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Optimization of the spray drying process conditions for acerola and seriguela juice mix

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Abstract

The spray drying process of a mixed juice of acerola and seriguela was optimized using a 2^4 full factorial design with 16 factorial points and 3 central points. The independent variables were different levels of inlet temperature (110°, 140° and 170 °C), feed flow (0.36, 0.60 and 0.84 L/h), amount of maltodextrin (14-26%) and maltodextrin dextrose equivalent (DE) (5, 10 and 15 DE). The responses were water activity (Aw), moisture content (MC), hygroscopicity (Hyg), powder recovery (PR) and retention of ascorbic acid (RAA). After optimization, an acceptance test and multiple comparison test were performed. Temperature exerted a great influence on Aw, MC and RAA. The optimal drying conditions to obtain acerola and seriguela juice mix powder were an inlet temperature of 140 °C, a flow rate of 0.60 L/h, 20% maltodextrin 10 DE. There was no significant difference in the acceptance of the quality attributes or in the multiple comparison test between the nectars made with the juice mix powder. Acceptance was approximately 70%. Therefore, this acerola and seriguela mix powder can be considered a good source of ascorbic acid and a potential ingredient for the food industry.

Keywords: factorial planning; dextrose equivalent of maltodextrin; sensory analysis.

Practical Application: Produce a juice powder with a high content of ascorbic acid and PR and low Aw, MC and Hyg.

1 Introduction

Seriguela (*Spondias purpurea*) has considerable social, economic and nutritional importance in the Brazilian semiarid region. Seriguela fruits and derivatives are widely marketed in popular fairs, supermarkets and restaurants in the northeastern Brazilian region. This fruit has a pleasant color and taste, and the quality characteristics of this fruit are considered important for its commercialization (Maldonado-Astudillo et al., 2014). In addition, seriguela fruit is rich in bioactive compounds. The proposal to mix seriguela with acerola (*Malpighia emarginata* DC) aims to contribute to species diversification, improve sensory characteristics and increase the nutritional contribution of the product. The use of acerola together with other fruits raises the ascorbic acid content, acting as an enriching agent in various fruit products (Maciel et al., 2009; Pelegrine et al., 2015). The recommended daily intake of vitamin C is 75 mg/day (Institute of Medicine, 2010), which is provided by two to four acerolas. The great diversity of bioactive compounds in tropical fruits and the interest in natural antioxidants have attracted the attention of researchers and food industries to their action in disease prevention and their nutritional value (Silva et al., 2013; Jeyakumari et al., 2016; Mishra et al., 2014).

As these fruits are seasonal and highly perishable, they require some processing for easier use. Among drying technologies, spray drying is the most used for the production of fruit juice powder because it is more profitable for the producer. This technique is 30 to 50 times less expensive than spray chilling (Edrisi Sormoli & Langrish, 2015; Muzaffar & Kumar, 2015a). In addition, fruit juice powders have advantages in that they facilitate transport and storage by allowing availability during the off-season and by preserving compounds that are thermosensitive (Largo Ávila et al., 2015).

The physico-chemical characteristics of the powder depend on the parameters of the spray drying process, such as the inlet temperature, feed flow rate and carrier agent concentration (Patil et al., 2014). It is important that the process be optimized to obtain products with better sensory and nutritional characteristics as well as better drying performance. For the development of a new product, it is essential to obtain information about the sensory characteristics with the purpose of achieving an integral balance that translates into an excellent quality and good acceptability. Sensory analysis is an important tool in this regard.

In spite of all the advantages related to the spray drying process, fruit juice powders usually present some handling problems due to the presence of sugars and low-molecular-weight acids, which have a low glass transition temperature. In this context, the use of encapsulating agents increases the glass transition temperature of

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the product, facilitating drying and storage (Bhusari et al., 2014). Maltodextrin has been used as an encapsulating agent of vitamin C (Mishra et al., 2014; Patil et al., 2014). Some researchers have studied the effect of the dextrose equivalent (DE) of maltodextrin in retaining ascorbic acid (Igual et al., 2014; Islam et al., 2016). However, few studies have been performed to evaluate the influence of DE on drying optimization.

The response surface method allows for the study of several input variables at the same time, thus reducing the number of experiments, and it is a statistical technique widely used to optimize processes and describe relationships between responses and independent variables (Largo Ávila et al., 2015; Ramírez et al., 2015). The objectives of this study were to evaluate the effects of the variables of the spray drying process on the resulting acerola and seriguela juice mix to identify the best drying conditions and to investigate the influence of the DE of maltodextrin on the sensory characteristics of the product.

2 Materials and methods

2.1 Materials

Seriguela and acerola fruit of the Sertaneja variety were purchased from the Supply Center of Pernambuco (Central de Abastecimento de Pernambuco – CEASA/PE). Carrier agents used were maltodextrin with 4-7% DE (5 DE) (GLOBE from Ingredion, São Paulo, Brazil), maltodextrin with 9-12% DE (10 DE) (*MOR-REX® 1910* from Corn Products, Mogi-Guaçu, Brazil) and maltodextrin with 15-17% DE (15 DE) (*MOR-REX® 1914*).

2.2 Methods

Obtaining the spray-dried acerola and seriguela juice mix

The fruits were selected based on the coloration and soluble solids as follows: yellow-orange for seriguela and purplish red for acerola and 11.7 and 7.1 °Brix of soluble solids for seriguela and acerola, respectively. The fruits were washed in running water, sanitized with Hydrosteril (50 ppm active chlorine) and pulped in a semi-industrial stainless steel pulp extractor (Bonina Compacta, Itabauna/BA). The pulps were packed in zipper low-density-polyethylene bags (Talge brand; 20 × 30 cm) and stored at -18 °C. The solution to be injected into the spray dryer was obtained from the 60:40 (acerola:seriguela) fruit pulp mixture, maltodextrin (14, 20 and 26%) and water in a 1:1 ratio of pulp and water. The drying process was performed by means of a mini spray dryer (Lab Maq, model MSDi 1.0, Ribeirão Preto/SP/Brazil), which operated with a liquid flow rate of 0.2-1.0 L/h, an injector nozzle of 1.2 mm in diameter, an air flow rate of 30 m^3/h and an air pressure of 0.6 bar. The juice mix powder was placed in a glass jar (240 mL), hermetically sealed and stored at room temperature (21 ± 2 °C) under light until the analytical determinations were performed.

Factorial design

The operating variables (independent variables) of the spray drying process were the feed flow rate (F), inlet temperature (T), concentration of carrier agent maltodextrin (C) and dextrose equivalent (DE). The study assessed the effects of these variables, which were applied in different combinations at two levels as follows: low (-1) and high (+1). The response variables were water activity (Aw), moisture content (MC), hygroscopicity (Hyg), powder recovery (PR) and retention of ascorbic acid (RAA). A 2^4 full factorial design with 16 factorial points and 3 central points for a total of 19 trials was used. A first-order model was used to fit experimental data as follows (Equation 1):

$$Y = \beta_0 + \beta_1 T + \beta_2 F + \beta_3 C + \beta_4 DE + \beta_5 TF + \beta_6 TC + \beta_7 TDE + \beta_8 FC + \beta_8 FDE \quad (1)$$

where: Y is the response; β_n is the regression coefficient of the regression model; and T, F, C and DE are the independent variables.

The quality of the model was evaluated by analysis of variance (ANOVA). The linear regression with a 95% confidence level was constructed using the experimental data of the factorial design. ANOVA, the lack-of-fit test (F-test), determination of regression coefficients and determination of response surfaces were performed with Statistica 10.0 software (StatSoft, Tulsa, USA). For the validation of the optimal response, the desirability function calculated with the aid of the program was considered. For the optimization, it was necessary to maximize and minimize some variables according to the desirability of the powder characteristic. The objective was to produce a juice powder with a high content of ascorbic acid and low Aw, MC and Hyg.

Physical and physico-chemical analysis of acerola and seriguela juice mix

The following determinations were performed to obtain the physical and physico-chemical profile of the acerola pulp, seriguela pulp and mixed pulps: Aw; MC; reducing and total sugars; soluble solids (SS); pH; titratable acidity (TA); protein; lipids; ash; ascorbic acid according to the method described in the A.O.A.C. standards (Association of Official Analytical Chemists, 2005); carotenoids according to the method described by Rodrigues-Amaya (1999); anthocyanins according to the method proposed by Lees & Francis (1972); and phenolics according to the method described by Wettasinghe & Shahidi (1999). For color determination, three readings were taken using the CIELab system parameters (L* indicates lightness; a* represents color and saturation on the red-green axis; and b* represents color and saturation on the yellow-blue axis) (McGuire, 1992). The physico-chemical analyses were performed in triplicate.

Physical and physico-chemical analysis of the spray drying of acerola and seriguela juice mix

All analyses were performed on the day of drying to minimize changes in the physico-chemical characteristics of the samples, thus avoiding analytical errors. Aw and MC at the beginning of the drying process and in the final encapsulated product were measured using an Aqualab water activity meter (model 4TE; Janiru/SP) at a temperature of 25 °C. The moisture lost during evaporation was expressed as a percentage. Hyg was determined according to the method of Cai & Corke (2000) with some modifications. The ascorbic acid content was analyzed according to the Association of Official Analytical Chemists (2005). The analyses were performed in duplicate after production of the juice powder with three independent experiments. All steps of this determination were conducted under light. To determine the RAA, the results were converted by taking into account the dry mass (m.s.) present in the feed mixture before injecting and after drying. The powder recovery (PR) after spray drying was calculated as the percentage of solids collected to the total solids mass in the feed solution.

Microbiological analysis

Microbiological analyses were performed in the optimized experiments of the acerola and seriguela juice mix with the 5 DE, 10 DE and 15 DE samples before the sensory analysis. Molds and yeasts were investigated as indicators of hygienic and sanitary conditions. The results are expressed in CFU/g of the sample according to Association of Official Analytical Chemists (2010) 997.02. *Salmonella* was expressed as present or absent according to Association of Official Analytical Chemists (2010) 967.26. Mesophyll count was expressed in CFU/g according to Association of Official Analytical Chemists (2010) 997.10.

Sensory evaluation of acerola and seriguela reconstituted juice mix powder was performed

Sensory evaluation, using the acceptance test and multiple comparisons, was performed with the objective of choosing the reconstituted juice mix with the best flavor and aroma obtained from the three types of powders with different maltodextrin DE (5 DE, 10 DE and 15 DE). These tests were conducted according to the ethics committee guidelines (CAAE: 62243116.8.0000.5188).

Preparation of acerola and seriguela reconstituted juice mix powder

For preparation of the standard juice, the mixed pulp was diluted in the proportion of 300 g in 1 L of mineral water. For the reconstituted juice mix, 30 g of powder was used in 1 L of mineral water. All juices were sweetened with 7% sucrose.

Acceptance test and purchase intention

The acceptance test was performed using the affective method. Each judge evaluated how much he or she liked or disliked the product, using a hedonic scale of 9 points with a variation of "strongly like" (score of 9) and "strongly dislike" (score of 1). The sensory attributes of color, aroma, taste and appearance were evaluated. Finally, the intention to buy samples with a variation of "certainly would not buy" (score of 1) and "certainly would buy" (score of 5) was evaluated. The acceptance test was performed with 100 untrained judges (International Organization for Standardization, 2013), including 82 women and 18 men between 18 and 50 years old, who were possible consumers of juice. The test was conducted in individual booths under white light. Samples were coded with random numbers of three digits presented monadically following an order of presentation in complete randomized blocks. The juices were served at 16 °C in 50 mL cups containing approximately 30 mL of juice accompanied by water and a cookie to clean the palate between samples.

The multiple comparison test was performed according to norms (Associação Brasileira de Normas Técnicas, 1995) using the discrimination method in which each judge evaluated the degree of difference between the coded sample and the control. A panel of 66 untrained judges was used. The judge received three samples plus one standard sample of reconstituted juice mix (approximately 30 mL each) in 50 mL white polyethylene cups, which were randomly coded with three-digit numbers. The juice obtained from the *in natura* mixed pulp of acerola and seriguela was considered the standard sample. The test was applied to evaluate the sensory attributes of aroma and flavor of the reconstituted juices using a nine-point scale ranging from "much better than the standard" (1) to "much worse than the standard" (9), with (5) indicating that it was equal to the standard. The test was conducted in individual booths under red light to mask differences in coloration between the reconstituted juice mixes.

Physical and physico-chemical analysis of the reconstituted juice mix of acerola and seriguela

To obtain the physical and physico-chemical profile of the reconstituted juice mixes and to identify the best juice, we measured Aw, MC, soluble solids, pH, titratable acidity and ascorbic acid according to the methodology described in the standards from Association of Official Analytical Chemists (2005). For color determination, three readings were made using the CIELab system parameters (McGuire, 1992). The physico-chemical analyses were performed in triplicate.

Statistical analysis

The results obtained by the sensory analysis and the intention-to-buy test were submitted to ANOVA, and the means were compared by the Tukey test at a 5% significance level. For the acceptance test and the multiple comparison test, the Dunnett test at 5% probability (bilateral) was performed using Assistat software (version 7.7). Principal component analysis (PCA) was applied to visualize the variation between the variables analyzed and the samples using MVSP software (version 3.13) (Kovach, 2006).

3 Results and discussion

3.1 Physico-chemical analysis of the acerola and seriguela pulps and pulp mixture

Physico-chemical analyses of the pulp are relevant for the development of new products, as they inform manufacturers if the technology employed preserves the nutritional value. The acerola fruit presented higher contents of ascorbic acid, anthocyanins, flavonoids and phenolic compounds than did seriguela fruit, while the latter had more total sugars, ash and carotenoids (Table 1). There was no identity or quality standard for the seriguela pulp. However, the values of SS, TA and total sugar were close to those previously reported (Maldonado-Astudillo et al., 2014).

Table 1. Characterization of pulps (dry mass).

	Acerola pulp	Seriguela Pulp	Mixed Pulp	Coefficient of variation (CV) (%)	Minimum significant difference (dms)
pH	3.14[b]	3.25[a]	3.09[c]	0.42	0.33
TA (mg/100 g of fruit acid)	13.58[a]	2.83[c]	10.92[b]	4.33	1.00
MC (g/100 g)	91.89[a]	77.59[c]	87.44[b]	0.97	2.07
Aw	0.990[a]	0.981[c]	0.986[b]	0.13	0.003
SS (°Brix)	7.06[c]	18.26[a]	11.43[b]	1.41	0.43
L*	28.95[c]	57.65[a]	34.21[b]	3.77	3.80
a*	40.55[a]	-0.42[c]	35.63[b]	2.29	1.46
b*	19.35[c]	40.92[a]	23.84[b]	5.73	4.02
Ash (g/100 g)	3.63[a]	2.26[b]	2.31[b]	9.49	0.64
Proteins (g/100 g)	8.42[a]	3.42[c]	5.51[b]	4.47	0.64
Reducing sugars (g/100 g)	65.97[a]	29.64[c]	50.16[b]	5.16	6.28
Total sugars (g/100 g)	84.77[a]	71.18[b]	65.92[b]	4.72	8.75
Non-reducing sugars (g/100 g)	8.15[c]	39.44[a]	15.42[b]	4.71	2.47
Total anthocyanin (mg/100 g)	245.71[a]	-	96.21[b]	12.24	1,471.6
Total flavonols (mg/100 g)	132.08[a]	-	65.79[b]	5.38	14.60
Ascorbic acid (mg/100 g)	28,722.51[a]	76.09[c]	9,107.35[b]	4.65	47.47
Carotenoids (mg/100 g of β carotene)	113.72[a]	69.30[b]	115.95[a]	5.85	12.06
Phenolic compounds (mg/100 g of Gallic acid)	17,345.10[a]	311.42[c]	7,048.95[b]	12.91	2,663.59

TA = titratable acidity; SS = Soluble solids; Aw = water activity; CV = Coefficient of variation; MC = moisture content. Different lowercase letters indicate in each variable a significant difference by Tukey's test at 5% probability.

3.2 Physical and physico-chemical analyses of the spray-dried acerola and seriguela juice mix

The moisture of the acerola and seriguela juice mix powder varied from 1.59 to 4.75 g/100 g indicating good stability (Table 2). These values were similar to those reported by Tontul & Topuz (2017). Low MC in juice powders may be an indication of the efficiency of the drying process, which limits the ability of the chemical structure of the water to bind with the encapsulating agent, causing agglomeration in the juice in addition to reducing the glass transition temperature (Akhavan Mahdavi et al., 2016; Tontul & Topuz, 2017). The negative signal effect of the temperature indicated that as the temperature increased, the responses of Aw and MC decreased (Table 2). Our results agreed with those of Chen et al. (2017), who studied spray drying of oyster. Fazaeli et al. (2012) explained that with increasing temperature, there is a higher rate of heat transfer between the particles, facilitating the outflow of water. Table 2 shows a negative signal effect of DE. A similar result was found by Carvalho et al. (2016) when studying the effect of the DE of maltodextrin on Jussara (*Euterpe edulis* **Martius**) powder extract. The positive signal effect of the maltodextrin concentration on Aw and MC may be due to the increase in viscosity, which causes a reduction in heat transfer, making the outflow of water difficult (Souza et al., 2015). The negative signal effect of the carrier agent concentration on Hyg was in agreement with the findings of Bazaria & Kumar (2016). Horuz et al. (2012) explained that increasing the amount of maltodextrin causes a decrease in the number of available binding sites, thereby reducing Hyg in the juice powders. In contrast, there was a positive signal effect of DE, which may have been due to the difference in the chemical structure of maltodextrin because greater DE values indicate the greater the number of branches with hydrophilic groups to absorb water (Negrão-Murakami et al., 2017). The percentage of explained variation adjusted for Hyg was 92%, indicating that the model fit the data well.

As shown in Table 3, the increase in temperature resulted in reduced RAA. A similar behavior was observed by Igual et al. (2014), who studied the influence of temperature on the pulp of lulo powder (*Solanum quitoense* L.). It is worth noting that the spray drying process uses high temperatures that can cause degradation of vitamin C (Sun-Waterhouse & Waterhouse, 2015). Several factors may have contributed to the observed 50% RAA, including the innate instability of ascorbic acid to heat, light, oxygen and presence of metals (Table 2) (Jaeschke et al., 2016).

According to Igual et al. (2014), bioactive compounds, including ascorbic acid, are positively affected by the increase in the carrier agent concentration. High DE protects against the oxidation of ascorbic acid, which is attributed to the ability of DE to form a film with plastic properties. Therefore, the acerola and seriguela juice mix was a good source of ascorbic acid with an extremely high content ranging from 2,728.17 to 6,117.42 mg of ascorbic acid per 100 g of powdered juice. The calculated R^2 of 0.93 suggested that the linear regression model for RAA was significant ($p < 0.05$) and satisfactory.

The negative signal effect of the carrier agent concentration and feed flow rate on powder recovery (PR) was in agreement with the findings of Muzaffar & Kumar (2016), who showed that the increase in feed flow has a negative effect on process powder recovery, which may be due to the slower heat and mass transfer that occurs when spray drying is performed at a higher feed flow rate. These authors explain that process yield decreases with the

Table 2. Coded and decoded experimental design of drying acerola and seriguela juice by spray drying.

Independent Variables (Coded and Decoded Values)					Dependent Variables				
Test	T (°C)	F (L/h)	C (%)	DE	Aw	MC (g/100 g)	Hyg (g/100 g)	RAA (%)	PR (%)
1	-1(110)	-1(0.36)	-1(14)	-1(5)	0.09 ± 0.00	2.72 ± 0.31	21.3 ± 0.1	50.7 ± 0.3	33 ± 0.1
2	+1(170)	-1(0.36)	-1(14)	-1(5)	0.04 ± 0.00	1.56 ± 0.02	18.7 ± 0.0	47.8 ± 0.3	40.1 ± 0.2
3	-1(110)	+1(0.84)	-1(14)	-1(5)	0.15 ± 0.01	3.75 ± 0.11	19.7 ± 0.1	54.4 ± 0.6	33 ± 0.1
4	+1(170)	+1(0.84)	-1(14)	-1(5)	0.07 ± 0.00	2.16 ± 0.24	19.8 ± 0.1	47.7 ± 0.7	42.7 ± 0.1
5	-1(110)	-1(0.36)	+1(26)	-1(5)	0.19 ± 0.00	3.72 ± 0.21	15.6 ± 0.1	58.7 ± 0.6	41 ± 0.2
6	+1(170)	-1(0.36)	+1(26)	-1(5)	0.05 ± 0.00	1.59 ± 0.19	15.2 ± 0.2	54.3 ± 0.5	29.2 ± 0.1
7	-1(110)	+1(0.84)	+1(26)	-1(5)	0.25 ± 0.00	4.75 ± 0.47	12.7 ± 0.0	54.1 ± 0.2	28 ± 0.1
8	+1(170)	+1(0.84)	+1(26)	-1(5)	0.11 ± 0.00	2.43 ± 0.32	15.4 ± 1.9	53.2 ± 0.7	29.8 ± 0.3
9	-1(110)	-1(0.36)	-1(14)	+1(15)	0.11 ± 0.00	2.59 ± 0.10	22.9 ± 0.1	52.6 ± 0.4	37.6 ± 0.1
10	+1(170)	-1(0.36)	-1(14)	+1(15)	0.05 ± 0.00	1.76 ± 0.29	23.7 ± 0.5	46.1 ± 0.4	37.8 ± 0.1
11	-1(110)	+1(0.84)	-1(14)	+1(15)	0.19 ± 0.00	3.71 ± 0.15	21.75 ± 0.33	52.6 ± 0.8	38.9 ± 0.2
12	+1(170)	+1(0.84)	-1(14)	+1(15)	0.08 ± 0.00	1.63 ± 0.36	23.6 ± 0.2	51.5 ± 0.4	40.4 ± 0.3
13	-1(110)	-1(0.36)	+1(26)	+1(15)	0.07 ± 0.00	2.24 ± 0.18	20.9 ± 0.15	58 ± 0.3	36 ± 0.1
14	+1(170)	-1(0.36)	+1(26)	+1(15)	0.03 ± 0.00	1.52 ± 0.41	20.3 ± 0.1	56 ± 0.8	32 ± 0.0
15	-1(110)	+1(0.84)	+1(26)	+1(15)	0.14 ± 0.00	3.26 ± 0.40	19.6 ± 0.1	58.8 ± 0.4	32.6 ± 0.2
16	+1(170)	+1(0.84)	+1(26)	+1(15)	0.05 ± 0.00	1.70 ± 0.43	21.4 ± 0.0	58.5 ± 0.4	31 ± 0.2
17	0(140)	0(0.60)	0(20)	0 (10)	0.19 ± 0.01	3.58 ± 0.01	19.9 ± 0.3	53.7 ± 0.5	33.9 ± 0.1
18	0(140)	0(0.60)	0(20)	0 (10)	0.18 ± 0.00	3.44 ± 0.24	20.9 ± 0.3	54.4 ± 0.1	33.2 ± 0.1
19	0(140)	0(0.60)	0(20)	0 (10)	0.19 ± 0.00	3.49 ± 0.34	19.8 ± 1.6	52.9 ± 0.0	33 ± 0.1

T = inlet temperature (°C); F = feed flow rate (L/h); C = concentration of maltodextrin (%); DE = dextrose equivalent; Aw = water activity; MC = moisture content; Hyg = hygroscopicity; RAA = retention of ascorbic acid; PR = powder recovery.

Table 3. Equations as a function of the regression coefficients.

Equation	R^2	Fc/Ft
Aw=**0.122-0.043(T)+0.025(F)+0.0061(C)-0.014(DE)-0.007(TxF)-.0075(TxC)+0.007(TxDE)**+0.0006(FxC)-0.0007(FxDE) -**0.023(CxDE)**	0.74	0.94
MC=**2.71-0.77(T)+0.35(F)+0.083(C)-0.26(DE)+0.169375(TxF)**-0.065(TxC) **+0.12(TxDE)**+0.028 (FxC) **-0.08 (FxDE) -0.20 (CxDE)**	0.83	1.87
Hyg=**19.65**+0.23(T)+0.29(F)**-1.88(C)+2.24(DE)**+0.57(TxF)+0.20(TxC) +0.25(TxDE)-0.090(FxC) +0.11(FxDE) **-0.68(CxDE)**	0.96	9.19
RAA=**53.48-1.55(T)**+0.41625(F) **+ 3.00(C) +0.82 (DE)** +0.42 (TxF)+0.59(TxC) +0.30 (TxDE)-0.71 (FxC) +0.68 (FxDE) +0.55 (CxDE)	0.93	4.74
PR=**34.90**+0.18(T)-**0.64(F) -2.74(C) +0.59 (DE) +1.24 (TxF)+2.13(TxC) -0.66 (TxDE)-1.45 (FxC) +0.58 (FxDE)** -0.14 (CxDE)	0.82	1.19

T = temperature; **F = feed flow rate**; C = concentration of maltodextrin; DE = dextrose equivalent.

increase of the carrier agent concentration. This phenomenon may be due to the increase in feed viscosity, causing more solids to paste in the drying chamber wall, thus reducing the process yield. The powder recovery varied from 28 to 42.7% (Table 2). Test 5 was similar to the findings of Du et al. (2014), who reported a value of 41.6% with 25% maltodextrin for the pulp powder of Persimmon (*Diospyros kaki* L.), and higher than the findings of Muzaffar & Kumar (2016), who reported a value of 9.51% for tamarind pulp powder.

Desirability is a widely used tool for optimizing process variables whose values range from 0 to 1 as follows: 0 represents completely undesired; 0.5 represents moderately desirable; and 1 represents the most desirable. Figure 1 shows that desirability values for RAA were reached at a lower inlet temperature, lower flow rate, higher amount of maltodextrin and higher DE. The desirability values were between 0.8 and 0.96 for RAA, which are considered satisfactory. The lowest Aw values were achieved at higher temperatures, lower feed flow rates, lower maltodextrin concentrations and higher DE with desirability values of 1.0. In the attempt to equalize this desirability, the inlet temperature of 140 °C, feed flow rate of 0.60 L/h, concentration of 20% maltodextrin 10 DE were selected (Table 2).

3.3 Sensory evaluation of acerola and seriguela reconstituted juice mix

Microbiological analysis showed that the sanitary and hygienic procedures were correctly followed in the development of spray-dried acerola and seriguela juice mix. Before the sensory analysis, the team of researchers responsible for this study found that the acerola and seriguela reconstituted juice mix powder was optimized with 20% maltodextrin. However, it was agreed that the juice was very sweet. Maltodextrin confers a sweet flavor, so a lower concentration of this carrier agent was used in the sensory analysis. Table 4 shows the results of the acceptance test of the reconstituted juice mixes of acerola and seriguela using maltodextrin at 14% with 5 DE, 10 DE and 15 DE. The reconstituted juice mixes with different DEs were similar in terms of color, aroma, taste and appearance attributes.

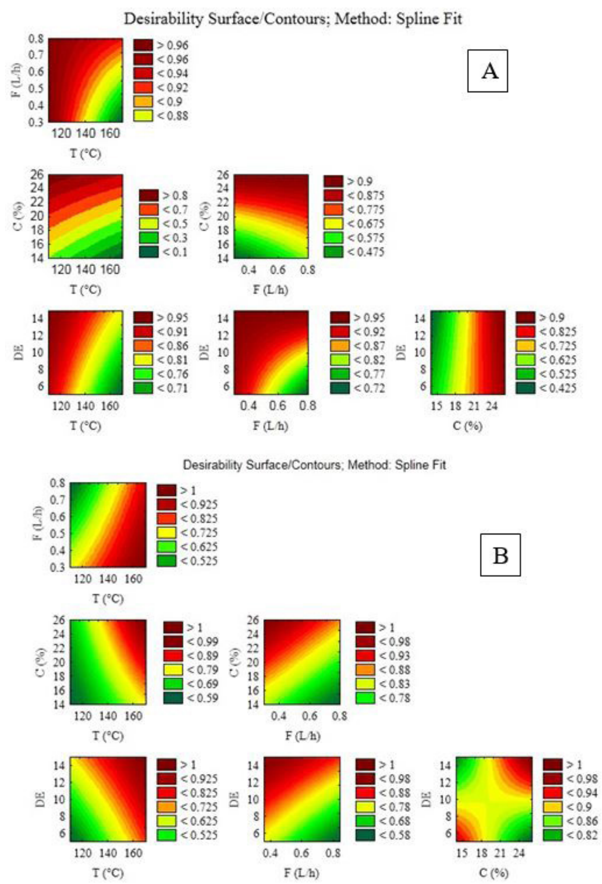

Figure 1. (A) Desirable surface/contour (retention of ascorbic acid); (B) Desirable surface/contour (water activity) T = inlet temperature (°C); F = feed flow rate (L/h); (C) concentration of maltodextrin (%); DE = dextrose equivalent.

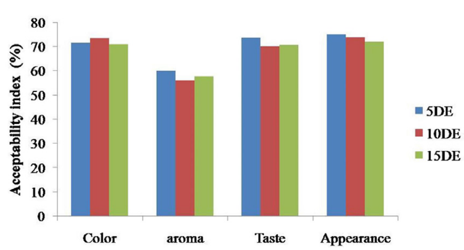

Figure 2. Acceptance index.

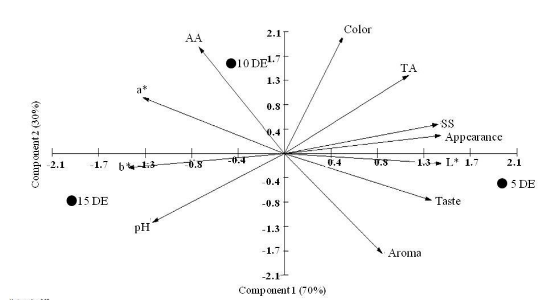

Figure 3. Principal component analysis for three spray-dried acerola and seriguela mixed juices. 5DE = dextrose equivalent; 10DE = dextrose equivalent; 15DE = dextrose equivalent; AA = Ascorbic Acid; TA = titratable acidity; SS = Soluble solids. Hunter values of a*, b*and L* = luminosity.

Table 4. Results (mean, dms and CV) of the acceptance test and multiple comparison test for acerola and seriguela reconstituted juice mix elaborated with maltodextrin 5, 10 and 15 DE powder juice.

Acceptance Test				
Samples	Color	Aroma	Taste	Appearance
5 DE	6.5 [a]	5.4 [a]	6.6 [a]	6.7 [a]
10 DE	6.6 [a]	5.0 [a]	6.3 [a]	6.6 [a]
15 DE	6.4 [a]	5.2 [a]	6.3 [a]	6.5 [a]
dms	0.55	0.60	0.64	0.52
CV %	25.55	34.43	29.94	23.29

MULTIPLE COMPARISON TEST		
	AROMA	Taste
Standard	4.4[b]	4.0[b]
5 DE	6.3[a]	6.1[a]
10 DE	6.4[a]	6.1[a]
15 DE	6.0[a]	5.2 [a]
dms	0.6	0.8
CV (%)	23.84	36.33

5DE = dextrose equivalent; 10DE = dextrose equivalent; 15 DE = dextrose equivalent; CV = Coefficient of variation; dms = Minimum significant difference. Different lowercase letters indicate in each variable a significant difference by Dunnett test at 5% probability.

The means for these attributes were greater than 6.0, indicating that the judges liked the juices slightly. Similar results were observed by Moura et al. (2015) evaluating cajá juice powder.

The attributes of color, appearance and taste had an acceptability index higher than 70% (Figure 2). Regarding the intention to purchase, 51% said they would buy or probably buy reconstituted juice mixes of spray-dried acerola and seriguela. Regarding the multiple comparison test, all the juices studied were evaluated with averages of approximately 6, which indicated "slightly worse than the control" (Table 4). Moura et al. (2015) observed that there is a significant loss of flavor attributed to the use of maltodextrin in the reconstituted juice of cajá, which may also have occurred with the acerola and seriguela mixed powder.

3.4 Principal component analysis

PCA was applied with the objective of evaluating the sensory and physico-chemical parameters (Figure 3). The PC1 and PC2 principal components accounted for 70% and 30% of the variance, respectively. The use of maltodextrin 10 DE provided greater influence on the concentration of ascorbic acid, a* value (red intensity) and color (sensory attribute) found in the negative region of PC1 and positive region of PC2. The result of the ascorbic acid content corroborated the optimization (Figure 1). Mixed juice with maltodextrin 5 DE presented higher scores for flavor, aroma attributes and soluble solids. Despite these higher scores for sensory parameters in the PCA analysis, the mixed juices with the different DEs were similar in acceptance and in the multiple comparison tests (item 3.3). Therefore, the choice was based on the juice with the highest ascorbic acid content.

4 Conclusion

The temperature had a negative signal effect on RAA and Hyg, but it had a positive signal effect on MC and Aw. Higher DE values resulted in higher RAA and Hyg values, but DE had a negative signal effect on Aw and MC. The mixed powdered juices produced low MC, Aw and Hyg, confirming the efficiency of maltodextrin. These results showed that the equation models for MC, Aw, Hyg, PR and RAA were statistically significant. The response surface method was successful in determining optimal processing conditions. Optimal conditions were achieved with an inlet temperature of 140 °C, a feed flow rate of 0.60 L/h, a maltodextrin concentration of 20%, and a maltodextrin dextrose equivalent of 10. Regarding the sensory analysis, there was no significant difference in acceptance and multiple comparison test with the different DEs. However, 51% of the judges said they would buy reconstituted juice mixes with a 70% acceptability index. Therefore, the juice mixes were considered well accepted. The use of acerola as an enrichment agent in powdered juices is highly feasible, as the mixed powder juice had a high content of ascorbic acid and was well accepted. Thus, spray drying is an efficient method to process acerola and seriguela juice mix powder, as it presents a juice with fast reconstitution in addition to providing compounds beneficial for health.

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