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Sensory approach to added sugar reduction in strawberry juices using fuyu persimmon

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Abstract

The aim of this study was to produce strawberry juice with reduced added sugar content, use the alternative natural sweetness of persimmon, and evaluate its physicochemical and sensory characteristics. Five different strawberry juice formulations were prepared with a 25% reduction in the added sucrose content with 0, 12.5, 25, 37.5, and 50% added persimmon pulp. Color, soluble solids, pH, and titratable acidity were evaluated, and CATA and acceptance sensory tests were performed with 100 consumers. In general, adding persimmon pulp to strawberry juice significantly affects both its physicochemical and sensory properties. From a physicochemical point of view, as the persimmon content increased, the strawberry juice tended to turn from red to orange, and there was an increase in soluble solids content and pH, as well as a decrease in acidity. From a sensory point of view, changes in sensory profile and product acceptability were also observed. However, persimmon showed potential as a natural sweetener in strawberry juice to reduce added sugar. Formulations with lower levels of persimmon pulp (12.5 and 25%) showed promise as these formulations maintained the valued sensory characteristics of strawberry juice and used the natural sweetness of persimmon to reduce added sugars, making them healthier beverage alternatives.

Keywords: CATA; mixed drink; persimmons; strawberry; sugar.

Practical Application: Fuyu Persimmon can be a promising alternative for sugar reduction in juices.

1 INTRODUCTION

Chronic noncommunicable diseases (NCDs) are the main cause of mortality in the world and are now considered one of the major public health problems, accounting for 74% of all deaths worldwide (WHO, 2023a). In Brazil, the scenario is similar, with NCDs being the health problem of the greatest magnitude. In 2019, NCDs were responsible for more than 40% of all premature deaths, that is, deaths of people between 30 and 69 years of age (Brazil, 2023).

The relationship between the excessive sucrose intake and the high sugar content in processed foods and the surge in NCD risk is well-documented and irrefutable (Singh et al., 2015; Guasch-Ferré & Hu, 2019). Such dietary habits, particularly the consumption of sugar-sweetened beverages, which include sodas, sweetened fruit juices, energy drinks, and similar products, are responsible for an estimated 184,000 deaths per year worldwide (Singh et al., 2015). While fruit juices are often perceived as healthier alternatives to sugar-sweetened beverages, they can contain equivalent amounts of sugar and calories (Guasch-Ferré & Hu, 2019).

Against this backdrop, the World Health Organization (WHO) has issued guidelines discouraging the use of non-sugar sweeteners (NSS) as a weight management strategy or as a sugar substitute to reduce the risk of NCDs. Based on a systematic review, using NSS has been shown not to offer long-term benefits in reducing body fat in both adults and children (Anvisa, 2023; WHO, 2023b). Consequently, there is an impetus to seek out alternative methods to decrease the intake of free sugars, favoring the consumption of foods containing natural sugars, like fruits, and encouraging the choice of unsweetened beverages (WHO, 2023b).

In response to these health challenges and in alignment with WHO recommendations, the beverage industry has initiated a pivot toward innovation, especially with fruit-based juice blends and mixed beverages. The development of mixed beverages is one avenue through which the industry seeks to offer unique beverages with new flavors and enhanced sensory attributes (Curi et al., 2017; Sobhana et al., 2014). The creation of these beverage blends also provides an opportunity to improve the nutritional profile of juices by combining the nutrients present in different fruits (Campos et al., 2020; Prado et al., 2022; Stavale et al., 2019).

Fruits serve not only to sweeten these beverages naturally but also to increase fiber content and bioactive compounds,

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contributing to a healthier product profile (Stavale et al., 2019). As a result, there is a growing consumer demand for foods that are simultaneously palatable, indulgent, and health-conscious. Fruits have emerged as ideal options due to their robust nutritional profile and appealing sensory characteristics. The strawberry is a fruit appreciated for its sensory characteristics, as well as its very favorable nutritional content and high economic value (Paparozzi et al., 2018). The persimmon is a fruit with a pleasant taste, high nutritional value, high sugar content, and an important source of vitamin C and mineral salts (Kluge & Tessmer, 2018).

Thus, highlighting the importance and interest of the food industry and consumers in providing and acquiring products with sensory and nutritional quality, the combination of a mixed strawberry and persimmons juice, using the natural sweetness of persimmons as a healthier sugar substitute, can be an interesting strategy. This strategy reflects an evolving trend toward healthy and enjoyable consumer products. In light of this, the objectives of this study were multifaceted:

- to formulate a strawberry juice with reduced sugar content, utilizing the natural sweetness of the persimmons to minimize the need for additional sugars;
- to characterize the juice in terms of physicochemical parameters;
- to evaluate the sensory characteristics of the different juice blends using the Check-All-That-Apply (CATA) methodology;
- to evaluate consumer acceptance.

2 MATERIAL AND METHODS

2.1 Juice preparation

Strawberries and Fuyu persimmons were obtained from a production lot grown in the Fruticulture Sector Orchard of the Universidade Federal de Lavras, UFLA. They were then transported to the Department of Food Science, DCA-UFLA, where they were identified, stored at -18°C, and prepared as juice formulations according to the flowchart in Figure 1. The juice formulations were prepared with concentrations, as indicated in Table 1. The sucrose concentration was established through pre-tests and set at 6%, chosen in compliance with regulations that allow for a maximum of 10% sucrose, calculated in grams of sucrose per 100 g of juice (Brazil, 2009).

A correlation was drawn between sucrose levels in the persimmon pulp and the sucrose content in each formulation. The amount of sucrose from the persimmon pulp at its highest stage of maturation was calculated based on the amount of

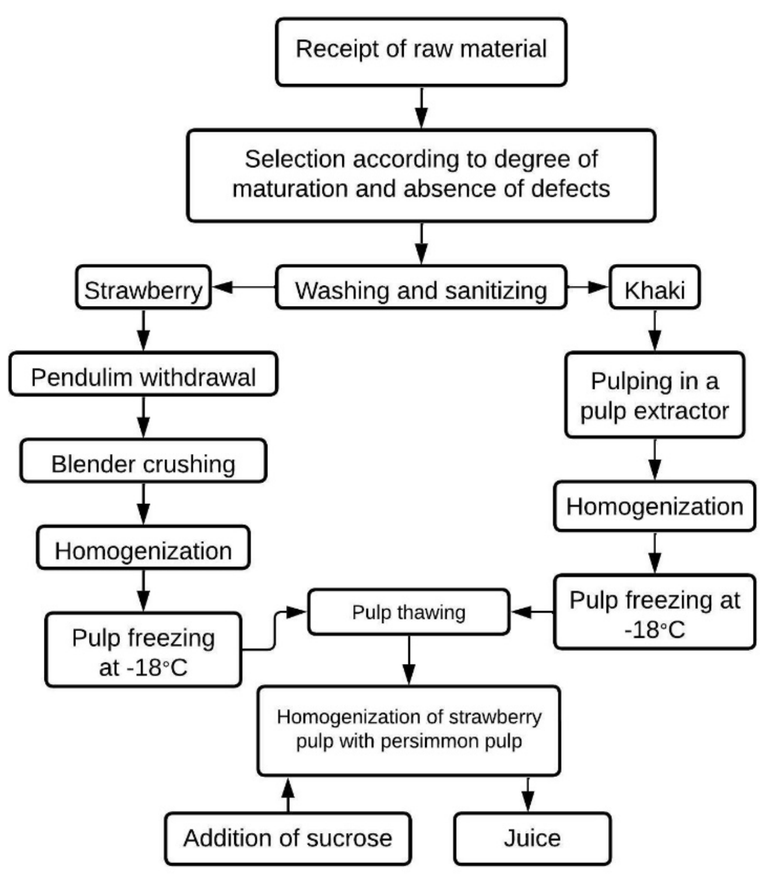


Figure 1. Production flowchart of strawberry juice added with persimmon pulp.

Table 1. Strawberry pulp, persimmon pulp, and sucrose concentrations used in the different juice formulations. Strawberry, persimmon, and sucrose pulp concentration.

Formulation	Strawberry pulp (g/100 g of juice)	Persimmon pulp (g/100 g of juice)	Sucrose from persimmon pulp (g)	Sucrose added in formulation (g)	Total sucrose (g)
1	100	0	0	6	6
2	87.5	12.50	0.48	4.5	4.98
3	75.0	25.00	0.96	4.5	5.46
4	62.5	37.50	1.44	4.5	5.94
5	50.0	50.00	1.92	4.5	6.42

sucrose in 100 g of dry matter of Fuyu persimmon, considering the moisture content of 81% and the sucrose content in the dry matter equal to 20.25 g (Elias et al., 2008; Senter et al., 1991). Based on the conversion of sucrose content in the dry matter to the total matter, a content of 3.85 g of sucrose was found in 100 g of persimmon pulp.

2.2 Physical and chemical characteristics

A Minolta CR 400 colorimeter was used for the instrumental color assessment, according to the CIELAB system (Minolta, 1998). The coordinates luminosity (L*), yellow index (b*), and red index (a*) were recorded. Saturation (C*) and hue angle (h, degrees) were also determined (Pathare et al., 2013) (Equations 1 and 2):

$$C^* = (a^*2 + b^*2)\ 0.5 \quad (1)$$

$$h = \tan-1\ (b^*/a^*) \quad (2)$$

Soluble solids were determined by refractometry using a digital refractometer previously calibrated with distilled water. The results were expressed in °Brix, according to the method of the Association of Official Analytical Chemists (AOAC, 2016). The pH was determined using a Schott Handylab pH meter, according to the AOAC technique (2016).

The titratable acidity was determined by titration with a 0.1 N sodium hydroxide (NaOH) solution, using phenolphthalein as the indicator, according to the Adolfo Lutz Institute (IAL, 2008). Results were expressed as a percentage of citric acid.

2.3 Sensory analysis

The study was performed in a standardized sensory environment (ISO 2007; ISO 8589) and following good sensory practices (Lawless & Heymann, 2010) at the Nutrition Department (DNU) and the Food Science Department (DCA) at the UFLA, Brazil. The UFLA Human Research Ethics Committee approved the study under code CAAE 09214419.1.0000.5148.

In total, 100 consumers of fruit juice and sweetened beverages (male and female, aged from 18–60 years old) performed the tests. They agreed to participate in the study by filling out a term approved by a research ethics board. All participants were informed that they would evaluate strawberry juice formulations, but without knowing about the addition of persimmon pulp.

During the CATA test, formulations were served one at a time (30 mL) at refrigerated temperature, with the serving order balanced across respondents (Macfie et al., 1989), accompanied by the respective answer sheet. Consumers were instructed to verify all the CATA terms (from the attribute list) that they considered adequate to describe each formulation (Amorim et al., 2023; Ares et al., 2014; Rodrigues et al., 2023).

The sensory terms used in the study (sour, sweet aroma, pumpkin aroma, banana aroma, persimmon aroma, papaya aroma, strawberry aroma, bright, creamy, sweet flavor, orange color, red color, orange-red color, opaque color, rosy-red color, smooth texture, thin/liquid texture, pumpkin flavor, banana flavor, persimmon flavor, papaya flavor, strawberry flavor, particle sensation texture, and viscous texture (thick)) were generated through a focus group composed of fruit juice consumers (Ares & Jaeger, 2015).

After answering the CATA questions for the products under analysis, tasters were asked to fill out the same CATA questionnaire for their ideal strawberry juice (Amorim et al., 2023; Ares et al., 2017; Bruzzone et al., 2015). Sensory acceptance was also assessed. Thus, the form also included a structured 9-point hedonic scale (score 1 for "disliked extremely" and score 9 for "liked extremely") (Stone & Sidel, 2004).

2.4 Data analysis

Data on physical and chemical parameters and sensory attributes obtained from the acceptance test were evaluated by comparing means using the Tukey test ($p \leq 0.05$). Global acceptance test data were also analyzed using principal component analysis with the SensoMaker® software (Pinheiro et al., 2013). For the CATA data, evaluations were based on the proportion of consumers choosing each term, perception maps, a Cochran's Q test, correspondence analysis, and penalty–rewards analysis (Meyners et al., 2013). The statistical analyses were performed using XLStat 2022 (Addinsoft, Paris, France).

3 RESULTS AND DISCUSSION

3.1 Physical and chemical characteristics

Table 2 shows the average results obtained from evaluating the physical and chemical properties of the juice formulations. Color is a key feature in any consumer product and is typically the initial aspect consumers observe (Nunes, 2014). The perception of color can reflect the quality of the product and influence consumer preferences (Segalla et al., 2015).

The color coordinates a* and b* are fundamental in this regard. The a* and b* parameters are chromatic coordinates, where a* goes from green to red ((+a*) indicates red and (-a*) indicates green) and b* goes from blue to yellow ((+b*) indicates yellow and (-b*) indicates blue) (Minolta, 1998). The brightness is measured by the L* parameter, which ranges from dark to light, while the chroma parameter (C*) indicates the saturation or intensity of the color, measured as the distance from the central axis, starting at zero. The hue angle (h°) then describes the actual hue, starting on the +a* axis and moving counterclockwise in degrees, with 0° representing red and 90° representing yellow (Pathare et al., 2013). These hue angles help identify the precise perception of colors that customers experience.

Table 2 demonstrates that the standard juice formulation (formulation 1), made exclusively with strawberry pulp, had the highest a* value (25.08), differing significantly from the other formulations, indicating a greater red color. This difference was significant in comparison to the other formulations. This greater red coloration can be credited to the presence of anthocyanins in strawberries (Ertan et al., 2020). Anthocyanins are natural pigments responsible for the red, blue, and purple hues of numerous fruits, leaves, and flowers (Souza et al., 2014).

On the contrary, formulations 4 and 5, which contained higher concentrations of persimmon pulp, showed increased b* values (14.63 and 14.67, respectively), differing significantly from the others, signifying a tendency toward orange tones. The color of persimmons varies from yellow or orange to dark red; this characteristic is closely linked to the concentration of carotenoid content (Yaqub et al., 2016).

The h° values, in turn, confirm this trend, in which the smallest angle represents the greater intensity of the red color (formulations 1 = 25.15 and 2 = 26.50). On the contrary, formulations 4 and 5 have the highest h° values of 33.19 and 35.36, respectively, indicating greater intensity of the yellow color. There was no significant difference in the luminosity (L*) and intensity (chroma) of the color of the juices evaluated—the addition of persimmon to strawberry juice results in copigmentation, leading to significant differences in color stability.

In addition, significant differences ($p > 0.05$) were observed about the soluble solids content. Formulations 4 and 5 had the highest soluble solids contents, 13.30 and 13.40 °Brix, respectively, standing out from the other formulations. Therefore, as the amount of persimmon pulp increased in the differing formulations, the soluble solids content also increased.

The concentration of soluble solids (SS) determines the fruit's sweetness during ripening and is linked to its flavor. Total soluble solids represent the content of soluble sugars, organic acids, and other minor constituents present in fruits (Chitarra, 2007). The results of soluble solids suggest a better sweetness profile, which comes from natural sugars in ripe persimmons, including glucose, fructose, and sucrose. This sweetness contributes not only to the flavor but also to the juice's perceived quality (Curi et al., 2017; Elias et al., 2008).

Total titratable acidity and pH are important factors that affect juice quality, flavor, stability, and safety (Cavalini et al., 2006). The analyzed formulations showed titratable acidity values between 0.17 and 0.23 g of citric acid/100 g and pH values ranging from 3.40 to 3.90. Statistically significant differences were observed among the formulations, with an overall trend of higher pH and lower acidity at higher concentrations of persimmon pulp. The study findings align with the established principles of Normative Instruction No. 37 of October 1, 2018, which outlines the minimum requirements for fruit juices and pulps. The regulation mandates a minimum soluble solids content of 6.5 °Brix and a pH of 3.3 for strawberry juice (Brazil, 2018).

Thus, the determination of pH, acidity, and the content of soluble solids are important parameters that enhance the flavor appreciation of the fruit and, by extension, its processed products. The concentration of soluble solids, in conjunction with acidity, represents one of the most important indicators for quality assessment, directly influencing the sensory characteristics of fruits and related products such as juices and fruit-based beverages (Azzolini et al., 2004; Cavalini et al., 2006).

3.2 Sensory analysis

Table 3 shows the citation frequency of the attributes consumers chose to describe the strawberry juice formulations evaluated. For strawberry juice, significant differences were observed ($p \leq 0.05$), determined by Cochran's Q test, for most of the attributes, except for sweet aroma.

Formulations 1, 2, and 3 had a similar sensory profile and were often characterized by attributes such as strawberry aroma, bright, strawberry flavor, particle sensation texture, and red color, frequently cited by over 50% of the consumers. These attributes were strongly associated with the ideal formulation (ID), which was mentioned by more than 50% of consumers. The ideal product concept refers to the standard of perfection, i.e., the consumer's description of the product's characteristics as perfect (Giménez-Sanchis et al., 2021). In this regard, for the attributes of strawberry aroma and flavor and red color, formulations 1, 2, and 3 showed no significant differences between each other and also

Table 2. Optical properties and physicochemical characteristics of different strawberry juice formulations.

Formulation	L*	a	b	C*	h*	SS	ATT	pH
1	29.27 a	25.08 a	11.80 bc	27.72 b	25.15 d	10.07 c	0.23 a	3.40 e
2	30.72 a	22.21 b	11.09 c	24.82 b	26.50 d	10.27 c	0.21 b	3.54 d
3	30.61 a	21.87 b	12.22 bc	25.06 b	29.15 c	11.50 b	0.20 c	3.66 c
4	29.54 a	22.32 b	14.63 a	26.69 b	33.19 b	13.30 a	0.19 d	3.80 b
5	31.19 a	20.66 b	14.67 a	25.35 b	35.36 a	13.40 a	0.17 e	3.90 a

ATT: total titratable acidity (g citric acid/100 g fw); SS: total soluble solids in °Brix; formulations: (1) 100% strawberry and sugar; (2) 87.5% strawberry, 12.5% persimmon and reduced sugar; (3) 75% strawberry, 25% persimmon and reduced sugar; (4) 62.5% strawberry, 37.5% persimmon and reduced sugar; and (5) 50% strawberry, 50% strawberry and reduced sugar. Mean values with equal lowercase letters in the column indicate that there is no significant difference between formulations ($p \leq 0.05$) from Tukey's test.

aligned significantly with the ideal product. Formulation 2 was more efficient in reducing the addition of sucrose in strawberry juice through the use of persimmon pulp at a concentration of 12.5% since this juice obtained characteristics and attributes similar to the juice standard (formulation 1) and the juice considered ideal (ID) from the perspective of consumers.

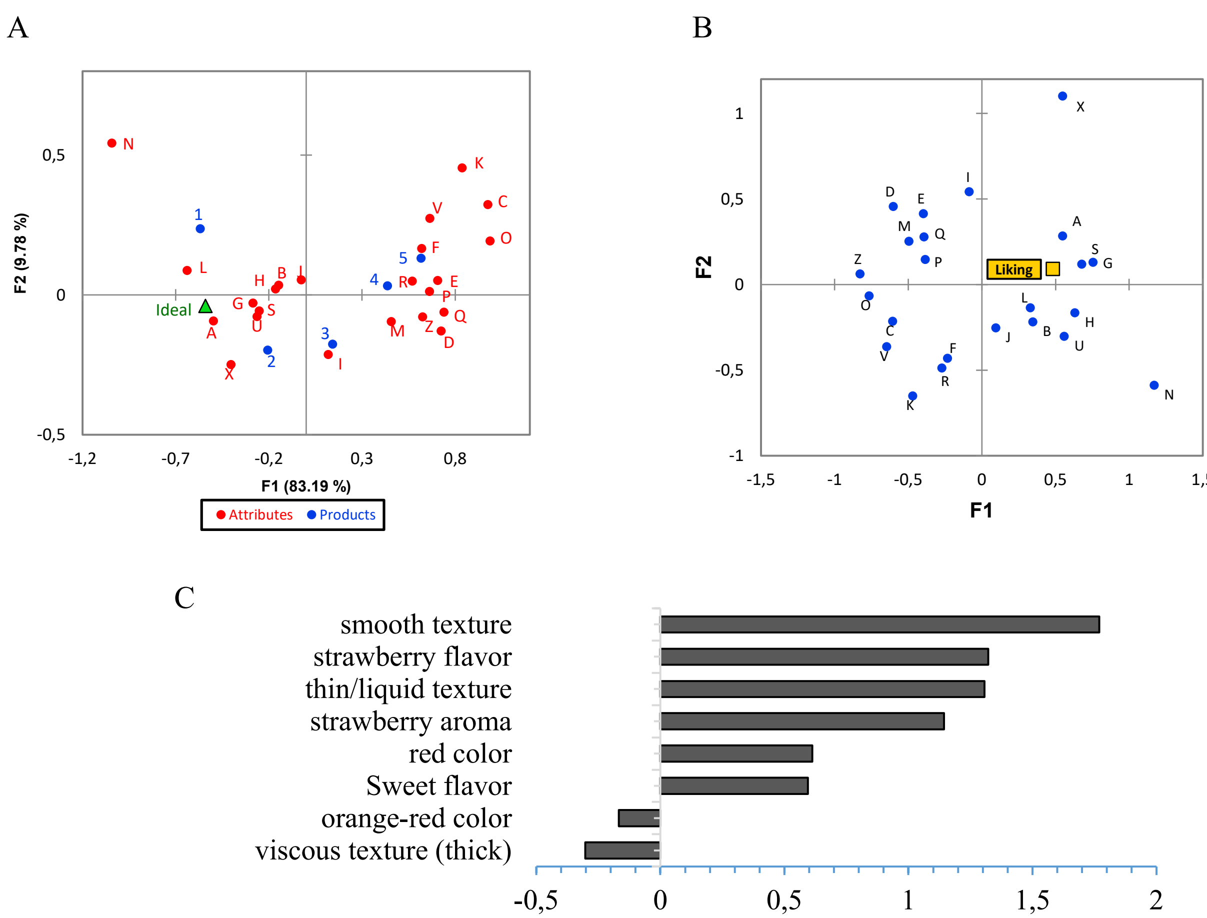
Formulations 4 and 5, which had a higher proportion of persimmon pulp, exhibited significantly similar results to each other but differed from the remaining formulations due to their more frequent attributes of orange-red color, sweet flavor, creamy, and bright. With the increase in persimmon pulp, there was an increase in mentions of the attributes of persimmon aroma, papaya aroma, opaque color, persimmon flavor, papaya flavor, and orange-red color, as well as a reduction in mentions of strawberry flavor and red color.

Figure 2 shows the representation of these attributes, the formulations, and the ideal product from the correspondence analysis, as well as the representation of the attributes about the degree of liking and the penalty analysis. The correspondence analysis obtained a 92.96% explanation of the data, characterizing the wealth of information generated by the CATA questionnaire. Figure 2A demonstrates a distinct separation between two groups: formulations 1, 2, 3, and the ideal formulation form one group, while formulations 4 and 5 compose the other.

It can be seen that juice formulations 1, 2, and ID are closest to each other and are characterized by the attributes sour, rosy-red color, strawberry aroma, red color, particle sensation texture, bright, thin/liquid texture, and sweet aroma. Formulation 3 is distinguished from these by its creamy attribute. Formulations 4 and 5 are characterized by orange-red color, persimmon aroma, papaya aroma, banana aroma, persimmon flavor, papaya flavor, banana flavor, opaque, and viscous texture (thick).

Increasing the concentration of persimmon pulp to 37.5 and 50% in formulations 4 and 5, respectively, results in characteristics such as persimmon flavor and aroma, orange color, and viscous texture. Nevertheless, these attributes are not typical of ideal strawberry juice, as depicted in Figure 2A and Table 3.

Figure 2B shows that the main attributes driving increased acceptance of strawberry juice are sourness, strawberry flavor,



Formulation: (1) 100% strawberry and sugar; (2) 87.5% strawberry, 12.5% persimmon and reduced sugar; (3) 75% strawberry, 25% persimmon and reduced sugar; (4) 62.5% strawberry, 37.5% persimmon and reduced sugar; (5) 50% strawberry, 50% strawberry and reduced sugar. Attributes: A: sour; B: sweet aroma; C: pumpkin aroma; D: banana aroma; E: persimmon aroma; F: papaya aroma; G: strawberry aroma; H: bright; I: creamy; J: sweet flavor; K: orange color; L: smooth texture; M: opaque color; N: thin/liquid texture; O: pumpkin flavor; P: banana flavor; Q: persimmon flavor; R: papaya flavor; S: strawberry flavor; T: particle sensation texture; U: red color; V: orange-red color; X: rosy-red; Z: viscous texture (thick).

Figure 2. (A) Representation of attributes, formulations, and ideal products from correspondence analysis, (B) representation of attributes about degree of liking, and (C) penalty analysis.

and aroma, which are also prominent in formulations 1, 2, and ID. A penalty analysis was also conducted to determine the attributes most related to overall acceptability by consumers, measuring how acceptability was penalized or boosted due to deviations in hedonic scores and sensory profiles between actual and ideal products (Amorim et al., 2023; Ares et al., 2014). Figure 2C shows which attributes positively and negatively impacted the average acceptance of the different strawberry juice formulations. Attributes such as smooth texture, strawberry flavor, thin/liquid texture, strawberry aroma, red color, and sweet flavor positively influenced the acceptance of the juice, ranging from 0.6 to 1.8 points. On the contrary, orange-red color and viscous texture (thick) negatively impact dislike by around 0.2 and 0.3 points.

Consumer acceptance was assessed using a nine-point hedonic scale. Table 4 shows the average acceptance scores for the sensory attributes of the different juice formulations, including color, aroma, flavor, texture, sweetness, and overall impression. The acceptance test revealed that formulations 1 and 2 showed no significant difference in acceptance for all the attributes evaluated: color, aroma, flavor, texture, sweetness, and overall impression. However, formulation 1 statistically differed from

Table 3. Proportion of consumers who selected descriptors in the CATA questionnaires to describe strawberry juices and the ideal product.

Attributes	1	2	3	4	5	ID
Sour *	0.441 (c)	0.402 (c)	0.294 (bc)	0.127 (ab)	0.108 (a)	0.451 (c)
Sweet aroma	0.549 (a)	0.471 (a)	0.382 (a)	0.422 (a)	0.363 (a)	0.422 (a)
Pumpkin aroma *	0.010 (a)	0.010 (a)	0.059 (ab)	0.147 (bc)	0.206 (c)	0 (a)
Banana aroma *	0 (a)	0.039 (ab)	0.137 (bc)	0.176 (c)	0.127 (bc)	0.010 (a)
Persimmon aroma *	0.029 (ab)	0.069 (abc)	0.167 (cd)	0.147 (bc)	0.284 (d)	0.010 (a)
Papaya aroma *	0.069 (a)	0.069 (a)	0.127 (ab)	0,235 (b)	0.245 (b)	0.010 (a)
Strawberry aroma *	0.814 (d)	0.706 (cd)	0.608 (bc)	0.480 (ab)	0.402 (a)	0.804 (d)
Bright *	0.765 (c)	0.667 (bc)	0.529 (ab)	0.559 (ab)	0.441 (a)	0.520 (ab)
Creamy *	0.216 (a)	0.578 (b)	0.569 (b)	0.520 (b)	0.529 (b)	0.441 (b)
Sweet flavor *	0.529 (ab)	0.441 (a)	0.480 (ab)	0.569 (ab)	0.618 (ab)	0.637 (b)
Orange color *	0.020 (a)	0 (a)	0.029 (ab)	0.049 (ab)	0.098 (b)	0 (a)
Smooth texture*	0.225 (bc)	0.098 (ab)	0.108 (ab)	0.049 (a)	0.049 (a)	0.294 (c)
Opaque color*	0.069 (ab)	0.137 (abc)	0.255 (cd)	0.176 (bcd)	0.284 (d)	0.039 (a)
Thin/liquid texture*	0.667 (d)	0.176 (bc)	0.029 (ab)	0.020 (ab)	0 (a)	0.343 (c)
Pumpkin flavor *	0 (a)	0 (a)	0.078 (ab)	0.147 (b)	0.157 (b)	0 (a)
Banana flavor *	0.029 (ab)	0.088 (abc)	0.118(bcd)	0.206 (d)	0.196 (cd)	0 (a)
Persimmon flavor *	0 (a)	0.088 (ab)	0.147 (bc)	0.196 (bc)	0.235 (c)	0.010 (a)
Papaya flavor *	0.059 (ab)	0.078 (ab)	0.167 (bc)	0.206 (c)	0.235 (c)	0.020 (a)
Strawberry flavor *	0.755 (c)	0.716 (c)	0.618 (bc)	0.461 (ab)	0.392 (a)	0.686 (c)
Particle sensation texture *	0.500 (b)	0.588 (b)	0.490 (b)	0.441 (ab)	0.451 (b)	0.265 (a)
Red color *	0.598 (bc)	0.500 (b)	0.588 (bc)	0.451 (ab)	0.284 (a)	0.725 (c)
Orange-red color *	0.167 (ab)	0.147 (ab)	0.216 (b)	0.510 (c)	0.647 (c)	0.020 (a)
Rosy-red color *	0.294 (cd)	0.412 (d)	0.235 (bc)	0.118 (ab)	0.049 (a)	0.186 (abc)
Viscous texture (thick)*	0.039 (a)	0.324 (b)	0.529 (c)	0.706 (cd)	0.755 (d)	0.108 (a)

Formulations: (1) 100% strawberry and sugar; (2) 87.5% strawberry, 12.5% persimmon and reduced sugar; (3) 75% strawberry, 25% persimmon and reduced sugar; (4) 62.5% strawberry, 37.5% persimmon and reduced sugar; (5) 50% strawberry, 50% strawberry and reduced sugar; ID: ideal formulation; *significant differences between formulations according to Cochran's Q test at p 0.05. Comparisons between pairs using the critical difference (Sheskin) procedure; different letters in the same line show significant differences for each attribute.

Table 4. Means of acceptance of sensory attributes for the different juice formulations.

Formulation	Color	Aroma	Flavor	Texture	Sweetness	Overall impression
1	7.78 ± 1.01 a	7.45 ± 1.31 a	7.08 ± 1.67 a	7.09 ± 1.39 a	6.98 ± 1.51 a	7.21 ± 1.20 a
2	7.52 ± 1.08 ab	7.20 ± 1.33 a	6.58 ± 1.49 ab	6.92 ± 1.42 a	6.49 ± 1.52 ab	6.90 ± 1.30 ab
3	7.19 ± 1.57 bc	6.55 ± 1.67 b	6.08 ± 1.85 bc	6.15 ± 1.79 bc	6.13 ± 1.89 b	6.30 ± 1.61 bc
4	6.76 ± 1.42 c	6.30 ± 1.83 bc	5.39 ± 2.00 cd	5.73 ± 1.87 c	6.03 ± 1.85 b	5.86 ± 1.76 cd
5	6.24 ± 1.60 d	5.83 ± 1.76 c	5.30 ± 2.01 d	5.61 ± 1.76 c	5.91 ± 1.85 b	5.69 ± 1.71 d

Formulations: (1) 100% strawberry and sugar; (2) 87.5% strawberry, 12.5% persimmon and reduced sugar; (3) 75% strawberry, 25% persimmon and reduced sugar; (4) 62.5% strawberry, 37.5% persimmon and reduced sugar; (5) 50% strawberry, 50% strawberry and reduced sugar. Mean values with equal lowercase letters in the column indicate that there is no significant difference between formulations ($p \leq 0.05$) from Tukey's test.

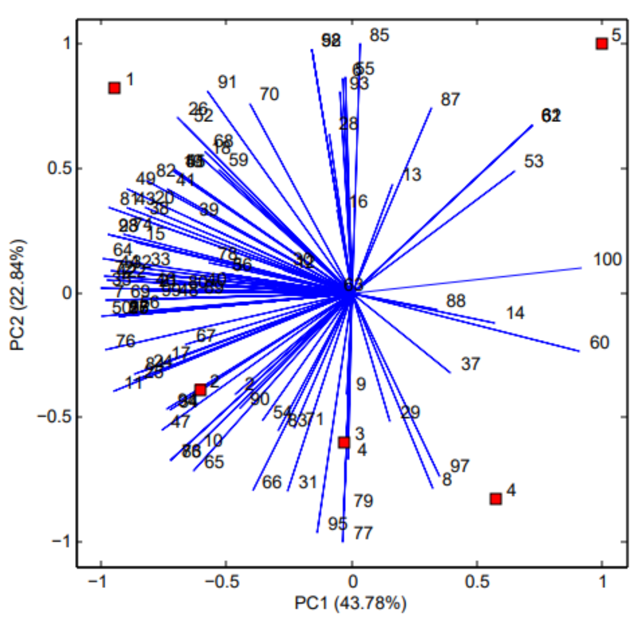
the other formulations (3, 4, and 5) in all attributes. Notably, formulations 4 and 5 received the lowest scores for all attributes. A trend observed was a decrease in acceptance ratings as the concentration of persimmon pulp in the juices increased, potentially due to the intrinsic characteristics of persimmon when present in higher concentrations in the formulations.

Studies show that sweetness drives consumer acceptance of many products (Barker et al., 2021; Hutchings et al., 2019), including juices (Kim et al., 2013). In a study on grape juice, sweetness was also associated with fruit flavor (Meullenet et al., 2008). However, despite the increase in sweetness with adding persimmon, the formulations showed lower acceptance, including for the sweetness attribute. According to Jeltema et al. (2016), consumer acceptance of a product is mainly driven by flavor and texture, and it is important to consider that both are directly related, as the perception of one can lead to changes in the sensory perception of the other.

The internal preference map was generated through principal component analysis (PCA) to facilitate the visualization of the scores obtained in the sensory analysis of global acceptance for different strawberry juice formulations (Figure 3). Vectors represent consumers. Therefore, a higher concentration of vectors near the formulation suggests greater acceptance. The two main components (PC1 and PC2) explained more than 60% of the acceptance data.

As was observed, a distinction for the descriptors of the juice (Figure 2A), for global acceptance, a clustering behavior of the formulations is also observed, the formation of two distinct groups.

Figure 3. Internal preference map generated for global acceptance of different strawberry juice formulations.



Samples: (1)100% strawberry and sugar; (2) 87.5% strawberry, 12.5% persimmon and reduced sugar; (3) 75% strawberry, 25% persimmon and reduced sugar; (4) 62.5% strawberry, 37.5% persimmon and reduced sugar; (5) 50% strawberry, 50% persimmon and reduced sugar

Most consumers, represented by vectors, are in the direction of formulations 1, 2, and 3 from one group. Formulations 4 and 5 form another group, which may be due to and related to the intrinsic characteristics of the persimmon added in higher concentrations in these formulations, mischaracterizing strawberry juice and consequently not contributing to good sensory acceptance.

In general, adding persimmon pulp to strawberry juice significantly affects both its physicochemical and sensory properties. On the contrary, persimmon has the potential to be used as a natural sweetener in strawberry juice to reduce added sugar. However, it is crucial to maintain an adequate balance between the flavors to guarantee the quality of the final product.

Among the different formulations assessed, two stand out: formulation 2, composed of 87.5% strawberry and 12.5% persimmon, and formulation 3, composed of 75% strawberry and 25% persimmon, both with reduced added sugar. These formulations proved promising as they achieved characteristics and sensory attributes comparable to the standard juice (formulation 1, which contains 100% strawberry and added sugar). These formulations maintain the appreciated sensory characteristics of strawberry juice while taking advantage of the natural sweetness of persimmons to reduce added sugars, making healthier drink alternatives.

4 CONCLUSIONS

This study investigated the preparation of various strawberry juice formulations by adding persimmon pulp to reduce the added sugar content. The research concluded that increasing the concentration of persimmon pulp results in significant changes in the physicochemical and sensory properties of strawberry juice.

From a physicochemical perspective, adding persimmon transitioned the color from the classic red hue of traditional strawberry juice to more orange nuances, alongside an increment in soluble solids, elevated pH, and reduced acidity. Sensory analysis revealed that formulations with a lower concentration of persimmon pulp (12.5 and 25%) retained desirable characteristics such as the flavor and aroma of strawberries, a thin and liquid texture, and a pleasing sweetness, garnering favorable consumer acceptance. In contrast, formulations with higher persimmon content (37.5 and 50%) exhibited less consumer acceptance, attributed to their orange-red color and viscous texture. However, persimmon showed potential as a natural sweetener in strawberry juice to reduce added sugar, underscoring the necessity for a balanced interplay of flavors to ensure the final product's quality. It can be concluded that a careful balance of fruit compositions can result in specific and healthy products. This study provides a promising direction for the beverage industry, encouraging innovation in developing fruit-based juice blends that meet health guidelines while satisfying consumer preferences.

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