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Influence of the addition of acerola residue on the physical characteristics of yougurt

Influência da adição do resíduo de acerola nas características físicas de iogurte

Influencia de la adición de resíduos de acerola en las características físicas del yogur

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Abstract
Acerola has acquired great importance due to its high vitamin C content and its potential for industrialization. However, during its processing, a quantity of waste (seed and bagasse) is generated, mainly from pulp processing. These residues can be used as new sources of food with high added value and contribute positively to the reduction of environmental impacts. Therefore, this research aimed to add value to the acerola by-product through the development of a functional yogurt. To develop this research, a complete 2² Factorial Planning and Response Surface Methodology were used. The planning included five different levels, with three central points totaling seven tests. The independent variables were: concentration of acerola by-product (%) and brown sugar (%). The responses analyzed were: water content (g/100g), acidity (g/100g), pH, ascorbic acid (mg/100g), reducing sugars (g/100g), and ash (g/100g). The Statística 7.0 software was used to analyze the results of the adopted planning. It was observed that the acerola by-product concentration factor had the greatest influence on the vast majority of responses studied.
Keywords: Dairy drink; Fruit; Sustainability.

Resumo
A acerola adquiriu grande importância devido ao alto teor de vitaminas C e por seu potencial para industrialização. Porém, durante seu processamento, é gerado quantidade de resíduos (semente e bagaço) provenientes principalmente do processamento da polpa. Esses resíduos podem ser utilizados como novas fontes de alimentos com alto valor agregado e contribuindo positivamente para a redução dos impactos ambientais. Logo, a presente pesquisa visou agregar valor ao subproduto de acerola a partir do desenvolvimento de um iogurte funcional. Para o desenvolvimento desta pesquisa, foi utilizado um Planejamento Fatorial completo 2² e a Metodologia de Superfície de Resposta. O planejamento contou com cinco níveis diferentes, com três pontos centrais totalizando sete ensaios. As variáveis independentes foram concentração de subproduto de acerola (%) e de açúcar mascavo (%). As respostas analisadas foram teor de água (g/100g), acidez (g/100g), pH, ácido ascórbico (mg/100g), açúcares redutores (g/100g) e cinzas (g/100g). Foi utilizado o software Statística 7.0 para análise dos resultados do planejamento adotado. Foi observado que o fator concentração de subproduto de acerola apresentou maior influência sobre a grande maioria das respostas estudadas.
Palavras-chave: Bebida láctea; Fruta; Sustentabilidade.

Resumen
La acerola ha adquirido gran importancia por su alto contenido en vitamina C y su potencial de industrialización. Sin embargo, durante su procesamiento se genera una cantidad de residuos (semillas y bagazo), principalmente provenientes del procesamiento de pulpa. Estos residuos pueden utilizarse como nuevas fuentes de alimentos con alto valor agregado y contribuyendo positivamente a la reducción de impactos ambientales. Por lo tanto, esta investigación tuvo como objetivo agregar valor al subproducto acerola mediante el desarrollo de un yogur funcional. Para desarrollar esta investigación se utilizó una completa Metodología de Planificación Factorial y Superficie de Respuesta 2^2. La planificación incluyó cinco niveles diferentes, con tres puntos centrales para un total de siete pruebas. Las variables independientes fueron concentración de subproducto acerola (%) y panela (%). Las respuestas analizadas fueron contenido de agua (g/100g), acidez (g/100g), pH, ácido ascórbico (mg/100g), azúcares reductores (g/100g) y cenizas (g/100g). Para analizar los resultados de la planificación adoptada se utilizó el software Statística 7.0. Se observó que el factor de concentración del subproducto acerola tuvo la mayor influencia en la gran mayoría de las respuestas estudiadas.
Palabras clave: Bebida láctea; Fruta; Sostenibilidad.

1. Introduction

The fruit growing sector in Brazil is expanding, where it is estimated that around 53% of production is sold fresh and 47% is destined for the agro-industrial sector for the production of juices, teas, frozen pulps, jellies, and others (Oliveira, 2018). Brazil produces around 45 million tons of fruit annually, making it the third-largest producer in the world. In this production, tropical fruits stand out due to their good adaptation to the Brazilian climate (Embrapa, 2020; Ramadan *et al*., 2019).

Realizing the potential of acerola, Brazil began to exploit it commercially and established a well-structured production chain, becoming one of the largest producers in the world and exporting large volumes of processed fruits, serving a global market that can reach US$17.5 billion by 2026 (Belwal *et al*., 2018). In this context, around 40% of the processed volume becomes waste, with 30% being made up of peels and seeds, while 10% is obtained with the clarification of the juice being formed from pulp remains (Poletto *et al*., 2021).

This waste generated is discarded, which represents a waste of raw materials that could be used to obtain energy or other products with greater added value. According to Rezende *et al*. (2018), there was a growing interest in technologies that generate low environmental impact and promote sustainability, so there is a search for the use of waste from fruit processing industries.

The composition of the residue obtained from acerola bagasse and peels also has a rich phytochemical profile, mainly in total anthocyanins, carotenoids, ascorbic acid, phenolic compounds, and total flavonoids, with a higher proportion when compared to its pulp, showing the importance of its use (Rezende *et al*., 2018). This byproduct may be interesting as a source of nutrients and other bioactive molecules. The dietary fibers present in by-products can be added to foods with the function of prebiotics and thus guarantee the reprocessing of waste (Albuquerque *et al*., 2019). Furthermore, they can be added to a functional diet, with the potential for transformation to be added to various foods (Nascimento *et al*., 2022).

Therefore, the inclusion of fruit residues in yogurt appears as a suggestion for the development of products with functional and nutritious properties (Barboza *et al*., 2021). According to Gouraji *et al*. (2019) new yogurt varieties with unique flavors and aromas, which simultaneously offer potential healthcare functions, have shown increased sales and greater consumer satisfaction. Furthermore, it is presented as the product that most arouses consumer desire when launched on the market, being considered a symbol of healthy food, and has the potential to grow even further with innovations that incorporate functionalities into products (Brazil Food Trends, 2020).

The use of acerola juice residue in the production of yogurt could serve as a source of nutrients and bioactive compounds that could increase its nutritional potential and act in a protective and preventive way in the human body and reach an even more diverse audience.

Given the above, the present article aimed to study the influence of agro-industrial acerola residue on the physical-chemical characteristics of the yogurt produced.

2. Methodology

Product development and chemical and physical-chemical analyses were carried out in the Food Engineering Laboratory, of the Food Engineering Academic Unit of the Federal University of Campina Grande – PB. The methodological treatment was characterized in a quantitative way, where data was collected through measurements of quantities, generating data that were analyzed using mathematical devices such as percentages, statistics, and probabilities, in addition to numerical methods, analytical methods, and generation of equations and mathematical formulas applicable to some process (Pereira *et al*., 2018).

The following materials were used to make the yogurt, obtained from local establishments in the city of Campina Grande: whole cow's milk, dairy culture, acerola fruits, and brown sugar. The acerola fruits purchased from the local market were washed, sanitized, rinsed with plenty of water, and subsequently processed in a domestic processor to obtain the pomace without adding water. The acerola pomace was frozen at a temperature of -18°C until the moment of use, when it was thawed at refrigerator temperature for approximately 12 hours, in quantities necessary for each test according to the adopted planning.

The preparation of the yogurt dough was carried out according to the methodology provided by the Brazilian Technical Response Service – SBRT (2008).

To prepare the yogurt formulations, a 2^2 factorial design was adopted with the concentrations of acerola pomace (%) and brown sugar concentration (%) as independent variables. The dependent variables were water content (g/100g), acidity (g/100g), pH, ascorbic acid (mg/100g), ash (g/100g) and reducing sugars (g/100g). All analyses were performed in triplicate. The computer program Statística 7.0 was used to analyze the experimental planning. Table 1 shows the levels of the independent variables. The planning included 5 different levels, totaling 7 tests with three central points.

Table 1 - Planning matrix for preparing yogurts added with acerola residue and brown sugar, with their respective independent variables and their real and coded levels.

Experiments	Independent variables	
	Concentration of acerola by-product (%)	Brown sugar concentration (%)
F1	-1 (7)	-1 (7)
F2	+1 (21)	-1 (7)
F3	-1 (7)	+1 (21)
F4	+1 (21)	+1 (21)
F5	0 (14)	0 (14)
F6	0 (14)	0 (14)
F7	0 (14)	0 (14)

Source: Authors.

3. Results and Discussion

In Table 2, it is possible to find the characterization data of the pomace from acerola juice.

Table 2 - Characterization of acerola by-product.

Analytics	Acerola pomace in nature	Standard deviation
Water content (g/100g)	89.352	0.028
Acidity (g/100g)	1.597	0.086
Ph	3.202	0.017
Ascorbic acid (mg/100g)	1894.097	0.082
Ash (g/100g)	0.302	0.002
Reducing sugars (g/100g)	3.360	0.557

Source: Authors.

In Table 3, it is observed that the water content value found for the acerola by-product was equal to 89.352 (g/100g), which is close to the value found in the literature by Alves (2019), Nascimento (2018) and Braga *et al*., (2011) in which they found values equal to 89.65, 93.61 and 89.9 (g/100g), respectively, for acerola residue.

When evaluating the titratable acidity, it is clear that the value obtained in this work is close to the values reported in the literature by Caldas *et al*., (2010), who found a value equal to 1.39 (g/100g). In work carried out by Sancho *et al*., (2015) they found a value equal to 3.60, which is above the value reported in the present work. Acidity is a relevant parameter in evaluating the conservation status of a food product (Castro *et al*., 2015). With the fruit maturation process, acidity is generally reduced, influencing the odor, flavor, color, maintenance of quality, and stability (Pereira *et al*., 2006).

The average pH value of the fresh acerola by-product found in the present work is close to the values reported in the literature by Sancho *et al*., (2015) and Mélo *et al*., (2014), in which they, respectively, showed values equal to 3.45 and 3.54. The pH can be variable depending on the species of acerola tree, harvest periods, growing regions, and other factors, which cause changes in the pH of the acerola and consequently in the residue (Ferreira, 2020).

In Table 2, the value found for ascorbic acid for the acerola by-product is equal to 1894.097 mg/100g, which is higher than those found in the literature by Alves (2019) and Nascimento (2018) who found values equal to 1116.67 and 1080.11, respectively. It was observed that the vitamin C content in acerola residues was higher than the amount found in some studies, thus showing the nutritional value of the peels that can be used in the production of vitamin C. Therefore, according to Sancho *et al*. (2015), acerola residue can also be considered an important source of ascorbic acid and should be used in food supplements.

When evaluating the ash content of the acerola by-product, it was observed that the average value found in the present work is close to the value reported by Alves (2019) who found an average ash value equal to 0.44 (g/100g). The percentage of ash found in the acerola residue in this study was 0.302 (g/100g), a lower value than in other studies carried out by Sancho *et al*. (2015), Silva *et al*. (2014) and Mélo *et al*. (2014) with agro-industrial acerola residues, which found values between 2.07 and 2.36 (g/100g).

It was observed that the average value of reducing sugars is close to those reported by Braga *et al*., (2011) who found values between 1.38 and 2.38 (g/100g). In the work carried out by Sancho *et al*. (2015) and Mélo *et al*. (2014), the authors found values equal to 15.29 and 9.40 (g/100g), which are well above what was reported in this study.

According to an observation carried out by Sancho *et al*. (2015), fruits are normally rich in sugars (glucose and fructose), the determination of which is important to evaluate the potential of these residues as raw material for fermentation. So, those fruits that have a high concentration of sugars would be suitable for fermentation, on the other hand, acerola would be suitable as a food supplement with a low sugar content. Cvetković *et al*. (2009) also found great variation in this parameter in their study, finding values of 9.72, 16.50, 23.23, and 61.21 (g/100g) for the following dried fruits: rosehip, wild apple, apricot, and blackberry, respectively.

The results of the 2² factorial design of the dependent variables, water content (g/100g), acidity (g/100g), pH, ascorbic acid (mg/100g), reducing sugars (g/100g) and ash (g/100g), in the process of making homemade yogurt using a by-product of the acerola juice agroindustry can be seen in Table 3.

Table 3 - Results of the complete experimental design 2²

Essay	Coded and real CSA (%)	Coded and real CAM (%)	Water content (g/100g)	Acidity (g/100g)	pH	Ascorbic acid (mg/100g)	Reducing sugars (g/100g)	Ash (g/100g)
1	-1 (7%)	-1 (3%)	86.784	0.661	4.114	194.614	3.659	0.528
2	+1 (21%)	-1 (3%)	82.795	0.709	3.958	428.554	4.528	0.616
3	-1 (7%)	+1 (9%)	81.315	0.556	4.181	172.10	4.039	0.515
4	+1 (21%)	+1(9%)	80.601	0.660	3.966	415.34	4.358	0.635
5	0 (14%)	0 (6%)	83.496	0.624	4.068	284.47	3.924	0.550
6	0 (14%)	0 (6%)	83.472	0.634	4.071	281.73	3.910	0.564
7	0 (14%)	0 (6%)	84.016	0.627	4.043	292.19	3.831	0.552

CSA - Concentration of acerola juice by-product; CAM - Brown sugar concentration. Source: Authors.

According to Table 3, about the composition of the yogurt prepared, it can be observed that the water content of the samples decreases as the concentration of brown sugar in the yogurt production increases. It can be seen that in all tests there were high water contents, which were above the values found by Bessa and Silva (2018), who found a value for the water content of tamarind yogurt equal to 83.72 (g/100g).

About acidity, according to the results expressed, the values follow the requirements of the Brazilian Normative Instruction for the product in question, which must be in a range of 0.6g to 1.5g of lactic acid/100g (Brazil, 2007). It can be generally observed that formulations with a lower concentration of acerola pomace presented a lower acidity value. In the work of Santos and Ellena (2021), studying the use of yellow passion fruit albedo flour in the formulation of Greek yogurt, the authors found a value of 0.68 and 0.72 g/100g of acidity, values close to those of the present research.

Regarding pH, according to IN nº 46 of October 24, 2007, of the Ministry of Agriculture, Livestock, and Supply (BRASIL, 2007), the ideal pH for the identity and quality of yogurt is between 3.6 and 4.5, framing the product of this study is in the recommended range. Research carried out by Bessa e Silva (2018) characterizing tamarind yogurt, found a pH value equal to 3.85. Similar results were described in the research by Gonçalves and Leão (2013), who, when studying the addition of fruit flours such as passion fruit, apple, and grape in the production of yogurt, found average values equal to 4.20, 4.54, and 4.60, respectively. According to Martin (2002), and Neres *et al*. (2015), typically yogurts with average pH values between 4.0 and 4.5 are more accepted by consumers, as they have a less acidic or less bitter flavor.

Analyzing the ascorbic acid content, it is clear that all tests presented high values for this parameter. Tests 2 and 4 with high concentrations of acerola residue were those that presented the highest ascorbic acid values and tests 1 and 3 with the lowest concentrations of pomace presented the lowest values. This fact confirms that the value of vitamin C is directly related to the increase in the concentration of the by-product of acerola juice. Data on ascorbic acid in dairy products is scarce, however, it is possible to verify that all formulations had a vitamin C content above 60 mg/100mL, the daily intake value recommended by ANVISA (2005), for healthy adult people. The acerola by-product contains a high amount of ascorbic acid, and when added to yogurt, it provides nutritional properties, obtaining a product with a high content of vitamin C.

Concerning the reducing sugars in the yogurt prepared, it was observed that the values found are lower than those found in the yogurt prepared by Borges *et al*. (2009). However, these values are similar to those found in the study carried out by Batista *et al*. (2014) for banana cv. terra yogurt.

Regarding the ash content response, it is clear that tests 2 and 4, with the highest concentration of residues, presented the highest values for the ash parameter. However, in general, the ash values found in this research are lower than those found by Januário *et al*. (2017) who found an ash content equal to 0.9 g/100 g for yogurts flavored with organic beet juice with carrot, cassava, and sweet potato or corn juice. The aforementioned authors observed that variations in the composition of yogurt are in accordance with the composition of the fruits and vegetables used, a similar behavior to that observed in this research, in which the highest ash values were found in tests with higher concentrations of acerola by-product.

With these results in hand, planning analysis was carried out to verify the effects of the independent variables on the responses studied. In Table 4, the analysis of variance (ANOVA) and the F test are presented with 95% ($p<0.05$) reliability only for the predictive variables, that is, with coefficients of determination greater than 80% in the processing of yogurts added with acerola juice residue.

Table 4 - Analysis of variance of the coded model for your responses.

Sources of variation	Quadratic Sum	Degrees of freedom	Quadratic Mean	$F_{calculated}$	$F_{tabulated}$	R^2
Water content (g/100g)						
Regression	23.597	1	23.597			89.768
Residue	3.595	5	0.719	32.813	6.61	
Total	27.193	6				
Acidity (g/100g)						
Regression	0.012	2	0.00594			91.010
Residue	0.001	4	0.00029	20.2473	6.94	
Total	0.013	6				
Ph						
Regression	0.0317	2	0.01585			85.17
Residue	0.0055	4	0.00138	11.4902	6.94	
Total	0.0372	6				
Ascorbic acid (mg/100g)						
Regression	58607.420	3	19535.807			70.21
Residue	24877.590	3	8292.530	2.355	9,28	
Total	83485.010	6				
Reducing sugars (g/100g)						
Regression	0.4655	1	0.46555			83.35
Residue	0.0930	5	0.01860	25.023	6.61	
Total	0.5586	6				
Ash (g/100g)						
Regression	0.01007	1	0.01007			85.66
Residue	0.00169	5	0.00034	29.858	6.61	
Total	0.01176	6				

Source: Authors.

The relationship between $F_{calculated}$ and $F_{tabulated}$ was analyzed at a confidence level of 95%. According to Table 6, it can be seen that the results obtained concerning the parameters of water content, acidity, pH, reducing sugars, and ash were statistically significant, since they presented a $F_{calculated}$ value greater than the $F_{tabulated}$ one, in addition, it was found that the coefficients of determination (R^2) of these parameters were greater than 80%, indicating a good fit to the experimental data.

Regarding the individual effects of the independent variables (acerola by-product and brown sugar) as well as the interaction between them on the response variables, they present a statistically significant model (Fc>Ftab). It can be seen in the Pareto diagrams (Figure 1) the factors that had the greatest influence on the preparation of yogurts.

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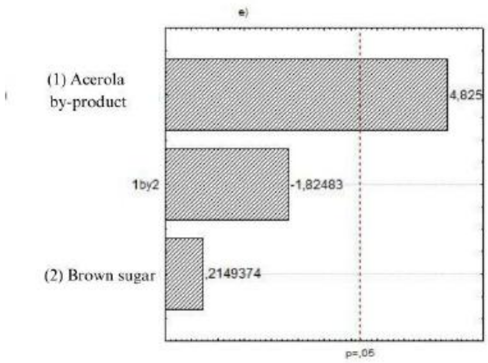
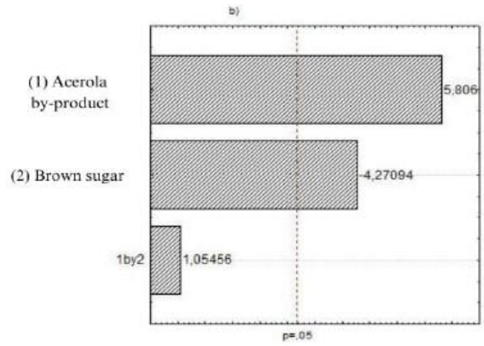
Figure 1 - Response surfaces for the parameters of a) water content; b) acidity; c) pH; d) ash and e) reducing sugars from yogurts, depending on the percentages of acerola by-product and brown sugar.

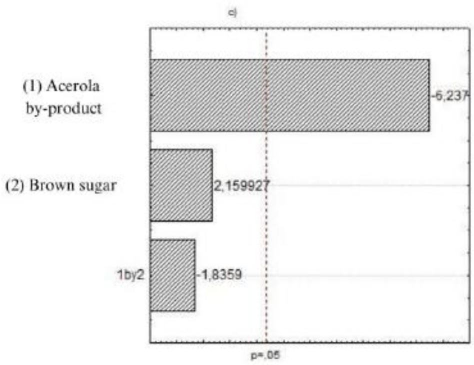
a)



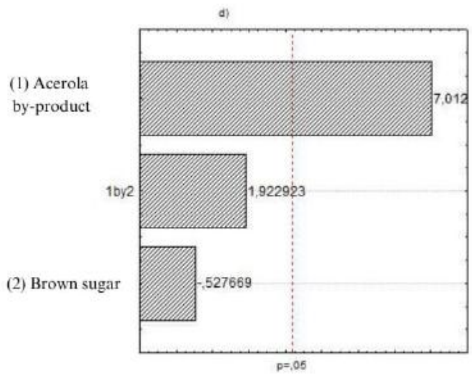
b)



c)



d)



Source: Authors.

It can be seen in Figure 1 that for acidity, the *concentrations* of the acerola juice byproduct and the concentration of brown sugar were statistically significant, showing a greater influence of these factors on the responses. Regarding the water content, pH, ash, and reducing sugars, it appears that the concentration of acerola juice by-product was a statistically significant factor with greater relevance to the dependent variable.

After analyzing the effects, regression analysis was carried out to extract possible mathematical models coded for each response under study.

Table 5 - Mathematical models adjusted to yogurt experimental data.

Parameters	Polynomial model
Water content (g/100g)	TA = 84.611 + 0.012CSA – 0.052 CAM
Total titratable acidity (g/100g)	ATT = 0.634 + 0.0008CSA – 0.0006CAM
Ph	pH = 4.081 – 0.001CSA + 0.0006CAM
Ascorbic acid (mg/100g)	AA = 239.982 + 1.879CSA – 0.635CAM
Ashes (g/100g)	C = 0.542 + 0.0008CSA
Reducing sugars (g/100g)	AR = 3.875 + 0.006CSA

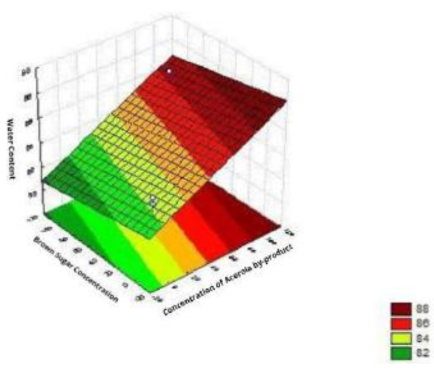
CSA - Concentration of acerola juice by-product; CAM - Brown sugar concentration. Source: Authors.

It was found that for the conditions studied in this work, for the water content and ascorbic acid responses, the increase in the acerola by-product concentration factor promoted an increase in the water and ascorbic acid content response. However, when the concentration of brown sugar was increased, there was a reduction in the responses in question. Likewise, for the acidity response, it was found that increasing the by-product concentration factor promoted an increase in the acidity response, on the other hand, the response was reduced when the brown sugar concentration factor was increased. Regarding the pH response, it was observed that by increasing the acerola by-product concentration factor, there was a reduction in the pH value. Regarding the responses to reducing sugars and ash, it was found that increasing the concentration factor of the by-product of acerola juice led to an increase in responses in the present study.

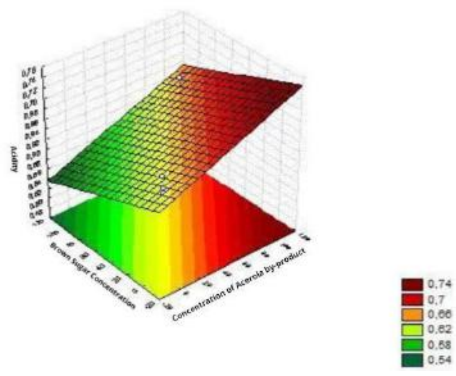
Figure 2 shows the response surfaces obtained for the physical and chemical analyses (response variables) that presented statistically significant models (Fc>Ftab).

Figure 2 - Response surfaces for the parameters of: a) water content; b) acidity; c) pH; d) ash; and e) reducing sugars in yogurts, depending on the percentages of acerola by-product and brown sugar.

a)



b)



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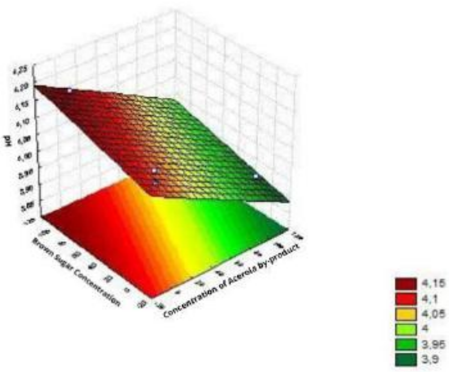
c)



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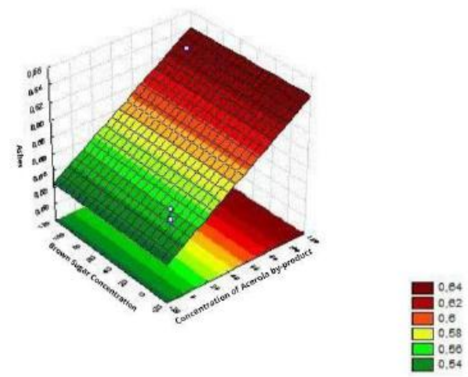
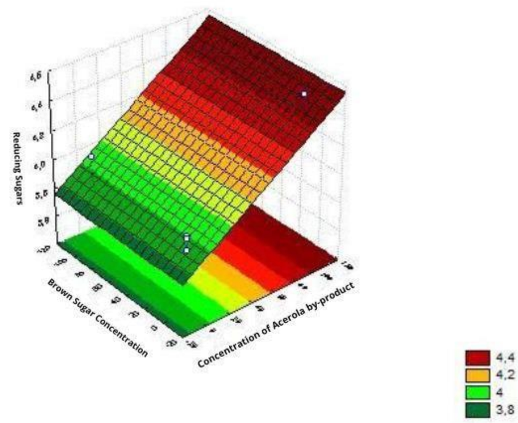


e)



Source: Authors.

4. Conclusion

Given the results, it is concluded that:

The independent variable concentration of acerola by-product had the greatest influence on the responses acidity, pH, ascorbic acid, reducing sugars, and ash.

The variable concentration of brown sugar had a greater influence on the reduction of water content.

Yogurt made with agro-industrial residue from acerola juice is presented as a product rich in vitamin C (428.55 mg/100g).

The technological use of by-products from the fruit industry can bring benefits such as: reducing environmental impact and providing the development of a good quality product with beneficial properties for the consumer.

In view of the above, despite ongoing research using fruit residues to prepare products, there is still a shortage in the literature regarding the acerola's residue incorporation in yogurt. Therefore, there is a need for future work with more comprehensive studies, aiming to study the product's characteristics, such as: color, texture and aroma, in addition to sensory analyses and in relation to the microbiological safety of the yogurt produced.

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