Article

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Development of tropical mixed juice with low added-sugar content: Sensory and nutritional aspects

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Abstract

The aim of the present study was to develop a mixed tropical fruit juice of cashew apple, acerola and melon with low added-sugar content considering sensory and nutritional aspects. Five formulations were developed varying the concentration of the different fruits. A total of 172 consumers rated their overall liking using a 9-point hedonic scale and described their sensory characteristics using a Check-all-that-apply question. In addition, the functional properties of the juices were evaluated by analyzing vitamin C, total phenolic compounds and antioxidant capacity. Results showed that the addition of sugar and fruit composition affected the sensory characteristics and consumer liking of the formulations. Samples without added sugar and with higher melon concentration showed lower liking scores ($p < 0.05$). In addition, the highest concentration of acerola had a positive effect on nutritional characteristics. The formulation with 50% of fruit pulp (60% of cashew apple, 30% of acerola and 10% of melon), 47% of water, and 3% of added sugar achieved the best results. The effect of aroma on sweetness perception was investigated by adding identical to natural aromas of melon, apple and pineapple to the selected formulation. However, aroma did not significantly modify sweetness perception, evaluated using a rate-all-that-apply question.

Keywords

Consumer study, cross-modal interactions, check-all-that-apply (CATA), rate-all-that-apply (RATA), antioxidant capacity

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INTRODUCTION

Brazil is the eighth largest producer of tropical fruits and exporter of tropical juices worldwide (Maia et al., 2019; FAO, 2020). Tropical fruits, such as cashew apple, acerola and melon, are characterized by a high concentration of bioactive compounds and antioxidant capacity (Rufino et al., 2010). The development of fruit juices from tropical fruits provides the opportunity to add value, avoid waste and decrease losses of fresh products (Curi et al., 2017).

Green and Detox juices obtained from mixtures of fruit and vegetables are the new trend in the fruit juice segment (Steffen, 2018). This strategy seeks to innovate

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by providing consumers with unique and differentiated juices, with new flavors, aromas and colors (Curi et al., 2017; Sobhana et al., 2015). Despite this, most industrialized juices are added with sugar, contributing to the excessive intake of this nutrient worldwide. Sugar intake has been linked with negative health outcomes, such as the increased risk of type 2 diabetes, cardiovascular diseases and obesity (Lustig et al., 2012; World Health Organization, 2015). This has motivated an increased interest in product reformulation and the development of products with low sugar content. Consumers have positively reacted to this trend by increasing their interest in healthier products with low sugar content. A recent study has shown that "no added sugar" was the main factor underlying the choice of fruit juice bottles of Brazilian consumers (Martins et al., 2020).

Sugar reduction in fruit juices has been mainly achieved by the use of non-caloric sweeteners (Di Monaco et al., 2018). However, this approach has several drawbacks, which have been identified as a major disincentive for the food industry to reduce the sugar content of their products (WHO, 2017). Sweeteners can negatively affect the sensory characteristics of products by producing bitter and/or metallic taste, as well as off-flavours (Reis et al., 2017). Furthermore, emerging evidence has risen concerns over the potential negative effects of sweeteners on glucose intolerance, diabetes, and gut microbiota (Ahmad et al., 2020; Burke and Small, 2015; Dalenberg et al., 2020; Rother et al., 2018; Suez et al., 2014).

Recently, multisensory integration has been progressively used to increase sweetness perception in the context of sugar reduction (Di Monaco et al., 2018). The addition of aromas can increase the intensity of sweet taste, due to cross-modal interactions (Alcaire et al., 2017; Velázquez et al., 2020). So far, a limited number of studies have demonstrated the potential of this strategy, mainly in dairy products. However, cross-modal interactions are strongly dependent on the characteristics of the food matrix (Alcaire et al., 2017; Poinot et al., 2013).

In this context, the aims of the present study were: i) to develop a mixed tropical juice of cashew, acerola and melon with low added-sugar content, based on sensory and nutritional aspects, and ii) to evaluate the effect of adding natural aromas on the sensory characteristics of the drink as a potential strategy for increasing consumer sweetness perception in the context of sugar reduction efforts.

MATERIALS AND METHODS

Cashew apple, acerola and melon were selected for the development of a mixed tropical juice based on results from a previous study aimed to identify a new flavor of mixed tropical juice (Deliza et al., 2019). Consumer expectations and sensory acceptance of six blends of fruit juices were evaluated. The blend of cashew apple, melon and acerola showed the highest average overall liking score in the blind evaluation.

Raw material

Fruit pulps were obtained from a Brazilian company (De Marchi Indústria e Comércio de Frutas Ltda., Jundiaí-SP, Brazil). Melon and acerola pulps were obtained after pulping the fruits and subsequently frozen. The cashew apple pulp was pasteurized before freezing.

Juice formulation

The proportions of cashew apple, acerola and melon pulps were selected according to a mixture design with lower and upper restrictions (Cornell, 2002) using the Xvert function of mixexp package in R software, version 1.0.136 (Table 1). The sum of the three pulp proportions corresponded to 100%. The maximum and minimum concentrations were selected based on results from preliminary studies and the nutritional content of each fruit according to Brazilian nutrient composition tables (NEPA, 2011): cashew apple pulp (maximum 70%, minimum 30%), acerola pulp (maximum 30%, minimum 10%), and melon pulp (maximum 50%, minimum 10%). To reduce the number of samples in the study, only the extreme vertices (F3, F4, F5, F6) and the central point (F13) were considered (Calado and Montgomery, 2003).

Mixed tropical juices were formulated with 50% pulp, which is the minimum required by Brazilian legislation (Brasil, 2003). The development of a mixed juice with low added-sugar content was compared to commercial juices available in the Brazilian market, without the addition of non-nutritive sweeteners. For this reason, they were formulated with no added sugar and with 3% added sugar (Refined Sugar União, Brazil). The formulation of the juices is shown in Table 1. All juices were stored at $4 \pm 2\,^{\circ}C$ until sensory, physical-chemical and nutritional analyses were carried out.

Sensory characteristics and consumer liking

Consumers. One hundred and seventy-two consumers older than 18 years were recruited at a supermarket in the city of Rio de Janeiro – RJ, based on their fruit juice consumption (at least rarely), and their interest in participating in the study. The characteristics of the participants is shown in Table 2.

Table 1. Mixture design with lower and upper restrictions used to formulate samples of mixed tropical cashew, acerola and melon juices.

Point of the mixture design	Mixture design			Formulation of mixed tropical juice				
	Pulp (%)			Pulp (%)				
	Cashew apple	Acerola	Melon	Cashew apple	Acerola	Melon	Sugar (%)	Water (%)
F3	70	10	20	35	5	10	0	50
							3	47
F4	40	10	50	20	5	25	0	50
							3	47
F5	60	30	10	30	15	5	0	50
							3	47
F6	30	30	40	15	15	20	0	50
							3	47
F13	50	20	30	25	10	15	0	50
							3	47

Table 2. Characteristics of the consumers who participated in the study and the two consumer segments identified using Cluster analysis performed on liking scores of mixed tropical fruit juices.

Characteristic		Participants (%)		
		Total sample (n = 172)	Cluster 1 (n = 83)	Cluster 2 (n = 89)
Gender	Female	58	65	52
	Male	42	35	48
	χ^2 (p-value)	2.63 (0.104)		
Age (years)				
	18–25	8	7	9
	26–35	28	33	25
	36–45	16	14	18
	46–55	18	18	18
	55–65	18	17	19
	>65	11	11	11
	χ^2 (p-value)	1.53 (0.909)		
Education				
	Incomplete primary school	8	11	4
	Incomplete primary school	10	12	9
	High school	35	31	39
	University degree	30	31	28
	Post-graduate studies	17	14	19
	χ^2 (p-value)	4.15 (0.386)		
Income (monthly in R$[a])				
	R$ 954.00 a 4.770.00	44	47	42
	>R$ 4.770.00 a 9.540.00	28	30	27
	>R$9.540.00 a 19.080.00	19	16	21
	>R$ 19.080.00 a 28.620.00	5	5	6
	>R$ 28.620.00	3	2	4
Frequency of consumption of fruit juice	χ^2 (p-value)	1.76 (0.778)		
	Never	0	0	0
	Rarely	10	8	3
	Frequently	55	34	30
	1-2 times a week	63	36	37
	Every day	44	22	29
	χ^2 (p-value)	3.00 (0.390)		

[a]Brazilian currency named Real.

Procedure. Consumers evaluated 10 formulations (F3, F4, F5, F6 and F13 with and without added sugar). Samples (25 mL at $10 \pm 2^{\circ}$ C) were presented to participants in disposable plastic cups (50 mL), coded with three-digit numbers. Samples were presented one by one, following a Williams' Latin square design. Consumers were asked to rate their overall liking using a 9-point hedonic scale ranging from "Dislike extremely" (1) to "Like extremely" (9).

Then, they were asked to describe the sensory characteristics of the juices using a Check-All-That-Apply (CATA) question. This is one of the most popular methods for sensory characterization based on consumer responses (Jaeger et al., 2020). CATA questions are a fast and easy tool that provides valid and reliable information about the sensory characteristics of products, which can be a great advantage in the early stages of product development (Ares et al., 2014a, 2015; Jaeger et al., 2020). Consumers were presented with a list of 17 terms and were asked to select all that applied to describe each of the samples: *Astringent, Watery, Heterogeneous appearance, Homogeneous appearance, Consistent, Yellow color, Reddish color, Orange color, Sweet Taste, Acid taste, Bitter taste, Barely sweet, Presence of particles, Refreshing, Acerola flavor, Cashew flavor and Melon flavor*. The terms were selected in a previous consumer study in which participants were asked to freely describe the juice samples. The presentation order of the terms was balanced across consumers. Mineral water was offered to participants between samples. Finally, consumers were asked to answer a series of socioeconomic questions.

Data analyses. Liking data were analyzed using analysis of variance (ANOVA). Two different approaches were used. In the first analysis, sample was used as source of variation and consumers as random effect. In the second analysis, ANOVA was used to evaluate the influence of sugar concentration and fruit composition, as well as their interaction on liking. When differences were significant at a 5% significance level, Fisher's test was used for post-hoc comparison of mean values.

Cluster analysis was used to identify consumer segments with different preference patterns, considering Euclidean distance and Ward's agglomeration method. The overall liking of the identified clusters for each of the samples was compared using Student's t-test.

The frequency of use of each of the terms of the CATA questions was determined by counting the number of consumers who used them to describe each sample. Cochran's Q test was used for evaluating significant differences among samples in the frequency of use of each of the terms. Correspondence analysis (CA) was used to obtain a graphical representation of the samples and the relationship between them and the terms of the CATA questions.

Physicochemical and nutritional characterization

The pulps and the juice formulations were characterized in terms of pH, total titratable acidity (TTA), and total soluble solids (TSS), using the methods described in AOAC (2010). Vitamin C content was determined using HPLC with external standardization, according to Rosa et al. (2007). The total phenolic compounds (TPC) were estimated by the Folin-Ciocalteu method (Singleton et al., 1999). A gallic acid calibration curve was used, and results were expressed as equivalent of gallic acid (mg EAG/100g). The readings were taken at an absorbance of 760 nm. Antioxidant capacity (ACp) was determined using the ABTS+ and ORAC methods. Analysis was performed according to the procedure described by Re et al. (1999). Once the $ABTS^{\cdot+}$ radical was formed, it was diluted in ethanol (95%) until an absorbance measurement of 0.70 ($\pm$0.02) was obtained at a wavelength of 754 nm. Results were expressed in TEAC, antioxidant activity equivalent to Trolox (6-hydroxy-2,5,7,8-tetramethylchromo-2-carboxylic acid) in μmol TEAC/g of sample using a standard curve prepared using Trolox solutions. The ORAC assay was performed according to the method described by Zulueta et al. (2009). Fluorescein solutions, the Trolox standard and the AAPH solution (2,2'-Azobis (2-methylpropionamide) dihydrochloride) were prepared on the day of analysis. For the calculations, the areas under the curves (AUC) of the samples were used and results were expressed in μmol Trolox/g of the extract. All analyses were performed in triplicate.

Data were analyzed using ANOVA. When differences were significant at a 5% level of confidence, Fishers' test was used for post-hoc comparison of mean values.

Effect of aroma addition on the sensory characteristics of the selected formulation

Samples. Identical to natural aromas of melon (0.02%) (Cantaloupe Flavor-505326 3 T, Firmenich), apple (0.01%) (Apple Flavor-541639T, Firmenich) and pineapple (0.04%) (Pineapple Flavor-541783T, Firmenich) were added in different concentrations to the selected formulation (with 0% and 3% of sugar) to evaluate the feasibility of using cross-modal interactions to increase sweetness perception. The concentrations used for each aroma were based on manufacturer's recommendations and preliminary studies.

Procedure. Samples were presented following the procedure described in 'Procedure' of the 'Sensory characteristics and consumer liking' section to 53 fruit juice consumers. Data were collected in sensory booths under artificial lighting and controlled temperature (23 °C). Participants were asked to try the juices and to describe their sensory characteristics using a Rate-All-That-Apply (RATA) question. RATA is a variation of CATA questions, in which consumers are asked to indicate the terms that apply to describe a particular product and, if they do, they must evaluate its intensity (Ares et al., 2014b; Vidal et al., 2018). Although studies have shown that both methods provide similar results RATA questions tend to show higher discrimination than CATA for products that have similar sensory characteristics but slightly differ in the intensity of those characteristics (Meyners et al., 2016). Consumers were asked to select the terms that applied to describe the juices using a list of 9 terms: *Sweet Taste*, *Astringent*, *Acid taste*, *Bitter taste*, *Fruit flavor*, *Cashew flavor*, *Acerola flavor*, *Melon flavor*, *Off flavor*. For the terms they selected, they had to rate their intensity using a three-point structured scale ('low', 'medium' and 'high'). The presentation order of the terms was balanced.

Data analysis. Data were analyzed as proposed by Meyners et al. (2016). ANOVA was used considering sample and consumer as fixed effects. When differences were significant Fisher's test was used for post-hoc comparison of means.

RESULTS

Identification of the most appropriate formulation of tropical mixed cashew apple, acerola and melon juice

Sensory characteristics and consumer liking of the mixed tropical juice formulations. The frequency of use of 15 of the 17 CATA terms significantly differed between the formulations. As shown in Figure 1, samples were sorted in the first dimension according to the composition of the juices. Samples F5, F6 and F13 without and with added sugar were located on the right side of the first dimension, and were characterized by the terms *Orange color, Acerola flavor,* and *Reddish color*. Samples F5 and F6 tended to be described using the term *Sour taste*. On the contrary, samples F3 and F4 were located on the left side of the first dimension and were described using the terms *Melon flavor*, *Cashew flavor* and *Yellow color*.

The second dimension sorted the formulations according to their sugar concentration. Samples with added sugar were located on negative values of the second dimension as they were characterized by the term *Sweet taste*, whereas samples without added

Figure 1. Correspondence analysis (CA) performed the frequency of use of the terms of the Check-all-that apply (CATA) question to describe formulations of mixed tropical juice considering data from all participants (n = 172). Formulations composed of 50% mixed pulp, where: F3: 70% cashew apple, 10% acerola and 20% melon; F4: 40% cashew apple, 10% acerola, 50% melon; F5: 60% cashew apple; 30% acerola, 10% melon; F6: 30% cashew apple, 30% acerola and 40% melon and F13: 50% cashew apple, 20% acerola and 30% melon.

Table 3. Average overall liking scores[a] of formulations of mixed tropical juices for the whole consumer sample and for the two consumer segments identified in Cluster analysis.

Formulation	Global average (n = 172)	Cluster 1 (n = 83)	Cluster 2 (n = 89)
F3 + 3% sugar	6.2 (±2.1)ab	6.6 (± 1.9) aA	5.8 (±2.2)abcB
F4 + 3% sugar	5.7 (±2.2)b	5.8 (±2.2) aA	5.6 (±2.1)bcdA
F5 + 3% sugar	6.2 (± 2.2)ab	6.3 (±2.2) aA	6.0 (±2.2)abA
F6 + 3% sugar	6.5 (±2.1)a	6.5 (±2.0) aA	6.4 (±2.2)aA
F13 + 3% sugar	6.4 (±2.0)a	6.3 (±2.0) aA	6.3 (± 2.1)aA
F3 without added sugar	4.4 (±2.3)c	3.6 (±2.2) bB	5.1 (±2.2)deA
F4 without added sugar	3.7 (± 2.2)d	3.3 (± 2.2) bB	4.3 (±2.1)fA
F5 without added sugar	4.2 (±2.4)cd	3.1 (±2.1) bB	5.3 (±2.2)cdeA
F6 without added sugar	4.2 (±2.3)cd	3.4 (±2.2) bB	4.9 (±2.3)eA
F13 without added sugar	4.2 (±2.5)cd	2.9 (±2.1) bB	5.4 (±2.2)cdeA

[a]Evaluated on a structured 9-point hedonic scale, ranging from 1: Dislike extremely to 9: Like extremely.
The juices were prepared with 50% mixed pulp. Formulations correspond to F3: 70% cashew apple, 10% acerola and 20% melon; F4: 40% cashew apple, 10% acerola, 50% melon; F5: 60% cashew apple; 30% acerola, 10% melon; F6: 30% cashew apple, 30% acerola and 40% melon and F13: 50% cashew apple, 20% acerola and 30% melon.
Mean values with the same lowercase letters within the same column do not significantly differ ($p > 0.05$) according to Fisher's test. Mean values with the same capital letters within the same line do not significantly differ ($p > 0.05$) according to Student's t test.

sugar were located at positive values of the second dimension.

Table 3 shows the average overall liking score of the formulations. Fruit composition ($p = 0.001$) and sugar ($p < 0.001$) significantly affected consumer liking. Sugar concentration had the largest effect: samples with 3% sugar had higher overall liking scores than formulations without sugar (6.2 ± 2.1 vs. 4.2 ± 2.3, $p \leq 0.05$). Regarding fruit composition, formulation F4 (4.73 ± 2.37) showed a significantly ($p \leq 0.05$) lower overall liking score than the other four (F3 5.29 ± 2.38; F13 5.29 ± 2.49; F5 5.20 ± 2.49 and F6 5.34 ± 2.49).

Cluster analysis on liking data identified two consumer segments with different preference patterns (Table 3). Although both groups differed in their hedonic reaction to the juices, no significant differences in their socio-demographic characteristics were found (all p-values higher than 0.05) (Table 2).

Liking scores of consumers in Cluster 1 ($n = 83$) were significantly affected by the sugar content of the formulation ($p < 0.001$). They provided higher liking scores to the formulations with added sugar (6.3 ± 2.1) than formulations without sugar (3.3 ± 2.1). For consumers Cluster 2 ($n = 89$), both fruit composition ($p = 0.001$) and sugar content ($p < 0.001$) significantly influenced liking. For this segment, formulation F4 with and without sugar showed the lowest liking score ($p \leq 0.05$). In addition, formulations with added sugar showed higher liking scores (6.0 ± 2.2) than formulations without sugar (5.0 ± 2.2). When comparing the segments, it can be concluded that Cluster 1 was the most sensitive to sugar. In addition, the biggest difference between segments was observed for F13 without added sugar (Table 3).

Physicochemical and nutritional characteristics of pulps and mixed tropical juice formulations. Table 4 presents the physicochemical and nutritional characteristics of the pulps and juice formulations in terms of pH, TTA, TSS, Vitamin C, total phenolic compounds (TPC) and ACp ($ABTS^{\cdot+}$) . Significant differences were found ($p \leq 0.05$) for all evaluated characteristics for both the pulps and the juice formulations.

Acerola pulp differed ($p \leq 0.05$) from the cashew apple and melon pulps as it presented a lower pH, higher acidity and higher levels of vitamin C, TPC and antioxidant capacity. The cashew apple pulp showed higher levels ($p \leq 0.05$) of TSS.

As expected, differences in the composition of the pulps had a large effect on the characteristics of the different formulations. All formulations had pH values below 4.5, which is a positive factor considering the safety of the juices. However, formulations F5 and F6 showed lower pH ($p \leq 0.05$) than the other formulations. Differences regarding acidity were found among formulations, with the highest value for F5. Regarding TSS, F4 and F6 showed lower values than the other formulations ($p \leq 0.05$). Finally, in relation to the Vitamin C, TPC and ACp ($ABTS^{\cdot+}$ and ORAC), F5 stood out from the rest due to its high average values for these characteristics. Conversely, formulation F4 had the lowest average values of these characteristics (Table 4).

Selection of the best formulation. Selection of the best formulation was performed based on results from sensory, physicochemical and nutritional characterization. Formulation F5 showed one of the highest overall liking scores, as well as the highest content of vitamin

Table 4. Average values and standard deviations of physicochemical characteristics of pulps and tropical mixed juice formulations: pH, total titratable acidity (TTA), total soluble solids (TSS), vitamin C, total phenolic compounds and antioxidant capacity (ACp).

Samples	pH	ATT (mg/100g of citric acid)	TSS (°Brix)	Vit. C (mg/100g)	TPC (mg ac. gal / 100g)	ACp (μmol Trolox/g)	
						ABTS	ORAC
Cashew pulp	4.19 (±0.070)^{B}	3.27 (±0.15)^{B}	10.0 (±0.0)^{A}	40.13 (±1.14)^{B}	467.6 (±18.48)^{B}	7.76 (±0.30)^{B}	–
Acerola pulp	3.29 (±0.020)^{C}	13.63 (±0.06)^{A}	7.0 (±0.0)^{B}	1802.01 (±20.89)^{A}	5676.39 (±833.78)^{A}	80.83 (±8.48)^{A}	–
Melon pulp	5.88 (±0.071)^{A}	0.81 (±0.01)^{C}	3.1 (±0.0)^{C}	ND	35.81 (±13.81)^{B}	0.78 (±0.06)^{B}	–
F3	4.15 (±0.014)^{b}	1.85 (±0.07)^{d}	7.0 (±0.0)^{a}	106.74 (±0.62)^{d}	278.15 (±19.64)^{d}	5.62 (±0.43)^{d}	10.39 (±0.69)^{b}
F4	4.35 (±0.042)^{a}	1.34 (±0.03)^{e}	6.0 (±0.0)^{c}	78.50 (±0.45)^{e}	207.05 (±7. 91)^{e}	4.61 (±0.83)^{d}	4.11 (±0.32)^{e}
F5	3.77 (±0.62)^{d}	2.84 (±0.07^{a}	6.9 (±0.0)^{b}	262.98 (±2.76)^{a}	557.55 (±17.86)^{a}	10.97 (±1.21)^{a}	11.20 (±0.20)^{a}
F6	3.79 (±0.035)^{d}	2.55 (±0.11)^{b}	6.0 (±0.0)^{c}	240.59 (±0.71)^{b}	479.60 (±28.17)^{b}	9.63 ± (0.54)^{b}	7.67 (±0.09)^{c}
F13	4.00 (±0.010)^{c}	2.10 (±0.04)^{c}	6.9 (±0.0)^{b}	177.72 (±1.20)^{c}	377.36 (±14.02)^{c}	7.73 ± (0.25)^{c}	5.31 (±0.14)^{d}

F3, F4, F5, F6 e F13: Formulations with 50% mixed pulp, 3% sugar and 47% water, where: F3: 70% cashew apple, 10% acerola and 20% melon; F4: 40% cashew apple, 10% acerola, 50% melon; F5: 60% cashew apple; 30% acerola, 10% melon; F6: 30% cashew apple, 30% acerola and 40% melon and F13: 50% cashew apple, 20% acerola and 30% melon.
Different capital letters within the columns indicate significant differences among pulps ($p \leq 0.05$) according to Fisher's test. Different lowercase letters within the same columns indicate significant differences among formulations ($p \leq 0.05$) according to Fisher's test.
ND: not detected.

C, total phenolic compounds and antioxidant capacity. For these reasons, it was selected as the best formulation. The effect of the addition of aromas on sweetness perception was evaluated using this sample.

Effect of adding aromas on the sensory characteristics of a mixed tropical juice

Table 5 shows the average intensity score of the terms included in the RATA question for the evaluated samples. Significant differences among samples were found for all the terms. However, sugar was the main responsible for differences in the sensory characteristics of the samples (Table 5). Added aroma did not significantly modify the average score of the term *Sweet taste* ($p = 0.958$). Instead, aroma significantly changed the perceived intensity of the terms *Cashew flavor*, *Acerola flavor*, *Melon flavor* and *Off flavor*. The addition of melon aroma reduced perceived *Cashew flavor* and *Acerola flavor* and increased the perceived intensity of *Melon flavor* and *Off flavor*. The intensity of the latter attribute also increased ($p \leq 0.05$) by the addition of the pineapple aroma. Finally, apple aroma caused the smallest effects in the sensory characteristics of the mixed tropical juice.

DISCUSSION

The present study aimed to develop a mixed tropical juice of cashew apple, acerola and melon with low content of added sugar and without non-nutritive sweeteners. Results showed that both fruit composition and sugar content had a significant effect on the sensory characteristics of the juices and consumer liking. Sugar was the main variable influencing consumer liking. Although a previous study showed that Brazilian consumers preferred tropical juices without added sugar (Martins et al., 2020), in the present study juices with added sugar showed the highest overall liking scores. This suggests that although consumers are willing to accept products without added sugar, they like sweet juices, in agreement with our innate preference for sweet taste (Loper et al., 2015; Schwartz et al., 2009). Juices without added sugar received average scores that indicated a negative hedonic reaction, in agreement with the fact that flavor is one of the main determinants of consumer food preferences, choice and intake of the consumers.

However, it should be acknowledged that the formulations with the highest overall liking scores had 3% sugar. This added sugar content is lower than most beverages available in the Brazilian market, which contain about 10% of added sugar. Overall liking scores for the evaluated juices were lower than the values reported in previous studies, in agreement with the

Table 5. Average scores of each of the terms of the Rate-all-that-apply (RATA) question to describe the sensory characteristics of mixed tropical juices formulations.

	Sample								p-value	
Attributes	F5SA	F5CA	F5SA+Me	F5CA+Me	F5SA+Ma	F5CA+Ma	F5SA+Ab	F5CA+Ab	Sugar	Aroma
Sweet taste	0.4 (±0.6)b	1.8 (±0.9)a	0.4 (±0.6)b	1.7 (±1.1)a	0.4 (±0.6)b	1.8 (±1.0)a	0.3 (±0.5)b	1.8 (±1.1)a	<0.001	0.958
Astringent	0.9 (±1.0)a	0.4 (±0.7)bc	0.9 (±1.1)a	0.3 (±0.7)c	0.9 (±1.0)a	0.4 (±0.6)bc	0.7 (±0.9)ab	0.5 (±0.8)bc	<0.001	0.941
Acid taste	1.3 (±1.1)a	0.7 (±0.9)b	1.4 (±1.1)a	0.5 (±0.7)b	1.3 (±1.1)a	0.7 (±0.8)b	1.3 (±1.2)a	0.8 (±1.0)b	<0.001	0.780
Bitter taste	0.5 (±0.9)a	0.2 (±0.5)b	0.6 (±1.0)a	0.2 (±0.4)b	0.6 (±1.0)a	0.2 (±0.5)b	0.6 (±1.0)a	0.2 (±0.5)b	<0.001	0.977
Fruit flavor	1.2 (±1.3)bc	1.5 (±1.3)ab	1.0 (±1.3)c	1.4 (±1.3)abc	1.3 (±1.4)abc	1.8 (±1.3)a	1.1 (±1.2)bc	1.3 (±1.3)abc	0.009	0.217
Cashew flavor	0.9 (±1.0)b	1.2 (±1.0)a	0.3 (±0.5)d	0.4 (±0.7)cd	0.9 (±1.0)b	0.8 (±0.9)b	0.7 (±0.9)bc	0.9 (±1.0)b	0.081	<0.001
Acerola flavor	1.9 (±1.2)a	1.9 (±1.0)a	0.7 (±0.9)c	0.6 (±0.9)c	1.5 (±1.2)b	1.4 (±1.1)b	1.6 (±1.2)ab	1.4 (±1.1)b	0.322	<0.001
Melon flavor	0.3 (±0.6)c	0.3 (±0.6)c	1.7 (±1.2)b	2.0 (±1.1)a	0.4 (±0.8)c	1.0 (±1.0)b	0.2 (±0.6)c	0.4 (±0.8)c	<0.001	<0.001
Off flavor	0.6 (±1.0)b	0.2 (±0.5)c	1.1 (±1.2)a	0.7 (±1.1)b	0.8 (±1.2)ab	0.2 (±0.6)c	0.9 (±1.1)ab	0.9 (±1.9)ab	<0.001	0.0001

Samples: F5SA: formulation F5 without added sugar (composed of 50% mixed pulp (F5: 60% cashew apple; 30% acerola, 10% melon) and 50% water); F5CCA - formulation F5 with added sugar (composed of 50% mixed pulp (F5: 60% cashew apple; 30% acerola, 10% melon) and 47% water and 3% sugar); F5SA + Me: formulation F5 without added sugar, with added melon flavor; F5CA + Me: formulation F5 with added sugar, added melon flavor; F5SA + Ma: F5 formulation without added sugar, with apple flavor; F5CA + Ma: formulation F5 with added sugar, added with apple flavor; F5SA + Ab: formulation F5 without added sugar, with pineapple flavor; F5CA + Ab: formulation F5 with added sugar, added with pineapple flavor.
Note: Mean values with the same letters within the same line do not significantly differ ($p > 0.05$) according to Fisher's test.

low sugar content of the juices. Deliza et al. (2019) reported that the formulation made of cashew apple, melon and acerola with 6% of added sugar showed a higher acceptance (7.6). Reducing exposure to sweetness could facilitate the adaptation to a lower sugar intake (World Health Organization, 2015; PAHO, 2016) and consequently increase liking for less sweet products over time as consumer preference for products with low sugar content can be increased by repeated exposure to products with lower sugar content in the diet (Cooke, 2007). The preference for a certain flavor is shaped by eating habits since childhood, and the learning process plays an important role in the acceptance of products. In this sense, Lima et al. (2019) found that children's liking of a grape nectar with lower added sugar content increased significantly after a nine-week exposure period, compared to the first exposure. This suggests that repeated exposure to the sample led to an increase in liking, possibly due to children's adaptation to less intense sweet taste. Increasing the availability of products with low sweetness intensity on the market may, therefore, be an important step towards adapting the population to fewer sweet products and, therefore, reducing sugar intake.

It is important to highlight that the perception of sweetness was inversely related to bitterness, acidity and consistency. All formulations without added sugar were perceived as more *Astringent*, *Acid taste*, *Bitter taste*, *Little sweet*, *Watery* and less *Consistent* than those with added sugar. Similar results were found by Lima et al. (2019) and Pineli et al. (2016) when working with nectars reduced in sugar. The increase in the perception of the term *Watery* can be explained by the increase in the water content of the formulations, which replaced the added sugar. In addition, sugar also influences other physical and sensory properties of products, such as color, viscosity and texture (Clemens et al., 2016; Di Monaco et al., 2018). It is also noteworthy that bitterness and acidity are generally reduced by sweetness (Green et al., 2010). Therefore, formulations with added sugar were perceived as less bitter and acid, which may also have affected consumer liking.

The identification of a consumer segment with a more positive hedonic response towards the formulations without added sugar suggests that there is a market niche to be explored. Although the preference pattern of the two segments was quite different, the groups did not differ significantly in terms of their socioeconomic characteristics, indicating that their liking may be defined by their habits, attitudes and psychological traits. Results from the present work suggest that Cluster 2 was composed of consumers

who were "more favorable" to less sweet or sugar-free juices.

Regarding the effect of fruit composition on consumer liking of the formulations, it was found that samples with the largest proportion of melon tended to receive lower overall liking scores. This result may be explained considering that juices with higher melon concentration were described as *Watery*, which matches the lower total soluble of melon pulp compared cashew and acerola pulps. In addition, this agrees with results from a previous study in which mixed tropical juices with melon received lower expected liking scores (Deliza et al., 2019).

Physico-chemical and nutritional characterization further contributed to the identification of the most adequate juice blend. Acerola pulp was the main responsible for high content of Vitamin C, TCP and ACp and high values of total titratable acidity, in agreement with results from Silva et al. (2017). Although it has been reported that cashew also has a high content of vitamin C and phenolic compounds (Rufino et al., 2010), the present study did not find the same results, possibly because pasteurized cashew apple pulp was used. Formulation F5 (60% cashew apple, 30% acerola and 10% melon) showed the best results in terms of vitamin C, total phenolic compounds and antioxidant capacity, suggesting its potential to be developed on an industrial scale. Thus, the use of non-pasteurized cashew pulp, with a high content of vitamin C and phenolic compounds could further increase the difference in nutritional characteristics between formulations.

Strategies aimed at increasing the perception of sweetness can contribute to the production of products with low sugar content with high consumer liking. One of the strategies studied to increase the perception of sweetness was the addition of the aroma in reduced sugar products, based on the principles of multisensory integration. Although previous studies with dairy products have shown its potential (Alcaire et al., 2017; Oliveira et al., 2015; Tournier et al., 2009; Velázquez et al., 2020), in the present study the addition of aromas did not significantly influence sweet taste intensity of the tropical mixed juice of cashew, acerola and melon. Additional research should be conducted to further explore the use of cross-modal interactions in the development of juices with low sugar content. It is advisable to study less complex fruit juices (e.g., with a single fruit) in order to minimize interferences in the taste-aroma interaction.

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The study was submitted and approved by to the Ethical Committee (Plataforma Brasil, CAAE - 02633612.2.0000.5291).

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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The data that support the findings of this study are available from the corresponding author upon reasonable request.

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