



## Development and optimization of the jam production process of *Pouteria cf. gardneriana* Radlk (guapeva)

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### Abstract

This work aimed to study the effect of citric acid and passion fruit albedo concentrations and pulp/sugar ratio in optimizing of jam production process of *Pouteria cf. gardneriana* Radlk (guapeva fruit) and evaluating the nutritional characteristics and functional properties of the developed jams. A factorial design 2<sup>3</sup> with 11 assays was used, considering citric acid concentration, pulp/sugar ratio, and albedo concentration as independent variables. Formulations containing a 50/50 pulp/sugar ratio proved to be excellent for quality parameters, the potential of phenolic compounds, antioxidants, and sensory properties. The formulation indicated as most desirable was the one containing a 40/60 sugar/pulp ratio. Guapeva proved to be a good alternative for jam production because even after thermal processing, it was possible to obtain jams rich in Vitamin C, phenolic compounds, and antioxidant potential.

**Keywords:** bioactive compounds; cerrado fruit; nutritional composition; passion fruit albedo.

**Practical Application:** Citric acid and pulp/sugar ratio positively affect the development of guapeva jam.

## 1 Introduction

With an immeasurable heritage, the Brazilian Cerrado is considered one of the richest biomes in the world that assemble a number of exotic native fruits, rich in bioactive compounds associated with antioxidants, anti-inflammatory, antitumor, antimicrobial and antigenotoxic properties (Schiassi et al., 2018; Li et al., 2016). The properties of these fruits make them potential sources to the development of new products for the food industry (Morzelle et al., 2015). However, countless fruits are still little explored commercially and scientifically (Silva et al., 2017), as is the case of *Pouteria cf. gardneriana* Radlk, which has favorable characteristics to contribute to a healthy diet.

The guapeva fruit belongs to the *Pouteria* Genus from the *Sapotaceae* family. The high technological potential is derived from its peel and pulp rich in antioxidants and phenolic compounds (Barbosa et al., 2016). Its fruits can be used in food preparation, contributing to the intake of nutrients that can help to prevent the development of chronic degenerative diseases, such as cancer and diabetes, in addition to not showing toxicological levels when tested on animals (Siqueira et al., 2017; Malta et al., 2013). However, the use of this fruit is still little explored due to the lack of knowledge about its benefits.

Based on this scenario, this work aimed to study the effect of citric acid and passion fruit albedo concentration, as well as pulp/sugar ratio in optimizing the jam production process from *Pouteria cf. gardneriana* Radlk, and evaluate the nutritional characteristics and functional properties of the jam.

## 2 Materials and methods

### 2.1 Fruit material

Guapeva fruit (*Pouteria cf. gardneriana* Radlk) were collected during the 2017-2018 season (between June and September) from plants that naturally occurred in the city of Palmas, Tocantins, Brazil. The fruits were harvested ripe and free from any uniformity or physical injuries. After sanitizing, pulps were extracted manually and kept at -20 °C until jam preparation.

### 2.2 Jam preparation procedures

The jams were processed in an open stainless-steel pan in an electric gas cooker. When the soluble solids content reached 65 °Brix, citric acid was incorporated, and the cooking was finished. The hot jams were packed into sterile 250 mL polyethylene flasks and weighed to obtain the yield of the final product, and after that, stored at 4 °C. The passion fruit albedo used as a source of pectin was produced as described by Silva et al. (2012).

### 2.3 Jam formulation -experimental planning

A response surface with a complete factorial design 2<sup>3</sup> was used to optimize the guapeva jams (*Pouteria cf. gardneriana* Radlk), according to the methodology described by Box & Draper (1987) (Table 1). The experimental design aimed to evaluate the influence of the independent variables (citric acid concentration, pulp/sugar ratio, and albedo concentration as a source of

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**Table 1.** Experimental design 2<sup>3</sup> for guapeva jams preparation.

Essay	Coded variables			Real variables		
	*X1	**X2	***X3	*X1 (%)	**X2 (w/w)	***X3 (%)
1	+1	+1	+1	1	60/40	3
2	-1	-1	+1	0	40/60	3
3	+1	-1	+1	1	40/60	3
4	-1	+1	+1	0	60/40	3
5	+1	+1	-1	1	60/40	0
6	-1	+1	-1	0	60/40	0
7	+1	-1	-1	1	40/60	0
8	-1	-1	-1	0	40/60	0
9	0	0	0	0,5	50/50	1,5
10	0	0	0	0,5	50/50	1,5
11	0	0	0	0,5	50/50	1,5

\*X1 = citric acid concentration (%); \*\*X2 = pulp/sugar ratio (w/w) and \*\*\*X3 = Albedo concentration (%).

pectin) on pH, total titratable acidity (TTA), non-reducing sugars (NRS), reducing sugars (RS), soluble solids (SS), yield, antioxidant activity (AA), vitamin C (VC), total phenolics (TP), protein (PR), crude fiber (CF), and texture (Hardness and Adhesiveness). The optimization model was estimated, including the interaction effect according to the determination coefficient (R<sup>2</sup>). The estimations significance for the coefficients was analyzed to determine which factor contributed to the best fit of the model (significance level of 0.05).

## 2.4 Analysis

### *pH, titratable acidity, soluble solids, sugars and proximate composition*

Guapeva jams were analyzed for pH, total titratable acidity, total soluble solids, reducing and non-reducing sugars, moisture, ash, lipid, crude fiber, and proteins according to the AOAC methods (Association of Official Analytical Chemists, 2012) and Instituto Adolfo Lutz (2008). The total carbohydrate content was determined by difference (obtained by the difference between 100 and the sum of the percentages of moisture, protein, fats, and ash). Total energy value (TEV) (kcal/100g) was estimated using the conversion factors of Atwater & Bryant (1906).

The color of jams was determined using the Konica Minolta colorimeter model CR400 (Minolta Corp., Osaka, Japan), as proposed by the Commission Internationale de l'Eclairage (1986).

### *Bioactive compounds and antioxidant activity*

The jams were dried in an oven, ground, and subjected to immersion in an extractive solution of ethanol/water (8:2). The extracts contained 1 g and 5 g of sample for each 100 mL of the solution to determine phenolic compounds and antioxidant activity, respectively. The extracts were centrifuged for 15 min in the dark, filtered, and packed in amber glass bottles.

The total phenolic content was determined as described by Singleton & Rossi (1965) with modifications. Briefly, 0.1 mL of jams extracts were added to a solution formed by 0.2 mL of Folin-

Ciocalteau (10%), 2 mL of distilled water, and 1 mL of sodium carbonate (4%). The mixture was homogenized and stored in the dark for 2 hours at room temperature. The absorbance was measured at 750 nm.

Vitamin C content was determined by the colorimetric method, described by Strohecker & Henning (1967), using 2,4-dinitrophenylhydrazine, and ascorbic acid as a standard. Total carotenoids were determined as proposed by Higby (1962).

The free radical scavenging ability was measured against 1,1-diphenyl-2-picrylhydrazyl (DPPH), according to Brand-Williams et al. (1995), with modifications by Rufino et al. (2010). The absorbance was measured at 515 nm, and the antioxidant activity was expressed as EC<sub>50</sub> (amount of antioxidant needed to reduce the initial DPPH concentration to 50%).

To evaluate the reducing power of extracts, the ferric ion reducing antioxidant power (FRAP) assay was carried out as described by Rufino et al. (2010). A calibration curve was constructed using different concentrations of ferrous sulfate heptahydrate (0–2000 µM). For each jam formulation, extracts were prepared with three dilutions, and then a 90 µL aliquot of each dilution of the extracts was mixed with 270 µL of distilled water and 2.7 mL of the FRAP reagent. The absorbance was measured at 595 nm. The results were expressed in µM of ferrous sulfate/g of fruit or jam.

## 2.5 Texture analysis

The hardness and adhesiveness of jams were carried out in a Texturometer TA-XT2, P5S geometry, in the Multi-User Analysis Laboratory, at the Federal University of Goiás, Goiânia, GO, Brazil.

## 2.6 Statistical analysis

The results were expressed as mean values ± standard deviation of the analyzes performed in triplicate and were treated using the Statistica 7.0 software. The coefficients and interaction between variables were observed, generating the response surface graph. The global desirability function was applied to determine the optimal proportions for each independent variable, optimizing the different response variables simultaneously to obtain the best formulation (Derringer & Suich, 1980).

## 3 Results and discussion

The results without statistical significance were discarded for optimizing the jam production process, resulting in adjusted models using coded variables (Table 2).

Figure 1a showed that citric acid has an influence on and pH; formulations without the addition of acid had values closer to the neutrality zone. According to Jackix (1988), for a stable gel formation, the pH should be between 3 and 3.2. pHs close to described by this author for guapeva jams were obtained in formulations with more significant citric acid addition (Figure 1a).

It can be seen in Figure 1b that the citric acid variable influenced the final acidity content of jams, showing that independently of the pulp/sugar ratio, the products with the most significant

acidity were those that contained citric acid. Guapeva is a fruit that has low acidity, which initially leads jam to values of 1 to 1.5 g. 100 g<sup>-1</sup> for this parameter (Table 3). The results obtained in this work for guapeva jam then corroborate with that described by Aguiar et al. (2019). These authors observed that fruits with

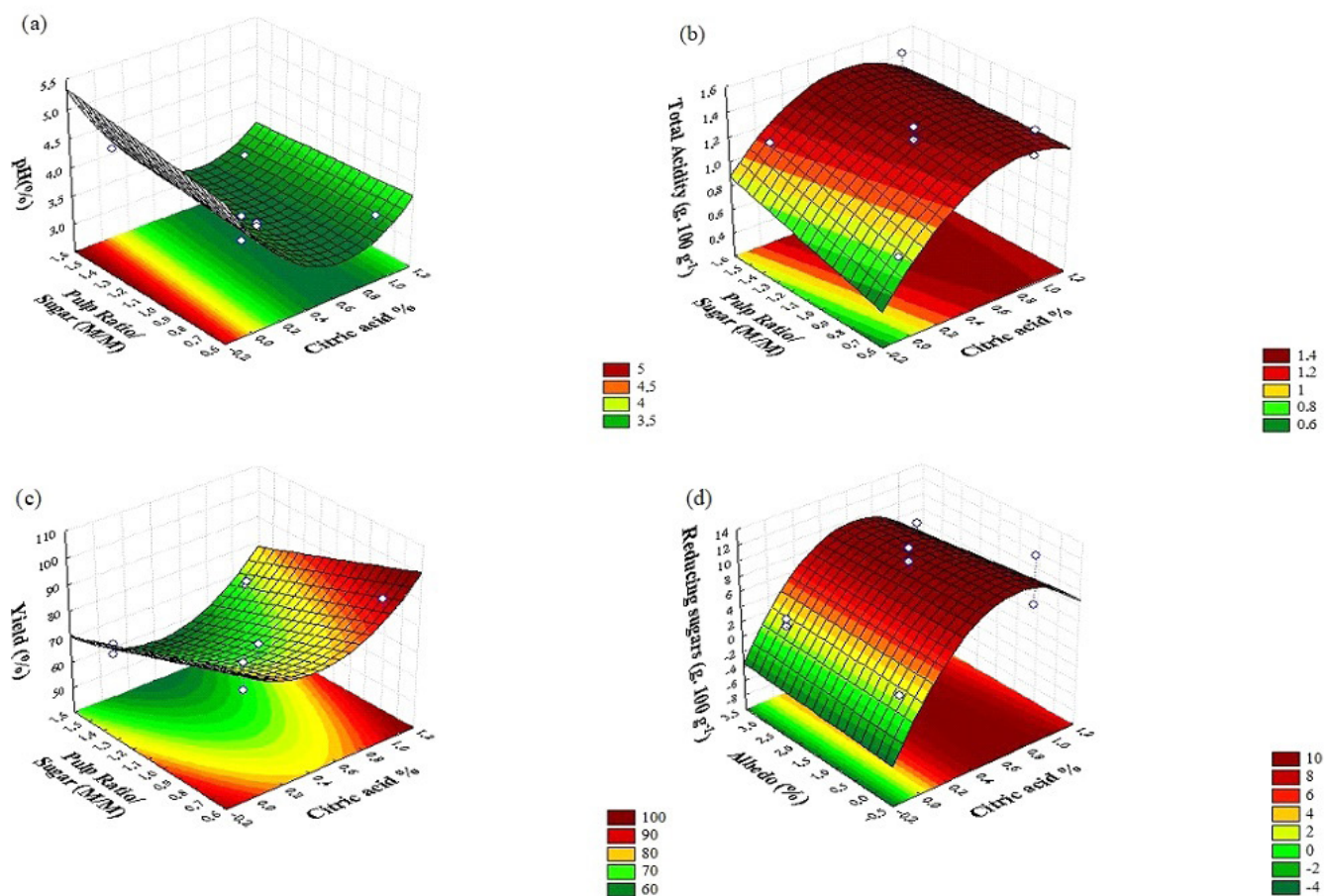
low acidity require the addition of acids to correct the pH and enable gel formation.

For the yield of the jam, the pulp/sugar ratio had results contrary to the citric acid variable, with formulations with higher proportions of sugar and pulp showing the best results (Figure 1c).

**Table 2.** Regression equations with coded variables, significance, and coefficients of determination of the complete models for the responses in dependent variables of guapeva jam.

Response variables	Estimated model	Prob >F	R <sup>2</sup>
pH	$y=3.96-2.94x+2.35x^2+0.36y-0.4xy$	0.259134	0.932
Total titratable acidity (g.100 g <sup>-1</sup> )	$y=0.58+1.42x-0.74x^2+0.32y-0.267xy$	0.258487	0.822
Reducing sugars (g.100 g <sup>-1</sup> )	$y=1.51+26.46x-18.67x^2+0.12y-0.65xy$	0.623748	0.764
Vitamin C (mg.100 g <sup>-1</sup> )	$y=18.49-36.14x+41.37x^2+4.23y+1.78xy$	0.553725	0.794
FRAP (μmol of ferrous sulfate.g <sup>-1</sup> of jam)	$y=23.12+135.25x-141.15x^2+6.77y+14.495xy$	0.014799	0.939
Carotenoids	$y=0.09-0.73x+0.99x^2+1.08y-0.92xy$	0.217858	0.701
Protein (g.100 g <sup>-1</sup> )	$y=2.65-3.51x+1.90x^2-0.14y+0.15xy$	0.158587	0.894
Crude fiber (g.100 g <sup>-1</sup> )	$y=0.81+0.02x-0.30x^2+0.15y+0.39xy$	0.091943	0.769
Yield (%)	$y=99.08-33.23x+37.41x^2-23.00y+1.04xy$	0.139457	0.901
Adhesiveness (N.s)	$y=-0.42+0.45x-0.05x+0.13y-0.25xy$	0.032456	0.778
Hardness (N.s)	$y=2.87-4.30x+1.50x^2-1.68y+1.83xy$	0.000180	0.951
L*	$2y=5.05+20.61x-17.40x^2+0.48y-5.65xy$	0.008280	0.831
a*	$y=6.814-10.25x+7.236x^2+.354y+1.476xy$	0.017780	0.779

F = Factors statistically calculates at 95% confidence (p ≤ 0.05) N.s = Newton second



**Figure 1.** Response surface plots for (a) pH, (b) total titratable acidity, (c) yield interactions with pulp/sugar ratio and citric acid, and (d) reducing sugars (g.100 g<sup>-1</sup>) interactions with citric acid and albedo.

Table 3. Dependent variables of guapeva jam (mean values  $\pm$  standard deviation).

Variables	Assays										
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
pH	3.3 $\pm$ 0.05	4.0 $\pm$ 0.14	3.2 $\pm$ 0.21	4.7 $\pm$ 0.15	3.3 $\pm$ 0.22	4.3 $\pm$ 0.15	3.5 $\pm$ 0.19	4.4 $\pm$ 0.19	3.3 $\pm$ 0.21	3.2 $\pm$ 0.18	3.3 $\pm$ 0.15
Total titratable acidity (g. 100 g <sup>-1</sup> )	1.5 $\pm$ 0.19	0.8 $\pm$ 0.12	1.4 $\pm$ 0.29	1.0 $\pm$ 0.015	1.2 $\pm$ 0.25	1.1 $\pm$ 0.22	1.2 $\pm$ 0.20	0.7 $\pm$ 0.24	1.3 $\pm$ 0.09	1.2 $\pm$ 0.48	1.4 $\pm$ 0.24
Soluble solids ( $^{\circ}$ Brix)	66 $\pm$ 0.00	67 $\pm$ 0.00	70 $\pm$ 0.00	64 $\pm$ 0.00	65 $\pm$ 0.00	66 $\pm$ 0.00	67 $\pm$ 0.00	65 $\pm$ 0.00	68 $\pm$ 0.00	67 $\pm$ 0.00	66 $\pm$ 0.00
TSS/TTA	40 $\pm$ 0.00	83.8 $\pm$ 0.00	50 $\pm$ 0.00	64 $\pm$ 0.00	53.3 $\pm$ 0.00	57.6 $\pm$ 0.00	55.8 $\pm$ 0.00	83.8 $\pm$ 0.00	52.3 $\pm$ 0.00	55.8 $\pm$ 0.00	47.1 $\pm$ 0.00
Reducing sugars (g.100 g <sup>-1</sup> )	8.6 $\pm$ 0.47	1.4 $\pm$ 0.06	6.8 $\pm$ 0.26	2.3 $\pm$ 0.19	6.1 $\pm$ 0.27	1.5 $\pm$ 0.05	12.5 $\pm$ 0.64	1.5 $\pm$ 0.07	10.7 $\pm$ 0.18	6.1 $\pm$ 0.20	12.5 $\pm$ 0.41
Non-reducing sugars (g.100 g <sup>-1</sup> )	25 $\pm$ 2.71	35 $\pm$ 1.54	30 $\pm$ 2.18	32 $\pm$ 1.59	29 $\pm$ 2.98	35 $\pm$ 0.101	20 $\pm$ 1.10	36 $\pm$ 1.42	26 $\pm$ 1.99	34 $\pm$ 3.12	22 $\pm$ 1.48
DPPH (EC <sub>50</sub> g. g <sup>-1</sup> of DPPH)	5.2 $\pm$ 0.24	1.6 $\pm$ 0.01	1.6 $\pm$ 0.03	3.4 $\pm$ 0.03	3.9 $\pm$ 0.36	3.1 $\pm$ 0.03	8.2 $\pm$ 0.48	3.0 $\pm$ 0.05	2.1 $\pm$ 0.06	2.4 $\pm$ 0.03	3.18 $\pm$ 0.19
FRAP ( $\mu$ mol of ferrous sulfate g <sup>-1</sup> of jam)	77.4 $\pm$ 4.12	46.9 $\pm$ 1.59	84.6 $\pm$ 1.31	24.8 $\pm$ 0.05	20.2 $\pm$ 1.39	26.5 $\pm$ 1.02	14.2 $\pm$ 0.03	19.6 $\pm$ 0.03	76.8 $\pm$ 0.63	76.3 $\pm$ 0.16	76.3 $\pm$ 1.23
Total phenolics (mg GAE.100 g <sup>-1</sup> )	561 $\pm$ 0.18	546 $\pm$ 0.10	520 $\pm$ 0.18	540 $\pm$ 0.46	531 $\pm$ 8.20	502 $\pm$ 0.21	510 $\pm$ 0.20	490 $\pm$ 1.00	502 $\pm$ 0.21	540 $\pm$ 0.46	531 $\pm$ 8.20
Vitamin C (mg/100 g <sup>-1</sup> )	51 $\pm$ 3.48	32 $\pm$ 4.46	32 $\pm$ 4.00	30 $\pm$ 4.91	28 $\pm$ 3.86	19 $\pm$ 3.54	19 $\pm$ 3.59	18 $\pm$ 1.48	17 $\pm$ 0.08	19 $\pm$ 3.56	19 $\pm$ 3.62
Protein (g.100 g <sup>-1</sup> )	1.7 $\pm$ 0.00	1.0 $\pm$ 0.00	1.0 $\pm$ 0.00	1.8 $\pm$ 0.00	1.7 $\pm$ 0.00	1.6 $\pm$ 0.00	1.1 $\pm$ 0.00	1.2 $\pm$ 0.00	1.3 $\pm$ 0.00	1.0 $\pm$ 0.00	0.8 $\pm$ 0.00
Crude fiber (g.100 g <sup>-1</sup> )	1.4 $\pm$ 0.00	1.1 $\pm$ 0.00	0.9 $\pm$ 0.00	1.0 $\pm$ 0.00	1.3 $\pm$ 0.00	1.1 $\pm$ 0.00	0.9 $\pm$ 0.00	0.8 $\pm$ 0.00	1.2 $\pm$ 0.00	1.1 $\pm$ 0.00	1.0 $\pm$ 0.00
Yield (%)	69 $\pm$ 0.00	78 $\pm$ 0.00	85 $\pm$ 0.00	66 $\pm$ 0.00	71 $\pm$ 0.00	62 $\pm$ 0.00	92 $\pm$ 0.00	89 $\pm$ 0.00	67 $\pm$ 0.00	67 $\pm$ 0.00	73 $\pm$ 0.00
L*	18.3 $\pm$ 3.24	24.2 $\pm$ 0.62	25.0 $\pm$ 2.15	24.4 $\pm$ 0.70	22.5 $\pm$ 2.19	27.0 $\pm$ 1.10	24.5 $\pm$ 0.26	26.3 $\pm$ 0.83	27.6 $\pm$ 3.80	29.1 $\pm$ 0.79	29.0 $\pm$ 1.22
a*	6.4 $\pm$ 0.77	7.3 $\pm$ 0.44	4.1 $\pm$ 0.26	7.4 $\pm$ 1.16	6.6 $\pm$ 0.18	7.2 $\pm$ 0.67	5.8 $\pm$ 0.60	6.7 $\pm$ 0.40	4.1 $\pm$ 0.35	5.8 $\pm$ 0.26	3.8 $\pm$ 0.20
b*	10.7 $\pm$ 1.68	12.7 $\pm$ 1.03	8.8 $\pm$ 1.41	12.7 $\pm$ 0.39	11.1 $\pm$ 0.63	11.6 $\pm$ 1.71	9.5 $\pm$ 1.38	10.3 $\pm$ 0.91	5.5 $\pm$ 0.73	11.3 $\pm$ 0.74	6.1 $\pm$ 0.54
h	58.0 $\pm$ 1.36	60.4 $\pm$ 0.74	64.6 $\pm$ 1.89	59.7 $\pm$ 0.26	59.3 $\pm$ 0.85	58.3 $\pm$ 1.21	58.4 $\pm$ 1.29	56.9 $\pm$ 4.80	53.4 $\pm$ 1.11	63.0 $\pm$ 0.48	57.4 $\pm$ 0.82
C	11.9 $\pm$ 1.79	14.6 $\pm$ 1.10	9.7 $\pm$ 1.49	14.7 $\pm$ 0.42	12.7 $\pm$ 0.64	13.6 $\pm$ 1.81	11.7 $\pm$ 1.56	12.3 $\pm$ 0.98	6.8 $\pm$ 0.80	12.7 $\pm$ 0.78	7.1 $\pm$ 0.59

The amount of sugar added in the formulations is related to the content of soluble solids and interferes with the yield. The greater the amount of sugar added, the shorter the processing time and the yield of the jam will increase. This reduction in processing time, in turn, leads to cost savings.

The reducing sugar were influenced just by citric acid (Figure 1d). Higher values of reducing sugars were found in formulations with acid addition (Table 3), and this can be explained because a higher acidity favors the hydrolysis of sucrose. Acidity, combined with heating, causes the breakdown of sucrose into glucose and fructose, which, according to Martins et al. (2017), allows a better solubility of sugars when compared to pure sucrose. This partial inversion prevents the product from having an unpleasant texture at the end of processing.

The pulp/sugar variable was the only one that proved to generate influence about the protein content in jams (Figure 2a and Figure 2b). The formulations with the highest concentration of proteins have the highest proportion of pulp (Table 3) because of the content of this macronutrient in guapeva. The protein values in this work are higher than other fruit jellies, such as grape 0.27 g.100 g<sup>-1</sup>, blueberry 0.31 g.100 g<sup>-1</sup>, strawberry 0.41 g.100 g<sup>-1</sup>, and tamarind 0.68 g. 100 g<sup>-1</sup> (Mohd Naeem et al., 2017; Cardoso et al., 2012).

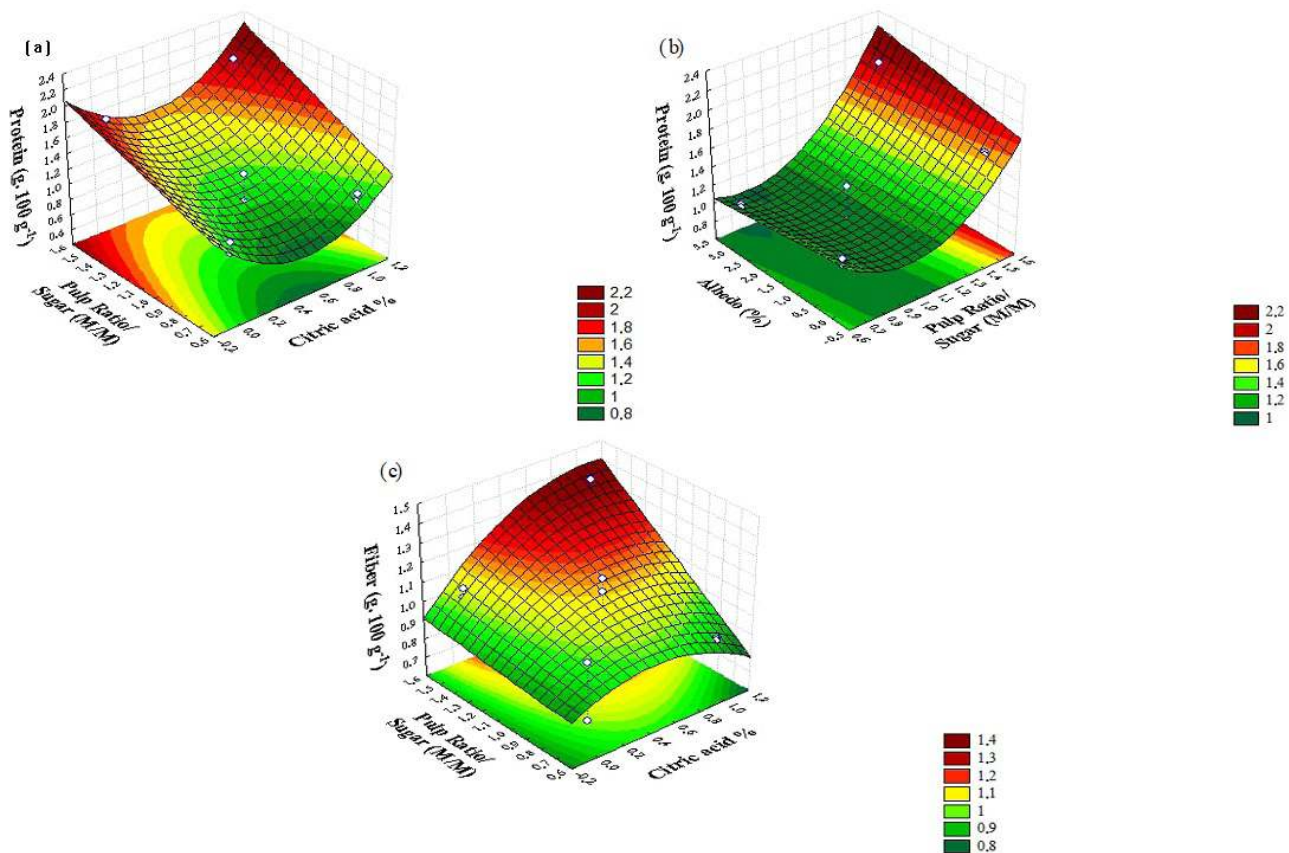
The pulp/sugar ratio influenced the crude fiber content for guapeva jams, independent of the acid concentration (Figure 2c).

As shown in Table 3, the formulations with the highest pulp concentration were the ones that showed the best results for crude fibers. Fiber values found for guapeva jams were higher than those described by Silva et al. (2018) for yellow and orange bocaiuva jams, which presented concentrations of 0.46 and 0.66 g. 100 g<sup>-1</sup>, respectively.

Figure 3a shows that the variables albedo and citric acid influence the content of vitamin C. The contents of this compound increased in formulations with higher proportions of albedo and citric acid. According to Table 3, the formulation F1 has the highest vitamin C average (51 mg.100 g<sup>-1</sup>).

The total carotenoids were affected just by pulp/sugar ratio (Figure 3b), in spite of citric acid and albedo concentrations. The carotenoid levels found in this work ranged from 0.37 to 2.15 mg.100 g<sup>-1</sup> (Table 3), and these values are higher than those determined by Lemos et al. (2019) for a mixed jam with jaboticaba and acerola that showed results from 0.0016 to 0.0046 mg.100 g<sup>-1</sup>. This behavior can be associated with the carotenoid content present in the guapeva fruit and the samples' exposure to high temperatures, and the variation of the components inserted in each formulation. As carotenoids are compounds studied as chemopreventive agents (Palioto et al., 2015), foods rich in these compounds, such as guapeva fruit and jam, can prevent diseases.

Regarding the sample's capacity to reduce ferric to ferrous ions measured by the FRAP method (Figure 4a), it is possible to



**Figure 2.** Response surface plots for (a) proteins (g.100 g<sup>-1</sup>) interactions with albedo, (b) proteins (g.100 g<sup>-1</sup>) interactions with citric acid, and (c) crude fiber (g.100 g<sup>-1</sup>) interactions with pulp/sugar ratio and citric acid.

observe that the citric acid variable had a significant influence, showing better results for formulations that contained acid in its composition (Table 3). In Figure 4b, the effect is related to the pulp/sugar ratio. In this case, formulations that contained a higher proportion of pulp showed better responses regardless of the albedo concentration. This behavior indicates that the antioxidant activity of guapeva jam is associated with the phenolic composition, since the antioxidant potential results from the synergistic effect between the phenolica compounds, vitamim C, carotenoids and others bioactive compounds.

None studied variable had a significant influence on the antioxidant potential of guapeva jams. The formulations had antioxidant potential  $EC_{50}$  that varied from de 1.63 to 8.17 g of jam.g<sup>-1</sup> of DPPH (Table 3). These results are relevant because, according to Cottica et al. (2011), as smaller the quantity in grams needed for free radical scavenging, the more expressive the antioxidant potential will be. The phenolic compounds had the same behavior that antioxidant potential, and presented

values considered high, ranging from 502 to 561 mg GAE. 100<sup>-1</sup> (Table 3). These results demonstrate that even with thermal processing, it was possible to obtain jams rich in antioxidant compounds, phenolic compounds, and vitamin C. According to Kim et al. (2018), the cooking process facilitates the release of phenolic compounds, causing an increase in the quantity and availability of bioactive compounds.

The concentration of citric acid had an inverse influence on the L\* value of guapeva jams (Figure 5a). Thus, the L\* showed a negative linear relationship (Figure 5b). However, the quadratic is significantly larger, indicating that as the proportion of citric acid increases, the L\* tone is reduced. The jams become darker, which may be directly associated with the degradation of red pigments. In general, the color change in a food product during thermal processing may be related to the destruction of these dyes, especially the carotenoids, causing a non-enzymatic browning, such as the Millard reaction and oxidation of ascorbic acid (Jabbari et al., 2018).

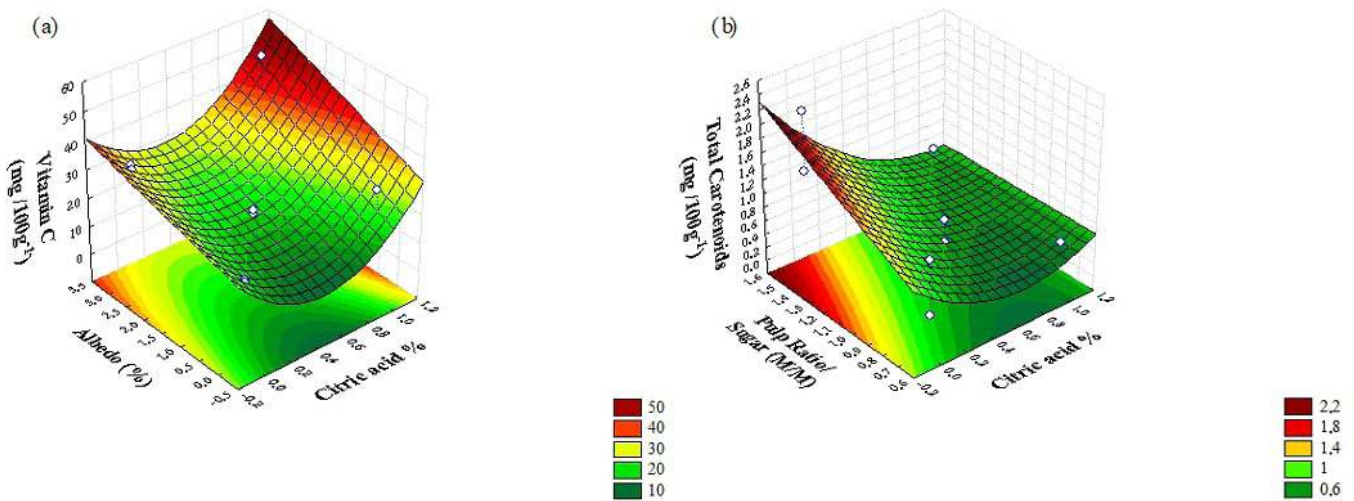


Figure 3. Response surface for (a) vitamin C (mg.100 g<sup>-1</sup>), and (b) total carotenoids (mg.100 g<sup>-1</sup>) interactions with pulp/sugar ratio and citric acid.

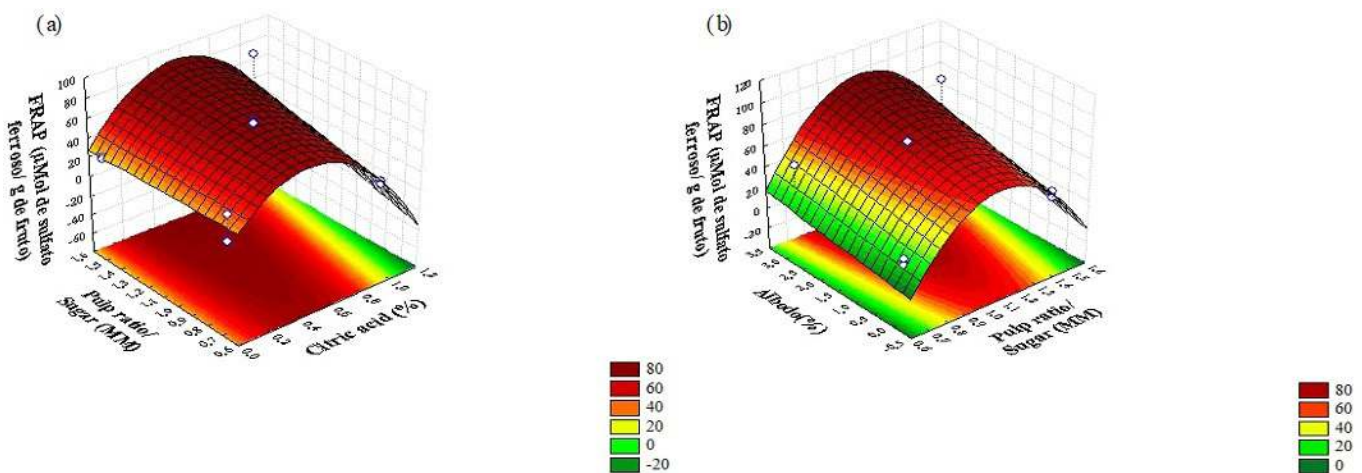


Figure 4. Response surface plots for (a) FRAP (µmol of ferrous sulfate.g<sup>-1</sup> of jam) interactions with pulp/sugar ratio and citric acid, and (b) FRAP (µmol of ferrous sulfate.g<sup>-1</sup> of jam) interactions with albedo and pulp/sugar ratio.

For chroma \*a, there was a significant non-linear behavior for the action of citric acid (Figure 6a). However, despite not being significant at  $\leq 0.05$ , the regression coefficient attributed to the linear parameter for this variable was negative (-2.44) (Figure 6b), indicating a tendency to reduce the red color, which can also be associated with the degradation of lycopene due to the reduction of the pH of the medium. The same behavior was determined by Kim & Choi (2020), who attributed the degradation of lycopene to reduced pH levels, evidencing the significant influence of this parameter on the pigment's rapid degradation. The binary interaction between the pulp/sugar ratio and the citric acid concentration has a positive effect, indicating a tendency to increase the red color, which is probably related to the influence of the interaction of these factors with the rupture of the matrix membranes, releasing the lycopene and enhancing color.

The addition of citric acid in the jams influenced the adhesiveness so that the greater the addition of acid, the more adhesive the products will be (Figure 7a). For hardness (Figure 7b), the citric acid variable had an inverse influence compared the

pulp/sugar ratio, showing that the greater the sugar addition in the lowest proportions of acid, the more force will be exerted on the jams. According to Szczesniak (2002) hardness is the necessary force for the material to reach a given deformation, this fact can be explained due to the decrease in the content of soluble solids, which were below 70 °Brix, indicating a high rate of water evaporation making the hardest and hardly breakable gel (Menezes et al., 2011). Central formulations (F9, F10, and F11) had values that correspond to the optimum point for adhesiveness and hardness (Table 3).

A desirability test was performed (Figure 8). This test presents the specifications for insertion in human food (minimum, optimal, and maximum) for the results from the optimized formulations considering the proportions of phenolic compounds and antioxidants. The desirability test indicated the best formulation of the mixture of citric acid at 1%, 60/40 pulp/sugar ratio, and albedo at 3%, which corresponds to formulation F1. For F1, the results for phenolic compounds and antioxidant potential varied between 561 mg GAE.

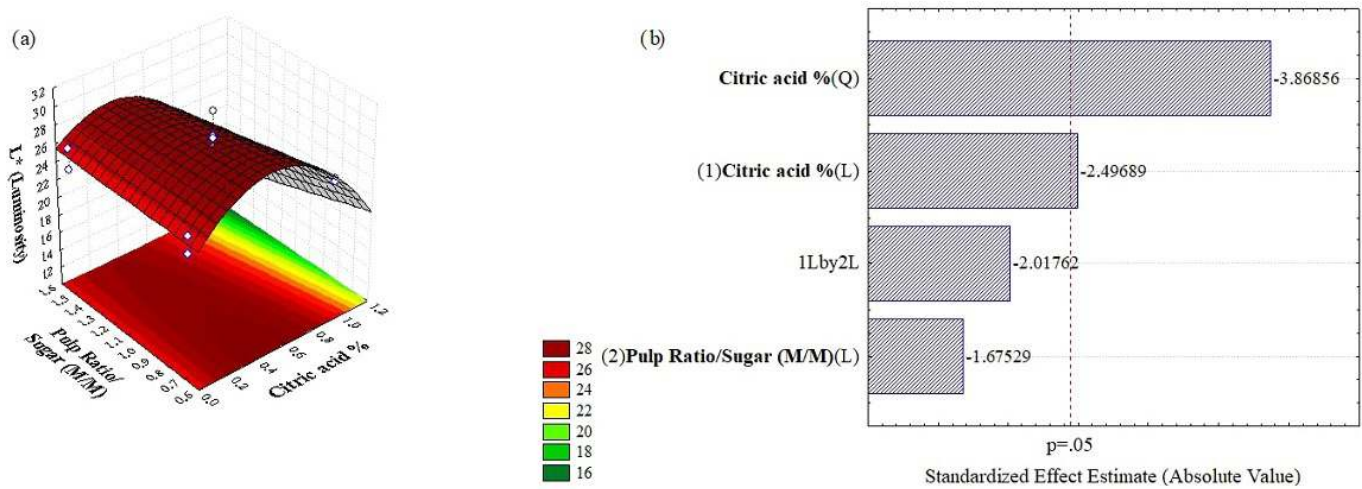


Figure 5. Response surface plots for (a) lightness (L\*) and pareto (b), interactions with pulp/sugar ratio and citric acid.

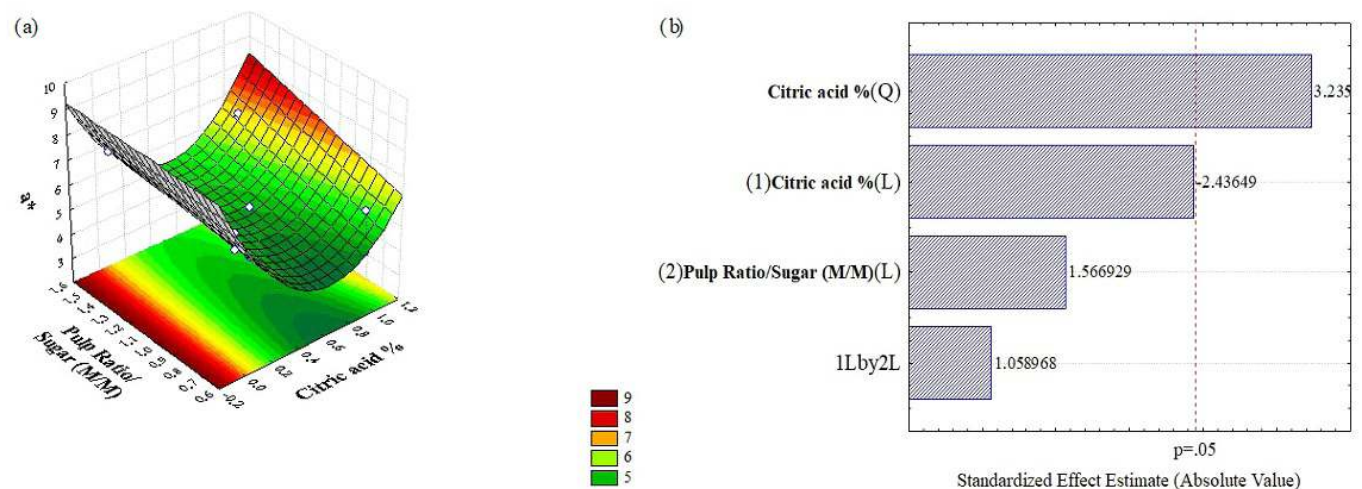


Figure 6. Response surface plots for (a) a\* red-green component and pareto (b), interactions with pulp/sugar ratio and citric acid.

100 g<sup>-1</sup> and 5.2 g of jam.g<sup>-1</sup> DPPH, respectively. According to Faller & Fialho (2009), the average availability of polyphenols in Brazil, consumed in teas, coffees, and fruits, is 48.3 mg per day.

Based on this, the insertion of guapeva jams in the population's diet can be considered a way to enhance the consumption of these compounds.

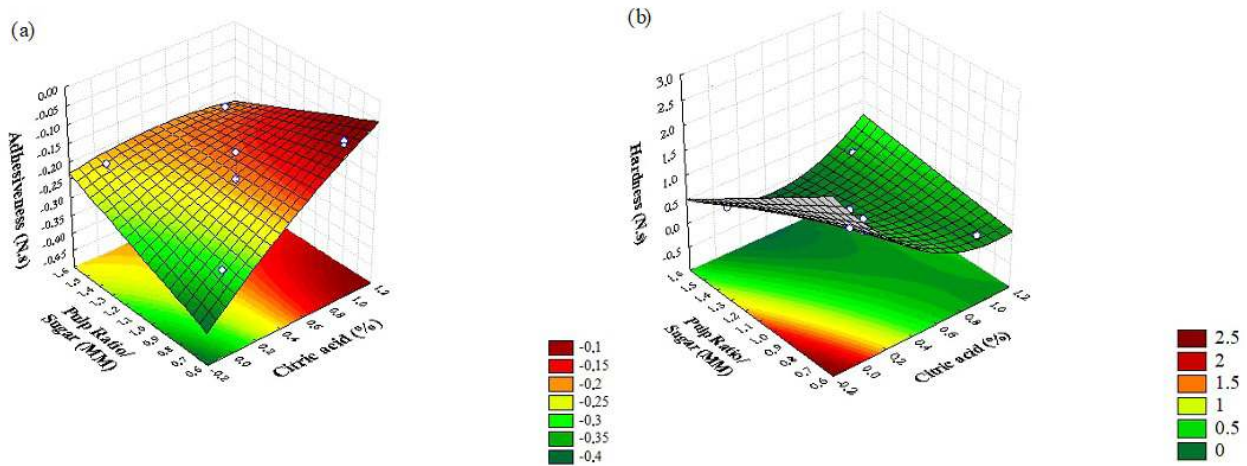


Figure 7. Response surface plots for (a) adhesiveness, and (b) hardness interactions with pulp/sugar ratio and citric acid.

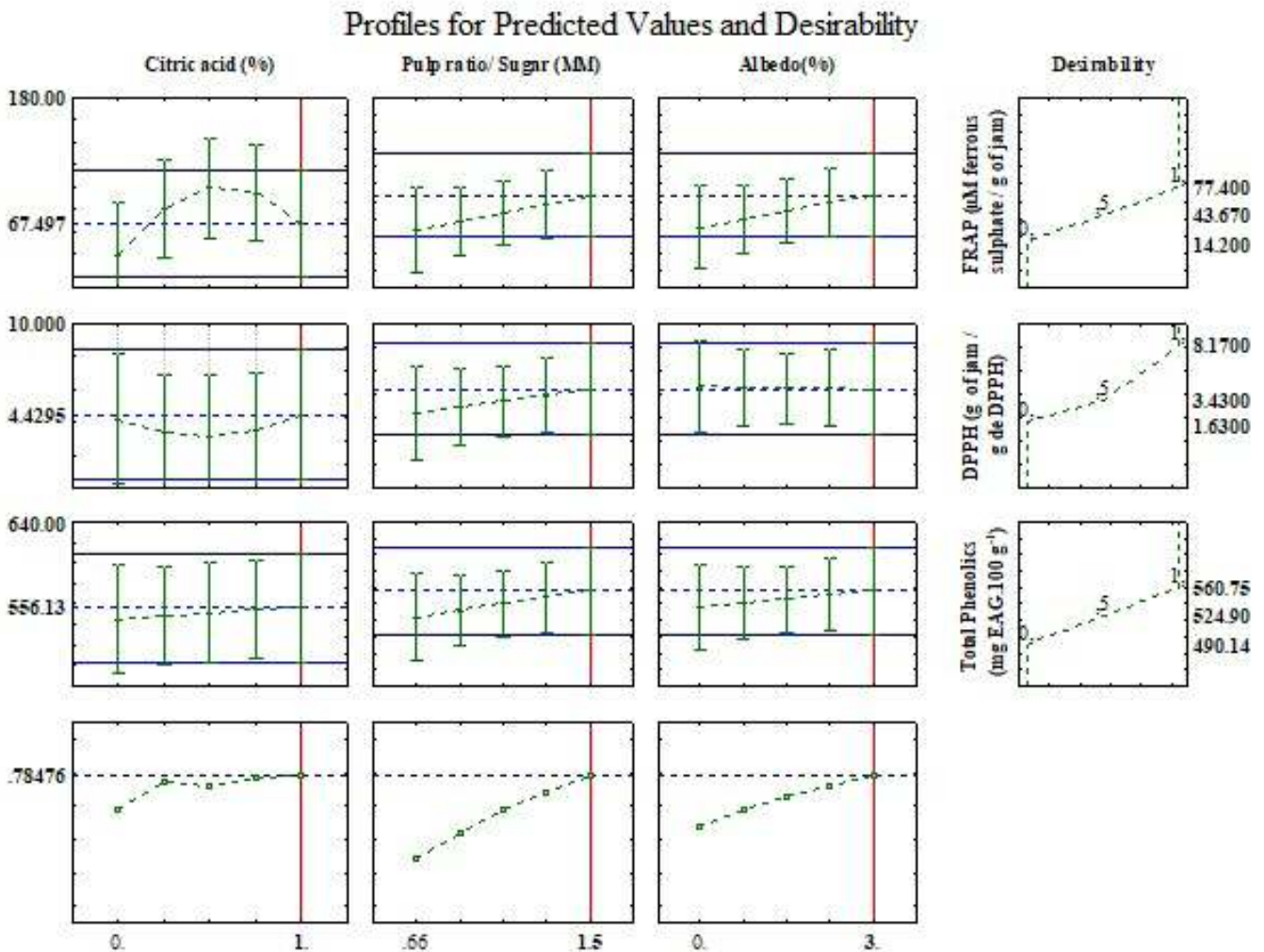


Figure 8. Profile of optimized values by desirability test for antioxidant potential and phenolic compounds in guapeva jams.



## 4 Conclusion

The results indicated that the citric acid and pulp/sugar ratio positively influenced the analyzed responses. The guapeva jams formulations indicated as optimal for the parameters pH, acidity, texture, and reducing sugars were F9, F10, and F11, showing better results for the ideal gel formation, and F1 with good percentages of phenolic compounds, antioxidant potential, fibers, proteins, and vitamin C. This work's results contribute to increased foods' insertion with a high nutritional value obtained from the Cerrado region's fruits in the consumer market.

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