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Quality characteristics of yogurt sweetened with stevia and enriched with date pulp*

Stevia ile tatlandırılmış ve hurma püresi ile zenginleştirilmiş yoğurdun kalite özellikleri

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Keywords: Date, fruit yogurt, quality characteristics, sensory evaluation, sweeteners

Anahtar sözcükler: Hurma, meyveli yoğurt, kalite özellikleri, duyusal değerlendirme, tatlandırıcılar

ABSTRACT

Objective: This study aimed to investigate the production of date yogurts with potentially improved functional and nutritional properties by incorporating different levels of stevia as a natural sweetener, in combination with date fruit and whey powder to increase dry matter content.

Materials and Methods: Date yogurts were produced from standardized cow's milk supplemented with whey powder (10%) and sweetened with date pulp and stevia (2% and 4%). The samples were analyzed during storage for physicochemical, microbiological, textural, antioxidant, and sensory properties.

Results: Replacing sucrose with stevia had no significant effect on pH, titratable acidity, or water-holding capacity, thereby maintaining physicochemical stability. Yogurts containing 4% stevia exhibited the highest viscosity and firmness, while total phenolic content ranged from 0.44 to 0.56 mg GAE/g, reflecting the antioxidant contribution of date pulp. Although slight variations in starter culture activity were observed, sensory evaluation confirmed the acceptability of yogurts formulated with 4% stevia.

Conclusion: The results indicate that stevia can be effectively used as a sugar substitute in date-enriched yogurt formulations, enabling the development of a reduced-sugar product with acceptable quality and sensory characteristics. All produced date yogurts complied with relevant quality standards.

ÖZ

Amaç: Bu çalışmada, prebiyotik lifler açısından zengin doğal ve fonksiyonel bir tatlandırıcı olan stevia ile yüksek lif ve antioksidan özelliği bilinen hurma ile zenginleştirilmiştir. Kuru madde peyniraltı suyu tozu ile arttırılmıştır. Üretilen üç farklı hurmalı yoğurtların kalite ve fonksiyonel özellikleri araştırılmıştır.

Materyal ve Yöntem: Yoğurt üretiminde, süt, peynir altı suyu tozu ile standardize edilerek, %10 hurma pulpu ve %2 ve %4 oranındaki farklı stevia ile tatlandırılmıştır. Örnekler, depolama sırasında fizikokimyasal, mikrobiyolojik, dokusal, antioksidan ve duyusal özellikler açısından analiz edilmiştir.

Araştırma Bulguları: Sakaroz yerine stevia kullanılması yoğurtların pH'ı, titrasyon asitliği veya su tutma kapasitesi üzerinde önemli bir etkisi olmadı ve böylece fizikokimyasal stabiliteleri korundu. %4 Stevia ile tatlandırılmış yoğurtlarda en yüksek viskozite ve sertlik görülürken, hurma pulpu ilavesi ile antioksidan ve toplam fenolik miktarı da (0,44-0,56 mg GAE/g) artmıştır. Starter yoğurt kültürü aktivitesinde küçük farklılıklar gözlemlense de duyusal değerlendirme %4 stevia içeren hurmalı yoğurtlar daha çok beğenilmiştir.

Sonuç: İlave şeker içermeyen, hurma püresi ilavesiyle daha sağlıklı ve fonksiyonel bir meyveli yoğurt geliştirerek, tüketicilerin düşük kalorili, doğal tatlandırılmış süt ürünlerine olan talebini karşılamış ve kalite standartlarına uymuştur.

INTRODUCTION

In recent years, excessive sugar consumption has been associated with increased energy intake and the prevalence of metabolic disorders, leading to a growing demand for reduced-sugar and functional dairy products. Yogurt, widely consumed due to its nutritional value and health benefits, represents a suitable matrix for the incorporation of natural sweeteners and functional ingredients.

With the rise in energy intake from excessive sugar consumption and the increasing prevalence of related diseases, sweeteners that can replace sugar have gained importance, and their use as food ingredients is growing daily (Carocho et al., 2017). The safety of stevia for human health has been confirmed through numerous studies, and it has been classified as "safe" by both the Food and Drug Administration (FDA) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA). The acceptable daily intake is set at 4 mg of steviol per kg body weight or 10 mg of stevioside per kg body weight. Toxicological studies have demonstrated that stevioside, when used as a sweetener, is not mutagenic, teratogenic, or carcinogenic, nor does it cause allergic reactions. Additionally, stevioside has been shown to increase insulin secretion in the pancreas and aid in the prevention of diabetes and other carbohydrate metabolism-related diseases (Schiatti-Sisó et al., 2023).

Date fruit (*Phoenix dactylifera* L.) is rich in dietary fiber, phenolic compounds, and antioxidants and has been reported to improve water-holding capacity and textural properties in food systems. Previous studies have demonstrated that the incorporation of date products into dairy formulations enhances antioxidant capacity and nutritional value while contributing to natural sweetness and consumer acceptability (El-Sohaimy & Hafez, 2010).

Whey is a by-product formed during cheese production and contains 20% of milk proteins. It is rich in proteins with high chemical, physical, and functional properties and is important not only nutritionally but also as a balanced source of amino acids. Whey proteins have functional properties, including improving texture, strengthening gel formation, creating emulsions, preventing water retention, and reducing syneresis. Due to these properties, one of the dairy products where whey is most frequently used is yogurt (Rocha-Mendoza et al., 2021).

Despite existing studies on the individual use of stevia, palm pulp, and whey powder in dairy products, limited information is available regarding their combined application in yogurt formulations. Therefore, the aim of this study is to evaluate the effects of replacing sucrose with stevia in combination with palm pulp and whey powder on the physicochemical, microbiological, textural, antioxidant, and sensory properties of yogurt throughout its storage period. Stevia and palm pulp concentrations were determined based on preliminary trials and literature data to achieve optimum sweetness, texture, and consumer acceptability. The goal is to develop a novel product with improved textural and sensory properties that are both functional and compatible with consumer demands.

MATERIALS and METHODS

Materials

In this study, raw cows' milk (9.72±0.02 % non-fat dry matter, 3.4±0.08 % fat, 3.30±0.1 % protein, 0.69±0.05 % ash, pH 6.82±0.05, acidity 0.20±0.07 % lactic acid) was obtained from the Department of Animal Science, Faculty of Agriculture, Ege University. The yogurt culture used in the production was a DVS yogurt culture (Chr. Hansen Lab, Denmark) containing *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* as starter cultures. Whey powder (Pınarsüt, Izmir), stevia (Takita Co., Izmir), and dates (*Phoenix dactylifera* L.) (Yükselen Co., Izmir) were supplied for production. For packaging, 100 ml polystyrene yogurt cups and lids were used.

Methods

The production and analyses were conducted in two replicates. The general composition analyses of yogurt samples, including total dry matter, protein, and fat, were performed on the first day of storage. pH, acidity, and microbiological analyses were performed on the 1st, 7th, 14th, 21st, and 28th days of storage. Hardness, syneresis, water-holding capacity, viscosity, and sensory analyses were conducted on the 1st, 14th, and 28th days of storage. Total phenolic content and antioxidant activity analyses were performed on the 1st and 28th days of storage.

Yogurt production

Dates were peeled and pitted, then crushed into pulp. The date pulp was pasteurized in a water bath at 65±2°C for 30 minutes and cooled to room temperature before incorporation into the yogurt. The soluble solid content of the pulp was measured as 17.25°Brix. Non-fat milk solids in raw milk were standardized to 12% using whey powder (WP). According to the experimental design (Table 1), sugar and stevia were added to the milk. The milk mixture was pasteurized at 85°C for 10 minutes and cooled to 44±2°C. It was then inoculated with *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* cultures and incubated at 42±2°C until the pH reached 4.6. The yogurt curd was mixed at 35±2°C, and 10% date pulp was added at 20±2°C and thoroughly mixed. Finally, the date yogurt was portioned into 100 ml cups and stored at 4±1°C (Figure 1).

Physical and chemical analyses

The pH values of the yogurt samples were determined using a pH meter (Hanna Instruments pH211, Portugal). The acidity of the yogurt samples was measured by the alkaline titration method, fat by the Gerber method, total dry matter by the gravimetric method, and protein by calculating the total nitrogen content using the Kjeldahl method, multiplying the nitrogen content by a factor of 6.38 to obtain the protein percentage (AOAC 2003).

Microbiological analyses

10 g of each yogurt sample was thoroughly mixed with 90 mL of sterile Ringer solution, and the mixture was diluted in a series according to the recommended dilution rates. The enumeration of *Streptococcus thermophilus* was performed using the pour plate method on M17 agar. Plates inoculated with appropriate dilutions were incubated aerobically at 37°C for 48 hours before colony counting. For *Lactobacillus delbrueckii* subsp. *bulgaricus* counts, MRS agar was used. Plates were inoculated with appropriate dilutions and incubated anaerobically at 42°C for 72 hours, utilizing Anaerocult A (Merck, Germany) for anaerobic conditions (Donkor et al., 2006).

Total phenolic content and antioxidant activity

The total phenolic compounds in yogurt samples were determined using the Folin-Ciocalteau method (Beskow et al. 2015). Briefly, phenolic compounds in the samples reduced the Folin–Ciocalteu reagent in alkaline medium, producing a color change measured spectrophotometrically at 760 nm (Multiskan Sky, Thermo Scientific, USA). A gallic acid calibration curve was used, and results were expressed as gallic acid equivalents (mg GAE/g). The analysis results were presented in the equation $y = 0.0036967x + 0.0683047$ with R^2: 0.0997.

DPPH* Scavenging Activity; the antioxidant activity was determined using the method of Brand-Williams et al. (1995) with modifications. A 100 µM stock DPPH solution (2,2-diphenyl-1-picrylhydrazyl, Sigma-Aldrich D9132, CAS 1898-66-4) in methanol (Merck, 106009, CAS 67-56-1) was prepared. Equal volumes (100 µL) of DPPH solution and sample were mixed in 96-well microplates, incubated in the dark at room temperature for 30 min, and absorbance was measured at 517 nm using a ThermoScientific Multiskan Sky spectrophotometer (USA). Radical scavenging activity was expressed as % inhibition:

$$\% \mathbf{RSA} = (\mathbf{Acontrol} - \mathbf{Asample}) \div \mathbf{Acontrol} \times \mathbf{100}$$

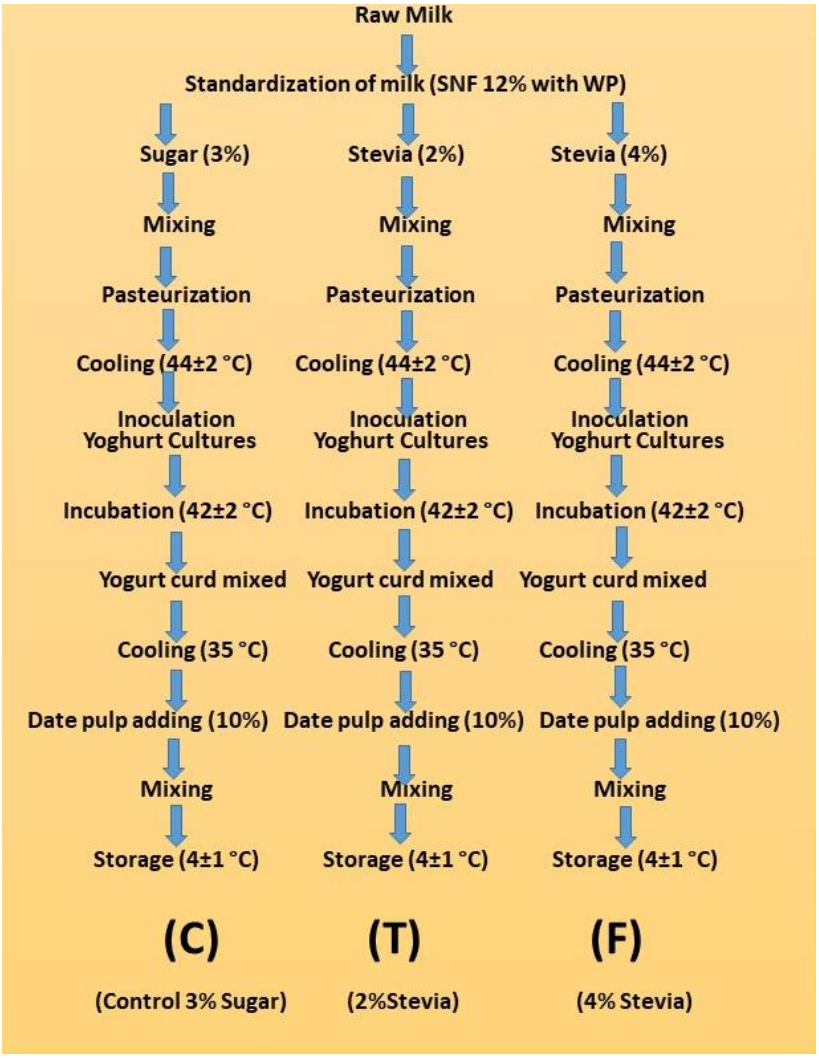


Figure 1. Date yogurt production.
Şekil 1. *Hurmalı yogurt üretimi.*

Textural analyses

The hardness of the yogurt samples was measured using a Brookfield CT 3 Texture Analyzer with appropriate attachments (Isanga & Zhang, 2009). Viscosity analyses of the yogurt samples were performed using a Brookfield Viscometer DV-II+ Pro (Saygılı et al., 2021). Syneresis was determined following the method described by Dannenberg and Kessler (1998), and the results were expressed as a percentage. The water-holding capacity (WHC) was evaluated using the centrifugation method of Bhullar et al. (2002), in which samples were centrifuged at 5000 rpm for 10 minutes.

Sensory analyses

A panel of six trained volunteers from the Dairy Technology Department, Faculty of Agriculture, Ege University, conducted sensory evaluation. Approximately 100 g of each yogurt sample was served in plastic containers labeled with three-digit random numerical codes in a statistically balanced order. Panelists scored the samples for taste, odor, texture and consistency, appearance, and overall acceptability, using a 5-point scale (1 = poor, 5 = excellent) as described by Bodyfelt et al. (1998).

Statistical analyses

Statistical analyses were performed separately for each storage day in order to evaluate the effect of sweetener type at a given storage time. For this purpose, one-way analysis of variance (ANOVA) followed by Duncan's multiple range test was applied. The research results were analyzed using IBM SPSS Statistics V22.0 (SPSS Inc., Chicago, USA). Storage time was evaluated as an observational factor to monitor changes during storage rather than as an independent factor in a factorial design.

RESULTS and DISCUSSION

Proximate composition

The non-fat dry matter, fat, and protein contents of the date yogurts are summarized in Table 1.

Table 1. Non-fat dry matter, fat, and protein contents of date yogurt

Çizelge 1. Hurmalı yoğurtların yağsız kurumadde, yağ ve protein içerikleri

Non-fat dry matter (%)	Fat (%)	Protein (%)
14,55±1,33[a]	2,87±0,10[a]	3,81±0,10
18,74±1,54[b]	3,30±0,14[b]	3,90±0,25
17,11±0,67[b]	3,50±0,14[b]	4,06±0,21

[a, b]: ±standard deviations in the same column with different superscript lowercase letters are significantly different (p<0.05).

T: 2% Stevia, F: 4% stevia, C: Control 3% Sugar.

Statistical analysis showed significant differences among the yogurt samples in non-fat dry matter and fat content (p<0.05), but no significant differences in protein content (p>0.05). All of the date yogurts' protein content values exceeded the minimum threshold of 2.7% specified in the Turkish Food Codex Fermented Milk Products Regulation and World Health Organization (WHO)/Food and Agriculture Organization's (FAO) Codex Alimentarius guidelines on fermented milk products, thus ensuring compliance with international standards (FAO, 2013, Anonymous, 2022). These findings align with previous studies on yogurts supplemented with similar ingredients (Peker & Aslan, 2017; Koca & Güven, 2018; Şahingil & Hayaloğlu, 2022; Dal Konuş & Turgay, 2023; Çalışkanlar et al., 2024).

pH and acidity

As shown in Figure 2, no statistically significant differences in pH were observed between storage days or among the samples (p>0.05). The use of stevia as a sugar substitute in date yogurt production did not affect the product's pH. Similarly, the pH values of date yogurts were found to be similar to those of yogurts produced with other fruits (Karaca et al., 2012; Karakuş et al., 2019; Osman et al., 2020; Ayaz et al, 2024). On the other hand, the use of dates instead of acidic fruit in yogurt production did not appear to alter pH significantly during storage. Similar to our findings, Guggisberg et al. (2011) found that adding a sweetener to yogurt did not affect the yogurt-making process or pH development. The pH of all samples increased during storage. Similarly, Hashim (2001) reported that the pH of yogurt increased with increasing amounts of date puree. Dal Konuş &Turgay (2023) also observed an increase in the pH of yogurts made with fresh and dried dates.

The difference between the % lactic acid values of the samples was found to be statistically insignificant (p>0.05). However, lactic acid content increased significantly during storage (p<0.05), aligning with the metabolic activity pattern of yogurt bacteria, which remain enzymatically active post-incubation but exhibit slowed growth (Robinson et al., 2006). The addition of pure stevia extract did not significantly affect the metabolic activity of these cultures. Lactic acid levels remained within the acceptable limits defined in the WHO/FAO Codex standards and maintained a minimum titratable acidity level of 0.6% throughout the storage period (FAO, 2013). This value is 0.3% in the Turkish Food Codex Fermented Milk Products Regulation, and our yogurts also comply with this value (Anonymous, 2022).

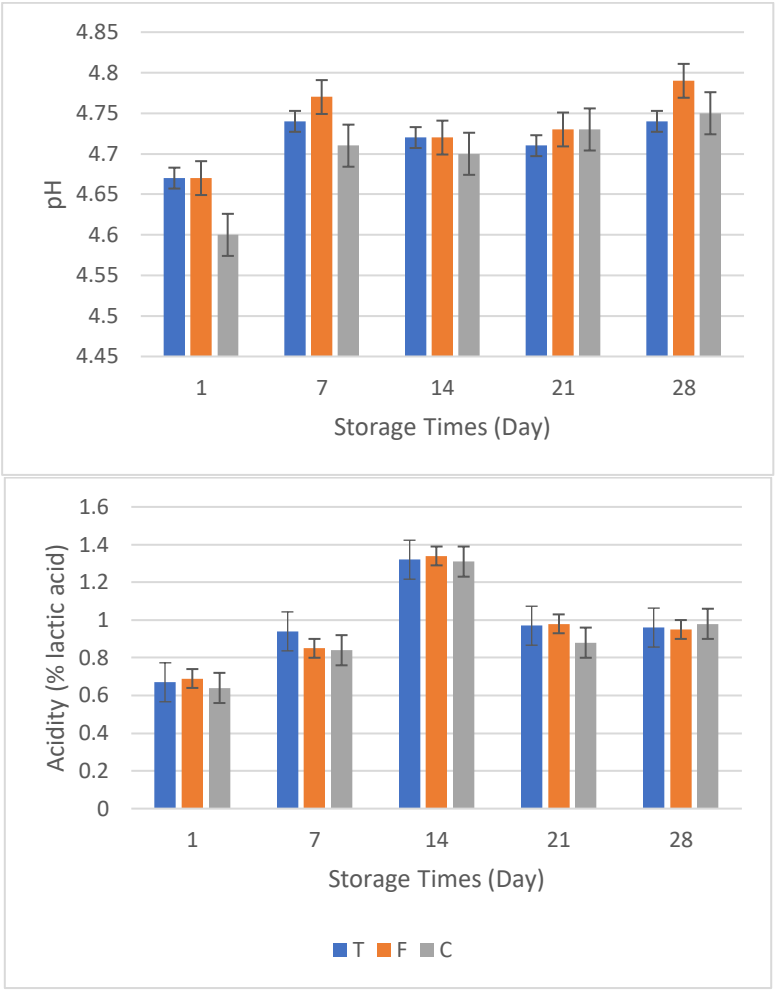


Figure 2. pH values and acidity of date yogurts.
Şekil 2. *Hurmalı yoğurtların pH ve asitlik değerleri.*

Viscosity, firmness, syneresis, and water holding capacity

The physical properties of date yogurts are presented in Table 2. The viscosity of the date yogurts sweetened with stevia was found to be higher than that of the yogurts sweetened with sugar, and this difference was statistically significant ($p<0.05$). Our results were higher than those reported by Koca & Güven (2018) for date kefir yogurts. On the other hand, our viscosity results align with those reported by Lisak et al. (2012) and Narayana et al. (2022). This and previous studies observed that the increase in viscosity is due to the interaction between stevia and milk proteins (Narayana et al., 2022). The statistically significant difference observed among the samples at the end of the storage period ($p<0.05$) is thought to be due to increased acidity and changes in microbial activity, which alter the physical structure and decrease viscosity.

As a result of the analyses, the highest firmness values were observed in the yogurts sweetened with stevia. In contrast, the firmness of the date yogurts sweetened with sugar was lower, and this difference was statistically significant ($p<0.05$). Both fermentation capacity and changes in the textural properties of yogurt are influenced by the addition of dietary fiber to milk (Sodini et al., 2004; Staffolo et al., 2004; Sendra et al., 2008). The firmness of the date yogurts did not change significantly during storage ($p>0.05$). Kalicka et al. (2017) reported that adding stevia increased yogurt firmness without affecting its consistency.

Table 2. Viscosity, firmness, syneresis, and water holding capacity of date yogurts
Çizelge 2. *Hurmalı yoğurtların viskozite, sertlik, su salma ve su tutma kapasitesi*

	Day	T	F	C
Viscosity (mPa.s)	**1**	3,26±0,92^{Aa}	3,29±0,71^{Aa}	2,90±0,59^{Ba}
	14	3,37±0,59^{Aa}	3,10±0,75^{Aba}	2.95±0,94^{Ba}
	28	2,38±0,03^{Ab}	2,72±0,38^{Ab}	3,27±0,45^{Bb}
Firmness (firmness; g)	**1**	54,50±2,82^{B}	62,75±7,42^{C}	47,37±3,71^{A}
	14	59,75±4,24^{B}	61,37±2,65^{B}	52,62±1,23^{A}
	28	60,62±22,80^{B}	66,37±11,13^{B}	45,37±7,60^{A}
Syneresis (%)	**1**	21,00±9,89^{B}	13,50±2,12^{A}	13,00±1,41^{Aa}
	14	22,00±8,48^{B}	14,70±0,42^{A}	13,00±4,24^{Aa}
	28	22,00±3,40^{B}	17,00±1,41^{A}	18,00±5,65^{Ab}
Water Holding Capacity	**1**	64,09±1,49^{a}	64,54±3,88	67,83±5,71
	14	64,59±3,38^{a}	66,02±4,06	68,57±6,18
	28	58,62±3,09^{b}	60,80±1,11	64,11±4,10

$^{a, b}$: In each analysis, differences between means expressed with different letters in the same column are significant (p<0.05).
$^{A, B, C}$: In each analysis, the difference between the means expressed with different letters within the row is significant (p<0.05).
T: 2% Stevia, F: 4% stevia, C: Control 3% Sugar.

In fermented dairy products such as yogurt, whey separation is considered a primary defect that can render the product unacceptable to consumers (Sandoval-Castillaa, 2004). Syneresis was lower in the S sample produced with 3% sugar and the F sample produced with 4% stevia than in the T sample produced with 2% stevia, and this difference was statistically significant (p<0.05). The higher dry matter content influences this outcome. Storage did not significantly affect syneresis in the yogurts, except for the C sample on day 28 (p>0.05). In our study, the lower whey syneresis rate is attributed to the use of date pulp, which contributed to the formation and stability of the yogurt gel structure. Dal Konuş &Turgay (2023) found in their study on yogurts containing fresh and dried dates that the highest whey separation occurred in plain yogurt, while the lowest separation occurred in yogurts with fresh fruit pulp and mixes without fresh fruit pulp. Çakmakçı et al. (2013) determined that using high-dry-matter fruit pulps in fruity yogurts reduced whey syneresis. Moreover, the absence of rapid acidification during storage also slowed down whey separation. Hernández-Rodríguez et al. (2017) reported that stevia can interact with milk proteins. In their research, they suggested that stevia's interaction with milk proteins, even at 100% sugar replacement levels, strengthens the yogurt gel matrix, leading to reduced whey syneresis and enhanced water retention capacity.

One of the most important features of set-type yogurt is the strength of the curd and its ability to retain water. Water holding capacity (WHC), a critical physical characteristic of the set-type yogurt gel, plays a significant role. The WHC reflects the stability of the curd and its ability to retain water within the yogurt matrix, thereby reducing whey syneresis. It is an essential index for evaluating yogurt quality, especially in set-type yogurt, where whey syneresis is considered a significant defect that can lead to consumer rejection (Narayana & Gupta, 2013). Higher dry matter and protein levels result in a denser gel structure in yogurt, which helps retain more water within the matrix (Sodini et al., 2004). The use of sugar and two different concentrations of stevia (2% and 4%) in the production of date yogurt did not affect the WHC; in the end, this difference was statistically insignificant (p>0.05). A similar trend was observed during storage, except for a significant change in the WHC of date yogurt sweetened with 2% stevia on day 28 (p<0.05). Torres et al. (2013) reported that sucrose contributes to moisture retention in yogurt gels. Narayana et al. (2014) found that the WHC of vanilla yogurts sweetened with stevia instead of sugar did not change, a result similar to ours.

Total phenolic content and antioxidant capacity

The total phenolic content (TPC) and antioxidant capacity of the date yogurts sweetened with stevia and sugar are presented in Table 3. The total phenolic content of the date yogurts, sweetened with stevia or sugar, ranged from 0.44 to 0.56 mg GAE/g, with a statistically significant difference observed on the 28th day of storage (p<0.05). The antioxidant effect of the date phenolic compounds is greater than that of ascorbic acid (Shivashankara et al., 2004). In the yogurt samples formulated without stevia, the observed total phenolic content can be primarily attributed to the presence of date pulp. Dates are known to be rich in phenolic acids and flavonoids, which have been extensively characterized in the literature and shown to contribute to antioxidant capacity in functional dairy products such as yogurt (Almusallam et al., 2021). Similar increases in total phenolic content and antioxidant activity have been reported in yogurts enriched with date-based ingredients, where phenolic retention depends on processing conditions and storage time (Arfaoui, 2020). This low phenolic content is likely due to the purification processes in commercial stevia sweeteners that reduce polyphenol activity. Shukla et al. (2009) studied *Stevia rebaudiana* and vanilla-flavored yogurts sweetened with stevia and also reported negligible increases in polyphenols, supporting these findings. Therefore, yogurts produced with different fruits (Bezzera et al., 2015; Özer, 2024) or fruit seed powders (Abdollahzadeh et al., 2018; Abdel-Hamid et al., 2020; Bchir et al., 2020; Çalışkanlar, 2024) have higher total phenolic content compared to date yogurts.

Table 3. Total phenolic content and antioxidant capacity of date yogurt

Çizelge 3. *Hurmalı yoğurtların toplam fenolik içerikleri ve antioksidan kapasiteleri*

	Day	T	F	C
Total Phenolic Content (mg GAE/g)	1	0,48±0,06	0,47±0,01	0,45±0,04
	28	0,56±0,10^{B}	0,51±0,17^{AB}	0,44±0,10^{B}
DPPH (%)	1	20±0,09^{A}	25±0,04^{AB}	30±0,06^{B}
	28	24±0,01	26±0,00	28±0,02

$^{A, B}$: In each analysis, the difference between the means expressed with different letters within the row is significant (p<0.05).

T: 2% Stevia, F: 4% stevia, C: Control 3% Sugar

Looking at the DPPH % radical scavenging results, the difference among samples T, F, and C was statistically significant on the first day of storage (p<0.05); however, it was not significant on the 28th day (p>0.05). In recent years, various studies have been conducted to improve not only the sensory appeal of fruit yogurts but also their health benefits. In this context, ways to enhance antioxidant capacity, which promotes the digestive system, are being investigated. To this end, yogurt combined with antioxidant-rich fruits, as well as various natural extracts that can enhance this content, has been used (Peker & Aslan, 2017). Our results were slightly higher than the DPPH % antioxidant scavenging levels of plain yogurts (Oliveira et al., 2015; Karnopp et al., 2017; Jaster et al., 2018), which is thought to be due to the addition of dates.

Microbiological analyses

Figure 3 shows the counts of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in the date yogurts. The microbiological analysis of date yogurts revealed that the counts of *Lactobacillus delbrueckii* subsp. *bulgaricus* ranged from 3.47 to 4.95 log CFU/g, with significant changes during the storage period *(p*<0.05), especially on days 7 and 14. In contrast, *Streptococcus thermophilus* counts were higher, ranging from 8.51 to 9.32 log CFU/g, and did not show significant differences between samples (p>0.05) over 28 days. The differences observed in samples T and F on the seventh day were statistically significant concerning the storage period (p<0.05). The *L. bulgaricus* and *S. thermophilus* counts in the stevia-sweetened date yogurts were higher than those in the sucrose-sweetened date yogurts. Narayanna et al. (2022) reported that the addition of sweeteners —whether sucrose, stevia, or a combination of both —did not affect the metabolic activity of the starter culture microorganisms.

An ideal ratio of *L. bulgaricus* to *S. thermophilus* in yogurt is 1: 1 (Tamime & Robinson, 2007). However, in our study, the *L. bulgaricus* count remained low (3.47-4.45 log CFU/g) throughout the storage period, whereas the *S. thermophilus* count was high (8.51-9.32 log CFU/g). Similarly, Dimitrellou et al. (2020) noted that the starter culture contained an increasing number of *S. thermophilus* and a lower amount of *L. bulgaricus*. Özer (2024) also observed that in apricot-flavored yogurts sweetened with stevia and containing EPS-producing cultures, the *L. bulgaricus* counts ranged between 1.91 and 3.19 log CFU/g. Dal Konuş & Turgay (2023) found that, in yogurts produced with dried and fresh dates, the highest probiotic bacteria counts were detected in plain yogurts, followed by those produced with fresh dates. The highest probiotic bacteria counts were detected in plain yogurts, followed by those produced with fresh dates.

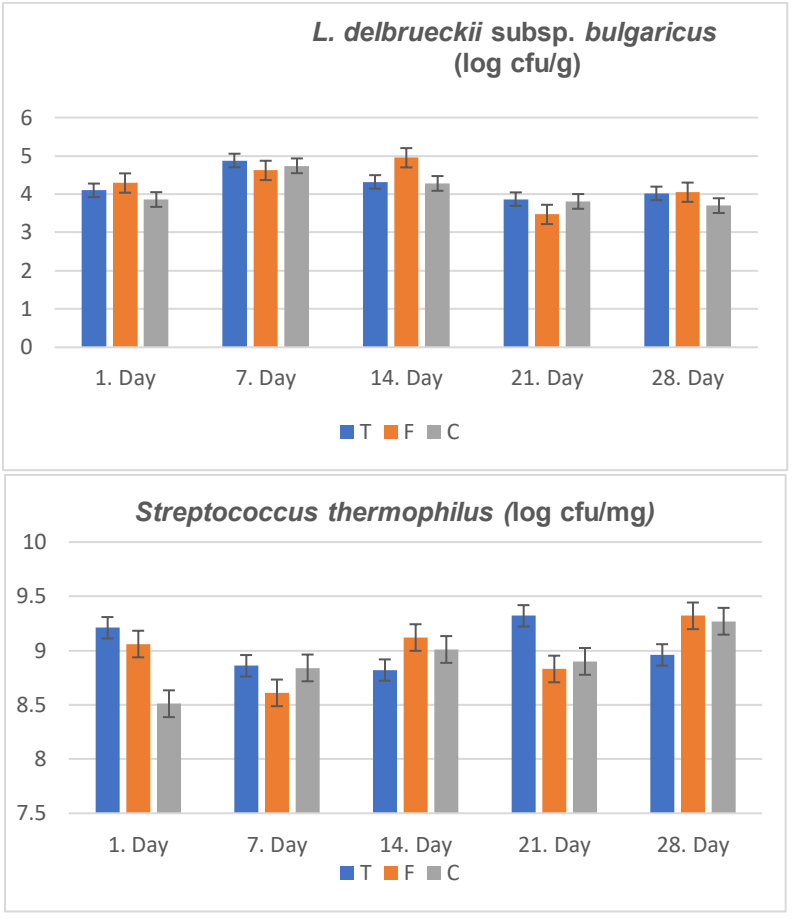


Figure 3. Counts of *L. delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in date yogurt (log CFU/g).
Şekil 3. *Hurmalı yoğurtlarda L. delbrueckii* subsp. *bulgaricus ve Streptococcus thermophilus sayıları (log CFU/g.*

A comparison of sucrose and stevia in yogurts containing grapefruit, apple, pomegranate, and blackberry showed that the highest *L. bulgaricus* count (6.29±0.89 CFU/g) and *S. thermophilus* count (6.97±0.01 log CFU/g) were observed in grapefruit yogurts sweetened with stevia. However, on the 14th day of storage, a decrease in *L. bulgaricus* counts was noted in the apple and sucrose, and pomegranate/sucrose samples. At the same time, an increase was observed in the other samples (Edebali, 2019). The results of Santo et al. (2012) and Demirci et al. (2017) were similar to those of our study overall, while the sweetener type influenced bacterial counts, the metabolic activity of starter cultures was not adversely affected by the addition of sucrose or stevia.

The counts of *Lactobacillus delbrueckii* subsp. *bulgaricus* observed in this study (3–4 log CFU/g) were lower than those typically reported for conventional yogurt. Similar reductions in *L. bulgaricus* counts have been reported in yogurts supplemented with plant-based ingredients, which may exert inhibitory effects on lactic acid bacteria due to their bioactive compounds (Rahmatalla et al., 2017). Moreover, the dominance of *Streptococcus thermophilus* during yogurt fermentation and refrigerated storage has been well documented and may limit the growth of *L. bulgaricus* through microbial competition (Glušac et al., 2015; Tekyiğit & Uysal, 2023). Despite the relatively low counts, the observed microbial levels were sufficient to ensure acceptable acidification and overall product quality. Similar reductions in *L. bulgaricus* counts have been reported in fruit- and polyphenol-enriched yogurt formulations, indicating that such ingredients may influence microbial dynamics without compromising technological quality (Tamime & Robinson, 2007).

Sensory analysis

he sensory properties of date yogurts sweetened with stevia and sugar were evaluated using five criteria: taste, odor, consistency, appearance, and overall acceptability. The sensory scores obtained and the overall average scores during storage are presented in Figure 4.

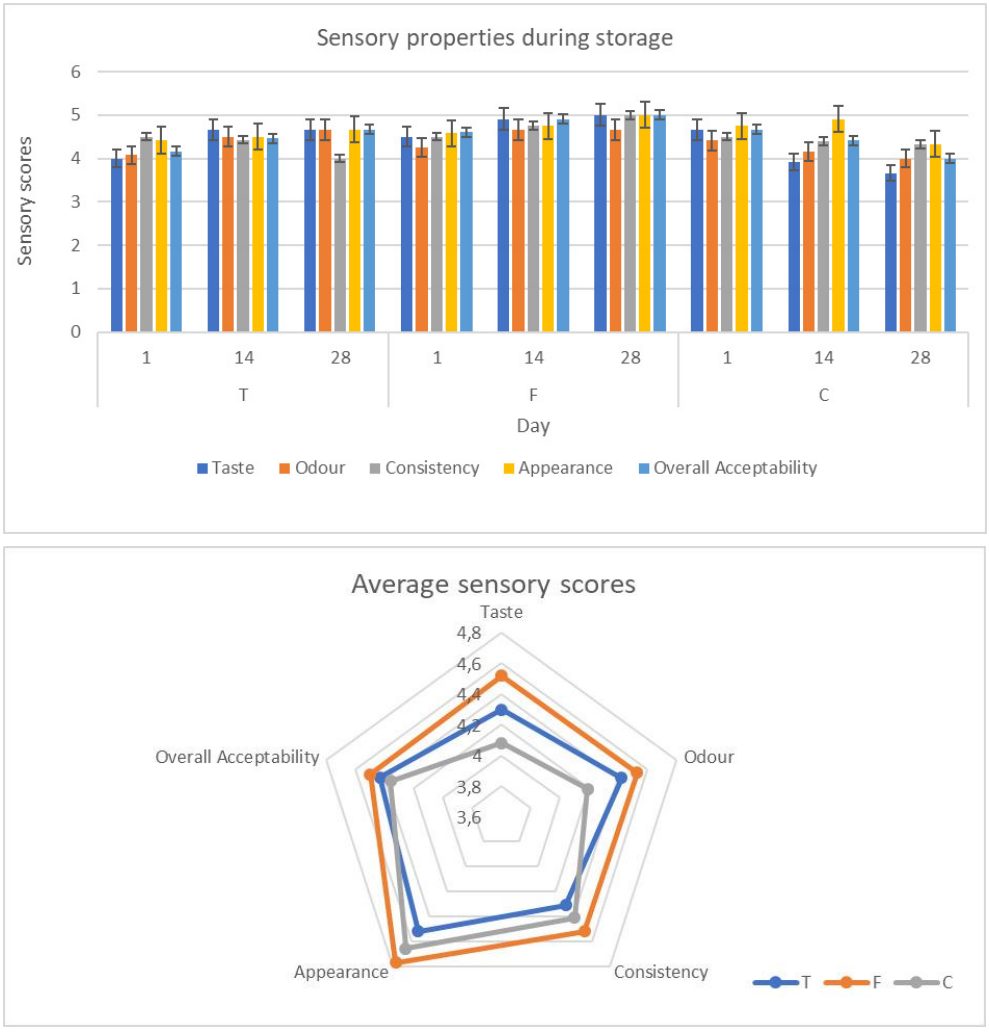


Figure 4. Sensory analysis results of the date yogurt.

Şekil 4. *Hurmalı yoğurtların duyusal analiz sonuçları.*

On the first day of storage, the sugar-sweetened sample (C) received the highest scores. However, at the 14th and 28th days, the 4% stevia (F) sample was preferred by panelists and received higher scores than the 2% stevia (T) and 3% sugar (C) samples. Averaging all sensory criteria, the 4% stevia sample (F) obtained the highest overall score. When directly comparing 2% stevia (T) and 3% sugar (C) samples, the former scored higher for taste, odor, and overall acceptability, while the sugar-sweetened sample was rated higher for texture consistency and appearance.

Interestingly, these findings contrast with some previous studies (Karakuş et al., 2019; Edebali, 2019; Narayana et al., 2022), which found that yogurt sweetened with stevia rather than sugar resulted in lower sensory scores. Dal Konuş & Turgay (2023) recommended adding sugar to yogurts made with dry and fresh dates. Nevertheless, this study found that using either stevia or sugar improved the sensory appeal of date yogurts.

Supporting these results, Lisak et al. (2012) reported similar aroma and color scores when using 100% sugar, 100% stevia, or a 50: 50 sugar-stevia blends in yogurt production. It is also noted that different stevia formulations available on the market may differently affect organoleptic qualities and other product characteristics, underscoring the importance of careful stevia selection to achieve desired sensory outcomes and consumer preferences (Narayanan et al., 2014).

CONCLUSION

The use of 2% and 4% stevia as sweeteners in the production of date yogurt, compared to 3% sucrose, did not statistically affect protein content, pH, acidity, total phenolic content, DPPH radical scavenging activity, or water-holding capacity ($p>0.05$). Similarly, no significant differences were observed in solid non-fat, fat, viscosity, and firmness between date yogurts sweetened with 4% stevia and those with 3% sucrose ($p>0.05$). From a quality standpoint, all products complied with the WHO/FAO Codex Alimentarius Commission yogurt standards and Turkish Food Codex Fermented Milk Products Regulation.

This study highlights the importance of carefully selecting both the type and concentration of stevia when producing yogurt varieties containing this sweetener. Furthermore, it suggests that adapting yogurt cultures to produce lower acidity, alongside choosing stevia sweeteners with appropriate purity and type, can optimize product quality. As consumers often seek sweetness in fruit yogurts, this study found that replacing sucrose with stevia did not present sensory challenges. Given the growing use of stevia sweeteners in functional foods such as yogurt, further research is needed to evaluate the effects of various stevia formulations on the viability and performance of yogurt cultures.

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Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: ÖG, RK, SB, CK; sample collection: ÖG, RK, SB, EÖ; analysis and interpretation of data: ÖG, RK, SB, EÖ; statistical analysis: ÖG, RK, SB, EÖ; visualization: CK; writing manuscript: CK, ÖG, EÖ, RK.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that an ethics committee is not required for this study.

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