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Evaluations of the physical and physicochemical properties and perception of liking of conventional and low-calorie orange jellies

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Highlights: “The article addresses the physical, physicochemical and sensory differences of conventional and low-calorie orange jellies and is important because consumers want a low-calorie product but similar to the conventional one.

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ABSTRACT - There is a growing demand for reduced-calorie products today due to changing dietary habits of the population. This challenges the food industry to design products that resemble conventional ones concerning physical, physicochemical, and sensory characteristics. Thus, the objective of this study was to evaluate the physical and physicochemical properties and perception of the liking of conventional and low-calorie orange jellies. Two different formulations (conventional and low-calorie) of each type of orange jelly were prepared and assessed under physical, physicochemical, sensory, and statistical analysis. The results showed that the formulated jellies presented differences in terms of the physical and physicochemical parameters studied, except for the color parameter a*. Conventional jelly had lower values of pH, acidity, and soluble solids, and higher moisture content. Additionally, conventional jelly was found to be lighter, more yellow, less rigid, and less viscous, than low-calorie orange jellies most likely due to its shorter cooking time. The two sensorial methodologies (time-intensity and temporal dominance of sensations analysis) used showed differences in perception of the evaluated stimuli, with the conventional orange jelly having higher dominance intensities for sweet taste and acidity. The low-calorie orange jelly presented a bitter taste, most likely due to the use of sweeteners.

Keywords: Fruit processing; *Citrus sinensis* L. *Osbeck*; Temporal analysis; Rheology.

INTRODUCTION

Jelly is a noble product, highly accepted by consumers (Curi et al., 2018). Its preparation consists of using fruits, sugar, pectin, and edible acids. Jelly making is one of the oldest food preservation processes, allowing the consumption of fruits in the off-season. Stabilization is achieved - in addition to heat treatment - by increasing solids content (reducing water activity) and acidity (reducing the pH) (Figueroa & Genovese, 2019).

However, consumers have been converting to healthier eating habits by eating lower-calorie foods (Foster et al., 2011; Pereira et al., 2019). Additionally, conditions, such as obesity, diabetes, and hypertension, have spurred a search for foods with reduced-calorie content (Abolila et al., 2015). Due to this, the market for low-calorie (light/diet) products has increased in supply and diversification to meet consumer demands (Lima et al., 2019).

In the preparation of fruit jellies, removal of sugar leads to a loss of the "body" of the product (Lima et al., 2019), decreasing the sweetness and texture, and increasing the water content of the final product (Sandrou & Arvanitoyannis, 2000). This makes it necessary to use various additives, such as sweeteners, preservatives, and thickening and gelling agents (Hracek et al., 2010).

Elaboration of a low-calorie product should begin with a detailed examination of the traditional product (Pereira et al., 2019). In conventional jelly formulations high-methoxy (HM) pectin is used, which forms firm and stable gels in media containing soluble solid contents >50% in the presence of an acid, which prevents pectin degradation and provides flexibility to the network formed. In comparison, low-calorie jellies are composed of low-methoxy (LM) pectin, which forms a gel in the presence of bivalent metal ions. By avoiding the use of sugars, product shelf life is reduced due to low soluble solids content, making the jelly more susceptible to syneresis, loss of color, and contamination by fungi and yeasts (Moura et al., 2009). Without sugar, LM pectin is unable to produce adequate gel formation. Due to this, hydrocolloids, such as carrageenan, are added to improve product characteristics. Carrageenan is a sulfated polymer extracted from red seaweed and acts as an emulsifier, gelling agent, and stabilizer. After an aqueous solution of the polymer undergoes cooling, it is able to hold particles in suspension as a gel (Nachtigall & Zambiazi, 2006).

Sweeteners used in products having no/reduced-sugar contents should have: no residual taste, chemical stability similar to sucrose, low-calorie content, a sweetening ability higher than or equal to sucrose, low toxicity/carcinogenicity, and economical accessibility (Pereira et al., 2017). Among the numerous sweeteners found on the market, two stand out, sucralose and acesulfame K (Catharino & Santos, 2011). Acesulfame K is a non-nutritive sweetener and potassium salt (Popova et al., 2012). Due to its bitter aftertaste at high concentrations (Pereira et al., 2013), it is often used in combination with other sweeteners such as sucralose (Chakraborty & Das, 2019). Sucralose is characterized as having a taste similar to sucrose while lacking any unpleasant aftertaste. Furthermore, sucralose has sweetness approximately 600 times that of sucrose and is stable at high temperatures and in a wide range of pH values (Pereira et al., 2017; Rahn & Yaylayan, 2010).

In the preparation of formulations with low-calorie content, it is also necessary to use thickening agents. Polydextrose, is a stable polymer that can be used in a wide range of pH and temperature values, has a long shelf life, is colorless, and has no residual taste (Pereira et al., 2013).

Oranges (*Citrus sinensis* L. *Osbeck*) contain nutritional compounds possessing various therapeutic benefits, including calming, antipyretic, antiviral, and gastric remediation effects. Additionally, they are rich in pectin, giving them enough acidity for use in the production of fruit jellies (Santos et al., 2019).

Brazil is the largest producer and exporter of orange juice (Albuquerque et al., 2019). As the main product of the citrus industry, this highlights the economic importance of citrus to Brazil's agroindustry, exceeding 18,000 t of oranges in 2019 (IBGE, 2020). A viable alternative for orange juice producing industries is the use of orange pulp to produce jellies, which would generate additional commercial value (Oliveira et al., 2016). Jelly is produced through concentration of fruit pulp or juice, with the addition of sugar, pectin, and acid up to the degree Brix (°Bx) suitable for gelling upon cooling (Lima et al., 2019).

Considering the differences between the jelly formulations (conventional and low-calorie), the objectives of this study were to evaluate the physical and physicochemical properties as well as drivers of liking of the jellies by temporal dominance of sensations (TDS) and time-intensity (TI) analyses.

MATERIAL AND METHODS

a) Material

The oranges (Pera Rio variety), acquired in the local market, were washed with neutral detergent, rinsed under running water, and immersed in a 2.5% hypochlorite solution for 15 min. The fruits were then cut in half, and their juice was extracted using an electric juicer. The juice was stored in labeled polypropylene jars and frozen (−18 °C) until processing.

Sugar crystals (Alvinho, Govervador Valadares, MG, Brazil), carrageenan (GastronomyLab, Brasília, DF, Brazil), HM pectin and LM pectin, potassium sorbate (Rica Nata, Piracema, MG, Brazil) and polydextrose, acesulfame K and sucralose (Nutramax, Catanduva, SP, Brazil) were also obtained.

b) Jelly formation process

Two jelly formulations, one conventional, one low-calorie, were produced in triplicate.

The conventional formulation, composed of 60% orange juice and 39% sugar, was added to an open stainless-steel pan and cooked at 70 °C (Souza et al., 2014). After the addition of 1% HM pectin, the mixture was cooked until reaching 65 °Bx (measured with a portable refractometer RT-82). The product was immediately packaged in sterile glass jars and stored in a temperature-controlled chamber at 25 °C.

The low-calorie formulation was similarly prepared, using 60% orange juice, 20% sugar (an approximate 50% reduction in sugar compared to the conventional formulation), and 18.925% polydextrose, which were added to an open stainless-steel pan and cooked until homogenized. After cooking, LM pectin (0.7%) and carrageenan (0.3%) were added until reaching 65 °Bx. A 0.01875% acesulfame K and 0.00625% sucralose mix was then added, followed by 0.05% potassium sorbate diluted in ≈ 2 mL of distilled water. The product was immediately packaged in sterile glass jars and stored in a temperature-controlled chamber at 25 °C. The amounts employed in each of the formulations were determined through previous tests.

c) Physicochemical evaluations of the conventional and low-calorie orange jellies

Moisture analysis (%) was carried out at 65 °C, up to constant weight, in 2 duplicates for each repetition according to AOAC guidelines (AOAC, 2005).

Total soluble solids (°Bx), acidity (% citric acid), and pH analyses were performed according to IAL (2008) and AOAC (2005) guidelines.

The color of the jellies was determined in quadruplicate, according to the methodology proposed by Lau et al. (2000). The values of L* (Luminosity), a*, and b* were determined using a Konica Minolta colorimeter (model CR-400), using D65 (daylight) illumination, and CIELab standards of L* varied from 0 (black) to 100 (white), a* varied from green (-) to red (+), and b* varied from blue (-) to yellow (+).

d) Physical evaluations of the conventional and low-calorie orange jellies

Rheological measurements were performed using a cone/plate-type rheometer (Brookfield model RV-III), with a CP-52 spindle, and Rheocalc v3.0 software. Samples (0.5 g) were analyzed at 25 °C from 1 to 250 rpm, increasing the speed by 50 rpm every 10 min, to obtain an upward curve. The procedure was also repeated oppositely, by progressively reducing the speed (250 to 1 rpm), to obtain a downward curve. Both sets of measurements were performed in duplicate. Experimental data for the flow curves were adjusted using the Power Law Model. The parameters included: the flow consistency index (K in $Pa \cdot s^n$), and the flow behavior index (n, dimensionless).

e) Sensory evaluation of the conventional and low-calorie orange jellies

This work was approved by the local Ethics Committee (827.360).

Forty participants were recruited based upon the following criteria: frequent consumption of jelly, availability, and interest in research participation (Souza et al. 2013).

Two tests were used to select individuals (tasters) from those initially recruited. First, the tasters had to be able to identify different basic tastes according to ISO standard guideline 8586:2012. Briefly, the recruits were asked to taste a number of solutions containing caffeine, citric acid, sucrose, sodium chloride, and monosodium glutamate, and requested to identify the basic tastes of bitter, sour, sweet, salty, and umami. Evaluation of participant sample discrimination abilities was performed using a series of triangular tests (Meilgaard et al., 2006). The second test used conventional orange jelly without the addition of citric acid and with the addition of 0.1% citric acid, defined in paired comparison tests to have a significant difference of 1% (Souza et al. 2011). The sequential analysis of Wald (Wald, 1945) was used to assess the panel's discriminative abilities. A Wald graph was constructed using the defined parameters ($p = 0.30$, $p1 = 0.70$, $\alpha = 0.05$, and $\beta = 0.05$), and tasters were selected or rejected based on the number of correct and total tests. The tasters performed at least ten taste-tests, three tests per day, for one week. A total of 20 tasters, university students between 18 and 35 years of age, were selected.

Time-intensity analysis

Both conventional and low-calorie jellies were evaluated by TI.

The sweetness parameters analyzed were Imax (maximum intensity), TI_5% (time to reach 5% of the maximum intensity on the increasing side of the curve), TD_5% (time to reach 5% of the maximum intensity on the decreasing side of the curve), TI_90% (time to reach 90% of the maximum intensity on the increasing side of the curve), TD_90% (time to reach 90% of the maximum intensity on the decreasing side of the curve), Plateau (the time interval when the intensity is >90% of the maximum intensity), and area (the region below the curve). The scale used for the analyses had 35 points, with 0 signifying no perception, and 35 signifying extreme perception of the taste evaluated (established according to previous tests).

Samples (about 15 g) were presented monadically, in balanced order, in triplicate, with the tasters using a computer to evaluate the intensity of sweet taste. First, the assessors were asked to put the sample in their mouth and score the intensity of sweetness perceived. During TI evaluation the panelists swallowed the sample when they considered it was ready to swallow. The total time of TI evaluation was fixed at 35 s.

Data acquisition and analysis were performed using SensoMaker v1.91, UFLA, Lavras, Brazil (Nunes & Pinheiro, 2013).

Temporal dominance of sensations analysis

The same taste testers were used for TDS analysis. The testers were familiarized with the test and sensory attributes. The jelly samples were evaluated in triplicate. The tasters were asked to identify the dominant flavor throughout the analysis time. For clarification, it was explained to the testers that the dominant sensation is the one that stands out and is perceived with the greatest clarity amongst all the others (Souza et al., 2013). Samples (15 g) were offered in monadic order, according to the samples presentation order suggested by Macfie et al. (1989), in disposable white plastic cups encoded with three-digit numbers, with participants instructed to place each sample in their mouth and begin the analysis for 30 seconds. The evaluated attributes were sweet, acidic, bitter, and orange flavors, defined in pre-tests with the help of the tasters and previous work. To avoid any error, the tasters were instructed that the dominant taste is the taste which is perceived with higher explicit and intensity, than the others (Souza et al., 2013). After the evaluation of each sample, the taster drank water to clean the palate. The analysis occurred in three replicates.

Data acquisition and analysis were performed using SensoMaker v1.91, UFLA, Lavras, Brazil (Nunes & Pinheiro, 2013).

f) Statistical analysis

The experiment was conducted randomly, in triplicate. The results of the physical and physicochemical evaluations were evaluated using analysis of variance (ANOVA) and Tukey average tests, at 5% significance, using Sisvar software (Ferreira, 2014).

The results obtained from each taster and parameter of the TI curve were analyzed by ANOVA, with the sources of variation being the sample and repetition. The tasters who obtained probabilities of $F_{sample} \geq 0.05$ and $F_{repetition} < 0.05$, in at least one of the parameters, were excluded. In other words, the tasters who did not have the capacity to discriminate between the samples and did not show repeatability were dismissed.

The results of the TI analysis were analyzed using SensoMaker v1.91 (Nunes & Pinheiro, 2013).

The results of the TDS analysis were also analyzed using SensoMaker v1.91 (Nunes & Pinheiro, 2013), using the methodology proposed by Pineau et al. (2009) to calculate the TDS curves. The curves generated by the software had two lines drawn, one for the "level of chance", and one for the "level of significance". The "level of chance", is the dominance rate that an attribute can obtain through chance, and the "level of significance", is the minimum value of the proportion required to be considered significant.

RESULTS AND DISCUSSION

a) Physicochemical evaluations of the conventional and low-calorie orange jellies

Table 1 presents the results of the pH, acidity, moisture, soluble solids, and color (L*, a*, and b*) of the orange jellies. A significant difference (p ≤ 0.05) between the two types of jellies was observed for all evaluated parameters, except for the color parameter a*.

Table 1. Averages values of the physicochemical evaluations of the conventional and low-calorie orange jellies

Parameters	Treatments	
	Conventional	Low-calorie
pH	4.26 ± 0.03^b	4.47 ± 0.02^a
Acidity (%)	0.50 ± 0.05^b	0.60 ± 0.03^a
Moisture (%)	31.94 ± 1.56^a	24.99 ± 1.96^b
Soluble solids (°Bx)	64.33 ± 1.03^b	66.46 ± 0.71^a
L*	39.67 ± 2.47^a	36.64 ± 2.82^b
a*	5.40 ± 0.64^a	5.10 ± 0.66^a
b*	24.50 ± 5.03^a	18.87 ± 2.45^b

n=6. Averages followed by the same letter in the line do not differ from each other by the Tukey test (p ≤ 5%)

The optimal pH range for the formation of HM pectin gel (conventional jelly) was 2.8 to 3.5, with pH values above or below this range decreasing the firmness of, and resulting in a more fluid, final product (Jackix, 1988). The pH values of the conventional jelly were found to be similar (Table 1) to those reported by Maciel et al. (2009) for mixed jams of mango and acerola, having values between 3.4 and 4.0, and obtaining good final acceptance by consumers. According to Ribeiro & Seravalli (2004), LM pectin forms gels in the pH range of 2.5 to 6.5, and it was concluded that the pH of the low-calorie jelly was within this range.

The acidity results of the jellies had variations of 0.50% (conventional jelly) and 0.60% (low-calorie jelly), ($p \leq 0.05$), presenting values within the range reported by Jackix (1988) for fruit jellies (0.3 to 0.8%) (Table 1).

The moisture contents of the two formulations were 24.99% (low-calorie jelly) and 31.94% (conventional jelly), ($p \leq 0.05$). It is important to note that moisture is directly related to product shelf life during storage. Mota (2006) reported higher water contents (42.84 to 46.44%) in jellies produced with blackberries and sucrose in proportions of 50 and 75%, respectively. The differences in moisture observed may be due to the differences in the concentrations of soluble solids, which were 64.33 (conventional jelly) and 66.46 °Bx (low-calorie jelly), ($p \leq 0.05$). The higher content of soluble solids in low-calorie jellies may have been responsible for the lower moisture content. Besides, according to Costa et al. (2019), the use of polydextrose, as it is a fiber, decreases the moisture of gels.

Conventional jellies were lighter than low-calorie jellies (Table 1). This was due to the presence of HM pectin, which greatly contributes to changes in luminosity due to its characteristic gelling ability when mixed with sugar and acid. As an amorphous jelly, a high amount of light is transmitted, giving the product a clear appearance (Cardoso, 2008). In addition, the shorter cooking time of the conventional jelly may have led to a clearer appearance due to reactions, such as the Maillard reaction, having less time to complete (Souza et al., 2014).

The color parameter a* values of the jellies had no statistical difference ($p > 0.05$) (Table 1). Higher positive values of a* indicate tendencies toward red coloration, while higher negative values indicate green coloration. Therefore, this parameter is not relevant for orange jellies, since orange has yellow coloration.

The positive values of the color parameter b* indicate a higher intensity of yellow. Thus, it was observed that the conventional jelly had a yellower coloration than the low-calorie jelly, ($p \leq 0.05$). As previously mentioned, the low-calorie jelly was subjected to a longer cooking time, which may have favored more completion of Maillard and caramelization reactions (Souza et al., 2014), and thus a lower yellow intensity product.

b) Physical evaluations of the conventional and low-calorie orange jellies

Table 2 shows the physical results of the orange jellies.

Table 2. Average values of the physical evaluations of the conventional and low-calorie orange jellies

Parameters	Treatments	
	Conventional	Low-calorie
Consistency index (K. Pa.s^n)	22197.67 ± 2.04^b	84424.00 ± 1.56^a
Flow index (n)	0.60 ± 0,06^a	0.33 ± 0,04^b

n=6. Averages followed by the same letter in the line do not differ from each other by the Tukey test ($p \leq 5\%$)

Flow index (n) values were 0.60 (conventional jelly) and 0.33 (low-calorie jelly). Since the values obtained were both under 1, this indicates that both jellies present non-Newtonian fluids, with pseudoplastic behaviors once the fluids become static, and have disorderly states. When subjected to shear stress, the molecules tended to move in the direction of the applied force. The higher the tension applied, the higher the structural order, and the lower the apparent viscosity (Lima et al., 2019). According to Funami (2011) the steady shear rheological properties are associated with the flow velocity of the food bolus (or viscosity), is that the flow index (n) values are related to sliminess perceived in the mouth. The lowest n values of low-calorie jelly indicate that it is likely to facilitate swallowing and reduce organoleptic viscosity (slimy feel) due to its higher pseudoplasticity, providing a pleasant and light mouthfeel (Vieira et al., 2020).

The consistency index (K) parameter was used to evaluate the viscosity of the products. The results showed that the low-calorie jelly presented a higher viscosity than the conventional jelly, ($p \leq 0.05$). The use of sucrose with LM pectin in low-calorie formulations produces more hydroxyl groups, which stabilize the gel structure formed through hydrogen bonding interactions. This leads to more immobilization of free water molecules, and consequently higher consistency of low-calorie jelly (Fu & Rao, 1999). In addition, according to Oliveira et al. (2015), jellies with higher soluble solids contents tend to have higher rigidity and are therefore more viscous.

c) Sensory evaluation of the conventional and low-calorie orange jellies

Table 3 shows the results of the TI analysis of the attribute of sweetness.

Table 3. Averages of the TI parameters for the sweet taste of the conventional and low-calorie jellies

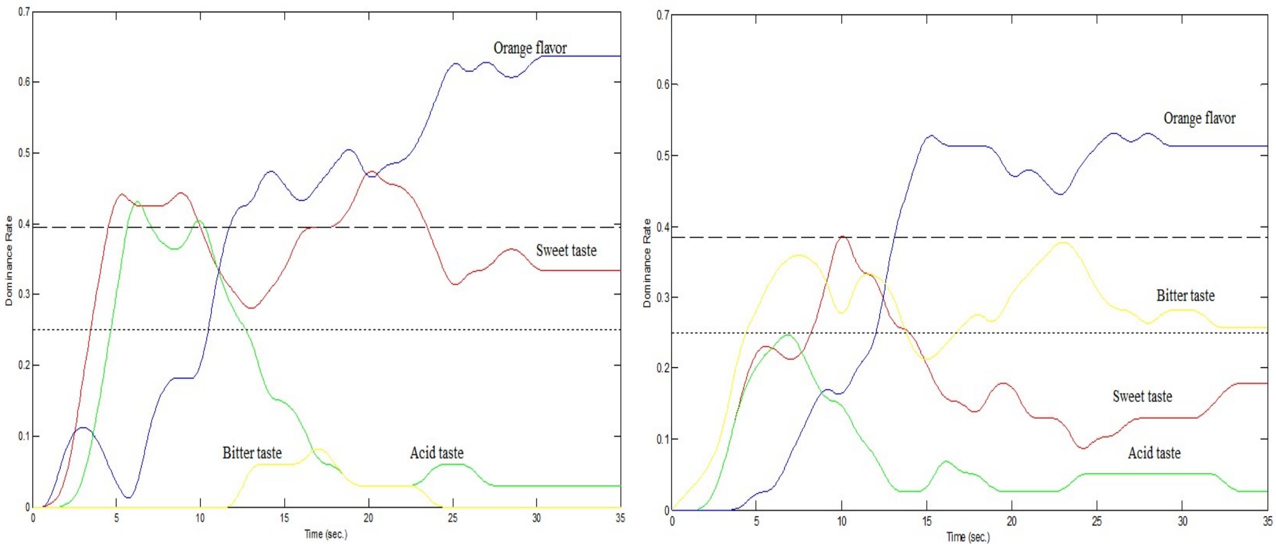
Parameters	Treatments	
	Conventional	Low-calorie
Imax	9.33 ± 1.00[a]	8.72 ± 2.00[b]
TI5%	1.11 ± 1.01[a]	0.91 ± 1.02[a]
TD5%	26.65 ± 6.10[a]	24.06 ± 7.04[b]
TI90%	6.35 ± 3.00[a]	6.19 ± 3.00[a]
TD90%	12.32 ± 3.08[a]	12.08 ± 4.02[a]
Platô	5.97 ± 3.00[a]	5.89 ± 3.00[a]
Área	140.41 ± 41.00[a]	120.64 ± 48.00[b]

n=39. Averages followed by the same letter in the line do not differ from each other by the Tukey test ($p \leq 5\%$). Imax (maximum intensity), TI_5% (time to reach 5% of the maximum intensity on the increasing side of the curve), TD_5% (time to reach 5% of the maximum intensity on the decreasing side of the curve), TI_90% (time to reach 90% of the maximum intensity on the increasing side of the curve), TD_90% (time to reach 90% of the maximum intensity on the decreasing side of the curve), Plateau (the time interval when the intensity is >90% of the maximum intensity), and area (the region below the curve)

Differences were observed between the formulations for the parameters of maximum intensity (Imax), time of the decline of maximum intensity (TD5%), and area, ($p \leq 0.05$) (Table 3). The conventional jelly showed higher values of Imax of sweet taste and TD5% than the low-calorie jelly. The area values showed that the conventional jelly presented a higher sensory response for sweet taste than the low-calorie jelly.

According to Souza et al. (2013), sweeteners with intensities equal to sucrose may present different TI curves. This shows that the use of the sucralose and acesulfame K mixture in the low-calorie jelly influenced the sweet taste intensity observed.

The TDS curves show that the orange and sweet taste attributes were significant in all formulations evaluated (Figure 1). Orange flavor perception was expected since 60% of the formulations were composed of the fruit.



(a) (b)

Figure 1. Graphic representation of temporal dominance of sensations of (a) conventional orange jelly and (b) low-calorie orange jelly

The sweet taste attribute of dominance was perceived by tasters within the first 5 seconds of analysis of the conventional jelly (Figure 1a) and 10 seconds of analysis of the low-calorie jelly (Figure 1b).

Albert et al. (2012) noted that initial dominance perception correlates with the fracture properties of a product, which corresponds to the results observed in this study. Perception of textural properties is primarily related to tactile sensations, which is directly dependent on the innervation of the inner surface of the mouth and muscle activity starting with mastication. Flavor and odor perception requires a link between receptors and active molecules before the process of perception can begin (Rosenthal, 1999). Since low-calorie jelly contains a combination of gelling agents, these may influence the perception of sweet taste, since, according to Bayarri et al. (2006), the concentration of gelling agents modifies the mechanical properties (diffusion) of the gel, thus influencing the perception of flavor.

The acid taste attribute was only significant in conventional jelly (Figure 1a). This may have been due to its pH value being lower than that of the low-calorie jelly (Table 1).

The bitter taste attribute was significant only in the low-calorie jelly (Figure 1b). This formulation contained a sucrose/acesulfame K blend, which may have contributed to its bitter taste, since, according to Chakraborty & Das (2019), artificial sweeteners cause a residual bitter taste.

CONCLUSION

The orange jellies evaluated had differences in all physical and physicochemical parameters studied, except for the color parameter a*. Compared to the low-calorie jelly, the conventional jelly had lower pH, acidity, and soluble solids values, with a higher moisture content value. The conventional jelly was also lighter, more yellow, less rigid, and less viscous than low-calorie orange jellies most likely due to its shorter cooking time.

The two sensorial methodologies applied showed differences in the perception of the evaluated stimuli between the two jelly types. The conventional orange jelly had a higher dominance of intensity for sweet taste and acidity, while the low-calorie orange jelly presented a bitter taste, most likely due to the use of sweeteners.

DECLARATION OF CONFLICTING INTERESTS

The authors have declared that there is no conflict of interest.

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