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Sensory characterization of stevia-substituted low-calorie apricot drinks*

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ABSTRACT

The objective of this study was to investigate the sensory characteristics of apricot drinks that were sweetened using stevia. The sensory examination of stevia powder revealed comparable levels of sweetness to sucrose, albeit with a more prominent perception of bitterness. When the substitution rate of stevia was 75%, the sweetness and overall preference parameters obtained the highest scores among the other apricot drink samples. Nevertheless, the utilization of pure stevia extract resulted in unfavorable flavor attributes (e.g., bitter, metallic, and acidic tastes, as well as chemical and synthetic odors). An increase in the concentration of stevia, combined with the reduction in sucrose content, resulted in a notable decrease in the energy content of the samples, while maintaining an acceptable sensory profile. The apricot drinks containing 75% stevia significantly decreased energy levels by 60% and received great ratings from the panelists. However, the utilization of pure stevia has led to the development of sour, pronounced, and metallic tastes, as well as disagreeable odors. On the other hand, the use of stevia at sucrose-substitution ratios of 25% or 50% showed positive taste characteristics.

1. Introduction

The increase in health awareness and the increasing incidence of metabolic diseases such as diabetes and obesity have increased the need for low-calorie foods (Anonymous 2014; Karaağaç and Pınarlı Falakacılar 2023; Anonymous 2024). Stevia (*Stevia rebaudiana* Bertoni) has started to attract great attention among the sweeteners used in the production of these foods due to its high sweetening power and low-calorie content. Stevia is an excellent substitute for sugar in a diverse range of food and drink items due to its sweetening strength (up to 300 times).

Several studies have shown that stevia has the ability to improve the nutritional and sensory characteristics of food products. Ewis (2021), in his research, prepared a functional yogurt drink with reduced calorie content by adding oat seed and stevia leaf powder. This is a great potential for stevia to act as a calorie reducer. However, further research is required for applications within alternative products such as fruit drinks to find an optimum position between taste and usefulness. This highlights the importance of stevia in providing a nutritionally enhanced product without sacrificing flavor. Hosseini et al. (2015) showed that the inclusion of stevia in low-calorie orange nectar successfully maintains levels of phenolic components, ascorbic acid, and stevioside throughout storage. These studies show that stevia can be successfully used in the production of foods whose nutritional content is enriched and whose functional compounds can be preserved without sacrificing taste.

Beyond the production of food with low calorie content, it has also been published that stevia helps to maintain the component stability of the foods to be produced. Indeed, Balaswamy et al. (2014) reported that when they used stevia in the production of ready-to-serve fruit beverages, they successfully preserved the organoleptic properties of the products they stored for six months. In a similar manner, Díaz-García et al. (2021) conducted an optimization process to create a natural tea with minimal calories that contains antioxidants. They achieved this by using purple corn cobs and stevia, which resulted in a tea with a significant antioxidant capacity and a high level of monomeric anthocyanins. Moreover, Tavares et al. (2021) reported that stevia can preserve the sensory properties of low-calorie peach drinks, and therefore this sweetener can be successfully used to produce an ideal product where the product sensory properties are acceptable, especially for people with glucose intolerance. Usman et al. (2024) also confirmed that orange beverages with added stevia have satisfactory sensory properties even after long-term storage, thus stevia usage is accepted as an advantage for product stability.

Sensory evaluation of stevia-sweetened products is critical due to the possibility of residual flavors with licorice or bitter-like notes, which are common complaints associated with this sweetener. In particular, this study aims at improving the sensory characteristics of low-calorie fruit drinks by optimizing the formulation to mask these unwanted taste profiles. The findings provide new insights into how to improve consumer acceptance of stevia-sweetened products in view of an increasing demand for healthier, low-calorie alternatives.

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2. Materials and Methods

2.1. Ethics Approval

The sensory analyses conducted in this study were undertaken under the ethical approval granted by the Akdeniz University Science and Engineering Sciences Scientific Research and Publication Ethics Committee (Document Number: 22.02.2024-861378, Meeting Date: 22.02.2024, Meeting Number: 03, Decision Number: 06).

2.2. Production of stevia-substituted fruit drinks

Stevia powder containing 60% pure total steviol glycosides, purchased from Güney Agripark Agricultural Research Co. Ltd., was used in these experiments. The control group (100 g sucrose, 20% fruit puree, 0.3% citric acid in 1 L of water) was an apricot drink that was prepared totally with sucrose. Then apricot drinks prepared using 0% (Control group: 100 g sucrose), 25% (75 g sucrose+0.238 g stevia powder), 50% (50 g sucrose+0.476 g stevia powder), 75% (25 g sucrose+0.714 g stevia powder), and 100% (0.95 g stevia powder) stevia substitution ratios were prepared after determining the relative sweetness value (Approx. 105-fold) of the stevia powder according to Wang et al.'s (2022) method. Then all samples were stored in the refrigerator until sensory analysis.

2.3. Methods

2.3.1. Sensory analysis

The sensory analysis of the fruit drinks was initiated by determining the flavor characterization of the stevia powder used in drink formulations. Subsequently, the fruit drinks were subjected to sensory analysis. Sensory panels were carried out on different days. The sensory tests was carried out with the aid of 13 panelists (8 female and 5 male), who are all pursuing graduate studies (either Master's or PhD) in the Department of Food Engineering, Faculty of Engineering of Akdeniz University. All had prior experience participating in sensory analysis panels and were therefore familiar with the assessment of food products. Although the panelists had not received special training for this specific study, their very broad previous experience ascertained consistency and reliability during the assessment of the samples.

2.3.1.1. Stevia powder

The first sensory evaluation investigated the taste characterization of stevia powder for use in fruit drinks. A 14% sucrose solution served as the control group, and a stevia solution with equivalent sweetness was prepared the day before the sensory panel. Both solutions were refrigerated at 4°C until delivery to the panelists (N= 12). Panelists assessed sweetness and bitterness using a 15 cm line scale at three intervals: in-mouth, 5 seconds after, and 1 minute after (Tao and Cho 2020). Nasal clips were used to focus on flavor intensity. "In-mouth bitterness and sweetness" referred to assessments with the solution in the mouth, while "Immediate bitterness and sweetness" referred to evaluations 5 seconds after removal. After evaluating immediate bitterness and sweetness, panelists noted any flavor variations (aftertaste) and selected corresponding tastes from a CATA list. They re-tasted the solutions without nasal clips and waited 1 minute before recording evaluations. Descriptive phrases from Tao and Cho (2020) included: "artificial", "bitter", "chemical", "honey", "licorice", "metallic", "minty", "pleasant", "pungent", "spicy", "sweet", "sour", "tingling", and "vanilla".

2.3.1.2. Stevia-substituted apricot drinks

In the second sensory evaluation, 9-point hedonic scale for product liking was assessed for the organoleptic characteristics (sweetness, bitterness, aroma, and overall preference) of apricot drinks with varying stevia and sucrose proportions (Stone et al. 2020). Cold apricot drink samples labeled with three non-sequential digits were served to panelists (N= 13) using a randomized balanced block design. Panelists evaluated quality attributes on the 9-point hedonic scale (1= extremely dislike, 9= like extremely). They rinsed their mouths with water and ate unsalted rusks between tastings. After evaluations, panelists noted any different tastes or odors and described them.

2.3.2. Energy value calculation

All samples were subjected to analyses for moisture (AOAC 1990a), total ash (AOAC 1990b), total fat (AOAC 1990c), total protein (AOAC 1990d) and dietary fiber (AOAC 1990e), and to determine their energy values. The total carbohydrate content was determined by subtracting the percentages of total fat, total protein, total ash, and total moisture from 100. The energy values of the samples were then calculated using the Atwater factors [4 kcal per gram (kcal g^{-1}) for protein, 4 kcal g^{-1} for carbohydrates and 9 kcal g^{-1} for fat] (FAO 2003).

2.3.3. Statistical analyses

The statistical analyses were conducted at a 5% significance level. Data from the comparative taste analysis of stevia powder and sucrose were analyzed using Kruskal-Wallis ANOVA and One Sample Wilcoxon Signed Rank tests (OriginPro 2019b, OriginLab Corporation, Northampton, MA, USA). For the stevia powder, CATA data analysis involved calculating frequency values for each descriptive value, followed by Cochran Q test and Marascuilo multiple comparison test (XLSTAT, AddinSoft, New York, NY, USA). Panelists' scores for the 9-point hedonic scale of stevia-substituted apricot drinks were examined using ANOVA and Tukey's multiple comparison tests. Additionally, thematic analysis was used to analyze panelists' subjective observations on tastes and odors in fruit drinks sweetened with Stevia, as defined by Braun and Clarke (2023). Comments were codified and themes created under similar codes. Calorie content of samples was calculated by comparing analyzed chemical properties using One-way ANOVA and Tukey's multiple comparison tests (OriginPro 2019b, OriginLab Corporation, Northampton, MA, USA).

3. Results and Discussion

3.1. Taste characterization of stevia powder

An analysis with 12 panelists examined the sensory characteristics of stevia powder. Panelists assessed sweetness and bitterness in 14% sucrose and stevia solutions using a 15 cm line scale. Data were analyzed with one-factor ANOVA. Findings showed both sweeteners had comparable "In-Mouth Sweetness" and "Immediate Sweetness" ($P>0.05$). The graph indicated minimal disparity in perceived sweetness between sucrose and stevia, both around 8.5-9. Stevia was slightly sweeter than sucrose in "Immediate Sweetness," but the difference was not statistically significant (Figure 1).

Stevia was found to be significantly more bitter than sucrose in “In-Mouth Bitterness” (P<0.05), with stevia rated at 3.5 and sucrose at 1.5. This indicates a more prominent bitterness perception for stevia. In “Immediate Bitterness,” stevia also elicited a more abrupt bitterness compared to sucrose (P<0.05). Thus, while stevia has a comparable sweetness to sucrose, it also has a more distinct and pronounced bitterness. This impacts the sensory characteristics of stevia. Although steviol glycosides impart a slight bitterness, they do not adversely affect overall product acceptability when used optimally (Parpinello et al. 2001).

Based on the results of the CATA (Check-All-That-Apply) descriptors analysis for stevia powder and sucrose, the panelists evaluated both sweeteners on a variety of taste and aroma parameters (Figure 2). In particular, positive descriptors such as sweetness, pleasant, vanilla and honey were more associated with sucrose. This suggests that sucrose was perceived by the panelists as having more sweetness and a pleasant taste.

Stevia has been associated with more negative taste profiles, including noticeably more bitter and metallic flavors compared to sucrose. Descriptors such as artificial, peppery, tangy, chemical, tart, minty, and tingling are also associated with it. This implies that stevia possesses more intricate and less desirable flavor characteristics compared to sucrose. Stevia's steviol glycoside (SG) profile is responsible for its complexity of flavor. Tao and Cho (2020) found that Rebaudioside (Reb) D and Reb M have similar favorable qualities to sucrose but are seen as artificial, whereas Reb A is noticeably bitter. These findings indicate that the taste of stevia sweeteners can differ greatly based on the SG composition, and modifying the SG profile could enhance the overall sensory perception of items sweetened with stevia.

3.2. Taste characterization of stevia-substituted apricot drinks

The panelists sensorily analyzed the fruit drinks for sweetness, aroma, bitterness, and overall preference using a 9-point hedonic scale (Figure 3). Based on the results, there were no notable variations in sweetness and overall satisfaction among the drinks for the control and 25%, 50% and 75% stevia-substituted ones (P>0.05).

Figure 3 also shows that the sweetness, aroma, bitterness, and overall preference scores exhibit similar proportions. However, apricot drinks that were completely replaced with stevia, with a substitution rate of 100%, were found to have significantly lower scores in terms of both sweetness and overall liking compared to other ratios (P<0.05). It is evident that the perception of sweetness and overall satisfaction are adversely affected by a high percentage of stevia. Nevertheless, studies have shown that integrating flavors, such as lime, into fruit beverages might offset the unappealing characteristics of stevia, such as its metallic or unpleasant odor (Mielby et al. 2016).

Thematic analysis was also conducted to examine in detail the effects of stevia substitution rates on the sensory properties of apricot fruit drinks (Table 1). Particularly at low and medium concentrations, the use of stevia as a substitute (at 0%, 25%, and 50%) is found to yield favorable outcomes in terms of sweetness and overall satisfaction. These ratios have the benefit of reducing calories while enhancing the taste profiles of the products. When 25% of stevia is used as a substitute, the drinks do not have a strange taste and are generally well-received in terms of sweetness.

On the other hand, the complete (100%) substitution of stevia with sucrose led to the perception of negative tastes such as acidic, pungent, bitter and metallic tastes. This indicates that product quality and acceptability may be adversely affected.

At a concentration of 25% stevia, the presence of spoiled fruit odors is identified; at 50%, medicinal odors are predominant; and at 100%, rotten fruit and chemical odors are perceived. These findings emphasize the importance of meticulous tuning of the stevia substitution rate. Research indicates that the partial substitution of natural sweeteners, such as stevia, yields an acceptable sensory profile and simultaneously diminishes undesirable off-flavors (Andersen et al. 2024). This study demonstrated that a 75% replacement with stevia significantly enhances these benefits, resulting in a notable reduction in perceived undesirable flavors and aromas, indicating a potentially optimal substitution ratio.

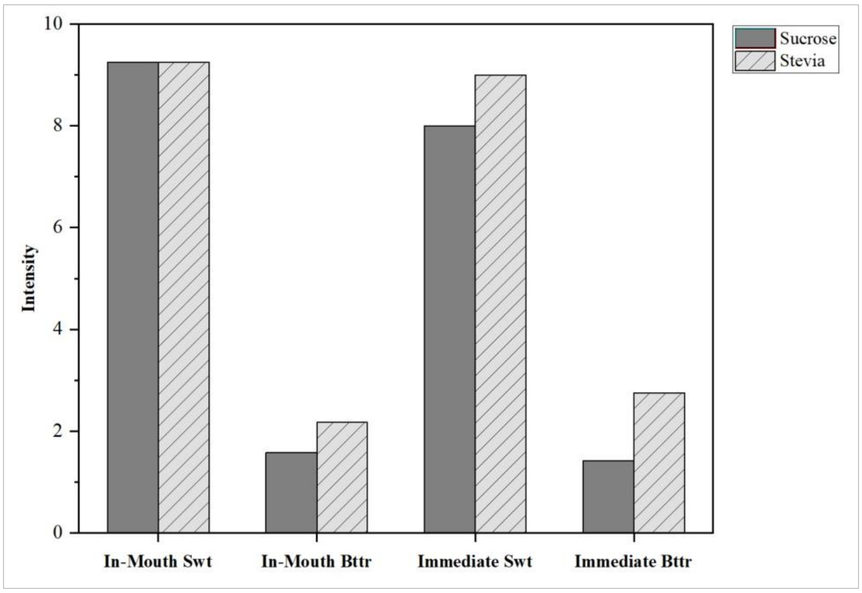

Figure 1. The sweetness and bitterness intensities of stevia and sucrose (Swt: Sweetness, Bttr: Bitterness).

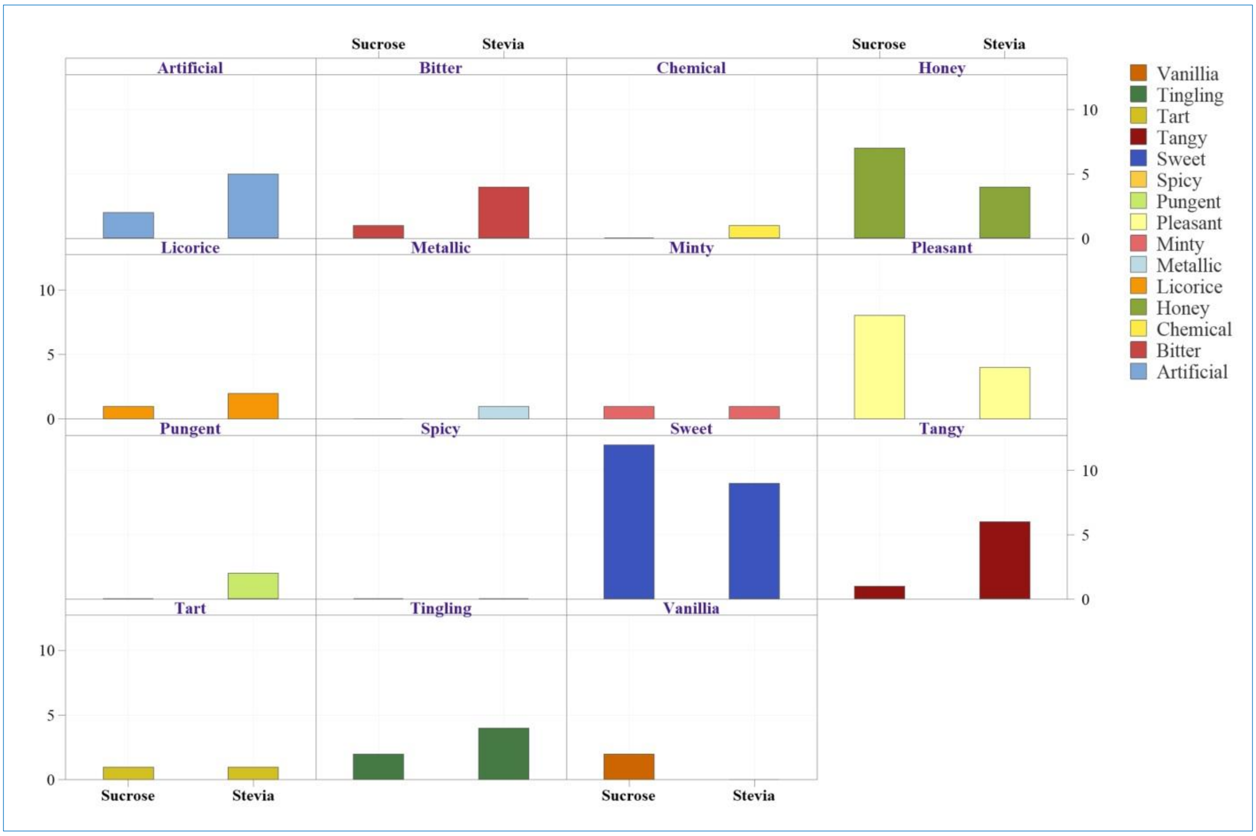

Figure 2. Comparative analysis of sensory profiles of sucrose and stevia solutions using the CATA (Check-All-That-Apply) method.

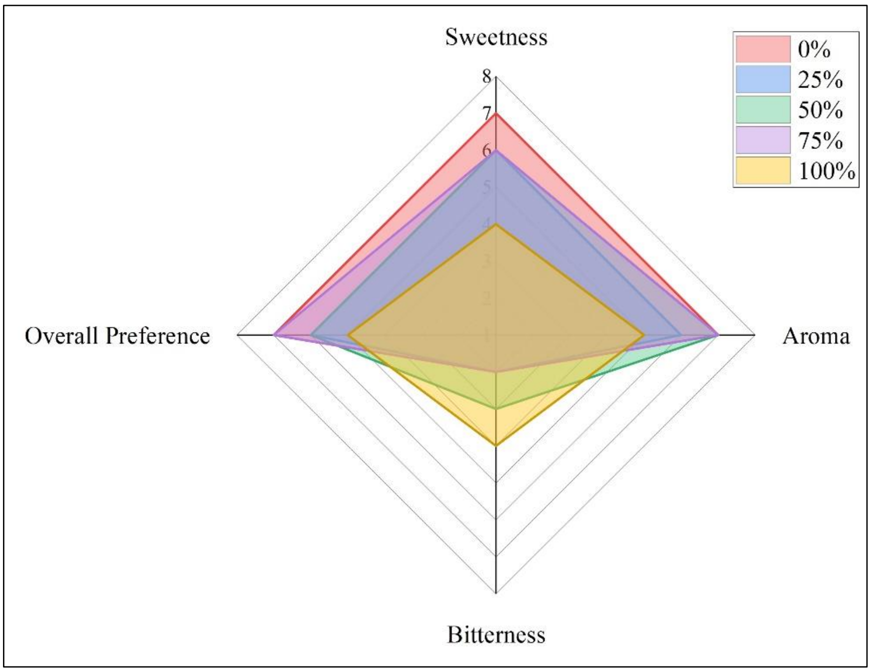

Figure 3. Effect of stevia substitution rates on the sensory properties of apricot drinks.

3.3. Approximate chemical composition and energy values of stevia-substituted fruit drinks

Analyses on the approximate chemical composition and caloric values of stevia-substituted fruit drinks were interpreted. When the stevia substitution rate was increased from 0% to 100%, different changes were observed on total protein, total moisture, total ash, crude fiber, and total carbohydrate contents. The total fat content could not be determined. Fruit drinks with stevia substitution rates between 0% and 25% had a constant total protein content, while higher substitution rates (50%, 75%, and 100%) had a decrease. Total moisture gradually increased as the rate of stevia substitution increased (*P*<0.05). The total ash and crude fiber contents of the fruit drinks generally remained stable but showed a slight increase at the highest substitution rates (75% and 100%). Total carbohydrate contents, on the other hand, decreased significantly as the stevia substitution rate increased (*P*<0.05).

The variations noted in physicochemical parameters, as presented in Table 2, are indicative of the influence that substitution of sucrose with stevia has on the chemical make-up of the beverages. Even though these were generally related to the reduction in sucrose content, there were no statistical interactions found between stevia and other product constituents, including dietary fiber and ash. These findings underline the importance of optimization in sweetener substitution levels so that desired product characteristics, such as calorie reduction and stability of physicochemical properties, are maintained.

The energy values of stevia-substituted apricot drinks were also calculated. Accordingly, increasing the rate of stevia substitution resulted in a significant decrease in the energy (kcal) value of apricot drinks (Figure 4). Indeed, the energy value of fruit drinks decreased by 19% when the stevia substitution rate was 25%, by 41% when it was 50%, by 60% when it was 75%, and by 85% when it was 100%. Reale et al. (2020) also reported high reduction in caloric value (43%) of sensorially like apricot nectars (Fruit content: 40%) sweetened with 0.07% stevia.

The substitution ratio of 75% stevia achieves an optimal balance between sweetness and overall preference, providing a comprehensive alternative in terms of flavor and well-being. This formulation not only significantly decreases the number of calories up to 60% but also preserves a desirable taste profile, resulting in high acceptance as evaluated by the sensory panel. This sensorially acceptable substitution rate was similar to the findings published by Alizadeh et al. (2014). They also reported that a 75% replacement of stevia with sucrose has enabled the production of fruit-based milk shakes at a sensorially acceptable level.

Table 1. Thematic analysis results of stevia-substituted fruit drinks

Main Theme	Sub-Themes	Frequency	Stevia Substitution Rate (%)	Comments
Sweetness	- Less sweet	1	0	Less sweet compared to the 50% replacement sample
	- Normal sweetness	1	0	The sweetness is normal, leaves a slight bitter aroma after swallowing
	- Sweet	2	25	No foreign taste, quite sweet
			50	The sweetness is just right
	- Sour taste	3	0	Slightly sour taste
			25	Gives a sourer taste on the palate
			50	The sourness is intense, like lemon
	- Herbal taste	2	25	Herbal taste
			100	Herbal-like taste
	- Other tastes:			
	- Acidic taste	1	100	Acidic taste that slightly overpowers the sweetness
	- Sharp taste	1	100	Sharp taste, leaves a bitter feeling
	- Carbonated taste	1	100	Sharp taste similar to carbonate
	- Bitterish	1	100	Bitterish
	- Metallic taste	1	100	Metallic
Main Theme	**Sub-Themes**	**Frequency**	**Stevia Substitution Rate (%)**	**Comments**
Odor	- Spoiled/Stale	1	25	Smells like it's spoiled or close to spoiling
	- Softened fruit	1	25	Smells like softened apricot
	- Medicinal odor	1	50	Smells like medicine
	- Rotten fruit odor	1	100	Smells like rotten fruit
	- Chemical odor	1	100	Smells chemical
	- Metallic odors	1	100	Smells like coins, metallic smell
	- Synthetic odors	1	100	Synthetic (like plastic) smell

Table 2. Effect of stevia substitution rates on the chemical composition of apricot drinks

Stevia Substitution Rate (%)	Total Fat* (g 100 mL^{-1})	Total Protein (g 100 mL^{-1})	Total Moisture (%)	Total Ash (%)	Dietary Fiber (%)	Total Carbohydrate** (%)
0	N.D.	0.14 ± 0.01^{a}	88.16 ± 0.00^{c}	0.07 ± 0.01^{b}	0.05 ± 0.01^{a}	11.60 ± 0.02^{a}
25	N.D.	0.14 ± 0.01^{a}	90.40 ± 0.53^{c}	0.09 ± 0.02^{b}	0.05 ± 0.00^{a}	9.34 ± 0.52^{b}
50	N.D.	0.10 ± 0.00^{b}	92.93 ± 0.12^{b}	0.08 ± 0.00^{b}	0.05 ± 0.00^{a}	6.85 ± 0.13^{c}
75	N.D.	0.03 ± 0.00^{c}	95.18 ± 0.22^{ab}	0.07 ± 0.01^{b}	0.07 ± 0.01^{a}	4.67 ± 0.22^{d}
100	N.D.	0.03 ± 0.00^{c}	98.10 ± 0.00^{a}	0.11 ± 0.02^{a}	0.07 ± 0.02^{a}	1.71 ± 0.01^{e}

*: N.D. Not detected, **: The total carbohydrate content was calculated by subtracting the percentages of total fat, total protein, total ash, and total moisture from 100.

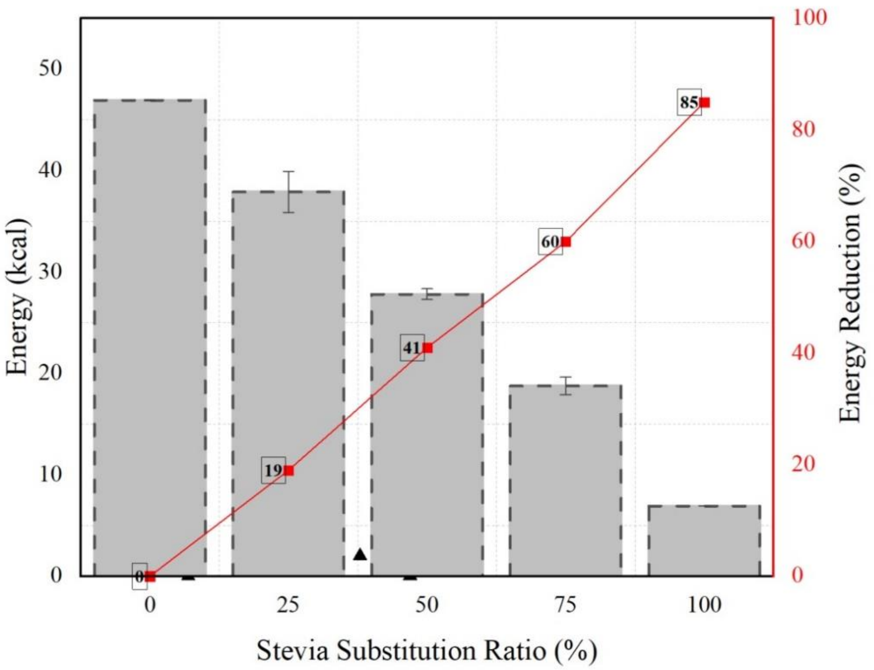

Figure 4. Change in energy values of fruit drinks according to stevia substitution rates.

4. Conclusion

This study examined the sensory characteristics of both stevia powder, and stevia-substituted apricot drinks by comparing them with sucrose-containing samples. Stevia had similar sweetness perceptions to sucrose. Particularly, 75% of stevia substitution provided an ideal balance in terms of sweetness and overall satisfaction for sensory acceptance. On the other hand, no significant difference was found in sweetness and overall satisfaction among the apricot drinks with 0%, 25%, 50% and 75% stevia substitution rates ($p>0.05$). The results of the thematic analysis indicated that favorable odor profiles were observed in drinks with 25% and 50% stevia substitutes. Especially 75% stevia substitution significantly reduced the calories (up to 60%) while maintaining the desired taste profile, increasing consumer acceptance. However, when sucrose was replaced totally with stevia, the apricot drinks received lower scores for sweetness and overall preference, possibly due to the masking effect of the bitter taste of the sweetener. This also shows that the total replacement of stevia negatively affects the perception of sweetness. The study suggests that stevia can be used as an active ingredient in the production of low-calorie beverages and provide an acceptable flavor profile. At a 75% substitution rate, stevia stands out as a highly effective sweetener that can enhance the sensory quality of fruit drinks.

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