



## Scientific Research

## The Effect of Replacing Different Levels of Sucrose with Stevia Sweetener on the Textural, Sensory, and Physicochemical Properties of Fruit pastille

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## ABSTRACT

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The rising prevalence of diabetes and increased health awareness have driven the demand for low- and sugar-free confectionery products. Among these, fruit gummies are widely favored across different age groups due to their appealing texture and flavor. This study aimed to evaluate the effects of replacing sucrose with varying levels of stevia sweetener on the physicochemical, textural, and sensory properties of strawberry-flavored gummy desserts. Formulations were prepared by substituting sucrose with stevia powder at 0%, 20%, 30%, 50%, 75%, and 100% (w/w) levels, and evaluations were conducted on days 1 and 5 after production. The results revealed that increasing stevia substitution significantly affected all measured parameters ( $p < 0.05$ ). Moisture content increased, while pH, Brix, total sugar content, and textural hardness decreased in both time points. Additionally, sucrose reduction led to a decrease in viscosity, which was partially compensated by higher levels of stevia. Sensory analysis showed that the sample with 100% stevia substitution consistently received the lowest acceptability scores, whereas the samples containing 20% and 30% stevia were rated favorably by the panelists. Based on these findings, partial replacement of sucrose with stevia at 20–30% levels is recommended for developing reduced-calorie gummy products with acceptable quality attributes.

## 1- Introduction

Nowadays, increased nutritional awareness, improvement of public health, and a growing tendency toward the consumption of natural and low-calorie foods have led to a shift in consumer preferences toward healthier products. Consequently, the food industry has responded to these demands by developing novel products with higher nutritional value and natural ingredients. Among such products, gelatin-based desserts such as gummy candies are widely popular due to their pleasant flavor, attractive appearance, and soft texture, and they are considered one of the most commonly consumed confectionery products, particularly among children and adolescents [1]. Despite their popularity, the high sucrose content in gummy candy formulations significantly increases their caloric value and may contribute to adverse health effects such as obesity, cardiovascular diseases, dental caries, and elevated blood glucose levels. This issue is especially critical for individuals with diabetes. In recent years, numerous efforts have been made to replace sucrose with alternative sweeteners that can maintain desirable sensory attributes while providing lower caloric content and improved safety. In general, sweeteners are classified into two main groups: nutritive and non-nutritive sweeteners. Nutritive sweeteners not only impart sweetness but also provide energy and are typically derived from natural sources such as fruits, honey, and sugar syrups. In contrast, non-nutritive sweeteners are calorie-free and are mainly used in the production of dietetic foods and products intended for diabetic patients [2,3]. Although some artificial sweeteners, including aspartame, saccharin, and cyclamate, exhibit high sweetening power, concerns have been raised regarding their potential side effects and possible carcinogenicity [4]. In recent years, stevia has attracted considerable attention as a natural, non-caloric sweetener. Stevia is extracted from the leaves of *Stevia rebaudiana* and possesses a sweetening power several times greater than that of sucrose. This compound is not only safe for diabetic individuals but, due to its natural origin, is also considered superior to synthetic sweeteners. Moreover, from an economic perspective, stevia has been proposed as a suitable alternative to sugar [5]. Consequently, the application of stevia in the formulation of various food products, including

gelatin-based desserts, has been increasingly explored.

Therefore, the present study was conducted to investigate the effects of replacing different levels of sucrose with the natural sweetener stevia on the physicochemical, textural, and sensory properties of fruit gummy candies, with the aim of evaluating the feasibility of producing a reduced-calorie product with desirable quality characteristics.

## 2- Materials and Methods

### Preparation of Samples

Gummy candy formulations were prepared using the following ingredients per 100 g of sucrose: 18 g edible gelatin (bovine, Bloom 225, Tos Iran), 8 g corn starch powder (Fadak, Iran), 4 g citric acid (Pouya Vision, Iran), 0.5 g ascorbic acid (vitamin C; Merck, Germany), 35 g glucose syrup (Arin Glucose, Iran), and 50 g strawberry puree (Varamin, Iran).

The prepared puree was mixed with gelatin powder, starch powder, and water and heated in a water bath at 90 °C. Subsequently, sucrose and glucose syrup were added, and the mixture was stirred for 5–10 minutes until a uniform, viscous consistency was achieved. Citric acid was then incorporated to adjust the pH to 3–4. The resulting gel mixture was poured into molds and refrigerated at 4 °C for 5 hours. The formed gummy candies were removed from the molds and dried in a fan-assisted dryer at ambient temperature for 2 hours [6].

Based on preliminary tests and a literature review, stevia (Takfa Company, Iran) was used to replace sucrose at varying levels (0, 20, 30, 50, 75, and 100% w/w). The following analyses were conducted on days 1 and 5: moisture content, °Brix, pH, total sugars, viscosity, texture profile, and sensory evaluation. The ratio of stevia to sucrose was calculated using the formula:

$$\text{Stevia (n\%)} \times 300 = \text{Sucrose 1\%} \times 100$$

Accordingly, the maximum amounts of sucrose and stevia used in the gummy formulations (100% replacement treatments) were 50 g and 16.5 g, respectively, while other sucrose–stevia ratios were adjusted as indicated in Table 1.

**Table 1** Different percentage of Sucrose, Stevia for Fruit Gummies preparation

Samples	T1	T2	T3	T4	T5	T6
Sucrose (%)	100	80	70	50	25	0
Stevia (%)	0	20	30	50	75	100

### Moisture Content Determination

Moisture content of the gummy samples was measured using the oven-drying method. Approximately 5 g of each sample was weighed on a precision balance ( $\pm 0.001$  g) and placed in pre-weighed aluminum plates. The samples were dried in a convection oven (Mettler, Germany) at 103 °C until a constant weight was reached, which required approximately 2 hours. After drying, the plates were cooled in a desiccator containing silica gel for 30 minutes before being reweighed. The moisture content was then calculated based on the weight loss [7].

### Brix Measurement

The Brix content (soluble solids) of the gelatin dessert samples was determined at room temperature using a refractometer (Atago, Japan) [7].

### pH Measurement

The pH of the samples was measured using a pH meter (Jenway, UK) after calibration. Homogenized gummy samples were placed in a beaker, and the pH electrode was immersed until a stable reading was obtained at room temperature. The results were then recorded [7].

### Total Sugar Determination

Total sugar content of the samples was determined using the Lane–Eynon method according to the Iranian National Standard No. 2682 [7]. Briefly, after preparation and standardization of Fehling solutions A and B using a standard invert sugar solution, gummy samples were extracted, filtered, and subjected to acid hydrolysis. Total sugar content was subsequently determined by titration with

Fehling's solution, based on the volume of sugar solution consumed.

The total sugar content per 100 g of sample after hydrolysis was calculated using the following equation:

$$Y = A \times 100 \times 100 \times 100 / V \times m \times 10 \times 1000$$

where:

- Y = total sugar content (%) per 100 g of sample
- A = corrected Fehling factor
- V = volume of the sample sugar solution consumed (mL)
- m = weight of the test sample (g)
- 1000 = conversion factor from mg to g

### Viscosity Measurement

Shear viscosity of the gelatin dessert samples was measured with minor modifications to the method described by [8]. Briefly, 500 mL of each sample was measured using a Brookfield viscometer (USA) equipped with an appropriate spindle at 40 °C, which is above the melting point of the desserts, and at a rotational speed of 200 rpm. Prior to measurement, the instrument was calibrated, and the sample was carefully placed in the viscometer to ensure that the thermometer did not interfere with the rotating spindle. Following adjustment of the spindle number and rotational speed, the viscosity value displayed on the instrument screen was recorded.

### Texture Analysis

The textural properties of the gummy samples were evaluated using a texture analyzer (Koupa Pazhouhesh, Iran) equipped with dedicated software [9]. Gummy samples were first prepared in dimensions of 1.8 × 2 × 2 cm (length × width × thickness) and placed on the lower fixed platform of the instrument. The

load cell was set to 5 kg-force (50 N). Compression was applied using the upper movable probe (7 × 7 cm) in two reciprocating cycles (two compressions and two releases) at a crosshead speed of 60 mm/min, compressing the sample to 50% of its original height (1 cm), followed by decompression.

### Sensory Evaluation

Sensory properties, including aroma and flavor, texture, appearance, and overall acceptability of the gummy samples, were evaluated using a 6-point hedonic scale by a panel of 10 trained assessors [10]. Scores were assigned as follows: 0 = unacceptable, 1 = poor, 2 = fair, 3 = acceptable, 4 = good, and 5 = excellent. The sensory evaluation was conducted on the first day of sample preparation.

### Statistical Analysis

The experimental data were analyzed using a completely randomized factorial design. The first factor was the percentage of sucrose replacement with stevia (0, 20, 30, 50, 75, and 100%), and the second factor was storage time (day 1 and day 5). All treatments were performed in triplicate. Data were subjected to analysis of variance (ANOVA) using SAS software (version 9.4) to evaluate significant differences among treatments. Mean comparisons were performed using Duncan's multiple range test, and statistical significance was considered at  $p < 0.05$ .

## 3- Results and Discussion

### Moisture Content

As shown in Figure 1, the lowest moisture content was observed in the control treatment (T1), whereas the highest was recorded in the treatment containing 100% stevia and no sucrose (T6). Significant differences were found among all treatments ( $p < 0.05$ ). In other words, increasing levels of stevia led to higher moisture content in the samples. This effect can

be attributed to the presence of sugar alcohols in stevia, which contain hydroxyl groups that have a strong affinity for water and contribute to moisture retention within the structure [11]. In addition to the hydroxyl groups of stevia sugar alcohols, the increase in moisture content in stevia-containing samples may also be due to proteins present in the formulation. These proteins can form a gel-like network that stabilizes the structure against heat and helps retain water within the three-dimensional gel matrix, ultimately increasing the moisture content of the final product. One of the advantages of stevia powder is its high water-holding capacity, which is likely associated with its protein content [5]. In a previous study, stevia was used at different levels as a sweetener in dessert formulations, and its properties were compared with a control. The results indicated that increasing stevia levels significantly increased the moisture content ( $p < 0.05$ ) [2]. Similarly, Jali et al. (2013) reported comparable findings in biscuit products [12], and Baba Ghasabha (2020) observed analogous results in low-calorie jujube jelly prepared with sucralose and maltitol [13]. Moisture content strongly influences the shelf life of gelatin desserts, with higher-moisture samples generally exhibiting lower stability. According to the present results, moisture content decreased in all samples during storage by day 5. This reduction may be due to microbial activity and the production of catabolic compounds, as well as water evaporation over time. These findings are consistent with those of Najafian et al. (2014), who reported a decrease in moisture in low-calorie pudding samples when sucrose was replaced with sucralose after seven days of storage [14]. Similarly, Sutwal et al. (2019) observed a decreasing trend in moisture during 28 days of storage in low-calorie apple jam sweetened with stevia [15]. As illustrated in Figure 1, no significant differences in moisture content were observed between treatment T5 on day 1 and T6 on day 2, or between T3 on day 1 and T4 on day 2.

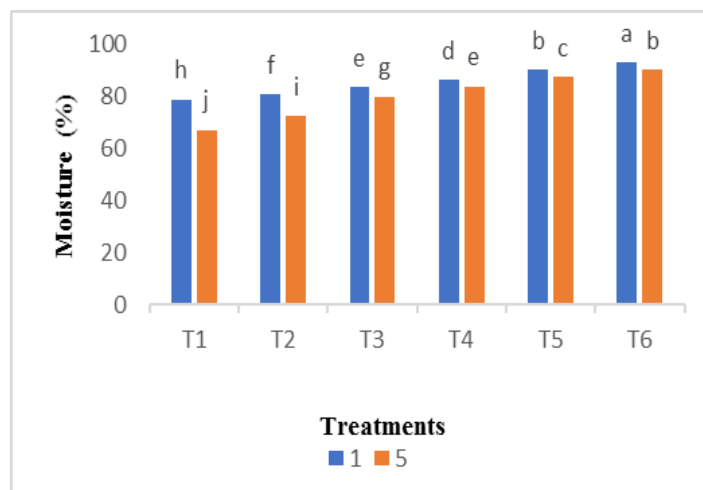
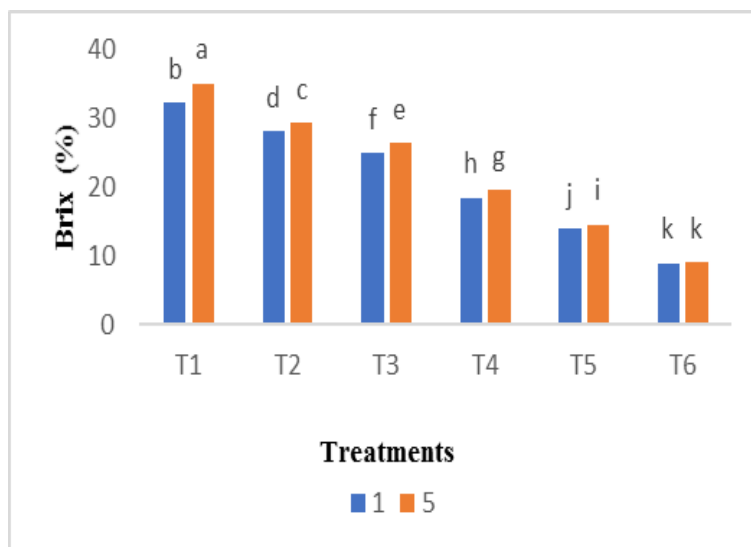


Fig 1 Effect of stevia powder and storage time on the moisture content of pastille samples  
Means with the same letters within each figure are not significantly different at ( $P < 0.05$ )

### Brix Content

As shown in Figure 2, stevia powder and storage time significantly affected the Brix content of the final product, causing a decrease and increase, respectively, with significant differences observed between the control and treated samples ( $p < 0.05$ ). Moreover, the interaction effect between sucrose replacement level and storage time was also significant ( $p < 0.05$ ). The lowest Brix values were recorded in samples with maximum sucrose replacement by stevia. The decrease in Brix with increasing stevia content can be explained by the fact that sucrose is the main contributor to soluble solids in gummy samples. As sucrose content decreases and stevia proportion increases, the percentage of water-soluble solids in the samples is reduced [16]. This trend aligns with the moisture content results, as lower moisture in stevia-rich samples is consistent with reduced soluble solids. BabaGhasabha and Abdolmaleki (2020) reported similar findings in low-calorie jujube jelly, where increased levels of sucralose and maltitol led to decreased Brix values [13]. Afifi et al. (2019) also

observed that replacing sugar with the low-calorie sweetener sorbitol in strawberry marmalade resulted in lower Brix levels [17]. Hadidi et al. (2023) reported that stevia as a sucrose substitute negatively affected soluble solids in non-dairy almond-based desserts, and noted that soluble solids significantly influenced other quality attributes, such as texture, viscosity, and syneresis [18]. The observed increase in Brix after five days of storage can be attributed to moisture evaporation, which concentrates the soluble solids, as confirmed by the moisture content measurements [19]. As illustrated in Figure 2, T6 showed no significant difference between day 1 and day 5 and exhibited the lowest Brix values. Ghadimi et al. (2016) investigated the effect of replacing sucrose with stevia, a natural sweetener, on the physicochemical and sensory properties of orange-flavored carbonated beverages. Their results indicated that increasing stevia content from 0 to 70% significantly reduced Brix values. The researchers concluded that sucrose, as the primary source of soluble solids, was responsible for the higher Brix in the control samples [20,21].

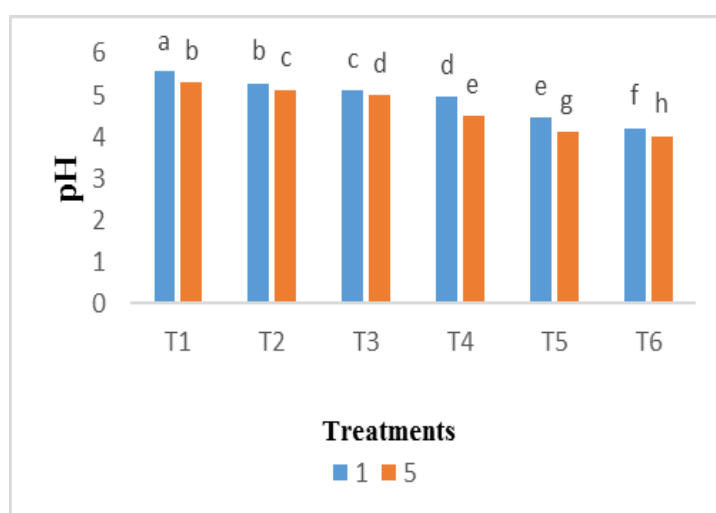


**Fig 2** Effect of stevia powder and storage time on the brix of pastille samples  
Means with the same letters within each figure are not significantly different at ( $P < 0.05$ )

### pH Measurement

As shown in Figure 3, increasing stevia content significantly reduced the pH of the samples ( $p < 0.05$ ). The pH values ranged from 4.57 to 5.21, which falls within the standard range for gelatin-based desserts. Samples containing higher levels of stevia powder exhibited lower pH compared to the control sample without

stevia. Similar trends have been reported by Hashemi et al. (2014) [22] and Ardali et al. (2014) [23], who observed a decrease in pH with increasing stevia content in saffron syrup and orange juice, respectively. Therefore, the observed differences in pH in the present study can be attributed to the concentration of stevia used. Moreover, pH values decreased during storage. This finding is consistent with the results of Sutwal et al. (2019) [15], who reported a decline in pH over time in low-calorie apple jam prepared with stevia.



**Fig 3** Effect of stevia powder and storage time on the pH of pastille samples  
Means with the same letters within each figure are not significantly different at ( $P < 0.05$ )

### Total Sugar Content

As shown in Figure 4, the total sugar content of the treatments containing stevia powder exhibited significant differences among

samples ( $p < 0.05$ ), with a pronounced decrease observed as stevia levels increased. Total sugar represents the sum of reducing sugars and sucrose; thus, replacing sucrose with stevia markedly reduced total sugar content. The

highest total sugar was observed in the control sample (100% sucrose), whereas treatments T2, T3, T4, T5, and T6, with increasing stevia substitution, showed a significant reduction in total sugar. Blowich et al. (2017) [24] reported that substituting sucrose with fructose and stevia reduced total sugar and carbohydrate content in jam, making the product suitable for diabetic patients. Similarly, in another study, the effects of sucralose and isomalt as sugar substitutes on the sensory properties of low-calorie fruit jelly powder were investigated. The results indicated that replacing sucrose with these sweeteners not only decreased total sugar but also enhanced sensory acceptance [25]. In a further study examining the effects of replacing sugar with stevia powder and tragacanth gum on the physicochemical,

rheological, and sensory properties of apricot nectar, a formulation with 50% sucrose replacement by stevia and 0.5% tragacanth gum showed a significant reduction in total sugar ( $p < 0.05$ ) [3]. According to Figure 4, the total sugar content of the control sample increased during 5 days of storage, from 59.83% to 68.9%, whereas the total sugar in the stevia-containing treatments remained relatively stable, showing no significant difference over time ( $p > 0.05$ ). The increase in total sugar in the control may be attributed to moisture loss and increased Brix during storage. Similarly, Sutwal et al. (2019) [15] reported a significant increase in total sugar over time in low-calorie apple jam in control samples, which is consistent with the present findings.

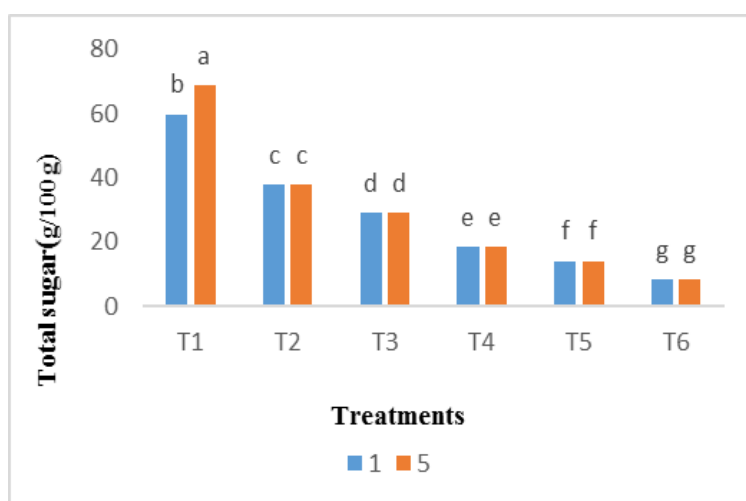


Fig 4 Effect of stevia powder and storage time on the total sugar of pastille samples  
Means with the same letters within each figure are not significantly different at ( $P < 0.05$ )

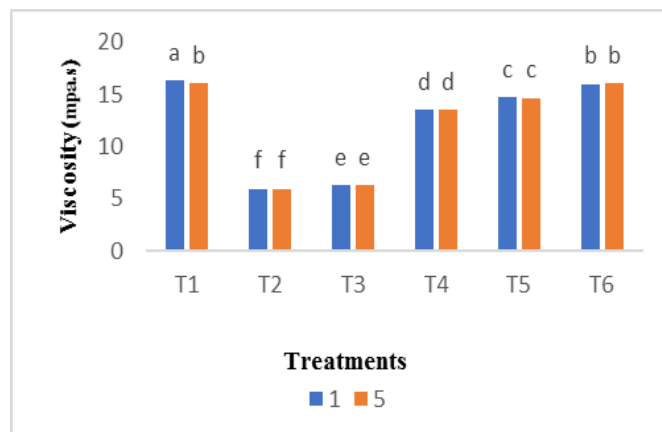
### Viscosity Measurement

As illustrated in Figure 5, the effect of different stevia levels on the viscosity of the samples was evaluated at various storage times. The results indicated no significant differences in viscosity among the treatments on days 1 and 5 ( $p > 0.05$ ), suggesting that the amount of stevia used did not substantially affect viscosity at these time points. However, the percentage of stevia did show a significant influence on viscosity within the same days ( $p < 0.05$ ). The data revealed that reducing sucrose content initially decreased viscosity. For instance, samples containing 20% stevia exhibited lower viscosity at all measured time points. Nevertheless, increasing stevia levels compensated for this reduction, improving the rheological behavior of the samples. No significant difference was

observed between the sample containing 50% stevia and the control ( $p > 0.05$ ). This phenomenon can be explained by the fact that most sugars, due to their high water-binding capacity and solubility, form concentrated solutions. Sugars establish hydrogen bonds with water molecules through their hydroxyl groups, thereby increasing viscosity [2,26]. Considering the chemical structure of the sweetener used in this study, higher stevia concentrations, which contain more available functional groups than sucrose, enhance hydrogen bonding, reduce free water mobility, and consequently increase the viscosity of the gelatin desserts. These findings are consistent with previous studies, including Jogisberg et al. (2011), who reported increased viscosity in yogurt containing stevia [27], and Lisak et al. (2011), who observed higher viscosity in

strawberry yogurt with added stevia [28]. Moreover, natural sweeteners exhibit hygroscopic properties, and their tendency to absorb water further contributes to increased viscosity. The extent of water absorption depends on the molecular size and weight of the sweetener; lower molecular weight sugars tend

to absorb water more readily, thereby enhancing viscosity [26,29]. Faghihzadeh Gorji and Sharifi (2019) also reported similar results for gelatin desserts containing stevia, confirming the effects on physicochemical, microbial, and rheological properties [2].

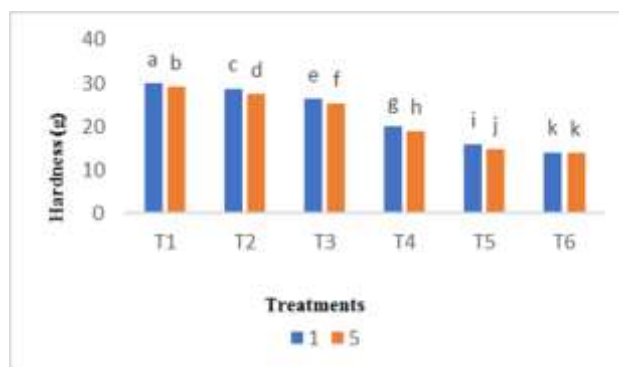


**Fig 5** Effect of stevia powder and storage time on the viscosity of pastille samples  
Means with the same letters within each figure are not significantly different at ( $P < 0.05$ )

### Texture Analysis

In the present study, the textural properties of the gelatin dessert samples were evaluated using a texture analyzer, and the results are presented in Figure 6. The independent effects of stevia addition, storage time, and their interaction on the samples were all significant ( $p < 0.05$ ). Analysis revealed that reducing sucrose content considerably decreased the hardness of the samples, with the control sample being the hardest and treatment T6 the softest. Sucrose plays a critical role in gel network formation and textural firmness. Reducing sucrose content decreases the Brix of the samples and increases moisture content, leading to a softer and less cohesive texture [19]. Furthermore, a reduction in solids content

diminishes gel network stability and water-binding capacity [25]. As previously noted in the Brix results, increasing stevia levels reduced the soluble solids of the samples, which corroborates the findings of the texture analysis. Similar results were reported by Hosseinizhad et al. (2015) [25] in a low-calorie fruit jelly powder formulation, where samples containing only sucralose exhibited the weakest gel strength and highest moisture content. In another study, Kaveh et al. (2018) [19] observed that incorporating dried stevia extract as a sugar substitute in aloe vera jelly significantly reduced gel strength. Regarding storage time, hardness decreased after five days, which is consistent with the observed reduction in Brix and increase in moisture content during this period.



**Fig 6** Effect of stevia powder and storage time on the hardness of pastille samples  
Means with the same letters within each figure are not significantly different at ( $P < 0.05$ )

## Sensory Evaluation

The sensory properties of the gelatin dessert samples containing stevia as a sucrose substitute were assessed on the first day of preparation, and the results are presented in a spider plot in Figure 7. The findings indicated that samples with higher levels of stevia were perceived by panelists as having softer texture, which aligns with the results of the instrumental texture analysis. Sucrose not only contributes to sweetness in products such as gummies but also plays a significant role in textural properties and volume. Its reduction or absence negatively affected the texture scores assigned by the panelists, suggesting that no single sweetener can fully replicate the functional properties of sucrose [30]. There was no significant difference ( $p > 0.05$ ) in perceived softness between the control sample and the sample containing 20% stevia, both of which received the highest scores for this attribute. However, as the level of stevia increased beyond this point, the softness index significantly increased (indicating a softer texture), resulting in lower scores from the panelists. Regarding aroma and flavor, stevia alone did not provide a desirable taste in the gummies, leaving a noticeable bitter

aftertaste even after consumption. Consequently, the control sample received the highest scores for aroma and flavor, followed by samples containing 20% and 30% stevia (T2 and T3), which were not significantly different from each other ( $p > 0.05$ ). Statistical analysis of the completed sensory questionnaires revealed no significant differences among treatments in terms of color ( $p > 0.05$ ). Overall acceptability scores indicated that samples containing 20–30% stevia as a sucrose substitute were well accepted by panelists and preferred over other treatments. Similar observations have been reported in previous studies. Hashemi et al. (2014) [22] investigated the effect of replacing sucrose with stevia in low-calorie saffron syrup and found that increasing stevia levels reduced sensory scores, with the highest acceptability observed in a sample containing 25% stevia and 75% sucrose. Additionally, Asgari (2018) [3] examined the effect of replacing sugar with stevia powder and tragacanth gum in apricot nectar. Sensory evaluation showed that samples containing 100% stevia had reduced acceptability, likely due to the inherent bitterness of stevia. The addition of tragacanth gum was able to partially mask this bitterness, thereby improving the sensory quality of the product.

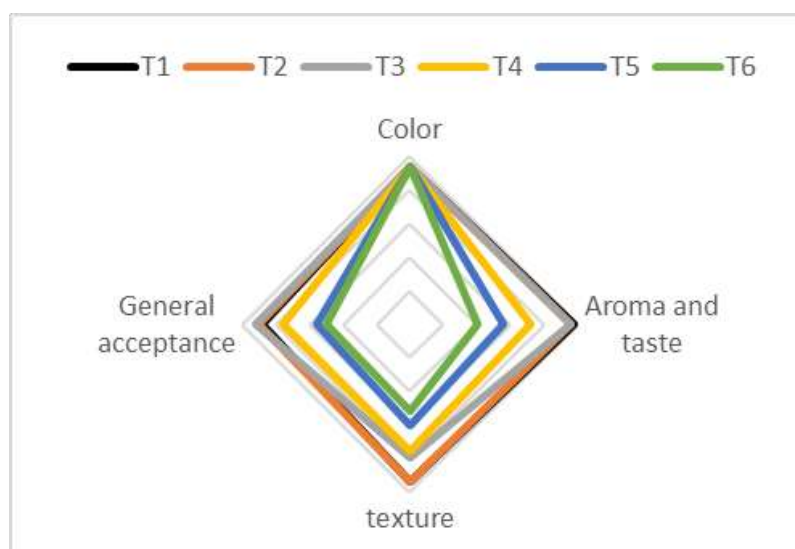


Fig 7 Effect of stevia powder and storage time on the Sensory characteristics of pastille samples

## 4- Conclusion

The present study investigated the effect of replacing varying levels of sucrose with stevia on the quality attributes of strawberry gummy samples. The results indicated that increasing the proportion of stevia powder in the formulation led to an increase in moisture content, while pH, Brix, total sugar, and texture hardness decreased on both day 1 and day 5. Moreover, reducing sucrose initially decreased viscosity; samples containing 20% stevia exhibited lower viscosity at all measured time points. However, increasing stevia levels compensated for this reduction, improving the rheological behavior, and no

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### Author Contributions

All activities were carried out by the author.

### Competing Interests

The author confirms that he / she has no financial conflicts of interest or competing interests in this study.

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significant difference was observed between the sample containing 50% stevia and the control. Regarding sensory properties, the lowest scores were consistently assigned to the sample containing 100% stevia without sucrose. In contrast, samples with 20–30% stevia received acceptable sensory ratings in most cases, indicating that these levels are optimal for producing low-calorie gummy products. In summary, partial replacement of sucrose with 20–30% stevia can be recommended as an effective strategy to reduce sugar content while maintaining desirable physicochemical, rheological, and sensory qualities in strawberry gummy formulations.

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اثر جایگزینی سطوح مختلف ساکارز با شیرین کننده استویا بر خصوصیات بافتی، حسی و فیزیکوشیمیایی پاستیل میوه ای

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اطلاعات مقاله	چکیده
تاریخ های مقاله :	همواره تلاش هایی برای تولید محصولات کم یا بدون قند انجام شده است تا مشکلات افراد مبتلا به دیابت را به حداقل رسانده و مصرف این محصولات را برای آنها ممکن سازد. پاستیل میوه ای از محبوب ترین محصولات قنادی به شمار می آید که در تمام سطوح جامعه مورد استفاده قرار می گیرد. از این رو در این پژوهش قابلیت جایگزینی پودر استویا با ساکارز بر ویژگی های فیزیکی شیمیایی و شاخص های حسی دسر پاستیل توت فرنگی در روزهای اول و پنجم پس از آماده سازی بررسی گردید. بدین منظور نسبت های مختلف استویا (۰، ۲۰، ۳۰، ۵۰، ۷۵ و ۱۰۰ درصد) وزنی/وزنی جایگزین ساکارز شد. تجزیه و تحلیل داده ها نشان داد که سطوح مختلف پودر استویا در فرمولاسیون دسر ژلاتینی، کلیه خصوصیات فیزیکوشیمیایی، بافتی و حسی را به طور معنی داری ( $p < 0.05$ ) تحت تاثیر قرار داده و موجب افزایش میزان رطوبت و کاهش pH، بریکس، قندکل و سختی بافت در روز اول و پنجم شده است. علاوه بر این، با کاهش درصد ساکارز در روز اول و پنجم، ویسکوزیته کاهش یافت؛ اما با افزودن مقادیر بیشتری از پودر استویا، این کاهش ویسکوزیته جبران شد. در میان تیمارهای آزمایش شده، نمونه ای که حاوی ۱۰۰ درصد پودر استویا بدون ساکارز بود، همواره کمترین امتیاز حسی را کسب کرد. در مقابل، نمونه های حاوی ۲۰ و ۳۰ درصد پودر استویا در بسیاری از موارد امتیاز قابل قبولی دریافت کرده و در نتیجه به عنوان بهترین سطوح پیشنهادی برای تولید پاستیل کم کالری معرفی می شوند.
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