ORIGINAL ARTICLE

Plant-based frozen desserts: temporal sensory profile and preference

Gelados comestíveis plant-based: perfil sensorial temporal e preferência

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Abstract

To respond to the growing demand for specific diets aimed at lactose intolerant and vegan consumers, chocolate-flavored frozen desserts with no addition of lactose and other animal-derived products were produced, and the temporal profile and the consumers' acceptance of the samples with sucrose substitution by sweeteners were also investigated. Six frozen dessert formulations were made, three made with soy protein and three with rice protein, sweetened with sucrose, sucralose, and stevia. Acceptance tests and Time-Intensity (TI) analysis were performed to assess the intensity and duration of the attributes sweet taste, bitter taste, chocolate flavor, and melting behavior. The results showed no effect of the different plant proteins on the temporal profile and the acceptance by consumers. The use of sweeteners altered the temporal sensory profile and negatively impacted the acceptance of the samples. The sucralose-sweetened formulations were characterized by a lower intensity of sweet taste, chocolate flavor, and bitterness, whereas the stevia-sweetened formulations showed greater intensity and duration of the bitter taste. Characteristics such as the low intensity of chocolate flavor and the increase in sweetness affected the final acceptance of the product. The melting time of frozen desserts has been extended with the use of body agents to replace sucrose.

Keywords: Time-intensity analysis; Penalty analysis; Plant-based; Frozen desserts; Sweeteners; Drivers of liking.

Resumo

A fim de atender à demanda de dietas específicas, destinadas a intolerantes à lactose e consumidores veganos, o estudo teve como objetivo formular gelados comestíveis sabor de chocolate sem adição de lactose e outros produtos de origem animal, além de caracterizar o perfil temporal das amostras com substituição de sacarose por edulcorantes e avaliar a aceitação por consumidores. Foram formuladas seis amostras de gelados comestíveis, sendo três com proteínas de soja e três com proteína de arroz, adoçadas com sacarose, sucralose e estévia. Foram realizadas análises de aceitação e Tempo-Intensidade para avaliação de intensidade e duração dos atributos gosto doce, gosto amargo, sabor de chocolate e derretimento. Os resultados mostraram que a utilização das diferentes proteínas vegetais não interferiu no perfil sensorial temporal e na aceitação pelos consumidores. A utilização de

edulcorantes alterou o perfil sensorial temporal e impactou negativamente na aceitação das amostras, sendo as amostras adoçadas com sucralose caracterizadas pela menor intensidade de gosto doce, sabor de chocolate e amargor, enquanto as formulações com estévia apresentaram maior intensidade e duração do gosto amargo. Características como a baixa intensidade de sabor de chocolate e o aumento na doçura tiveram influência na aceitação final do produto. O tempo de derretimento dos sorvetes foi prolongado com a utilização de agentes de corpo na substituição de sacarose.

Palavras-chave: Análise tempo-intensidade; Análise de penalidade; *Plant-based*; Gelados comestíveis; Edulcorantes; Direcionadores de preferência.

1 Introduction

The interest in veganism has increased worldwide, ranging from 1 to 5% of the population that consume plant-based meals in several countries such as the United States of America (USA) (2%), Israel (5%), United Kingdom (UK) (2%), Australia (1%), and Germany (1%) (Radnitz et al., 2015). Veganism is a diet and lifestyle choice that avoids the consumption of all animal products, including meat, dairy products, eggs, honey, and other products (Cramer et al., 2017). There are other diets with variations in these restrictions, such as strict vegetarianism, which avoids the consumption of animal-derived foods (Animal Source Foods (ASF)), including dairy products (Craig & Mangels, 2016). There are several reasons for the practice of veganism, including moral, ethical, spiritual, and religious aspects, animal welfare, sensory preferences, lifestyle, dietary restrictions, and the search for improvements in health, with emphasis on issues related to health and ethics (Fox & Ward, 2008; Ruby, 2012; Dyett et al., 2013).

In this scenario, products made with plant-based proteins may be an alternative for the replacement of bovine milk in the treatment of allergies, lactose intolerance, and in the vegan diet. However, despite their high nutritional and functional potential, foods containing soy and rice derivatives are not well accepted by consumers due to the unpleasant flavor from the compounds present in the grain or formed during processing (Assumpção, 2008; Casé et al., 2005; Miyamoto & Auler, 2008). These undesirable attributes can be minimized with the use of plant-based protein isolates, which contain at least 90% of protein and are considered a versatile alternative to improve the organoleptic characteristics and the nutritional values of food (Tseng et al., 2009), in addition to having specific functional properties (Hagenimana et al., 2007).

The growing demand for products intended for specific diets, with no harmful compounds (Crizel et al., 2014) and characteristics similar to traditional foods (Cruz et al., 2009) makes the ice cream an attractive alternative, containing ingredients with nutritional and physiological properties (Aboulfazli et al., 2016). Ice cream has high consumers' acceptability, being a highly consumed product worldwide, with a great consumption demand in cold climate countries such as New Zealand, Canada, and Australia, with a preference for the chocolate flavor, both worldwide as well as in Brazil (Associação Brasileira de Indústrias de Sorvetes, 2010).

Although vegan foods bring health benefits (Key et al., 2006; Spencer et al., 2003), they can contain high sugar, salts, and fat levels (Radnitz et al., 2015), with negative effects on humans' health. Therefore, studies to develop acceptable modified formulations are required, which can offer a pleasant experience for the consumer. In this context, sweeteners appear as an alternative to replace sucrose, considering the high sucrose content used in these formulations, including the ice cream, which can contain from 10 to 14% of sucrose (Goff, 2018) even in traditional formulations.

Time-intensity (TI) is a method widely used for temporal perception study when compared to other methodologies such as Temporal Dominance of Sensations (TDS) and Temporal Check All That Apply (TCATA) (Silva et al., 2018; Wu et al., 2019; Lima et al., 2020a; Harwood et al., 2020). In fact, TI brings information about the perception regarding the duration of the sensory attributes that can positively or

negatively impact the final acceptance of the product, becoming an important tool for the evaluation of substitute ingredients (Lima et al., 2020b; Medeiros et al., 2020; Tavares Filho et al., 2020)

Therefore, the present study aimed to produce low-calorie chocolate-flavored frozen desserts with no addition of lactose and other animal-derived products and to evaluate the temporal profile and the consumers' preference of the samples.

2 Materials and methods

2.1 Sampling

Six frozen desserts formulations were made, free of lactose and other animal-derived ingredients, as follows: three soy protein-based formulations (S) and three rice protein-based formulations (R); sweetened with sucrose (SAC); sucralose (SUC); and steviol glycoside extract (STE). The ingredients and the respective concentrations are shown in Table 1.

Table 1. Ingredients and concentrations used in the manufacture of six chocolate-flavored frozen desserts formulations.

Ingredients (% w / w)	Formulations					
	RSAC	RSUC	RSTE	SSAC	SSUC	SSTE
Cassava starch	8.50	8.50	8.50	8.50	8.50	8.50
Rice protein	1.70	1.70	1.70	-	-	-
Soy protein	-	-	-	1.70	1.70	1.70
Potable water	55.15	55.15	55.15	55.15	55.15	55.15
Cocoa powder	9.00	9.00	9.00	9.00	9.00	9.00
Cocoa butter	7.00	7.00	7.00	7.00	7.00	7.00
Glucose	3.00	3.00	3.00	3.00	3.00	3.00
Stabilizer	0.40	0.40	0.40	0.40	0.40	0.40
Vanilla flavor	0.15	0.15	0.15	0.15	0.15	0.15
Cocoa flavor	0.10	0.10	0.10	0.10	0.10	0.10
Sucrose	15.00	-	-	15.00	-	-
Inulin	-	6.97	6.83	-	6.97	6.83
Maltodextrin	-	8.00	8.00	-	8.00	8.00
Sucralose	-	0.026	-	-	0.026	-
Stevia extract	-	-	0.166	-	-	0.166

Rice protein with sucrose (RSAC); Rice protein with sucralose (RSUC); Rice protein with steviol glycoside (RSTE); Soy protein with sucrose (SSAC); Soy protein with sucralose (SSUC); Soy protein with steviol glycoside (SSTE).

The following ingredients were used: cassava starch (Akio®, São Paulo, Brazil); rice protein; soy protein; potable water; cocoa powder (Harald®, São Paulo, Brazil); cocoa butter (Barry Callebaut®, São Paulo, Brazil); glucose (Arcolor®, São Paulo, Brazil); stabilizer (Starmix premium, Kerry®, São Paulo, Brazil); vanilla flavor (Duas Rodas®, Santa Catarina, Brazil); cocoa flavor (Duas Rodas®, Santa Catarina, Brazil); sucrose (União®, São Paulo, Brazil); inulin (Orafti® HSI, Beneo Latino Americana Ltda., São Paulo, Brazil); maltodextrin; sucralose (Sweetmix®, São Paulo, Brazil); and steviol glycoside extract (Rebaudioside A 97%) (Steviafarma®, Paraná, Brazil).

The ingredients were pre-homogenized and the mixture was pasteurized at 85 °C for 25 minutes, cooled, and matured at 5 °C for 8 hours. After homogenization, the mixture was beaten in an ice maker (Cuisinart-220V ICE-21) and the frozen desserts was stored in a freezer at -18 ± 2 °C (Medeiros et al., 2019).

2.2 Sensory evaluation

The sensory evaluation was carried out at the Laboratory of Sensory Science and Consumer Research at State University of Campinas (Unicamp) - Brazil (Sensory Science and Consumer Research (LCSEC/UNICAMP), according to ISO 8589: 2007 (International Organization for Standardization, 2007). The samples were served (8 g) at 4 ± 1 °C, in a monadic sequential way and balanced complete blocks (Stone et al., 2012), in disposable 50 mL plastic cups, coded with three digits (Meilgaard et al., 2015) in an air-conditioned environment (21 ± 2 °C) and individual cabins. Potable water and cracker biscuits (Bauducco®, Minas Gerais, Brazil) were served for palate cleansing.

Pre-tests were carried out to determine the ideal sucrose concentration and the sweetness equivalence of sweeteners related to sucrose (Medeiros et al., 2019).

2.3 Training and selection of assessors for time-intensity analysis

For the selection of the assessors, individuals were recruited from graduate students and staff from UNICAMP, interested in participating in the study, with at least one year experience in descriptive sensory analysis and ability to use a computer. Sixteen assessors were previously selected through the WALD sequential analysis (Meilgaard et al., 2015) using triangular tests. The assessors were trained in at least three sessions of approximately one hour each, for attribute recognition, the formation of sensory memory of the maximum and minimum references for each attribute, use of the software, and records of the sensations perceived with precision and reliability. The assessors were selected in accordance with ISO 8586: 2012, taking into account the repeatability (p of F_{sample} <0.50) of the results and discrimination between samples (p of $F_{repetition}$> 0.05), in addition to a consensus with the team (American Society for Testing and Materials, 2011; International Organization for Standardization, 2012, 2016). The maximum intensity references were milk chocolate (Nestlé®) for sweetness, semi-dark chocolate (Lacta®) for the attributes bitter taste and chocolate flavor, and the maximum melting rate was considered as the total time for complete melting of the frozen desserts.

2.4 Time-intensity analysis

The TI profile was determined for the attributes sweet taste, bitter taste, chocolate flavor, and melting behavior, separately, according to the International Standard Guide for Time-Intensity Analysis (American Society for Testing and Materials, 2011). Data collection performed using the TI Analysis of Flavors and Tastes (TIAFT) (Bolini, 2012).

Twelve selected assessors evaluated the six samples (8 g) at 4 ± 1 °C in three repetitions, and the intensity of each attribute was recorded as a function of the time, using a mouse in a 9 cm unstructured linear scale (0 = none; 4.5 = moderate; 9 = strong) (Cadena & Bolini, 2011). At the first warning issued by the computer, the assessor was instructed to place and keep the sample in the mouth, recording the attribute perceived; at the second beep, the assessor should swallow the sample, recording the attribute until the end of the perception, and the third beep indicated the end of the test.

The evaluation times for the attributes sweet taste, bitter taste, and chocolate flavor were 5 seconds of initial waiting, 15 seconds of residence in the mouth, and 60 seconds after ingestion. For the melting rate, the time of 5 seconds of initial waiting and 60 seconds of residence in the mouth was considered. The parameters of the TI curves were: the maximum intensity of the attribute (I_{max}); the time to reach maximum intensity (TI_{max}); the total area under the curve (A_{tot}); and the total duration time of the attribute (T_{tot}) (American Society for Testing and Materials, 2011). The results of the TI analysis were analyzed by Analysis of Variance (ANOVA), and Tukey's test ($p \leq 0.05$), and the TI curves were constructed using the averages of the parameters as a function of time, for each sample in relation to each attribute. Data were analyzed using the software XLSTAT for Windows version 2012.5 (Addinsoft, Paris, France)

2.5 Acceptance tests

For the acceptance test, 120 consumers (Hough et al., 2006), male and female aged between 18 and 60 years, representative of the target audience (Stone & Sidel, 2004), evaluated the overall impression of the samples using a 9-cm unstructured linear hedonic scale, anchored at the ends by the terms "I disliked it very much" on the left, and "I liked it very much" on the right (Lawless & Heymann, 2010). The purchase intention was assessed using a 5-point scale, ranging from "certainly not buy it" to "certainly buy it" (Meilgaard et al., 2015). The ideal intensities of the attributes sweet taste, chocolate flavor, and creaminess were also evaluated, using the Just-About-Right (JAR) scale with five (5) categories, being "much less than ideal", "less than ideal", "ideal", "more than ideal" and "much more than ideal". The results were collected using the FIZZ Network Sensory software (version 2.47b - Biosystemes, Couternon, France). The averages were analyzed by ANOVA and Tukey's test ($p \leq 0.05$), and the purchase intention was analyzed by frequency histograms. Data from the JAR scale were subjected to penalty analysis. Data from the overall impression were correlated with the parameters of the TI curves of sweetness, bitterness, chocolate flavor, and melting behavior, using Partial Least Squares (PLS) regression analysis. All data were analyzed with the aid of the program XLSTAT for Windows version 2012.5 (Addinsoft, Paris, France).

3 Results and discussion

3.1 Time-intensity analysis (TI)

The results obtained through ANOVA and Tukey's test are shown in Tables 2, 3, 4, and 5, and the TI curves are shown in Figure 1 for the attributes sweet taste, bitter taste, chocolate flavor, and melting behavior, respectively.

3.1.1 Sweet taste

Concerning the attribute sweet taste, no significant differences were observed between the formulations (Table 2) for the parameters Timax (Time to reach maximum intensity) and Ttot (Total time) ($p > 0.05$). For the maximum intensity (Imax) of this attribute, the sucralose-sweetened samples (RSUC and SSUC) showed the lowest values, and the soy protein-based sample (SSUC) differed from the soy protein-based sample sweetened with sucrose and stevia (SSAC and SSTE), whereas the sample RSUC was different only from SSAC. A similar result was found for the Area, also differing from the rice protein-based sample sweetened with steviol glycoside (RSTE).

Table 2. ANOVA and Tukey's test of Time-Intensity (TI) parameters for the sweet taste of the six chocolate-flavored frozen desserts formulations.

Attributes	RSAC	RSUC	RSTE	SSAC	SSUC	SSTE
Timax	18.51[a]	18.81[a]	19.15[a]	17.87[a]	19.39[a]	18.00[a]
Imax	6.33[abc]	5.97[bc]	6.66[abc]	7.05[ab]	5.72[c]	7.37[a]
Ttot	36.08[a]	36.82[a]	40.36[a]	37.42[a]	33.73[a]	37.13[a]
Area	118.16[abc]	109.36[bc]	142.87[a]	135.78[ab]	98.55[c]	149.18[a]

Rice protein with sucrose (RSAC); Rice protein with sucralose (RSUC); Rice protein with steviol glycoside (RSTE); Soy protein with sucrose (SSAC); Soy protein with sucralose (SSUC); Soy protein with steviol glycoside (SSTE). Averages with the same letter on the same line do not present a significant difference at $p \leq 0.05$.

3.1.2 Bitter taste

Significant differences were observed for the time to reach the maximum intensity of the bitter taste only between RSTE and SSAC (Table 3), and the soy protein-based sample sweetened with sucrose showed the shortest time. The stevia-sweetened samples (RSTE and SSTE) showed higher values for maximum intensity

(Imax), total duration (Ttot), and Area under the curve (Area), whereas the sucralose-sweetened samples showed the lowest values, with significant differences between them ($p \leq 0.05$). The soy protein-based sample sweetened with sucrose (SSAC) was different from the stevia-sweetened samples (RSTE and SSTE) and similar to the rice protein-based sample sweetened with sucrose (RSAC), which differed from the sucralose-sweetened samples (RSUC and SSUC). Although the bitter taste is correlated with the use of steviol glycoside (Peres et al., 2018; Freitas et al., 2016; Voorpostel et al., 2014; Cadena et al., 2013), the bitter taste of the samples of this study may be due to the natural bitterness of the cocoa powder used in the formulations.

Table 3. ANOVA and Tukey's test of Time-Intensity (TI) parameters for the bitter taste of the six chocolate-flavored frozen desserts formulations.

Attributes	RSAC	RSUC	RSTE	SSAC	SSUC	SSTE
Timax	16.95[ab]	16.91[ab]	19.14[a]	15.92[b]	17.19[ab]	17.99[ab]
Imax	7.02[bc]	5.72[d]	8.01[a]	6.36[cd]	5.50[d]	7.70[ab]
Ttot	32.34[ab]	28.32[b]	36.84[a]	30.32[b]	28.08[b]	37.93[a]
Area	137.20[ab]	97.77[c]	166.09[a]	111.38[bc]	101.24[c]	165.47[a]

Rice protein with sucrose (RSAC); Rice protein with sucralose (RSUC); Rice protein with steviol glycoside (RSTE); Soy protein with sucrose (SSAC); Soy protein with sucralose (SSUC); Soy protein with steviol glycoside (SSTE). Averages with the same letter on the same line do not present a significant difference at $p \leq 0.05$.

3.1.3 Chocolate flavor

No differences were observed among the samples ($p \leq 0.05$) for the parameters Timax and Ttot of the chocolate flavor (Table 4). However, the sucralose-sweetened samples (RSUC and SSUC) showed the lowest intensities of this attribute, not differing from the soy protein-based sample sweetened with steviol glycoside (RSTE). Regarding the attribute Area, the sample RSTE had a higher average, differing from the sucralose-sweetened samples (RSUC and SSUC).

Table 4. ANOVA and Tukey's test of the Time-Intensity (TI) parameters for the chocolate flavor of the six chocolate-flavored frozen desserts formulations.

Attributes	RSAC	RSUC	RSTE	SSAC	SSUC	SSTE
Timax	16.21[a]	16.82[a]	16.62[a]	16.31[a]	16.96[a]	17.94[a]
Imax	6.66[a]	5.23[b]	6.02[ab]	6.39[a]	5.01[b]	6.41[a]
Ttot	27.82[a]	23.83[a]	28.20[a]	27.59[a]	25.98[a]	29.71[a]
Area	114.21[ab]	90.05[bc]	110.71[ab]	106.98[ab]	80.51[c]	116.44[a]

Rice protein with sucrose (RSAC); Rice protein with sucralose (RSUC); Rice protein with steviol glycoside (RSTE); Soy protein with sucrose (SSAC); Soy protein with sucralose (SSUC); Soy protein with steviol glycoside (SSTE). Averages with the same letter on the same line do not present a significant difference at $p \leq 0.05$.

3.1.4 Melting behavior

The samples differed significantly ($p \leq 0.05$) only for the total melting time, and the samples made with sucrose substitution (RSUC, RSTE, SSUC, and SSTE) showed a longer time for a complete melt, not differing from each other, with significant differences from the sucrose-sweetened samples (RSAC and SSAC) (Table 5). The use of inulin and maltodextrin as body agents to replace sucrose may have prolonged the melting time (Góral et al., 2018).

Table 5. ANOVA and Tukey's test of Time-Intensity (TI) parameters for melting of the six chocolate-flavored ice cream formulations.

Attributes	RSAC	RSUC	RSTE	SSAC	SSUC	SSTE
Ttot	19.83[c]	23.70[ab]	25.53[a]	20.49[c]	24.95[a]	24.10[ab]
Area	100.83[a]	88.43[a]	98.13[a]	79.90[a]	95.93[a]	92.85[a]

Rice protein with sucrose (RSAC); Rice protein with sucralose (RSUC); Rice protein with steviol glycoside (RSTE); Soy protein with sucrose (SSAC); Soy protein with sucralose (SSUC); Soy protein with steviol glycoside (SSTE). Averages with the same letter on the same line do not present a significant difference at $p \leq 0.05$.
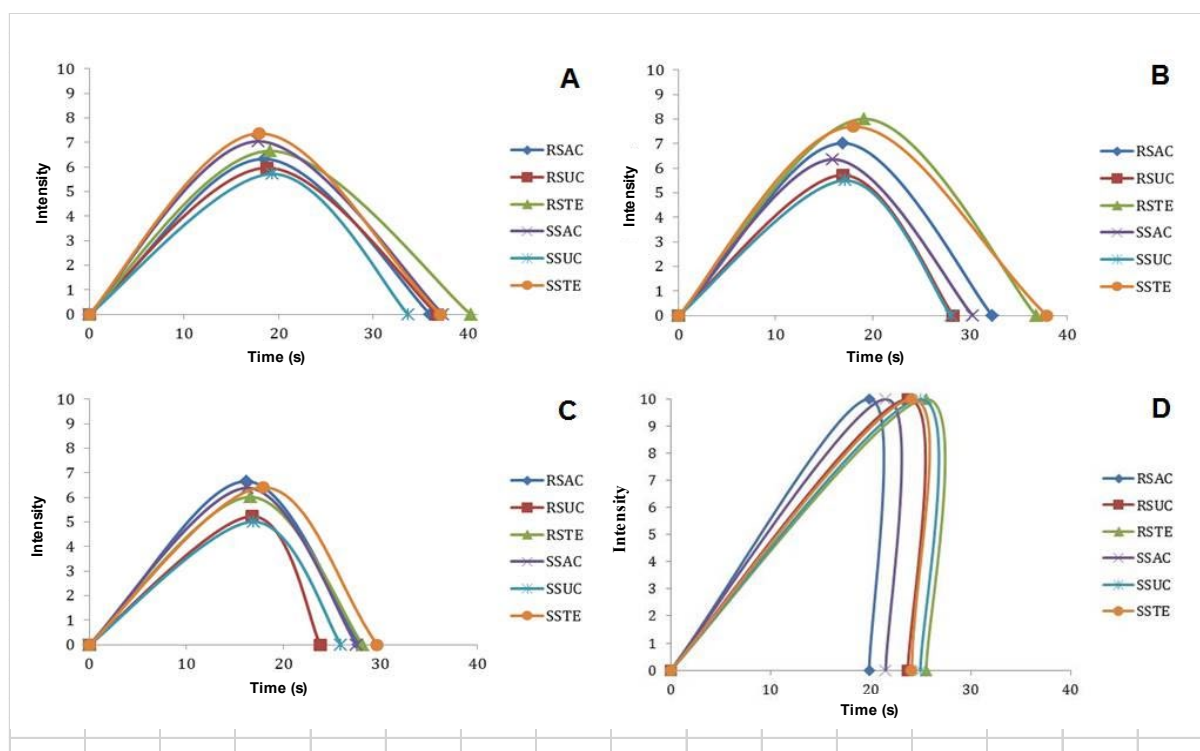
Figure 1. Time-intensity (TI) curve for the attributes sweet taste (A), bitter taste (B), chocolate flavor (C), and melting (D) of the six chocolate-flavored frozen desserts formulations.

3.2 Acceptance test

The results of the acceptance test analyzed by ANOVA and Tukey's test ($p \leq 0.05$) for the overall impression are shown in Table 6, and the internal preference map is shown in Figure 2. The principal components 1 and 2 explained 52.13% of the variance for the acceptance of the samples, indicating a clear division between consumers.

Table 6. ANOVA and Tukey's test for the overall impression of the six chocolate-flavored frozen desserts formulations.

	RSAC	RSUC	RSTE	SSAC	SSUC	SSTE	MSD
Overall impression	6.17[a]	5.51[bc]	5.42[c]	7.30[a]	5.62[bc]	5.76[bc]	0.67

Rice protein with sucrose (RSAC); Rice protein with sucralose (RSUC); Rice protein with steviol glycoside (RSTE); Soy protein with sucrose (SSAC); Soy protein with sucralose (SSUC); Soy protein with steviol glycoside (SSTE); Minimum significant difference (MSD). Averages with the same letter on the same line do not present a significant difference at $p \leq 0.05$.

The sucrose-sweetened samples were the most preferred, differing ($p \geq 0.05$) from the samples sweetened with sweeteners, which showed lower acceptance, with scores above 4.5 (indifference) considering the hedonic scale from 0 to 9 cm. This result can be seen in Figure 2, which showed that the SSAC and RSAC were positioned close to most consumers (represented by red dots), whereas the other samples were located on the opposite side, far from most consumers.
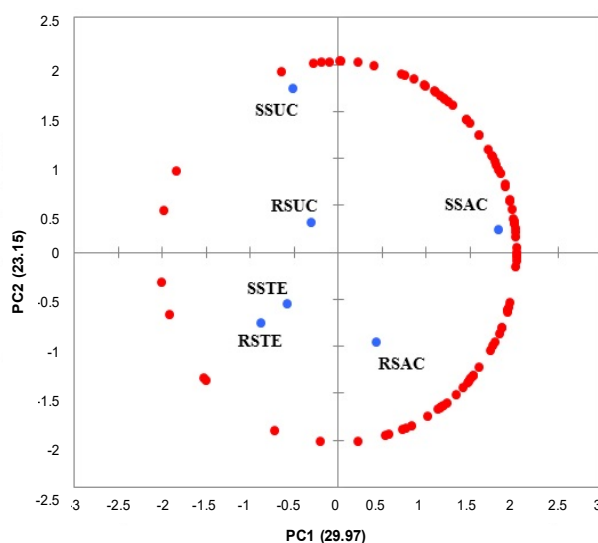
Figure 2. Internal preference map (PC1 × PC2: 53.12%).

3.3 Purchase intention

The purchase intention was analyzed using histograms with the distribution of responses of the consumers in the acceptance test of the chocolate-flavored frozen desserts (Figure 3).

The sucrose-sweetened samples (RSAC and SSAC) showed positive purchase intent, with 57% of consumers showing interest in buying ("certainly would buy it" and "probably would buy it") the rice protein-based sample (RSAC), and 80% in buying the soy protein-based sample (SSAC). The rice protein-based samples sweetened with sucralose (RSUC) and stevia (RSTE) had a greater number of undecided consumers, 30 and 31% respectively, with a similar number of consumers with positive (35 and 32%, respectively) and negative intentions (32 and 38%, respectively). The soy protein-based samples sweetened with sucralose (SSUC) and stevia (SSTE) showed a greater distribution throughout the five points of the scale, with an emphasis for SSUC and SSTE in the responses "probably would buy it" (30%) and "I probably would not buy it" (26%), respectively.

These data corroborate with the results found in the overall impression, in which the sucrose-sweetened samples were more preferred, and the soy protein-based sample (SSAC) presented the higher scores, with no significant differences ($p \geq 0.05$) from RSAC. This greater purchase intention for the soy protein-based formulation may be due to the familiarization of vegan consumers with soy-based products.
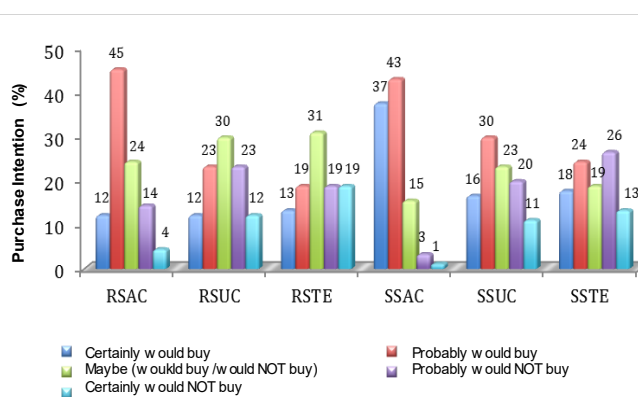

Figure 3. Distribution histograms of the consumers' purchase intention of chocolate-flavored frozen desserts formulations.

3.4 Penalty analysis

The penalty analysis allowed correlating the results from the JAR scale and the overall impression, evaluating the attributes that hindered the consumers' acceptance, corresponding to the lowest scores of the acceptance test (Laguna et al., 2013). The JAR scale was divided into three categories as following: "less than ideal" (1-2); "ideal" (3); and "more than ideal" (4-5), and the percentage of consumers who scored in each category was calculated for each sample (Palazzo & Bolini, 2017). Figure 4 shows the penalties analysis graph, representing the percentages of consumers (x-axis) as a function of the penalties (y-axis) of each attribute (sweet taste, creaminess, and chocolate flavor). The attribute was considered significant when selected by at least 20% of consumers (Laguna et al., 2013).

In general, the chocolate flavor impaired the consumers' preference when the intensity was below the ideal, and 36.63% of consumers reported this characteristic for the formulations with the lower acceptance scores. Concerning the sweet taste, a lower consumers' preference was observed for the formulations with scores above the ideal sweetness, which was reported by 20.14% of consumers.
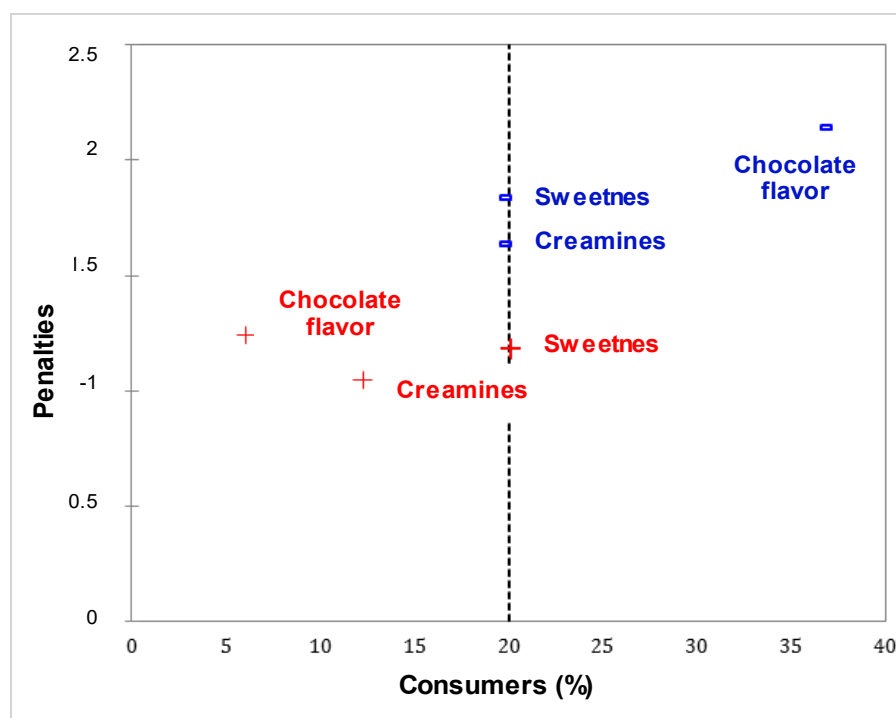

Figure 4. Penalties analysis graph of the attributes creaminess, sweetness, and chocolate flavor for the overall impression evaluated by 120 consumers. Cutoff point: 20% of consumers.

3.5 Temporal drivers of linking

The results obtained in the TI analysis were correlated with the overall impression, using the multivariate statistics partial least squares regression (PLS), aimed to obtain the drivers of liking of the plant-based frozen desserts formulations. The overall impression was considered as the dependent variable, and the TI parameters were associated with the independent variables.

The parameters of the TI curves (TImax) of sweetness, bitterness, and chocolate flavor (orange color bars in Figure 5) contributed negatively to the consumers' acceptance. The longer the time to start the perception of maximum sweetness, bitterness, and chocolate flavor, lower the overall impression.
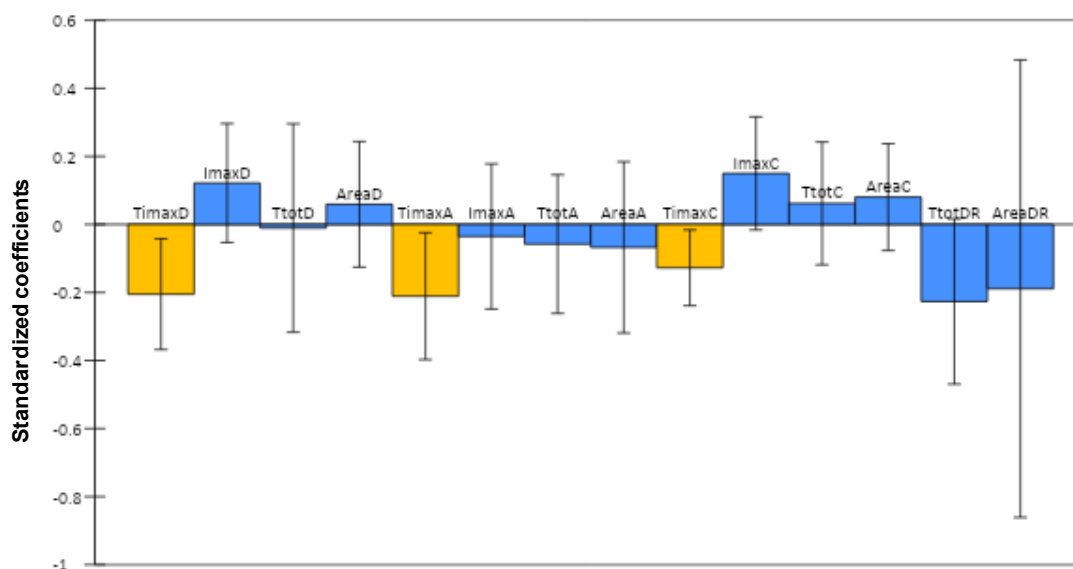
Figure 5. Partial least squares regression analysis of the Time-Intensity (TI) curves for sweetness, bitterness, chocolate flavor, and melting behavior of the samples, and the overall impression by consumers.

4 Conclusion

No significant differences ($p \leq 0.05$) were observed in the temporal profile of the plant-protein based frozen desserts.

The use of sweeteners provided changes in the formulations, and the replacement of sucrose by sucralose provided a lower intensity of sweetness, bitterness, and chocolate flavor of the frozen desserts, whereas the stevia-sweetened formulations showed greater intensity and duration of the bitter taste. The use of body agents directly affected the texture of the frozen desserts, prolonging the melting time in the mouth. The use of sweeteners had a negative impact on the consumers' acceptance, and the samples were characterized by presenting a less intense chocolate flavor and sweetness higher than ideal.

Although all samples showed satisfactory acceptance, only the sucrose-sweetened samples exhibited a positive purchase intention. Further studies are needed to optimize and improve low-calorie vegan formulations.

Acknowledgements

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