been widely used to quickly obtain the sensory profile of products for consumers [11]. The CATA consists of a predefined list of attributes that are presented, and the participants are instructed to select all that apply [12, 13].

The objective of this study was to characterize the physicochemical characteristics, bioactive compounds, and sensory attributes of the acerola-ceriguela mixed pulp (ACMP) obtained by different drying methods (spray-drying, spouted bed drying, and freeze-drying) and to select the one that maintains the highest content of bioactive compounds and the most accepted by the consumers in the final product.

2. Materials and Methods

2.1. Materials. Acerolas (soluble solids 7.23 Brix and moisture content 91.61%) and the ceriguelas (soluble solids 17.73 Brix and moisture content 75.59%) were obtained from the Center of Supply and Logistics of Pernambuco (CEASA/PE). The carrier agent used was maltodextrin (MOR-REX® 1910) 10 DE from Corn Products (Mogi Guaçu, Brazil).

2.2. Obtaining Acerola-Ceriguela Mixed Pulp (ACMP). The fruits of acerola and ceriguela were selected by their stage of maturation with the characteristic colouration of each one. They were washed, sanitized in 2.5% sodium hypochlorite solution, and pulped (Bonina Compacta, Itabuna/BA). The pulp was packed in low-density polyethylene bags, immediately frozen, and stored at −18°C. The proportion of pulp used to prepare the ACMP was 60% acerola and 40% ceriguela in relation to the mass of the pulp (g) [14].

2.3. Production of the ACMPs Obtained Using Different Drying Methods. The ACMP was subjected to drying in a spray dryer (MSD 1.0, LABMAQ do Brazil LTDA, Ribeirão Preto, Brazil) using the conditions optimized for mixed acerola and ceriguela juice [14]. The mixture was stirred continuously in a homogenizer (TE-102, Tecnal, Piracicaba, Brazil) until it was completely dissolved before its injection into the atomizer. The ACMP was subjected to drying in the spouted bed (FBDJ 1.0, LABMAQ do Brazil LTDA, Ribeirão Preto, Brazil) using the air pressure (4 bar) and 1 kg of polystyrene particles of type 849. For freeze-drying, 20 g of the ACMP was placed in polyethylene Petri dishes (90 mm × 15 mm) and frozen at −22°C. These plates were subsequently subjected to dewatering in a freeze dryer (Genesis 25 L Pilot Sp Scientific, VirTis, Warminster, USA). The drying conditions used to produce the ACMP were selected from previous studies and are given in Table 1.

2.4. Physicochemical Analyses of the ACMPs Obtained Using Different Drying Methods. To obtain the physicochemical characterization of the ACMPs, the following determinations were performed: water activity, moisture, soluble solids (SS), pH, titratable acidity (TA), and SS/TA ratio, as previously described by AOAC [15].

2.5. Colour Parameters. The colour parameters of the powders were determined using a colorimeter (CR-200, Minolta Co., Japan) and expressed using the Hunter colour values, L, a^*, and b^*, where $L = 100$ and $L = 0$ denote lightness and darkness; $+a^*$ and $-a^*$ denote redness and greenness; and $+b^*$ and $-b^*$ denote yellowness and blueness. The colour difference was calculated using the colour average (ΔE^*) between the pulp *in natura* and the powdered product based on

$$\Delta E^* = \left(\left(L^* - L_0\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2 \right)^{0.5}, \quad (1)$$

where $L_0{}^*$ and L ($p < 0.05$) are the luminosities, $a_0{}^*$ and a* are the intensities of the red or green colour, and $b_0{}^*$ and b* are the intensities of the yellow or blue colour of the mixed pulp *in natura* and the powdered product, respectively.

The colour intensity was expressed as the Chroma value equation (2) and H° hue angle equation (3). The pure colours of red, yellow, green, and blue are denoted by the hue angle values of 0°, 90°, 180°, and 270°, respectively.

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

$$H^\circ = \tan^{-1}\left(\frac{b^*}{a^*}\right), \quad (3)$$

where a^* and b^* are the intensities of the red or green colour and intensities of the yellow or blue colour of the mixed pulp powdered product, respectively.

2.6. Determination of the Bioactive Compounds of the ACMPs. The ascorbic acid content (AA) was determined with 2,6-dichlorophenol indophenol as previously described by AOAC [15]. The total carotenoid content was determined as described before by Rodrigues-Amaya [16]. The phenolic compound (PC) contents were determined using the Folin–Ciocalteu [17]. The PC content was calculated using a standard curve prepared with gallic acid (1 mg/mL) and expressed in mg gallic acid equivalent (GAE)/100 g of powder. The results were converted into retention terms factoring in the dry basis (d.b.) present in the ACMP before drying.

Table 1: Conditions used to produce ACMP by different drying methods.

Operating conditions	Spray-drying	Freeze-drying	Spouted bed drying
Temperature (°C)	140	−20	75
Suspension flow rate (mL/min)	10	—	5
Chamber pressure (mTorr)	—	500	—
Carrier agent concentration (%)	14	25	15

2.7. Sensory Evaluation. The preparation of the mixed juice was conducted with the ACMP powder obtained by different drying methods and was based on the equivalence of the soluble solids (°Brix) of the *in natura* pulp. The mixed juice was prepared by diluting 30 g of powdered ACMP in 1 L of potable water. All the mixed juices were sweetened with 8% sucrose, prepared one hour in advance, and stored at 7 ± 2°C until they were served to the assessors.

The sensory evaluations were performed in standardized individual booths according to guidelines of the ISO 8589: 2007 standard [18] and conducted at the Laboratory of Sensory Analysis from the Federal Rural University of Pernambuco (UFRPE) after approval from the Research Ethics Committee of the University of Pernambuco (UPE) (Process no. 2.701.238; CAAE 87896318.7.0000.5207). A total of 102 consumers, with ages ranging from 18 to 30 years, were recruited based on the consumption habit of acerola and/or ceriguela juice and refreshments.

All samples (50 mL) were blind-labeled with a three-digit random code and presented in balanced order to account for first-order and carryover effects (Williams design) and were presented monadically in disposable cups at 10°C ± 0.5°C. Following the CATA methodology [19], the consumers were asked to try the samples and evaluate them according to beverage tasting dynamics (visual, olfactory, and flavour aspects), reducing the cognitive effort of the evaluators. At first, the consumers had to indicate all the terms that they considered appropriate to describe the sample from a list containing 24 sensory attributes (5 visual, 7 olfactory, 2 texture, and 10 flavour attributes), all presented in a balanced order within each category. In the end, the panel had to evaluate the overall liking of samples using a 9-point structured hedonic scale.

2.8. Antioxidant Capacity of the Freeze-Dried ACMP. The antioxidant capacity was determined using the DPPH method with modifications [20, 21]. The results were expressed as the EC_{50} (concentration of the extract in μg/mL capable of reacting with 50% of the radicals present in the DPPH solution). The ABTS method was conducted as described before, expressed as equivalent to the antioxidant capacity of TROLOX (μM TEAC g^{-1}) [22].

2.9. Statistical Analysis. The experiments and determinations were conducted in triplicate. The data were analyzed statistically using the SPSS software (SPSS 20.0, SPSS Inc., Chicago, USA), and the means were compared using a Tukey test ($p < 0.05$). All the data are presented as the means with the standard deviations.

The acceptance data were submitted to an analysis of variance followed by a Tukey test to verify if there was any difference between the samples at $p < 0.05$ using the software Assistat (version 7.7, UFCG, João Pessoa, Brazil). The frequency of the mention of each sensory term was determined by counting the number of consumers who used that term to describe each sample of refreshment, thus generating the contingency table. The data were submitted to Multiple Factorial Analysis (AFM), and the acceptance data were considered as a supplementary variable using the software (XLSTAT, Addinsoft, New York, NY).

3. Results and Discussion

3.1. Physicochemical Characterization of the Powders. The physicochemical characterization of the ACMPs (60% acerola and 40% ceriguela) obtained by spray-drying, freeze-drying, and spouted bed drying is given in Table 2. The proportion of pulp used to prepare the ACMP was 60% acerola and 40% ceriguela in relation to the mass of the pulp (g) [14].

The ACMP that presented the highest aw was the one obtained using the spouted bed drying 0.32 (Table 2). Similarly, Germer et al. [23] found water activity values between 0.27 and 0.34 in a spouted drying study of manga pulp using 3% corn starch and 0.5% glyceryl monostearate. The sugar remained in the wall of the drying chamber during the process, which impacted the quality of the final product. The configuration of the spouted bed, which used a temperature of 75°C, facilitated the caramelization of the low molecular weight sugar present in the fruit [8]. Spray-drying of the ACMP resulted in lower and significant moisture content (2.89%, $p < 0.05$). Similarly, Germer et al. [23] found moisture values between 1.00 and 4.00% in a spouted drying study of manga pulp. The drying temperature used in the spray-drying (140°C) assisted in the process of the evaporation of water. As the temperature increases, the rate of the heat transfer to the particle is larger, providing a larger conduction force for the evaporation of the moisture [24]. The values of the total soluble solids, pH, total acidity, and TSS/TA ratio in the ACMP obtained by the different drying methods did not differ significantly ($p < 0.05$) (Table 2).

3.2. Colorimetric Parameters of the Powder. The colour of the powder products is a crucial factor in consumer acceptance even if it is used as an ingredient in other food matrices [8]. Table 3 provide the colorimetric parameters for the ACMP powders obtained by the different drying methods.

The ACMPs powder had high L^* values between 83.71 and 90.34 (Table 3). The values of the coordinates a^* and b^*

Table 2: Physicochemical characterization of acerola-ceriguela (60% acerola and 40% ceriguela) mixed pulp obtained by spray-drying, freeze-drying, and spouted bed drying.

Physicochemical parameters	Spray-drying	Freeze-drying	Spouted bed drying
Aw	$0.17^{b} \pm 0.03$	$0.19^{b} \pm 0.01$	$0.32^{a} \pm 0.01$
Moisture (%)	$2.89^{c} \pm 0.12$	$4.51^{b} \pm 0.15$	$5.49^{a} \pm 0.03$
Total soluble solids (°Brix)	$8.64^{a} \pm 0.30$	$7.83^{a} \pm 0.30$	$7.80^{a} \pm 0.40$
pH	$3.42^{a} \pm 0.06$	$3.35^{a} \pm 0.04$	$3.40^{a} \pm 0.07$
Total acidity (g/100 g of citric acid)	$0.36^{a} \pm 0.02$	$0.34^{a} \pm 0.03$	$0.32^{a} \pm 0.01$
TSS/TA ratio	$23.65^{a} \pm 2.13$	$23.10^{a} \pm 1.15$	$23.62^{a} \pm 0.64$

*Triplicate mean ± standard deviation. Means in each line followed by different superscript letters were significantly different ($p < 0.05$), by Tukey's test.

Table 3: Colorimetric parameters of acerola-ceriguela (60% acerola and 40% ceriguela) mixed powder pulps obtained by the different drying methods.

Colorimetric parameters	Spray-drying	Freeze-drying	Spouted bed drying
L*	$85.38^{b} \pm 0.19$	$83.71^{c} \pm 0.14$	$90.34^{a} \pm 0.11$
a*	$10.53^{a} \pm 1.46$	$6.13^{b} \pm 0.10$	$1.58^{c} \pm 0.09$
b*	$20.46^{b} \pm 0.98$	$30.28^{a} \pm 0.40$	$17.37^{c} \pm 0.18$
Colour difference (ΔE^*)	$39.91^{b} \pm 0.38$	$32.84^{c} \pm 0.74$	$43.51^{a} \pm 0.26$
Chromaticity (C)	$23.05^{b} \pm 0.50$	$30.89^{a} \pm 0.40$	$17.44^{c} \pm 0.18$
Hue angle (H°)	$66.39^{c} \pm 0.17$	$78.54^{b} \pm 0.17$	$84.30^{a} \pm 0.27$

*Triplicate mean ± standard deviation. Means in each line followed by different superscript letters were significantly different ($p < 0.05$), by Tukey's test.

resulted in significant differences among the ACMP powders. ACMP spray-drying resulted in a higher value for coordinate a* (10.53), that is, a higher intensity of the red colour. ACMP freeze-drying resulted in a greater b* coordinate value (30.28), that is, a higher yellow colour intensity between the ACMPs. The addition of maltodextrin, which produces a white colour, contributed to a decrease in the values of a* and b*, since it acts as a "diluent" of the pigments in the powders [25].

The colour difference (ΔE) was lower in the ACMP that was subjected to freeze-drying (32.84%), while the ACMPs obtained by the drying methods with higher temperatures, such as spray-drying and the spouted bed drying, resulted in a ΔE of 39.91% and 43.51%, respectively. Freeze-dried powder showed less ΔE due to the temperature used during drying, which avoided the loss of bioactive compounds, such as carotenoids, present in the ceriguela, responsible for the yellow-orange colour of the powders, while powders obtained in a spouted bed and spray-drying presented higher ΔE due to the degradation of the pigments and change in the colour of the final product. Some authors state that the higher contact surface area with the sample tends to favour pigment oxidation [8] and, in the case of spray-drying and the spouted bed drying, these conditions are enhanced by high temperatures and feed rates to the dryer, while freeze-drying avoids colour changes in the dry foods compared to the other drying techniques [26].

The chromaticity for the ACMP freeze-drying (30.89) was higher in comparison to the ACMPs obtained by the two other drying methods studied. Some authors used maltodextrin in the drying process of orange, graviola, and camu-camu, respectively, and also obtained values for chromaticity in the range of 7.07 to 26.92, respectively [26–28]. The hue angle values correspond to the regions of red (0°) to yellow (90°), and the ACMPs obtained by the different drying methods had angles close to 70°. Therefore, it is characterized as a product whose yellow colour is more intense. The addition of maltodextrin (white colouration) contributes to the reduction of the chromaticity and hue angle [29].

3.3. Bioactive Compounds of the Powders. The initial values related to ascorbic acid, total carotenoids, and total phenolic contents of acerola-ceriguela mixed pulp were 815,44 mg/100 g, 15,07 μg/g, and 279,48 mg GAE.100 g^{-1}, respectively. Table 4 provides that the particles produced by freeze-drying resulted in the higher retention of ascorbic acid (93.65%) followed by the samples produced by spray-drying (76.86%) and spouted bed drying (60.24%). Due to the use of a low temperature (−20°C), there was less degradation of the AA during the freeze-drying process. The retention of ascorbic acid in the ACMP spray-drying was higher than the retention of ascorbic acid obtained using the spouted bed drying, although the temperature used in spray-drying (140°C) was higher than that used in the spouted bed drying process (75°C). In the spouted bed, the material being dried remains subject to temperature throughout the drying time compared to spray-drying, which is very fast drying with a low dwell time of the material exposed at high temperature.

The caramelization of the sugars present in the fruit resulted in the accumulation of pulp in the drying chamber, which contributed to the loss of bioactive compounds due to the low glass transition points (Tg) resulting from the high content of sucrose (62°C), fructose (5°C), and glucose (32°C). They may stick to the dryer chamber wall during drying, leading to poor product performance and operational problems [8]. Drying by freeze-drying resulted in higher retention of ascorbic acid, and the values obtained were close to those obtained before who studied freeze-dried graviola pulp [27].

Table 4: Bioactive compounds of acerola-ceriguela mixed pulps obtained by different drying methods.

Retention of bioactive compounds	Spray-drying	Freeze-drying	Spouted bed drying
Ascorbic acid (%)	$76.86^{b} \pm 1.16$	$93.65^{a} \pm 1.67$	$60.24^{c} \pm 0.68$
Total carotenoid (%)	$33.40^{b} \pm 2.85$	$45.00^{a} \pm 0.62$	$22.13^{c} \pm 0.28$
Total phenolic (%)	$48.13^{c} \pm 0.78$	$66.90^{a} \pm 2.72$	$61.50^{b} \pm 0.80$

*Triplicate mean ± standard deviation. Means in each line followed by different superscript letters were significantly different ($p < 0.05$), by Tukey's test.

Freeze-drying ACMP resulted in higher retention of the total carotenoids (45.0%). Carotenoids are compounds that are sensitive to several factors, including high temperatures. Thus, lower temperatures cause less degradation of these compounds. Freeze-dried ACMP was produced using 25% of the carrier agent, which may have contributed to the protection of the compounds, while spray-drying (14%) and spouted bed drying (15%) resulted in lower values. Although the increase in the maltodextrin content causes some "dilution" of the product pigments, this proves the effectiveness of the drying method and the encapsulating agent in the retention of the compounds of interest among the methods studied [5, 29].

Phenolic compounds can be found in fruits and vegetables, and their extracts contain antioxidant properties. Because of their significant antioxidant effects, phenolic compounds are useful in disease prevention and cancer control [30]. ACMP freeze-drying resulted in the higher retention of phenolic compounds (66.90%), while fewer compounds were retained after ACMP spray-drying (48.13%). The increase in the maltodextrin concentration is favourable for obtaining a high total amount of the phenolic compounds [31]. The stability of the fruit encapsulated was done by freeze-drying and spray-drying and observed higher retention of phenolic compounds in the freeze-drying fruit that used 20% of the encapsulating agent concentration [5].

3.4. Sensory Analysis. The sensory panel consisted of 102 regular juice consumers, including 54.90% female testers. The testers were 18–30 years old (67.65%) and university students (59.80%). Table 5 provides the averages for the acceptability of the mixed juice prepared with the ACMP obtained by the different drying methods. It is observed that the sample of the mixed juice developed with the freeze-dried ACMP differed significantly from the other mixed juices and resulted in greater acceptance. In general, the acceptance averages were in the range of 5 to 7, which corresponded to "moderately liked."

Figure 1 shows the graph resulting from the multiple factor analysis (AFM). The first two factors explain 100% of the total variance of the data, allowing significant discrimination of the samples based on the characteristics evaluated [32].

The first factor (F1) explained 76.78% of the variance, and the positive part of the axis was represented by "soft yellow-orange colour," "slight texture," "unpleasant aroma," "opaque colour," "unpleasant residual taste," "typical acidity," "high sweetness," and "intense aroma of ceriguela." The negative part of the axis was represented by the preference and the attributes "smooth taste of ceriguela," "low acidity,"

Table 5: Mean of the acceptance* of the mixed juice made with ACMP obtained by different drying methods ($n = 102$).

Sample (drying method)	Acceptance
A (spouted bed drying)	$5.63^{b} \pm 1.73$
B (spray-drying)	$5.71^{b} \pm 1.78$
C (freeze-drying)	$6.52^{a} \pm 1.21$

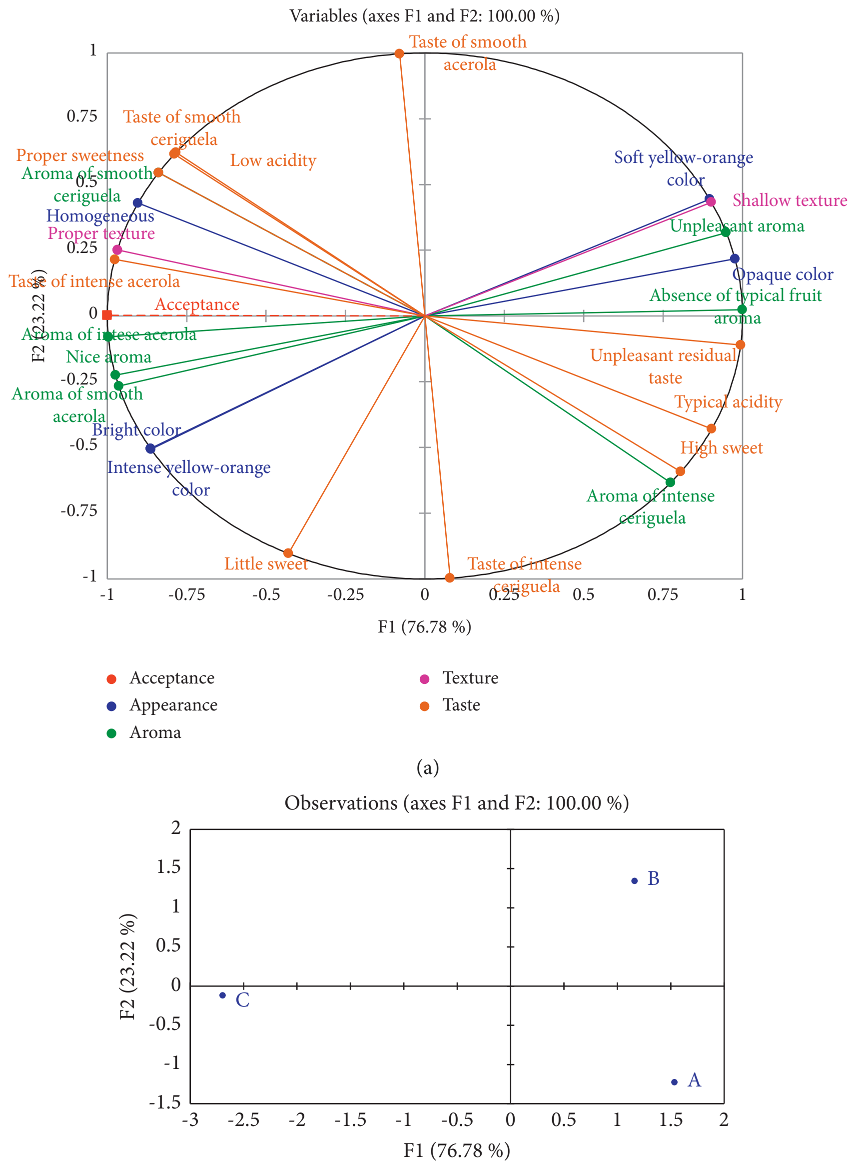
*Mean ± standard deviation. Means in the column followed by different superscript letters were significantly different ($p < 0.05$), by Tukey's test. Evaluated on a structured hedonic scale of 9 points, ranging from 1 (extremely disliked) to 9 (extremely liked).

"adequate sweetness," "aroma smooth of ceriguela," "homogeneous," "intense acerola aroma," "pleasant aroma," "aroma of smooth acerola," "bright colour," and "intense yellow-orange colour." The second dimension (F2) explained 23.22% of the variance with the positive part of the axis related to the attribute "smooth acerola flavour," and the negative part of the axis was characterized by "little sweet" and "intense taste of ceriguela."

In addition to identifying the relationships between the terms and samples and showing the sensory map, the MFA is able to balance the influence of each variable and compare several datasets [33]. It is observed that the samples of mixed juice prepared with the ACMPs obtained by different drying methods were separated into two groups, indicating different qualities. According to Figure 1(b), the freeze-drying sample (C) was characterized by positive attributes relative to factor 1 and negatively to attributes related to factor 2, in addition to the variable "preference."

Figure 1(b) shows that the mixed juices prepared with the ACMP spouted bed drying (A) and obtained in the spray-drying (B) remained in the same set, confirming similar characteristics, characterized by the attributes that do not denote quality opaque colouration, the absence of typical fruit aroma, slight texture, unpleasant aroma, and unpleasant residual taste, which are opposed to the acceptance of the evaluators and which correspond positively to factor 1. The acceptability of grapefruit juice elaborated from rehydrated freeze-dried and spray-dried fruit was studied and compared with a natural freshly squeezed juice and a commercial one. The samples with the lowest level of acceptability were those that were submitted to spray-drying; they were associated with attributes such as "not overly sweet," "bitter," and "artificial taste" [34].

The colouration of the opaque staining can be explained due to the ΔE of the spray-drying ACMP (39.91%) and in the spouted bed drying (43.51%), which resulted in high values, according to Table 3. The high retention of the bioactive compounds of the freeze-dried ACMP (Table 4) explains why the mixed juice prepared with the freeze-dried ACMP



At where: A= Spouted bed; B= Spray-drying and C=Freeze-drying.

(b)

Figure 1: Multiple factorial analysis (MFA) of CATA data. (a) Representation of the terms used to describe the three mixed juice prepared with ACMP obtained by the different drying methods (spouted bed drying, spray-drying, and freeze-drying) and their acceptance and (b) representation of mixed juice obtained by ACMPs.

was characterized by the positive attributes that represent good quality of the product and indicate the acceptance by the evaluators. These compounds are responsible for the characteristics of the powder and the refreshment, its colour, astringency, taste, and body [35].

Considering the intention to purchase, the mixed juice prepared with the ACMP obtained by freeze-drying, spouted bed drying, and spray-drying resulted in 48.04%, 31.37%, and 30.40% of the tasters stating that they would probably or would probably buy, respectively. The freeze-drying process is the most suitable drying method to preserve the compounds that offer nutritional value and antioxidant capacity of the fruit and the compounds responsible for the colour, flavour, and aroma of the product [27]. Freeze-drying products exhibit excellent quality as most of the deteriorative and microbiological reactions cease owing to the low temperature and absence of liquid water in the drying process [36].

3.5. Antioxidant Activity of the Freeze-Dried ACMP. The mixed juice prepared with the freeze-dried ACMP received better acceptance based on the results of the sensorial analysis. Therefore, it was used to determine the antioxidant potential. The extract of the freeze-dried ACMP with an EC_{50} of 8.97 $\mu g/mL^{-1}$ presented an important capacity of radical sequestration. In a study on the drying of camu-camu pulp using different methods, the authors observed that the freeze-drying pulp resulted in higher antioxidant activity than the pulp dehydrated in the spouted bed drying [28].

The antioxidant activity (ABTS) equivalent to TROLOX (TEAC) presented by the freeze-drying ACMP showed a high antioxidant potential of 541.96 mM TROLOX/g^{-1}. High TEAC values demonstrate a high antioxidant capacity since the antiradical action is directly related to the TEAC value. In a study conducted with fruit belonging to the family *Myrtaceae*, including guava-yellow, gabiroba, and uvaia, this fruit presented higher total phenolic content and antioxidant activity using the ABTS method [37]. The antioxidant potential of the ACMP is primarily due to the high content of the phenolic compounds in the acerola-ceriguela pulp. In this sense, several authors report a high correlation between the total phenolic content and antioxidant capacity (evaluated by the ABTS method) of fruit [38]. These results suggest the importance of the use of different tests for the safe and conclusive determination of the antioxidant activity since each method has its own specificity and acts at a particular site of action [39].

4. Conclusions

The best results for physicochemical characteristics, greater retention of bioactive compounds, and a high capacity to sequester the DPPH and ABTS radicals were achieved when ACMP was freeze-dried. The freeze-drying technique allowed the determination of the ACMP with colour that is more attractive and presented sensorial characteristics that contributed to the greater acceptance and intent to purchase, in addition to improving its characterization by attributes that denote good quality to the product. Thus, freeze-dried ACMP offers added value and desirable characteristics for its production, and it can be used in the elaboration of mixed juices or as an ingredient in the production of new food products.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brasil (CAPES), Finance Code 001. The authors also acknowledge the National Institute of Science and Technology of Tropical Fruits and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support (309443/2019–9). The authors acknowledge Corn Products Ltd. for providing the maltodextrin 10 DE (MOR-REX® 1910).

References

[1] M. C. E. V. Schiassi, V. R. Souza, A. M. T. Lago, L. G. Campos, and F. Queiroz, "Fruits from the Brazilian cerrado region: physico-chemical characterization, bioactive compounds, antioxidant activities, and sensory evaluation," *Food Chemistry*, vol. 245, pp. 305–311, 2018.

[2] Y. I. Maldonado-Astudillo, I. Alia-Tejacal, C. A. Núñez-Colín et al., "Postharvest physiology and technology of spondias purpurea L. and S. mombin L," *Scientia Horticulturae*, vol. 174, pp. 193–206, 2014.

[3] A. Prakash and R. Baskaran, "Acerola, an untapped functional superfruit: a review on latest frontiers," *Journal of Food Science & Technology*, vol. 55, no. 9, pp. 3373–3384, 2018.

[4] F. Habibi and A. Ramezanian, "Vacuum infiltration of putrescine enhances bioactive compounds and maintains quality of blood orange during cold storage," *Food Chemistry*, vol. 227, no. 1–8, pp. 1–8, 2017.

[5] M. J. Ramírez, G. I. Giraldo, and C. E. Orrego, "Modeling and stability of polyphenol in spray-dried and freeze-dried fruit encapsulates," *Powder Technology*, vol. 277, pp. 89–96, 2015.

[6] J. M. Orjuela-Palacio and M. C. Lanari, "The impact of moisture sorption properties on the color and bioactives concentrations of black currant-yerba mate instant drinks," *Journal of Berry Research*, vol. 6, no. 3, pp. 303–319, 2016.

[7] I. Tontul and A. Topuz, "Spray-drying of fruit and vegetable juices: effect of drying conditions on the product yield and physical properties," *Trends in Food Science & Technology*, vol. 63, pp. 91–102, 2017.

[8] S. M. Jafari, M. G. Ghalegi Ghalenoei, and D. Dehnad, "Influence of spray drying on water solubility index, apparent density, and anthocyanin content of pomegranate juice powder," *Powder Technology*, vol. 311, pp. 59–65, 2017.

[9] M. R. I. Shishir and W. Chen, "Trends of spray drying: a critical review on drying of fruit and vegetable juices," *Trends in Food Science & Technology*, vol. 65, pp. 49–67, 2017.

[10] D. P. Chielle, D. A. Bertuol, L. Meili, E. H. Tanabe, and G. L. Dotto, "Spouted bed drying of papaya seeds for oil production," *LWT - Food Science and Technology*, vol. 65, pp. 852–860, 2016.

[11] L. Antúnez, L. Vidal, L. Saldamando, A. Giménez, and G. Ares, "Comparison of consumer-based methodologies for sensory characterization: case study with four sample sets of powdered drinks," *Food Quality and Preference*, vol. 56, pp. 149–163, 2017.

[12] N. Alexi, E. Nanou, O. Lazo, L. Guerrero, K. Grigorakis, and D. V. Byrne, "Check-All-That-Apply (CATA) with semi-trained assessors: sensory profiles closer to descriptive analysis or consumer elicited data?" *Food Quality and Preference*, vol. 64, pp. 11–20, 2018.

[13] M. Miraballes and A. Gámbaro, "Influence of images on the evaluation of jams using conjoint analysis combined with check-all-that-apply (CATA) questions," *Journal of Food Science*, vol. 83, no. 1, pp. 167–174, 2018.

[14] C. M. C. M. Ribeiro, L. C. S. A. Magliano, M. M. A. Costa, T. K. A. Bezerra, F. L. H. Silva, and M. I. S. Maciel, "Optimization of the spray drying process conditions for acerola and seriguela juice mix," *Food Science and Technology*, vol. 39, no. suppl 1, pp. 48–55, 2018.

[15] AOAC, *Official Method of Analysis*, Association of Official Analytical Chemists, Washington, DC, USA, 2016.

[16] B. B. Rodrigues-Amaya, *A guide to carotenoid analysis in foods*, ILST Press, 1999.

[17] M. Wettasinghe and F. Shahidi, “Evening primrose meal: a source of natural antioxidants and scavenger of hydrogen peroxide and oxygen-derived free radicals,” *Journal of Agricultural and Food Chemistry*, vol. 47, no. 5, pp. 1801–1812, 1999.

[18] *ooms*, International Organization for Standardization, Geneva, Switzerland, 2007.

[19] G. Ares and P. Varela, “Consumer-based methodologies for sensory characterization,” *Methods in Consumer Research*, vol. 1, pp. 187–209, 2018.

[20] W. Brand-Wiliams, M. E. Cuvelier, and C. Berset, “Use of a free radical method to evaluate antioxidant activity,” *Food Science and Technology*, vol. 28, pp. 25–30, 1995.

[21] C. Sánchez-Moreno, J. A. Larrauri, and F. Saura-Calixto, “A procedure to measure the antiradical efficiency of polyphenols,” *Journal of the Science of Food and Agriculture*, vol. 76, no. 2, pp. 270–276, 1998.

[22] R. Re, N. Pellegrini, A. Proteggente, A. Pannala, M. Yang, and C. Rice-Evans, “Antioxidant activity applying an improved ABTS radical cation decolorization assay,” *Free Radical Biology and Medicine*, vol. 26, no. 9/10, pp. 1231–1237, 1999.

[23] S. P. M. Germer, I. P. Tonin, J. M. de Aguirre, I. D. Alvim, and C. C. Ferrari, “Influence of process variables on the drum drying of mango pulp,” *Drying Technology*, vol. 36, no. 12, pp. 1488–1500, 2018.

[24] M. Igual, S. Ramires, L. H. Mosquera, and N. Martínez-Navarrete, “Optimization of spray drying conditions for lulo (*Solanum quitoense* L.) pulp,” *Powder Technology*, vol. 256, pp. 233–238, 2014.

[25] C. C. Ferrari, C. P. Ribeiro, and J. M. Aguirre, “Secagem por atomização de polpa de amora-preta usando maltodextrina como agente carreador,” *Brazilian Journal of Food Technology*, vol. 15, no. 2, pp. 157–165, 2012.

[26] J. Barbosa, S. Borges, M. Amorim et al., “Comparison of spray drying, freeze drying and convective hot air drying for the production of a probiotic orange powder,” *Journal of Functional Foods*, vol. 17, pp. 340–351, 2015.

[27] A. M. Ceballos, G. I. Giraldo, and C. E. Orrego, “Effect of freezing rate on quality parameters of freeze dried soursop fruit pulp,” *Journal of Food Engineering*, vol. 111, no. 2, pp. 360–365, 2012.

[28] A. Fujita, K. Borges, R. Correia, B. D. G. M. Franco, and M. I. Genovese, “Impact of spouted bed drying on bioactive compounds, antimicrobial and antioxidant activities of commercial frozen pulp of camu-camu (Myrciaria dubia Mc. Vaugh),” *Food Research International*, vol. 54, no. 1, pp. 495–500, 2013.

[29] O. A. Caparino, J. Tang, C. L. Nindo, S. S. Sablani, and J. R. Powers, J. K. Fellman, Effect of drying methods on the physical properties and microstructures of mango (Philippine ‘Carabao’ var.) powder,” *Journal of Food Engineering*, vol. 111, no. 1, pp. 135–148, 2012.

[30] S. Insang, I. Kijpatanasilp, S. Jafari, and K. Assatarakul, “Ultrasound-assisted extraction of functional compound from mulberry (*Morus alba* L.) leaf using response surface methodology and effect of microencapsulation by spray drying on quality of optimized extract,” *Ultrasonics Sonochemistry*, vol. 82, Article ID 105806, 2022.

[31] D. Krishnaiah, R. Sarbatly, and R. Nithyanandam, “Microencapsulation of *Morinda citrifolia* L. extract by spray-drying,” *Chemical Engineering Research and Design*, vol. 90, no. 5, pp. 622–632, 2012.

[32] N. Piclin, M. Pintore, C. M. Lanza et al., “Sensory analysis of red wines: discrimination by adaptive fuzzy partition,” *Journal of Sensory Studies*, vol. 23, no. 4, pp. 558–569, 2008.

[33] Y. Le Fur, V. Mercurio, L. Moio, J. Blanquet, and J. M. Meunier, “A new approach to examine the relationships between sensory and gas Chromatography−Olfactometry data using generalized procrustes analysis applied to six French chardonnay wines,” *Journal of Agricultural and Food Chemistry*, vol. 51, no. 2, pp. 443–452, 2003.

[34] N. Martínez-Navarrete, M. M. Camacho, C. Agudelo, and A. Salvador, “Sensory characterization of juice obtained via rehydration of freeze-dried and spray-dried grapefruit,” *Journal of the Science of Food and Agriculture*, vol. 99, no. 1, pp. 244–252, 2019.

[35] S. López-Miranda, A. Serrano-Martínez, P. Hernández-Sánchez et al., “Use of cyclodextrins to recover catechin and epicatechin from red grape pomace,” *Food Chemistry*, vol. 203, pp. 379–385, 2016.

[36] I. D. Paul and M. Das, “Effect of freeze, microwave-convective hot air, vacuum and dehumidified air drying on total phenolics content, anthocyanin content and antioxidant activity of jamun (*Syzygium cumini* L.) pulp,” *Journal of Food Science & Technology*, vol. 55, no. 7, pp. 2410–2419, 2018.

[37] M. C. Pereira, R. S. Steffens, A. Jablonski et al., “Characterization and antioxidant potential of Brazilian fruits from the Myrtaceae family,” *Journal of Agricultural and Food Chemistry*, vol. 60, no. 12, pp. 3061–3067, 2012.

[38] V. R. de Souza, P. A. P. Pereira, F. Queiroz, S. V. Borges, and J. D. S. de Deus Souza Carneiro, “Determination of bioactive compounds, antioxidant activity and chemical composition of Cerrado Brazilian fruits,” *Food Chemistry*, vol. 134, no. 1, pp. 381–386, 2012.

[39] Y. R. R. S. Rezende, J. P. Nogueira, and N. Narain, “Microencapsulation of extracts of bioactive compounds obtained from acerola (*Malpighia emarginata* DC) pulp and residue by spray and freeze drying: chemical, morphological and chemometric characterization,” *Food Chemistry*, vol. 254, pp. 281–291, 2018.