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PHYSICOCHEMICAL AND MICROBIOLOGICAL PARAMETERS OF FROZEN ACEROLA PULP (*Malpighia emarginata*) MARKETED IN PARAISO DO TOCANTINS, BRAZIL

PARÂMETROS FÍSICO QUÍMICO E MICROBIOLÓGICOS DA POLPA DE ACEROLA (*Malpighia emarginata*) CONGELADA COMERCIALIZADA EM PARAÍSO DO TOCANTINS, BRASIL

PARÁMETROS FÍSICOS, QUÍMICOS Y MICROBIOLÓGICOS DE LA PULPA CONGELADA DE ACEROLA (Malpighia emarginata) COMERCIALIZADA EN PARAÍSO DO TOCANTINS, BRASIL

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Abstract

This study evaluated the physicochemical and microbiological parameters of frozen acerola (*Malpighia emarginata*) pulps sold in supermarkets in Paraíso do Tocantins, Brazil. A total of 48 samples from four distinct brands (A, B, C, and D) were collected monthly throughout 2024. Physicochemical analyses included pH, titratable acidity, total soluble solids (°Brix), total solids, reducing sugars, and ascorbic acid content. Results were compared with the standards established by Normative Instruction SDA No. 37/2018 from the Ministry of Agriculture (MAPA). All brands met the required standards, except for brand C, which showed an ascorbic acid content below the legal minimum. Significant differences among brands were observed, attributed to factors such as ripening stage, processing conditions, and storage practices. Principal Component Analysis (PCA) revealed distinct profiles: brand A showed higher acidity, suitable for products with intense flavor; brand C stood out for its sweeter and more nutritious profile; brand B demonstrated a balance between acidity and sweetness; and brand D presented a less defined profile. Microbiological analyses included coliforms at 45 °C and Salmonella spp., following Normative Instruction No. 161/2022 from ANVISA. All samples were within legal limits, indicating good hygienic-sanitary quality. In conclusion, acerola pulps sold in Paraíso do Tocantins generally exhibit satisfactory quality and are safe for consumption. Continuous monitoring of these parameters is essential to ensure food safety and guide commercial and industrial decisions.
Keywords: Consumer safety; Food quality control; Quality monitoring.

Resumo

Este estudo avaliou os parâmetros físico químicos e microbiológicos de polpas congeladas de acerola (*Malpighia emarginata*) comercializadas em supermercados de Paraíso do Tocantins, Brasil. Foram analisadas 48 amostras de quatro marcas distintas (A, B, C e D), coletadas mensalmente ao longo de 2024. As análises físico-químicas incluíram pH, acidez titulável, sólidos solúveis totais (°Brix), sólidos totais, açúcares redutores e teor de ácido ascórbico. Os resultados foram comparados com os padrões estabelecidos pela Instrução Normativa SDA nº 37/2018 do MAPA. Todas as marcas atenderam aos parâmetros exigidos, exceto a marca C, cujo teor de ácido ascórbico ficou abaixo do mínimo legal. Diferenças significativas entre as marcas foram observadas, atribuídas a fatores como estágio de maturação, condições de processamento e armazenamento. A análise de componentes principais (PCA) revelou perfis distintos entre as marcas: a marca A apresentou maior acidez, ideal para produtos com sabor intenso; a marca C destacou-se pelo perfil mais doce e nutritivo; a marca B mostrou equilíbrio entre acidez e doçura; e a marca D apresentou perfil menos definido. As análises microbiológicas incluíram coliformes a 45 °C e Salmonella spp., conforme a Instrução Normativa nº 161/2022 da ANVISA. Todas as amostras estavam dentro dos limites legais, indicando boa qualidade higiênico-sanitária. As polpas de acerola comercializadas em Paraíso do Tocantins apresentam, em geral, qualidade satisfatória, sendo seguras para o consumo. O monitoramento contínuo desses parâmetros é essencial para garantir a segurança alimentar e orientar decisões comerciais e industriais.
Palavras-chave: Segurança do consumidor; Controle de qualidade alimentar; Monitoramento de qualidade.

Resumen

Este estudio evaluó los parámetros físico químicos y microbiológicos de pulpas congeladas de acerola (*Malpighia emarginata*) comercializadas en supermercados de Paraíso do Tocantins, Brasil. Se analizaron 48 muestras de cuatro marcas distintas (A, B, C y D), recolectadas mensualmente a lo largo del año 2024. Las evaluaciones fisicoquímicas incluyeron pH, acidez titulable, sólidos solubles totales (°Brix), sólidos totales, azúcares reductores y contenido de ácido ascórbico. Los resultados se compararon con los estándares establecidos por la Instrucción Normativa SDA n.º 37/2018 del MAPA. Todas las marcas cumplieron con los

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parámetros exigidos, excepto la marca C, cuyo contenido de ácido ascórbico estuvo por debajo del mínimo legal. Se observaron diferencias significativas entre las marcas, atribuidas a factores como el grado de maduración, las condiciones de procesamiento y almacenamiento. El análisis de componentes principales (ACP) reveló perfiles diferenciados entre las marcas: la marca A presentó mayor acidez, ideal para productos de sabor intenso; la marca C se destacó por un perfil más dulce y nutritivo; la marca B mostró equilibrio entre acidez y dulzura; y la marca D presentó un perfil menos definido. Los análisis microbiológicos incluyeron coliformes a 45 °C y *Salmonella spp.*, conforme a la Instrucción Normativa n.º 161/2022 de ANVISA. Todas las muestras estuvieron dentro de los límites legales, lo que indica buena calidad higiénico-sanitaria. En general, las pulpas de acerola comercializadas en Paraíso do Tocantins presentan calidad satisfactoria y son seguras para el consumo. El monitoreo continuo de estos parámetros es esencial para garantizar la seguridad alimentaria y orientar decisiones comerciales e industriales.
Palabras clave: Seguridad del consumidor; Control de calidad alimentaria; Monitoreo de calidad.

1. Introduction

Fruit pulps are widely consumed products in Brazil, especially due to their practicality, nutritional value, and versatility in food preparation. Used in juices, desserts, and industrial formulations, these pulps offer an alternative to the consumption of fresh fruits, allowing for greater preservation and large-scale distribution (Silva *et al.*, 2022). However, the quality of these products depends on several factors, including physicochemical and microbiological parameters, which are essential to ensure food safety and compliance with current legislation (Silva *et al.*, 2022).

Physicochemical analyses involve the evaluation of characteristics such as pH, titratable acidity, soluble solids (°Brix), moisture, and antioxidant activity, which directly influence the flavor, stability, and nutritional value of the pulps (Nascimento *et al.*, 2023). Studies show that variations in these parameters may occur depending on the fruit species, ripening stage, processing conditions, and storage time (Costa *et al.*, 2024). Standardizing these indicators is crucial to ensure the sensory and nutritional quality of the final product.

From a microbiological standpoint, fruit pulps are susceptible to contamination by pathogenic microorganisms such as total and fecal coliforms, *Salmonella* spp., molds, and yeasts. This contamination can occur at various stages of the production chain, from raw material handling to storage and transportation (Gomes *et al.*, 2025; Lima *et al.*, 2025). Several studies indicate that pulps sold in informal settings, such as street markets and small businesses, present a higher microbiological risk due to the lack of adequate sanitary control (Santos *et al.*, 2021; Moraes; Machado, 2021).

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Acerola pulp stands out for its high nutritional and functional value. Rich in vitamin C, acerola contains up to 100 times more of this nutrient than citrus fruits like oranges, making it one of the most potent natural sources of ascorbic acid (Mezadri *et al.*, 2006).

This characteristic gives the pulp antioxidant and immunomodulatory properties, helping to prevent infections, combat premature aging, and protect against cardiovascular diseases. Additionally, acerola is a source of carotenoids, flavonoids, and minerals such as iron, calcium, and phosphorus, which contribute to the health of the skin, bones, and nervous system (Mezadri *et al.*, 2006).

Another relevant benefit of acerola pulp is its contribution to weight-loss diets and glycemic control. Due to its soluble fiber content and low caloric value, acerola prolongs digestion time and promotes satiety, reducing excessive food intake throughout the day (Nobre; Monteiro, 2003). Its slightly acidic and refreshing flavor also enhances sensory acceptance in juices and desserts, making it an attractive option for health-conscious consumers. These attributes reinforce the importance of ensuring the physicochemical and microbiological quality of acerola pulp during processing and commercialization.

Therefore, this study proposes monitoring frozen acerola pulps sold in supermarkets in the municipality of Paraíso do Tocantins–TO, evaluating their physicochemical and microbiological parameters, and comparing the results with Normative Instruction SDA No. 37/2018 from the Ministry of Agriculture, Livestock and Supply (MAPA).

2. Methodology

Between January and December 2024, monthly samples of frozen acerola pulp were collected, packaged in 100-gram plastic containers, within their respective expiration dates, from four distinct brands (A, B, C, and D), purchased from commercial establishments in the city of Paraíso do Tocantins. A total of 48 samples were analyzed throughout the experiment.

The samples were transported in thermal boxes to the Food Laboratory of the Federal Institute of Education, Science and Technology of Tocantins – IFTO,

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Paraíso do Tocantins campus, where they were stored at –10 °C. Analyses were performed using 100 mL of mesocarp from previously thawed and homogenized fruits at 25 °C.

Procedures for determining total sugars (AT, g/100 g), titratable acidity (ATT, expressed as citric acid, g/100 g), ascorbic acid (AA, mg/100 g), hydrogen potential (pH), total soluble solids (STT, in °Brix at 20 °C), and total solids (ST, g/100 g) were conducted in triplicate, following the analytical methods described by the Adolfo Lutz Institute (IAL, 2008). The physicochemical results were compared with the standards established in Annex II of Normative Instruction SDA No. 37/2018 from the Ministry of Agriculture, Livestock and Supply – MAPA (BRAZIL, 2018).

Microbiological analyses, including the quantification of fungi (molds and yeasts), coliforms at 45 °C, and *Salmonella* spp., were performed according to the method proposed by Silva et al. (2007), and the results were compared with the limits established by Normative Instruction No. 161/2022 from the National Health Surveillance Agency – ANVISA (BRAZIL, 2022), which sets the maximum microbiological values for frozen fruit pulps: presence of *Escherichia coli* per gram and absence of *Salmonella* in 25 g.

To verify the occurrence of significant differences among the results, analysis of variance (ANOVA) was applied, followed by Tukey's test at a 5% significance level, using Sisvar software, version 5.6 (Ferreira, 2019).

Additionally, Principal Component Analysis (PCA) was employed to explore relationships among the data and the different treatments, aiming to group physicochemical variables according to their similarities. The process involved constructing, selecting, and interpreting the principal components, allowing identification of the variables with the greatest influence on each component's composition. PCA was conducted using PAST software, following the methodology described by Hammer, Harper, and Ryan (2001).

3. Result and discussion

The table 1 presents the results obtained for the physicochemical parameters of frozen acerola pulps marketed in Paraíso do Tocantins, Brazil. The

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physicochemical parameters were in compliance with Normative Instruction No. 37/2018 – MAPA, except for the ascorbic acid content in brand C, which showed a value below the level established by legislation. A statistically significant difference was observed at the 5% probability level ($p<0,05$)

Table 1 – Physicochemical and microbiological parameters of frozen acerola pulps marketed in Paraíso do Tocantins–TO.

Parameters	Brand A	Brand B	Brand C	Brand D	IN Nº37/2018
AT (g/100g)	$6,70^{D} \pm 0,34$	$7,14^{C} \pm 0,42$	$7,23^{B} \pm 0,41$	$7,12^{A} \pm 0,44$	Minimum 4,0
ATT (g/100g)	$1,15^{A} \pm 0,07$	$1,13^{B} \pm 0,07$	$1,15^{A} \pm 0,05$	$1,13^{B} \pm 0,69$	Minimum 0,8
AA (mg/100g)	$803,50^{C} \pm 54,86$	$807,40^{D} \pm 60,69$	$787,91^{B} \pm 60,04$	$806,77^{A} \pm 52,15$	Minimum 801,0
pH	$3,45^{A} \pm 0,25$	$3,45^{A} \pm 0,36$	$3,33^{B} \pm 0,33$	$3,32^{C} \pm 0,28$	Minimum 2,8
STT (ºBrix 20°C)	$7,95^{D} \pm 1,02$	$8,40^{A} \pm 0,79$	$8,17^{C} \pm 1,14$	$8,34^{B} \pm 1,16$	Minimum 5,5
ST(g/100g)	$6,60^{C} \pm 0,60$	$6,75^{A} \pm 0,57$	$6,72^{B} \pm 0,58$	$6,36^{D} \pm 0,51$	Minimum 6,0

Different letters in the columns differ at the 5% level ($p < 0.05$) by Tukey's test.
Source: Authors (2025).

The significant differences observed may be associated with the fruit's ripening stage, processing temperature, oxygen exposure, and light contact. The ascorbic acid content found in acerola pulp from brand C, which was below the level established by legislation, can be explained by the fact that vitamin C tends to decrease as the fruit matures, as well as due to processing and storage conditions (Lima *et al.*, 2015).

A study conducted by Viroli *et al.* (2023) found that acerola pulp samples were in compliance with physicochemical standards, except for one brand whose ascorbic acid content was below the minimum required. Acerola pulps analyzed in Santarém-PA by Sousa et al. (2020) showed pH values within the physicochemical standards established by legislation. However, titratable acidity, soluble solids, and total solids were below the minimum required, while the elevated ascorbic acid content highlighted acerola as an excellent source of antioxidants.

The table 2 presents the average results obtained from the microbiological analysis of coliforms at 45 °C and *Salmonella* in frozen acerola pulps marketed in Paraíso do Tocantins, Brazil. All analyzed samples showed average values in accordance with current legislation.

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Table 2 – Average values for Coliforms 45°C and Salmonella.

Acerola	Coliforms 45 °C	Salmonella	*IN nº 161/2022
Brand A	5,03 $x10^0$ ± 2,85	Absence	
Brand B	5,02 $x10^0$ ± 3,25	Absence	Coliforms 45 °C ≤ 10^2 NMP/g
Brand C	5,79 $x10^0$± 3,00	Absence	Absence of Salmonella in 25g
Brand D	5,01 $x10^0$± 2,40	Absence	

Source: Authors (2025).

The low count of coliforms in frozen acerola pulp is associated with acceptable quality, likely resulting from proper processing and storage practices. Silva *et al.* (2022) and Sousa *et al.* (2020) did not detect coliforms or average values above the legal limits in their studies on frozen acerola pulp. Literature also reports studies by Sousa et al. (2020) and Costa et al. (2024), which investigated *Salmonella* in frozen acerola pulp and found no presence of the microorganism in any of the samples analyzed.

Microbiological assessments for thermotolerant coliforms and *Salmonella* spp. conducted by Silva *et al.* (2020) on 30 samples of frozen fruit pulps sold in supermarkets in Belém–PA showed that 93.34% of the samples complied with current legislation regarding thermotolerant coliforms, and 100% showed absence of *Salmonella* spp. in 25 g. In a study of 60 samples of frozen pulps from six different flavors, industrialized in the municipality of Muriaé–MG, Alvarenga *et al.* (2017) observed the presence of total coliforms in 50% of the samples. Research conducted on three brands (A, B, and C) of frozen pulps of acerola, mango, and passion fruit, sold in Vitória da Conquista–BA by Santos *et al.* (2017), found that all samples were within the legal limits for total coliforms, *Escherichia coli*, and *Salmonella* spp.

In order to interpret the data more efficiently and identify patterns of similarity or distinction among the analyzed brands, the Principal Component Analysis (PCA) technique was employed, considering the physicochemical variables described in Table 3. The application of PCA enabled the projection of the data onto the two most relevant principal components, along with their respective eigenvalues, percentage of explained variance, and cumulative variance, as presented in the same table.

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Table 3. Principal components (PC), eigenvalues and percentage of variance explained.

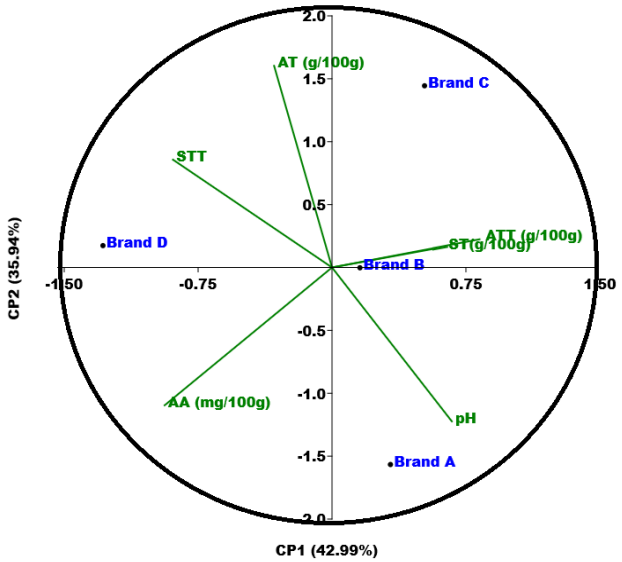
PC	Eigenvalue	% Variance
1	2.58	42.99
2	2.16	35.94
3	1.26	21.08

Source: Authors (2025).

According to the results of the Principal Component Analysis, the eigenvalues and variance percentages presented in Table 3 indicate that the first principal component (PC1) accounts for 42.99% of the data variability, while the second component (PC2) contributes 35.94%. Together, PC1 and PC2 account for a substantial portion (78.93%) of the total variance, effectively representing the dispersion between the samples analyzed (Abdi & Williams, 2010).

Graph 1 shows the principal components (CP1) and (CP2), displaying their respective weights, making it possible to visualize the main groupings in the set of variables.

Figure 1. Graph of the principal component analysis for formulations and physical-chemical parameters.



Source: Authors (2025).

The analysis of acerola samples from brands A, B, C, and D using

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Principal Component Analysis (PCA) reveals significant differences in their physicochemical characteristics. Brand A shows a strong correlation with total titratable acidity (ATT) and pH, positioning itself along the CP2 axis, which represents the acidic profile. This indicates a sample with high acidity and low pH ideal for products that require a more intense acidic flavor, such as concentrated juices.

In contrast, Brand C stands out on the CP1 axis, which is heavily influenced by variables such as reducing sugars (AT), total solids (TS), and Brix (TSS), suggesting a sweeter and more nutritious profile. This brand is potentially more appealing for fresh consumption or products aimed at a milder taste preference.

Brand B occupies an intermediate position on both axes, reflecting a balance between acidity and sweetness, which may make it versatile for various applications. Brand D, however, shows low correlation with both axes, indicating a less defined or diluted profile, with weaker expression of the analyzed variables.

Therefore, PCA proves to be an effective tool for distinguishing samples and guiding commercial and industrial decisions, enabling the selection of varieties based on the desired flavor, acidity, or nutritional profile.

5. Conclusion

The evaluation of frozen acerola pulp showed compliance with the standards established by Brazilian legislation, except for brand C, whose ascorbic acid content was below the regulatory limit. Microbiological analyses indicated a low incidence of contamination, with parameters properly controlled, classifying the product as safe for consumption. The results highlight the importance of monitoring physicochemical and microbiological aspects to ensure food quality and reduce risks to public health.

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