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Sensory acceptability of taperebá nectar formulation: physicochemical and microbiological characterization

Aceitabilidade sensorial de formulação de néctar de taperebá: caracterização físico-química e microbiológica

I. R. Martins[1,2]*; C. A. Figueiredo[2]; J. P. M. Lins[3]; J. H. S. Martins[4]; L. H. S. Martins[5,6,7]; A. C. A. Pelais[8]

[1]*Programa de Pós-graduação em Desenvolvimento Rural e Gestão de Empreendimentos Agroalimentares, Instituto Federal de Educação, Ciência e Tecnologia do Pará, 68740-970, Castanhal-PA, Brasil*
[2]*Núcleo de Estudos em Engenharia, Ciência e Tecnologia de Alimentos, Instituto Federal de Educação, Ciência e Tecnologia do Pará, 68740-970, Castanhal-PA, Brasil*
[3]*Laboratório de Corantes Naturais e Compostos Bioativos, Departamento de Tecnologia de Alimentos, Universidade Federal de Viçosa, 37570-900, Viçosa-MG, Brasil*
[4]*Secretaria de Estado de Educação, 66050-400, Belém-PA, Brasil*
[5]*Instituto de Saúde e Reprodução Animal, Universidade Federal Rural da Amazônia, 66077-830, Belém-PA, Brasil*
[6]*Prograna de Pós-Graduação em Ciência e Tecnologia de Alimentos, Universidade Federal do Pará, 66075-110, Belém-PA, Brasil*
[7]*Programa de Pós-Graduação em Biotecnologia Aplicada à Agropecuária, Universidade Federal Rural da Amazônia, 66077-830, Belém-PA, Brasil*
[8]*Departamento de Tecnologia em Alimentos, Universidade do Estado do Pará, 66095-015, Belém-PA, Brasil*

**ingrydlmp@hotmail.com*
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Industries seek to expand the market for products that meet consumer expectations in terms of state and nutritional quality. Therefore, this study sought to develop taperebá nectar using Response Surface Methodology (RSM). Physicochemical (pH, total soluble solids and titratable acidity) and microbiological (coliforms, *E. coli*, *Staphylococcos aureus* and mesophilic aerobic bacteria) characteristics were evaluated in the pulp and in 11 taperebá nectar trials. Sensory acceptance was made on the nectars prepared, which was evaluated through the attributes state, overall impression and purchase intention. The nectars had a maximum pH of 3.25, titratable acidity (TA) of 0.74 g/100 g and total soluble solids (TSS) of 22.73 ºBrix. The nectars met legal standards for TSS while the pH and TA values, but not specified by legislation, were in line with other tropical nectars. The microbiological analysis showed results with acceptable limits for current legislation. Formulation 9, with 20.85% taperebá pulp and 14% sugar, was the most accepted in terms of state, overall impression and purchase intention. The MRS revealed that taperebá pulp had a linear effect on sensory acceptance, with the lowest percentages of pulp being the most preferred. The sugar content had a quadratic effect, but not significant ($p \geq 0.05$). The nectar developed showed good acceptance by consumers for the attributes judged, with the provision of physical-chemical and microbiological characterizations, in accordance with Brazilian legislation, for the development of drinks based on taperebá.
Keywords: *Spondias mombin* L., exotic fruit, RSM.

As indústrias buscam expandir o mercado de produtos que atendam às expectativas do consumidor em sabor e qualidade nutricional. Dessa forma, este estudo buscou desenvolver um néctar de taperebá usando a Metodologia de Superfície de Resposta (RSM). Foram avaliadas características físico-químicas (pH, sólidos solúveis totais e acidez total titulável) e microbiológicas (coliformes, *E. coli*, *Staphylococcos aureus* e bactérias aeróbias mesófilas) na polpa e em 11 ensaios de néctares de taperebá. A aceitação sensorial foi feita nos néctares elaborados, a qual foi avaliada por intermédio dos atributos sabor, impressão geral e intenção de compra. Os néctares apresentaram pH máximo de 3,25, acidez total titulável (TA) de 0,74 g/100 g e sólidos solúveis totais (TSS) de 22,73 ºBrix. Os néctares atenderam aos padrões legais para TSS enquanto os valores de pH e TA, mas não especificados pela legislação, estavam em consonância com outros néctares tropicais. A análise microbiológica mostrou resultados com limites aceitáveis para a legislação vigente. A formulação 9, com 20,85% de polpa de taperebá e 14% de açúcar, foi a mais aceita em termos de sabor, impressão geral e intenção de compra. A MRS revelou que a polpa de taperebá teve efeito linear na aceitação sensorial, sendo as menores porcentagens de polpa as mais preferidas. O teor de açúcares teve efeito quadrático, mas não significativo ($p \geq 0,05$). O néctar desenvolvido apresentou boa aceitação pelos consumidores para os atributos julgados, com o fornecimento das caracterizações físico-químicas e microbiológicas, em conformidade com a legislação brasileira, para o desenvolvimento de bebidas à base de taperebá.
Palavras-chave: *Spondias mombin* L., fruta exótica, RSM.

1. INTRODUCTION

Brazil is currently one of the largest producers of fresh, frozen or processed fruits in the form of pulp, nectar, concentrated juices, sweets, jellies, and its large production allows for the development of new products that meet consumer expectations in terms of properties. nutritional and sensory characteristics. Therefore, tropical fruits stand out for exhibiting numerous health benefits, in addition to presenting typical states that satisfy the preferences of certain consumer groups [1-2]. With the growing interest in healthy and therapeutic products, industries are increasingly focused on the development of functional foods. These foods aim to be sources of nutrients that provide health benefits to consumers [3].

Regarding the agri-food scenario, there is a huge demand for distinctive products from the Brazilian Amazon, namely cupuaçu (*Theobroma grandiforum*), bacuri (*Platonia insignis*) and taperebá (*Spondias mombin* L.), emerging as species of significant agro-industrial potential for the production of juices and nectars. This predilection arises not only from its particular sensorial characteristics, but also from its physical-chemical characteristics, which are promising and present viability for the production of beverages, with a view to meeting the demands of a select group of people who are concerned with a healthier eating [4].

Taperebá, which is part of the *Anacardiaceae* family, is one of the most valued tropical fruits found in the North of Brazil. The pulp has a yellow hue and is often little consumed raw due to its notable acidity. However, it is widely used in the preparation of drinks, such as juices and nectars [5].

Given the aforementioned arguments, aiming to determine the ideal mixture between the quantities of fruits in the formulation of a drink with appropriate sensory characteristics, it is possible to employ the Response Surface Methodology (RSM). This strategy is based on the simultaneous variation of several elements (independent variables), chosen in advance for their influence on the process properties (dependent variables or results). To this end, through mathematical and statistical approaches, experimental results point to a combination of element levels within an optimal region [6-7]. RSM has been used in the development of new products in the food industries, achieving significant results in continuous improvements and process optimization [8-9].

Based on this information, this work aimed to develop a nectar-type drink made from taperebá pulp, carry out the physical-chemical characterization and evaluate the effects of pulp and sugar percentages on sensory acceptability through RSM.

2. MATERIALS AND METHODS

2.1 Materials

To prepare the nectars, taperebá pulp, acquired by cooperatives linked to family farming in the Municipality of Castanhal—Pará, and commercial sucrose (crystal sugar) were used.

2.2 Pulp characterization

To characterize the pulp, the pH was determined using a pH meter, while the total soluble solids (TSS) content was determined by refractometry, using a digital refractometer expressed in ºBrix. Titratable acidity (TA) was performed by titrimetry, using 0.1 mol. L^{-1} NaOH solution and 1% phenolphthalein alcoholic solution as an indicator, with the result expressed in citric acid (g/100g), following the methodological recommendations recommended by the AOAC (1997) [10].

2.3 Experimental design and preparation of formulations

Firstly, the concentrations of fruit pulp and sugar in drinks were defined using the Central Composite Design (CCD), with 4 factorial points (levels ± 1), 3 central points (level 0) and 4 axial points (levels ± α), totaling 11 assays (Table 1), which were carried out in triplicate, with the exception of the central point (C).

To develop the nectars, the taperebá pulp and commercial sucrose were weighed and homogenized with drinking water, according to the drink resulting from each treatment. The nectars prepared were subjected to the pasteurization process applying the binomial temperature/time (90 °C/60 s) in a stainless-steel container in a water bath. The nectar was filled hot into sterile glass bottles with a volumetric capacity of 300 mL. After closing with screw-on plastic lids, the bottles were cooled by spraying them with chlorinated water at 5 ppm, and when they reached room temperature, they were refrigerated for 24 h before carrying out analyzes on the 11 nectar formulations.

Table 1 shows the 11 nectar formulations created from the CCD. Thus, a minimum value of taperebá pulp and minimum concentration of sugar in the nectar was defined based on Normative Instruction nº 12, of September 4, 2003, for cajá nectar, which stipulates a minimum value of 25% of cajá pulp or juice and a minimum of 11.0 ºBrix [11]. Thus, 11 nectar samples were prepared using different levels of taperebá pulp and sugar and submitted to sensory analyses. A model with a greater coefficient of determination (R^2) and adjusted coefficient of determination (R^2adj) and, consequently, greater values, non-significance ($p < 0.05$) in lack of fit were considered to be predictive for the responses.

Table 1: Experimental design of taperebá nectar formulations.

Formulations	X_1	X_2	Pulp (%)	Sugar (%)
1	-1	-1	25	13
2	-1	+1	25	15
3	+1	-1	45	13
4	+1	+1	45	15
5 (C)	0	0	35	14
6 (C)	0	0	35	14
7 (C)	0	0	35	14
8	+ α	0	49.15	14
9	- α	0	20.85	14
10	0	+ α	35	15.41
11	0	- α	35	12.58

2.4 Physicochemical evaluation of nectars

The 11 formulations obtained were subjected to physical-chemical analyzes of pH, TSS and TA as described in item 2.2. Analyses were performed in triplicate for each repetition of the 11 assays, with the exception of the central point.

2.5 Microbiological evaluation of nectars

The microbiological quality of the nectars was assessed for total coliforms, *E. coli*, mesophilic aerobic bacteria and *Staphylococcos aureus* on Petrifilm® plates (3M Company, St. Paul, MN, USA), which were incubated according to official methods (AOAC 991.14), (AOAC 990.12) and (AOAC 990.12) [10], respectively. After the respective incubation periods, colonies were counted and the result was expressed in colony forming unit ($CFU.mL^{-1}$).

2.6 Sensory evaluation of taperebá nectars

The sensory evaluation of the 11 nectars obtained was carried out in accordance with Minim (2013) [12], after prior approval by the ethics and research committee (CAAE: 86093618.1.0000.5174). The acceptance test was carried out by 80 untrained judges, using a structured hedonic scale of nine points with terms ranging from "disliked extremely" (score 1) to "liked extremely" (score 9) for the sensory attributes taste and overall impression. In the same section, the judges assessed the intention to purchase the nectar using a structured five-point scale with terms ranging from "I would certainly buy" (score 5) to "I would certainly not buy" (score 1). The samples were presented to the judges sequentially in 50 mL plastic cups at 8 ºC. To wash the taste buds between tasting the samples, mineral water at room temperature and unsalted biscuits were used.

2.7 Statistical analysis of results

The results found from the central composite planning were analyzed in the STATISTICA for Windows software (version 7.0; USA), through analysis of variance and response surface, considering taperebá pulp (%) and sucrose (g) as independent variables and as response variables, state, overall impression and purchase intention.

The results of the other analyses were subjected to analysis of variance (ANOVA) and the means compared with each other by the Tukey test at a 5% significance level ($p \leq 0.05$), using the BioEstat 5.0 statistical program.

3. RESULTS AND DISCUSSION

3.1 Characterization of taperebá pulp

The results of the physicochemical characterization of taperebá pulp for pH was 2.74 ± 0.1, TA was 1.11 ± 0.01 g/100g and TSS were 5 ± 0.1 ºBrix. Brazil (2003) [11] establishes the following minimum values for the standard of identity and quality of cajá pulp: pH of 2.20, TA expressed in citric acid of 0.90 g/100 g and TSS of 9.00 ºBrix. Therefore, the pulp used in this work meets the standards established only for pH and TA, since the values found for these characteristics are above the recommended minimum values. For Dias et al. (2020) [13], fruits with high TSS levels are generally preferred for fresh consumption and for industrialization, as they offer the advantage of providing greater processing yield, due to the greater quantity of nectar produced by amount of pulp.

3.2 Physicochemical evaluation of nectars

The values of the physicochemical analyses of the nectar formulations are represented in Table 2.

Formulations 5, 7, 10 and 11 did not show a significant difference ($p \geq 0.05$) between them for TA, probably due to the similar percentage of taperebá pulp used in the preparation of nectars. For pH, the nectar values were not statistically different ($p \geq 0.05$), while most TSS results differed ($p \leq 0.05$), except for treatments 4 and 5, due to the similar concentration of sugar in the nectars.

The acidity analysis showed compliance with Brazilian legislation for cajá nectar, which establishes a minimum value of 0.2 g/100g. Formulation 8 (+α) showed higher acidity, as it has a higher concentration of taperebá pulp. The °Brix found is also presented in accordance with current legislation, which recommends a minimum value of 11.0 ºBrix [12]. The legislation does not establish standards for pH; however, the formulations presented pH and TA values consistent with those of nectars, which are a mixture of pineapple (*Ananas comosus*) peel and pulp combined with the tropical fruits pineapple, taperebá, and guava (*Psidium guajava* L.), as reported by Silva

et al. (2017) [14]. These values ranged from 3.44 to 3.85 for pH and 0.71 to 0.87 g/100g for TA, respectively.

Table 2: Experimental design and physicochemical characteristics of taperebá nectar formulations.

Formulations	Pulp (%)	Sugar (%)	TA g/100g	pH	TSS (ºBrix)
1	25	13	0.35 ± 0.04^{e}	3.25 ± 0.30^{a}	16.33 ± 0.71^{g}
2	25	15	0.36 ± 0.00^{de}	3.13 ± 0.06^{a}	17.73 ± 0.10^{efg}
3	45	13	0.70 ± 0.01^{b}	2.91 ± 0.46^{a}	20.40 ± 1.80^{b}
4	45	15	0.71 ± 0.01^{b}	2.89 ± 0.02^{a}	19.73 ± 0.20^{bcd}
5 (C)	35	14	0.55 ± 0.01^{d}	2.97 ± 0.05^{a}	19.60 ± 0.20^{bcd}
6 (C)	35	14	0.61 ± 0.01^{c}	2.92 ± 0.00^{a}	22.73 ± 0.50^{a}
7 (C)	35	14	0.53 ± 0.00^{d}	2.98 ± 0.02^{a}	18.93 ± 0.30^{bcde}
8	49.15	14	0.74 ± 0.12^{a}	2.84 ± 0.02^{a}	20.06 ± 0.10^{bc}
9	20.85	14	0.31 ± 0.00^{f}	3.10 ± 0.02^{a}	17.06 ± 0.10^{fg}
10	35	15.41	0.54 ± 0.02^{d}	2.95 ± 0.00^{a}	18.33 ± 0.10^{bcdef}
11	35	12.58	0.52 ± 0.01^{d}	2.96 ± 0.05^{a}	18.06 ± 0.10^{defg}

Triplicate results expressed as mean ± standard deviation. Values in the same column accompanied by different letters show a significant difference between them using the Tukey test ($p \leq 0.05$). TA: titratable acidity; TSS: total soluble solids.

Jesus et al. (2019) [15], Santos and Thom (2020) [16] and Hoang et al. (2023) [17] who evaluated the identity and quality standards of pasteurized fruit nectar such as cupuaçu (*Theobroma grandiflorum*), passion fruit (*Passiflora edulis*) and acerola (*Malpighia glabra* L.), obtained with the physical-chemical analyses, average pH values of 3.46, 3.25 and 3.52, respectively. These values are close to those found in this work and guarantee the stability of the products. Since a pH below 4.0 is less favorable for the emergence and growth of certain microorganisms, such as the bacteria *Salmonella* spp., thus allowing better quality in food preservation [18].

3.3 Microbiological evaluation of nectars

Table 3 shows the results of microbiological analyzes of total coliforms, thermotolerant coliforms, *Staphylococcos aureus* and mesophilic aerobic bacteria.

Table 3: Results of counting colony forming units (CFU.mL^{-1}) at 35 ºC and 45 ºC in taperebá nectars.

Formulations	Total Coliforms (CFU.mL^{-1})	Thermotolerant coliforms (CFU.mL^{-1})	*Staphylococcos aureus* (CFU.mL^{-1})	MAB (CFU.mL^{-1})
1	< 10	< 10	< 10	< 10
2	< 10	< 10	< 10	< 10
3	< 10	< 10	< 10	< 10
4	< 10	< 10	< 10	< 10
5	< 10	< 10	< 10	< 10
6	< 10	< 10	< 10	< 10
7	< 10	< 10	< 10	< 10
8	< 10	< 10	< 10	< 10
9	< 10	< 10	< 10	< 10
10	< 10	< 10	< 10	< 10
11	< 10	< 10	< 10	< 10
Pulp	< 10	< 10	< 10	< 10

MAB: mesophilic aerobic bacteria; CFU: colony forming unit; mL: milliliters.

The heat treatment applied to nectars proved to be efficient in microbiological control, as the results obtained in all analyzes were within the standards established by Brazil (2022) [19] which recommends a maximum value of 10^2 CFU.mL^{-1}, demonstrating sanitary, satisfactory hygienic conditions.

The same was observed by Bastos et al. (2008) [20] when evaluating the efficiency of pasteurization in taperebá pulp, where heat treatments of 90 ºC/60 s were sufficient to reduce the concentration of coliforms and mesophilic aerobes, causing a reduction of approximately 99.99% in the initial load of these microorganisms.

3.4 Sensory evaluation of taperebá nectars

The results obtained from the sensory analyzes for the attributes state, overall impression and purchase intention are presented in Table 4. Observing the overall impression and state values, it can be seen that they all obtained averages above 5 (I neither liked nor disliked). The means, between the formulations, of the set of attributes showed a statistically significant difference at 5% probability, using the Tukey test.

Table 4: Average results of the sensory evaluation of taperebá nectar formulations.

Formulations	Pulp (%)	Sugar (%)	Overall impression	State	Purchase intention
1	25	13	7.40^{b}	7.16^{b}	4.05^{b}
2	25	15	7.28^{b}	7.02^{b}	4.00^{b}
3	45	13	6.68^{c}	6.20^{c}	3.36^{c}
4	45	15	6.52^{c}	6.27^{c}	3.29^{c}
5 (C)	35	14	6.44^{c}	5.28^{d}	3.18^{c}
6 (C)	35	14	6.32^{c}	5.20^{d}	3.13^{c}
7 (C)	35	14	6.39^{c}	5.22^{d}	3.15^{c}
8	49.15	14	6.70^{c}	5.76^{d}	3.10^{c}
9	20.85	14	7.92^{a}	8.08^{a}	4.38^{a}
10	35	15.41	6.41^{c}	5.33^{d}	3.11^{c}
11	35	12.58	6.34^{c}	5.25^{d}	3.10^{c}

Triplicate results expressed as mean ± standard deviation. Values in the same column accompanied by different letters show a significant difference between them using the Tukey test ($p \leq 0.05$).

In the sensory evaluation for the attributes state and overall impression, formulation 9 (20.85% pulp and 14% sugar) presented higher percentages, with averages of 8.08 and 7.92 respectively, indicating that for both attributes the formulation showed good acceptance with positive scores on the hedonic scale, falling between the terms “I liked it moderately and I liked it a lot”. Comparatively, Silva et al. (2015) [21] in the preparation of umbu-cajá (*Spondias bahiensis*), cauliflower (*Brassica oleracea*) and ginger (*Zingiber officinale*) nectar, they obtained averages of 7.10 and 7.18 for the attributes state and overall impression, respectively.

The same was observed for purchase intention, which obtained an average of 4.38 for formulation 9. A similar result was found by Hunaldo et al. (2020) [22], when evaluating the development and sensory evaluation of mixed passion fruit (*Passiflora edulis*) nectar, kale and linseed flour, they obtained an average score above 3, which corresponds to “I would probably buy” on the 5-point scale, which according to the authors indicate the population's interest in healthier and more exotic products, becoming an interesting way of adding value to the product.

Table 5 shows the parameters of models for overall impression, state and purchase intention. R^2 and R^2adj indicated values above 90% of the total variation, p-values and lack of adequate fit, therefore the models can predict responses and are statistically significant.

Table 5: Data from the predictive model for the linear, second-order polynomial and interaction effects of the percentages of teperebá pulp and sugar on the sensory attributes of nectars.

Coefficients	Overall impression	State	Purchase intention
Constant	19.03	54.73	18.31
X	0049	0098	0032
X^2	-3723	-8230	-2525
Y	-7540	-8644	-1.43
Y^2	0274	1674	0512
XY	-0009	0053	0005
R^2	0.98	0.93	0.98
R^{2adj}	0.95	0.90	0.96
P-value	0.00	0.00	0.00
Lack of fit	0.16	0.15	0.16

X: linear effect of taperebá pulp; X^2: quadratic effect of taperebá pulp; Y: linear effect of sulgar; Y^2: quadratic effect of sulgar; R^2: determination coefficient; R^2 adj: adjusted determination coefficient.

Analyzing the response surfaces for the state attribute (Figure 1A), it is clear that the taperebá pulp showed linear behavior (Table 5), with greater acceptance at lower percentages of pulp. In relation to sugar mass, a quadratic effect was observed for the set of attributes evaluated (Table 5), and, through the contour graph (Figure 1A, 1B and 1C), it is observed that the percentage of sugar did not have any effect on the dependent variables, which infers not to be significant ($p > 0.05$).

A similar result was observed by Ribeiro et al. (2016) [23], in the development of umbu (*Spondias* tuberosa) nectar, where they observed that the higher percentage of sugar had a positive effect on increasing the overall acceptance of nectars, unlike the percentage of pulp, where its increase had a negative effect on acceptance. Souza et al. (2012) [24], in the preparation of kiwi (*Actinidia deliciosa*) nectar, evaluating the sensorial sweetness profile, they obtained a regular average, for a value of 11.2 ºBrix; however, they obtained a low average for acidity, which was well accepted by the tasters.

Evaluating the purchase intention through the response surface (Figure 1C), a behavior similar to the state attribute (Figure 1A) is observed, in which the pulp presents a linear regression coefficient and the amount of sugar has a quadratic behavior (Table 5), where the formulation with the highest scores is located in the region with the lowest percentage of taperebá pulp, however, the percentage of sugar had no significant effect on the scores of the sensory judges.

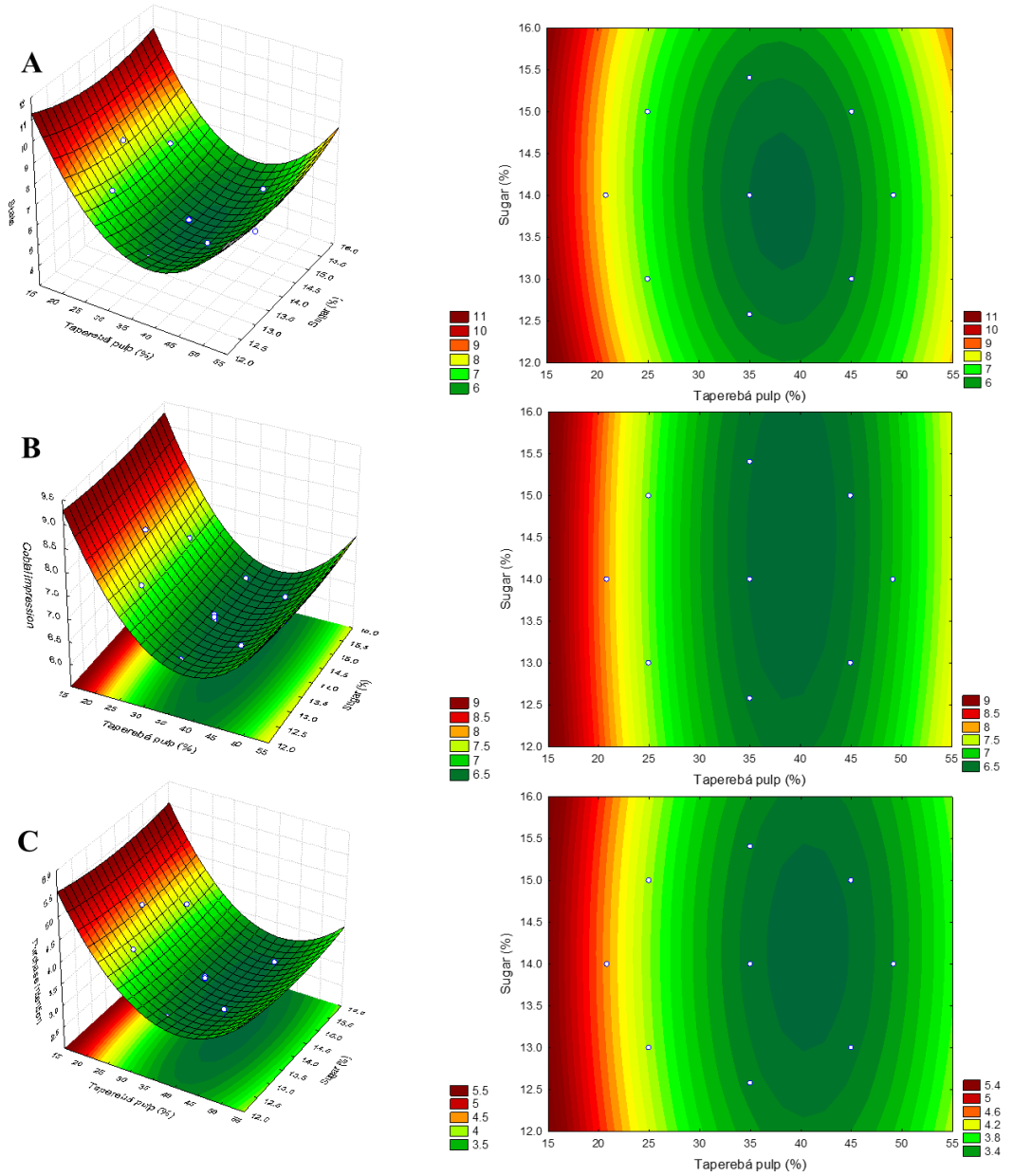

*Figure 1: Response surface and contour of the effect of taperebá pulp (%) and sugar mass (%) on state (**A**), overall impression (**B**) and purchase intention (**C**) in taperebá-based nectar.*

In a similar study by Aniceto et al. (2021) [5] with the development of drinks using RSM to optimize functional and sensorial characteristics, they observed that the areas of greatest acceptance were found in formulations with the lowest percentages of muruci pulp (*Byrsonima crassifolia* (L.) Kunth) for all sensory attributes evaluated, displaying results accordingly. However, in the same study, the increase in sugar concentration showed significant behavior ($p < 0.05$), already showing a different result in relation to sugar mass (%).

Divergent results were found by Braga et al. (2015) [25], who when developing, also 11 where nectar formulations, papaya (*Carica papaya* L.) and studying the interaction between sugar, inulin and oligofructose, realized that the acceptability in relation to state and overall increased as the increase of the sugar percentage. The acceptance of nectars from exotic Amazonian fruits was evaluated by Carvalho et al. 2015 [26] through acceptability, based on a study with consumers, which found that cupuaçu (*Theobroma grandiforum*) nectar was accepted by consumers.

According to Mattietto et al. (2007) [27], this similar behavior between the variable's acceptance and purchase intention, was already expected since the taster's acceptance of a product is generally related to the intention or not of purchasing it.

Based on the results obtained through the response surface, the formulation with the highest acceptability rates, in terms of state requirements, overall impression and purchase intention, corresponds to formulation 9 (20.85% pulp and 14% mass of sugar), which was confirmed through the highest scores obtained for its sensory acceptance; which was found in regions with lower percentages of pulp and, regardless of the percentages of sugar, which despite the latter having presented a quadratic effect, it was observed, through the contour graph, greater acceptance under the tasters' judgment for percentage of 14%.

4. CONCLUSIONS

The physical-chemical and microbiological characterization of the nectar formulations met the quality standards required by Brazilian legislation for fruit nectars. However, the pH and TA parameters, although not specified by the current regulations, fell within the typical ranges observed for other tropical fruit nectars. Thus, the potential use of taperebá is evidenced in the development of beverages with matrices from the northern region of the Brazilian Amazon, as well as highlighting the efficiency of pasteurization as a method of microbiological control in terms of safety and conservation.

The analysis of the response surface obtained by the CCD proved to be an essential tool for evaluating the sensory quality of beverages, allowing the identification of the formulation with the greatest sensory acceptability and statistical desirability. The confirmation of the results for overall impression, flavor and purchase intention indicated linear behavior in the preference for lower levels of taperebá pulp, while the scale of sugar levels revealed quadratic behavior, although not significant ($p \geq 0.05$). These factors were developed for a superior sensory acceptability of formulation 9, in which they presented lower concentrations of pulp (20.85%) and sucrose (14%).

Regarding the food trends for increasingly healthier beverages, future studies can be directed to evaluate the nutritional and bioactive properties of nectar formulated with taperebá. In addition, you can infer the replacement of sugar by alternative educators, attracting specific audiences with restrictive diets, such as diabetics or people who prefer products with lower calorie contents. This approach can also favor better sensory accessibility of the beverage, allowing even higher pulp concentrations and resulting in a product with better nutritional content.

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