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# TECHNOLOGICAL QUALITY AND VOLATILE PROFILE OF SET AND STIRRED YOGURTS FORTIFIED WITH WILD SOUR APPLE (*Malus sylvestris* MILL.) SAUCE PREPARED WITH DIFFERENT SUGAR LEVELS

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## ABSTRACT

Alternative set and stirred fruit yogurt were produced using wild sour apple (*Malus sylvestris* Mill.) sauce (WSA sauce) prepared with sugar addition at two different concentrations (20% and 25%). The physicochemical, microbiological, and sensory properties were monitored over a 14-day period. Furthermore, the volatile composition was determined using HS-SPME-GC-MS. The study aimed to evaluate the potential application of WSA sauce in fruit yogurt and to identify the optimal sugar concentration and production method based on the examined parameters. The incorporation of WSA sauce increased the dry matter and apparent viscosity while reducing syneresis. Throughout the storage, *Lactococcus* and *Lactobacillus* remained above 107 CFU/g. According to the results, 74 volatile compounds were identified, and the WSA-supplemented yogurt exhibited a composition rich in terpenes and alcohols. Based on sensory attributes and aroma composition, the set-type sample containing WSA sauce prepared with 25% sugar can be recommended as the most suitable formulation for industrial production.

**Keywords:** Wild sour apple, *Malus sylvestris* Mill., Fruit yogurt, Sugar rate, Aroma, Bayburt

# FARKLI ŞEKER SEVİYELERİYLE HAZIRLANAN *Malus sylvestris* MILLER (YABANİ EKŞİ ELMA) SOSLU SET VE ÇIRPILMIŞ YOĞURTLARIN TEKNOLOJİK KALİTE VE UÇUCU BİLEŞEN PROFİLİ

## ÖZ

Bu çalışmada, %20 ve %25 olmak üzere iki farklı oranda şeker ilavesi ile hazırlanmış yabani ekşi elma (*Malus sylvestris* Mill.) sosu (YEE sosu); kullanılarak alternatif set ve çırpılmış meyveli yoğurtlar elde edilmiştir. Yoğurt örnekleri, bazı fizikokimyasal, mikrobiyolojik, duyusal nitelikleri 14 gün süresince analiz edilmiş, ayrıca HS-SPME-GC-MS kullanılarak uçucu bileşen kompozisyonu belirlenmiştir. Böylece incelenen nitelikler bakımından, meyveli yoğurt örneklerinde yabani ekşi elma sosunun kullanılabilme potansiyeli, en uygun şeker oranı ve üretim yöntemi belirlenmeye çalışılmıştır. YEE sosu ilavesi yoğurt örneklerinin kurumadde ve görünür viskozitesini artırmış, serum ayrılmasını azaltmıştır. Depolama süresince tüm örneklerde *Laktokok* ve *Laktobasil* sayısı 107 kob/g seviyesinin üzerinde bulunmuştur. Sonuçlara göre, yoğurt örneklerinde toplam 74 bileşen tanımlanmıştır. Uçucu bileşenler açısından WSA ilaveli yoğurtların terpenler ve alkoller açısından zengin bir kompozisyona sahip olduğu belirlenmiştir. Duyusal özellikler ve aroma kompozisyonu göz önüne alındığında, %25 şekerle hazırlanan YEE soslu set tipi numune, endüstriyel üretim için en uygun formülasyon olarak önerilebilir.

**Anahtar kelimeler:** Yabani ekşi elma, *Malus sylvestris* Mill., meyveli yoğurt, şeker oranı, aroma, Bayburt

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## INTRODUCTION

Anatolia is considered one of the most biologically significant regions in the world due to its rich flora. Numerous wild fruit species grow naturally within this region. In addition to fresh consumption, these fruits can be processed into a variety of food products. Fruits and vegetables are indispensable to human nutrition, as they contain numerous valuable components, including vitamins, minerals, and dietary fiber (Pal and Molnár, 2021). Currently, there is a growing consumer trend toward including food sources grown under natural conditions, without pesticides or synthetic fertilizers, in daily diets. Consequently, wild fruits represent a potential resource for the organic food market. Scientific research elucidating the health-promoting functional and bioactive components of wild plants has stimulated interest in these species (Demir, 2006; Fatima et al., 2025). Wild plants, and particularly wild fruits, contain compounds exhibiting high antioxidant activity. Many biological functions, including antimutagenic, anticarcinogenic, and anti-aging effects, are attributed to these antioxidants (Akbari et al., 2022).

Apples, one of the most frequently consumed fruits, serve as a source of minerals, monosaccharides, dietary fiber, various biologically active compounds, Vitamin C, and phenolic compounds, which are natural antioxidants in human nutrition (Wu et al., 2007; Mierczak and Garus-Pakowska, 2024). The presence of substances in apples that help protect against certain types of cancer, diabetes, asthma, and cardiovascular diseases (Hyson, 2011) has also influenced research on functional foods (Arslaner and Salık, 2022). The Bayburt wild sour apple is a yellow-skinned, white-fleshed, fragrant, and aromatic fruit that is traditionally consumed by the local population of the Bayburt province during winter months as an acidic alternative to lemon in tea. Regionally, this fruit is also utilized in dried or pickled forms. In folk medicine, it is recognized for its ability to regulate blood sugar levels and for its diuretic properties. A review of the literature reveals a scarcity of studies regarding this species, indicating that it has not been processed into products other than herbal tea and jam (Güldemir, 2016; Güldemir et al., 2020; Arslaner and Salık, 2020).

In a study investigating the effects of different drying techniques on the antioxidant and phenolic properties of wild sour apples grown naturally in Bayburt, the dry matter, water-soluble dry matter, Vitamin C, total acidity, malic acid, glucose, and water activity values were determined as 16.06%, 13.35%, 30.7 mg/L, 2.95 g/L, 9.6 mg/L, 46 mg/L, and 0.93, respectively (Güldemir, 2016). In another study examining the various attributes of marmalades produced from wild fruits via traditional methods, the pH, titratable acidity (TA), dry matter, and water-soluble dry matter (WSDM) values of wild sour apples obtained from Bayburt were determined as 2.76, 3.16%, 17.63%, and 17.09%, respectively. The same researchers reported pH, TA, dry matter, WSDM, and water activity values of 2.66, 1.81%, 53.65%, 52.28%, and 0.894, respectively, in marmalades produced from wild sour apples (Arslaner and Salık, 2020)

Yogurt is a fermented milk product possessing high nutritional value and functional properties, produced by the inoculation of milk-following necessary pre-treatments such as clarification, separation, homogenization, and heat treatment-with yogurt starter bacteria (*Lactobacillus delbrueckii* subsp. bulgaricus and Streptococcus thermophilus) to convert lactose into lactic acid (Garavand et al., 2023; Yıldız Küçük and Bakırcı, 2025).

The association of food additives with emerging health concerns has driven consumers toward natural, organic, and synthetic additive-free foods, thereby generating significant demand within the functional food market. The present study aims to develop an alternative functional fruit yogurt to address these consumer demands. Consequently, the value-added potential and consumption of wild apples are expected to increase through their processing into diverse products such as sour apple sauce and yogurt supplemented with sour apple sauce.

To this end, fruit sauces were prepared by adding sugar at two concentrations (20% and 25%) to wild sour apples (*Malus sylvestris* Mill.) from the Bayburt province; these sauces were subsequently incorporated into yogurt at a 30% ratio. This novel research is the first to investigate the effects of supplementing set and stirred yogurt with Bayburt wild sour apple (*Malus sylvestris* Mill.) sauce prepared with different sugar concentrations on technological quality and sensory parameters. Furthermore, the present study evaluates the impact of this wild fruit-which enriches the yogurt matrix with vitamins, minerals, fiber, phenolics, and antioxidants-on the viability of yogurt starter bacteria and the volatile compound composition of the final product.

## MATERIALS AND METHODS

### Materials

The wild sour apple (*Malus sylvestris* Mill.) fruit used for the preparation of the fruit sauce, granulated sugar, lemon, pasteurized cow milk (13.49% total solids, 3.70% protein, 3.5% fat, 0.1% titratable acidity, and pH 6.75), starch, and pectin were purchased from local markets operating in the province of Bayburt, Turkey. Milk powder was obtained from Enka Süt ve Mam. San. Tic. A.Ş. (Turkey). Commercial freeze-dried starter cultures consisting of *Lactobacillus delbrueckii* subsp. bulgaricus and *Streptococcus thermophilus* (1:1 ratio) were supplied by Chr. Hansen (Istanbul, Turkey).

### Methods

### Production of wild sour apple (*Malus sylvestris* Miller) sauce

The production stages and processing parameters for the wild sour apple (WSA) sauce are detailed in the flow diagram presented in Figure 1a (created via Biorender.com). Figure 1b presents images of the WSA sauce production process under laboratory conditions. Excluding wild sour apples, table sugar, and lemon, no preservatives, colorants, or flavoring agents were employed in the fruit sauce formulation. No preservatives, colorants, or flavoring agents were used in the fruit sauce formulation, aside from wild sour apples, table sugar, and lemon. Wild sour apples were processed by sorting, rinsing, peeling, and pitting, then boiled at 90°C for 5 minutes with 10% water added. The boiled fruits were pulped using a Waring blender (7011HS). The resulting pulp was divided into two equal portions; 20% sucrose was added to the first portion and 25% sucrose to the second. Both pulps were heated to 90°C for 20 minutes. Lemon juice (5%) was then added until the pH reached 2.8-3.5, and heating continued for an additional 5 minutes. After cooking, the fruit sauce (≥55 Brix) was transferred into sterile jars and stored under refrigeration (4°C) until utilized in yogurt production.

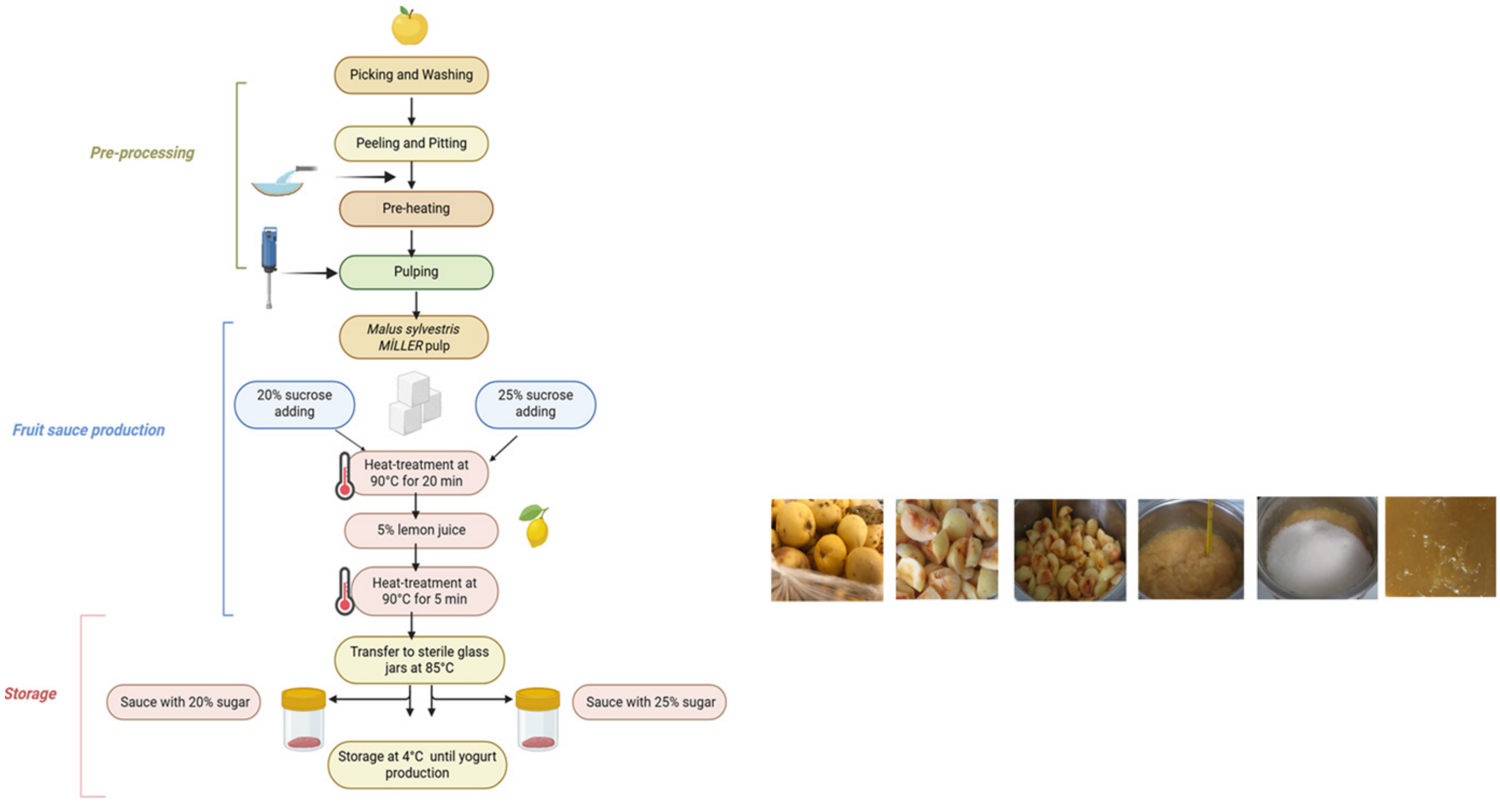

Figure 1. (a) Production process of wild *Malus sylvestris* MILLER fruit sauce (biorender.com) (b)The production stages of WSA sauce under laboratory conditions

### Production of wild fruit-supplemented yogurt

The total solids content of the milk was adjusted to 16-17% by adding 3% milk powder, 1% starch, and 0.1% pectin (Arslaner et al., 2021). Following pasteurization at 90°C for 15 minutes, the milk was cooled to 43°C and inoculated with 0.3-0.6% starter culture (*Lactobacillus delbrueckii* subsp. bulgaricus and Streptococcus thermophilus; 1:1). To achieve a final product with 30% fruit sauce content, the fruit sauce was dispensed into jars prior to the milk. Subsequently, the jars were filled with the inoculated milk and incubated at 43°C. Fermentation was terminated when the pH reached 4.7 (approximately 3 hours), and the samples were transferred to the cooling stage. After the yogurt samples were refrigerated for 24 hours, a portion of each batch was mechanically mixed to produce the stirred-type fruit yogurt. Both set-type (B, C) and stirred-type (D, E) yogurts were stored under refrigeration for 14 days, with analyses conducted on days 1, 7, and 14. The sample codes and their formulations are presented in Table 1.

Table 1. Trial design

| Sample code | Fruit sauce rate | Sugar rate | Method |
|---|---|---|---|
| A | 0% | 0% | Set |
| B | 30% | 20% | Set |
| C | 30% | 25% | Set |
| D | 30% | 20% | Stirred |
| E | 30% | 25% | Stirred |

### Physicochemical analysis of fruit yogurts

The total solids and protein contents were determined by the gravimetric and micro-Kjeldahl methods, respectively (AOAC, 2005). Apparent viscosity (cP) was measured at 4±1°C using a digital Brookfield viscometer (Model DV-II, Brookfield Engineering Laboratories, Stoughton, MA, USA) equipped with a No. 6 spindle rotating at 50 rpm.

To determine syneresis (serum separation), a 25 g yogurt sample was filtered through filter paper at 4°C for 2 hours. The weight of the separated serum was recorded, and the results were expressed as a percentage (Atamer and Sezgin, 1986; Arslaner et al., 2021). Titratable acidity (expressed as % lactic acid) was determined by titration (Bradley et al., 1992), while pH was measured with a pH meter (Mettler Toledo Seven Compact S220; Mettler-Toledo International Inc., Im Langacher Greifensee, Switzerland).

Color analysis was performed according to the CIE (Commission Internationale de l'Éclairage) system, using three-dimensional color parameters (L*, a*, and b*) measured with a colorimeter (CR-400, Minolta Co.). In this system, L□ indicates lightness ranging from 0 (black) to 100 (white); a* represents chromaticity on the green-red axis, where negative values indicate green and positive values indicate red; and b* represents chromaticity on the blue-yellow axis, where negative values indicate blue and positive values indicate yellow. All physicochemical analyses were conducted on days 1, 7, and 14 of storage. The entire study was carried out in duplicate.

### Microbiological analysis of fruit yogurts

A 10 g aliquot of the yogurt sample was weighed into 90 mL of sterile physiological saline (0.85% NaCl) and homogenized for 2 minutes using a Stomacher (Interscience BagMixer® 400, France) to prepare the initial dilution (10-1). Subsequently, 1 mL aliquots were transferred via an automatic pipette into tubes containing 9 mL of sterile diluent. Serial decimal dilutions were performed up to 10-9 (Chouchouli et al., 2013). During the storage period, *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. bulgaricus were enumerated on M17 Agar (Merck, Germany) at 37°C for 3 days and MRS Agar (Merck, Germany) in an anaerobic jar at 37°C for 3 days, respectively (Dave and Shah, 1996). Additionally, the samples were monitored for the presence of yeasts and molds using Potato Dextrose Agar (PDA) at 25°C, for 3 to 5 days, and for coliform bacteria using Violet Red Bile Agar (VRBA) at 35 to 37°C for 24 h (Harrigan, 1998).

### Analysis of volatile compounds

Five-gram aliquots of the yogurt samples were weighed into 40 mL vials (Supelco, Bellefonte, PA, USA). The vials were placed in a thermal block (Supelco) and equilibrated at 40°C for 30 minutes to facilitate the accumulation of volatile compounds in the headspace. For volatile extraction, a 75 µm carboxen/polydimethylsiloxane (CAR/PDMS) fiber (Supelco, USA) was exposed to the headspace at the same temperature for 30 minutes. Subsequently, the fiber was inserted into the injection port of a gas chromatograph (GC, Agilent Technologies 6890N) coupled to a mass spectrometer (MS, Agilent Technologies 5973) for thermal desorption. Separation was performed using a DB-624 capillary column (60 m × 0.25 mm i.d., 1.4 µm film thickness; J&W Scientific). The GC oven temperature program was configured as follows: initial hold at 40°C for 6 minutes, increased to 110°C at a rate of 3°C/min, then to 150°C at 4°C/min, and finally to 210°C at 10°C/min, where it was held for 12 minutes (total run time: 56.33 minutes). Helium was employed as the carrier gas at a constant flow rate of 1 mL/min. Identification of volatile compounds was achieved by comparing their mass spectra with those in the NIST, WILEY, and FLAVOR libraries and confirmed using authentic standards. The analysis was conducted on days 1, 7, and 14 of storage. The entire study was carried out in duplicate (Marco et al., 2004; Arslaner, 2020).

### Sensory analysis

To assess the sensory attributes, a scoring card based on the standard TS 1330, defined by the Turkish Standards Institute (TSE), was modified and used (Bakırcı and Arslaner, 2007; Arslaner et al., 2021). Yogurt samples fermented in 80-100 cc sterile sample containers were presented to each panelist at refrigerator temperature (4±2°C). The sensory properties of the yogurt samples-specifically appearance, consistency by spoon, consistency in the mouth, odor, and taste-were evaluated by a panel of ten trained judges from the Department of Food Engineering at Bayburt University. Evaluations were conducted on days 1, 7, and 14 of storage at 4±1°C, utilizing a 5-point scale ranging from 1 (extremely poor) to 5 (excellent). The Ethics Committee of Bayburt University granted ethical approval with decision number 263354 for the sensory analysis.

### Statistical analysis

The experiment utilized a factorial arrangement; incorporating three levels of sugar (0%, 20%, 25%) two methods (set and stirred), and three storage periods (1, 7, 14 days), with two replications, following a Randomized Complete Block Design. Data was analyzed by analysis of variance using the SPSS software package (SPSS Inc., Chicago, IL, USA). Duncan's Multiple Range Test was applied to identify statistically significant group differences.

## RESULTS AND DISCUSSION

### Physicochemical properties

The incorporation of WSA sauce significantly influenced all physicochemical parameters evaluated in the yogurt samples ($P<0.01$). As presented in Table 2, the values for total solids, fat content, protein content, apparent viscosity, syneresis, titratable acidity, and pH ranged from 18.47% to 20.15%, 2.85% to 3.50%, 3.20% to 4.66%, 3993 to 10234 cP, 30.73% to 41.84%, 1.08% to 1.20%, and 4.04 to 4.46, respectively. While total solids, apparent viscosity, and titratable acidity were significantly higher in the fruit-supplemented samples ($P<0.01$), the incorporation of fruit sauce resulted in a significant reduction in fat content, protein content, syneresis, and pH values ($P<0.01$). The proportional reduction in fat content observed in supplemented samples compared to plain yogurt is expected, attributed to the dilution effect of the fruit sauce (Tuorila et al., 1993; Remya et al., 2019). Similarly, the decrease in pH upon adding fruit sauce is attributed to the organic acids inherent to the wild sour apple. Conversely, Dal Konuş and Turgay (2023) reported that fruit supplementation increased pH and decreased titratable acidity in yogurt fortified with dried and fresh persimmon.

Table 2. Physicochemical analysis results of set and stirred yogurt with WSA sauce

| | | Total Solids % | Fat % | Protein % | Viscosity cP | Syneresis % | Titratable Acidity % TA | pH |
|---|---|---|---|---|---|---|---|---|
| Samples | A | 18.47±0.42$^{d}$ | 3.50±0.05$^{a}$ | 4.66±0.02$^{a}$ | 3993±804$^{b}$ | 41.84±1.91$^{a}$ | 1.04±0.03$^{c}$ | 4.46±0.03$^{a}$ |
| | B | 18.85±0.31$^{c}$ | 3.01±0.12$^{b}$ | 3.26±0.02$^{b}$ | 9574±2602$^{a}$ | 31.60±4.82$^{b}$ | 1.08±0.07$^{b}$c | 4.18±0.09$^{b}$ |
| | C | 20.15±0.04$^{a}$ | 2.87±0.05$^{d}$ | 3.20±0.06$^{b}$ | 10234±3735$^{a}$ | 31.16±6.49 $^{b}$ | 1.20±0.09$^{a}$ | 4.12±0.05$^{bc}$ |
| | D | 19.69±0.23$^{b}$ | 2.92±0.02$^{c}$ | 3.28±0.03$^{b}$ | 8221±2018$^{a}$ | 30.73±5.75$^{b}$ | 1.18±0.14$^{ab}$ | 4.01±0.02$^{c}$ |
| | E | 19.64±0.23$^{b}$ | 2.85±0.04$^{d}$ | 3.22±0.05$^{b}$ | 6862±3033$^{ab}$ | 32.76±4.20$^{b}$ | 1.20±0.02$^{a}$ | 4.07±0.04$^{bc}$ |
| | Sig. | ** | ** | ** | ** | ** | ** | ** |
| Storage (Day) | 1 | 19.21±0.78 | 3.04±0.28 | 3.52±0.01 | 4963±1648$^{c}$ | 31.75±5.05$^{b}$ | 1.13±0.07$^{b}$ | 4.25±0.19 |
| | 7 | 19.32±0.74 | 3.03±0.22 | 3.54±0.03 | 8003±2265$^{b}$ | 29.83±5.99$^{b}$ | 1.07±0.08$^{b}$ | 4.16±0.18 |
| | 14 | 19.53±0.47 | 3.02±0.27 | 3.48±0.06 | 10364±3393$^{a}$ | 39.26±2.78$^{a}$ | 1.22±0.10$^{a}$ | 4.09±1.19 |
| | Sig. | ns | ns | ns | ** | ** | ** | ns |

a-d: Different letters indicate significant differences in the column.

**: $P<0.01$; *: $P<0.05$; ns: $P>0.05$; TA: Titratable Acidity

A: plain yogurt; B: set yogurt+%30 WSA with %20 sugar; C: set yogurt+ 30% WSA with 25% sugar; D: stirred yogurt+%30 WSA with 20% sugar; E: stirred yogurt+30% WSA with 25% sugar

The effect of storage on the mean total solids, fat, protein, and pH values was found to be statistically insignificant ($P>0.05$). However, more pronounced changes were observed in the yogurt's titratable acidity than in its pH during storage. The increase in percentage acidity during storage is a result of lipid hydrolysis and the formation of free fatty acids, as well as the accumulation of non-volatile acids (such as pyruvic, oxalic, and succinic acids) and, most notably, lactic acid synthesized by *S. thermophilus* and *L. delbrueckii* subsp. bulgaricus (Köse and Ocak, 2014). Various researchers have similarly reported that yogurt's titratable acidity increases over storage (Sezgin et al., 1988; Terzioğlu et al., 2023). It has also been reported that the presence of buffering constituents in the yogurt matrix-such as proteins, citrates, phosphates, and lactates-may result in less distinct pH changes than titratable acidity changes (Tamime and Deeth, 1980; Ścibisz et al., 2019). Increased sugar concentration was observed to significantly affect the titratable acidity and fat content of the yogurt samples ($P<0.01$) (Table 2). Samples containing fruit sauce prepared with 25% sugar exhibited lower fat content (2.85-2.87%) and higher titratable acidity values (1.20%). In light of these findings, it cannot be stated that the production method (set vs. stirred) caused a distinct difference in the physicochemical attributes of the fruit yogurt.

The highest mean syneresis (41.84%) and the lowest viscosity (3993 cP) were observed in the plain yogurt sample ($P<0.01$). Apple pomace contains high-methoxyl (HM) pectin (O'Shea et al., 2015) and other soluble fiber components that dissolve in the yogurt serum and can bind water, thereby increasing the viscosity of the surrounding medium. Furthermore, it has been reported that while apple pomace contains significant amounts of insoluble dietary fiber-which potentially disrupts the continuity of the protein gel structure and increases syneresis-its soluble components bind water and increase the viscosity of the continuous phase, ultimately leading to a reduction in syneresis (Wang et al., 2019). Indeed, pectin is widely utilized to prevent syneresis in various fermented dairy products (Amal et al., 2016).

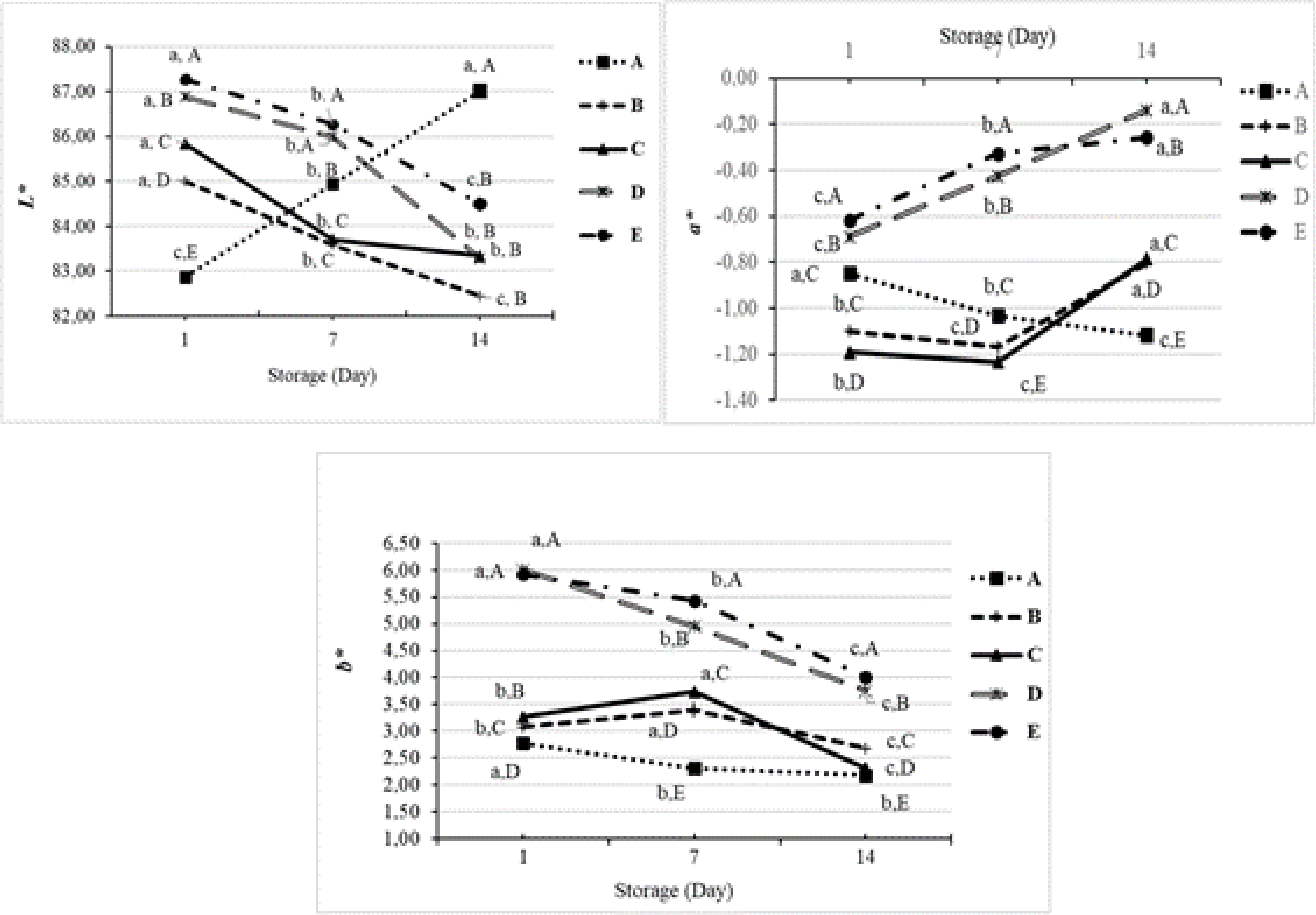

Figure 2. Analysis results for the color parameters of yogurt samples

A: plain yogurt; B: set yogurt+30% WSA sauce with 20% sugar; C: set yogurt+30% WSA sauce with 25% sugar; D: stirred yogurt+30% WSA sauce with 20% sugar; E: stirred yogurt+30% WSA sauce with 25% sugar Different capital letters (between samples at the same storage day) and different lower letters (during storage days) given on the chart indicate significant differences (*P*<0.05)

The changes occurring in fruit-supplemented and plain yogurt samples during storage, as a function of WSA sauce incorporation and production method, are presented in Figure 2. It was observed that the L* (lightness) values of the samples supplemented with apple sauce were higher at the beginning of storage; however, a significant increase throughout the storage period was observed only in the plain yogurt (A) sample (*P*<0.01). Significantly higher L* and a* (+: red; -: green) values were recorded in the fruit sauce-supplemented stirred yogurt (*P*<0.01). The most distinct difference among the samples was observed in the b* values (+: yellow; -: blue), where the stirring process was found to enhance the yellowness (+b*). Consequently, the lowest b* values were determined in the plain yogurt samples. Furthermore, an increase in sugar content was associated with higher L* values, a finding consistent with reports by other researchers (Akal et al., 2018).

Microbiological analysis results

The results regarding the microbiological counts of the samples are presented in Table 3. Analyses conducted to monitor the microbiological quality of the yogurt samples throughout storage revealed that neither coliform bacteria nor yeasts or molds were detected in any of the samples.

Table 3. Microbiological analysis results of set and stirred yogurt with WSA sauce (log CFU/g)

| | | *Lb. bulgaricus* | *S. thermophilus* | Yeast & Mold | Coliform group |
|---|---|---|---|---|---|
| Samples | A | $8.763\pm0.700^{ab}$ | $9.370\pm0.132^{a}$ | <2 | <1 |
| | B | $9.059\pm0.471^{ab}$ | $8.916\pm0.543^{b}$ | <2 | <1 |
| | C | $8.590\pm0.336^{b}$ | $8.772\pm0.169^{b}$ | <2 | <1 |
| | D | $9.396\pm0.541^{a}$ | $8.870\pm0.153^{b}$ | <2 | <1 |
| | E | $8.971\pm0.374^{ab}$ | $9.080\pm0.387^{ab}$ | <2 | <1 |
| | Sig. | * | * | ns | ns |
| Storage (Day) | 1 | 9.102±0.599 | $9.285\pm0.298^{a}$ | <2 | <1 |
| | 7 | 9.002±0.554 | $8.754\pm0.281^{b}$ | <2 | <1 |
| | 14 | 8.763±0.464 | $8.967\pm0.326^{b}$ | <2 | <1 |
| | Sig. | ns | ** | ns | ns |

a-d: Different letters indicate significant differences in the column.
**: $P<0.01$; *: $P<0.05$; ns: $P>0.05$; LA: lactic acid
A: plain yogurt; B: set yogurt+ 30% WSA with 20% sugar; C: set yogurt+30% WSA with 25% sugar; D: stirred yogurt+30% WSA with 20% sugar; E: stirred yogurt+30% WSA with 25% sugar

Regarding *Lactobacillus delbrueckii* subsp. bulgaricus, the highest mean count (9.396 log CFU/g) was recorded in sample D, whereas the lowest mean count (8.590 log CFU/g) was identified in sample C. The mean values for the stirred fruit yogurt containing 20% sugar were higher than those for the plain yogurt sample. Similarly, Dal Konuş and Turgay (2023) reported that mesophilic lactic acid bacteria count in persimmon-supplemented yogurt were higher than those in plain yogurt. The slight decrease observed in *Lactobacillus delbrueckii* subsp. bulgaricus counts during storage were statistically insignificant. However, an increase in sugar content in the fruit yogurt samples resulted in a significant reduction in *Lactobacillus delbrueckii* subsp. bulgaricus counts ($P<0.05$). While higher counts were observed in stirred samples at the same sugar concentration, higher sugar levels negatively affected the viability of *Lactobacillus delbrueckii* subsp. bulgaricus.

The highest mean *Streptococcus thermophilus* count (9.370 log CFU/g) was detected in the plain yogurt sample. In comparison, the lowest count (8.870 log CFU/g) was found in sample C, which was statistically not different from samples B and D. It is evident that the incorporation of fruit sauce relatively reduced the *Streptococcus thermophilus* counts ($P<0.05$). According to the Communiqué on Fermented Milk Products, these products must contain specific microorganisms that remain viable, active, and abundant throughout the shelf life. The minimum required limit for yogurt is 107 CFU/g. The plain and fruit-supplemented yogurt produced within the scope of the present study complies with the Turkish Food Codex Communiqué on Fermented Milk Products (Anonymous (2019).

**Volatile compound profile**

A total of 74 compounds were identified in the volatile fraction of the yogurt samples, comprising 8 aldehydes, 11 ketones, 5 alkanes, 12 alcohols, 8 acids, 7 esters, 12 terpenes, 4 heterocyclic compounds, and 7 compounds from mixed groups (Table 4). The flavor profiles assigned to the volatile compounds in the text were obtained from the official database of the U.S. Flavoring and Extract Manufacturers Association (FEMA, 2025). Aroma compounds, which are the primary source of a food's unique flavor, directly influence consumer perception and preference (Menis-Henrique, 2020; Arslaner, 2020; Han et al., 2024). The volatile composition of processed fruit products may vary depending on the technological processes employed and the concentrations of fruit and sugar (Simunek et al., 2013; Arslaner, 2020).

The table shows that the ratios of aldehydes, ketones, and acids were significantly higher in plain yogurt samples than in the fruit-supplemented groups. Conversely, samples containing fruit sauce exhibited a richer composition of alcohol and terpene content ($P<0.05$, $P<0.01$, $P<0.001$).

According to the HS-SPME-GC-MS results, the most abundant volatile compounds belonging to the carbonyl group-particularly in the plain group-were acetaldehyde (green, fruity, and almond), hexanal (apple, fat, fresh, green, oil), 2-propanone (pungent), 2,3-butanedione (butter, pastry, yeast), 2,3-pentanedione (creamy), acetoin (butter, creamy), 3-(methylthio)-1-propene (sulfur), 2-heptanone (cheese), and ethyl acetate (aromatic, brandy, grape) (Table 4). The incorporation of Wild Sour Apple (WSA) sauce significantly reduced the concentration of aldehyde and ketone compounds in the yogurt samples ($P<0.05$).

Acetaldehyde is the most commonly encountered aroma compound in yogurt. It has been reported to produce "green, fruity, and almond" aromas at different concentrations and is detected at lower concentrations in fruit-flavored yogurt (Han et al., 2024). In the stirred yogurt sample containing 25% sugar, the mean concentrations of 2-furaldehyde (almond, baked potatoes, bread, burnt, spice), 2-heptenal (almond, fat, fruit), and nonanal (fat, floral, green, lemon) were higher than in other fruit-supplemented samples ($P<0.05$). Benzaldehyde (bitter almond, burnt sugar, cherry, malt, roasted pepper) was detected exclusively in the fruit-supplemented group.

Ketones are the primary compounds responsible for the milky and creamy aroma. The highest mean ketone proportion (45.46%) was determined in the plain yogurt sample. Han et al. (2024) reported similar findings in their comparative study on fermented, milky, fruity, and cheesy aroma compounds in yogurt. Of the 11 ketones identified in the present study, 3-hexanone (grape) and 6-methyl-5-hepten-2-one (citrus, mushroom, pepper, rubber, strawberry) remained below detectable limits in Sample A (plain). The concentration of 2-nonanone (fragrant, fruit, green, hot milk) in Sample A was found to be significantly lower than in the fruit group. Aside from a decrease in 2-propanone (pungent) concentration during storage ($P<0.05$), the effect of the storage variable on the concentrations of carbonyl group compounds was found to be insignificant. It cannot be asserted that the increase in sugar concentration in the fruit sauce or the production method (set or stirred) caused a distinct increase or decrease in carbonyl compound concentrations. Among the alkanes, n-decane had the highest concentration in the yogurt samples. n-Undecane and pentadecane were identified only in fruit-supplemented yogurt samples.

Esters are formed through the esterification of carboxylic acid derivatives and alcohols (Forney and Song, 2017). They enhance the desirable flavor of yogurt and mask undesirable tastes such as astringency and bitterness (Liu et al., 2022). Of the 7 esters identified, ethyl acetate (aromatic, brandy, grape) had the highest concentration. The concentration of ethyl acetate was significantly higher in Sample A ($P<0.001$). Butanoic acid, 3-methyl butyl ester (fruit) was identified only in plain yogurt; whereas butanoic acid, 3-methyl-, hexyl ester (fruit) and hexanoic acid, butyl ester (fruit, grass, green) were identified only in fruit yogurt samples. Compared to Sample A, the concentration of butanoic acid, hexyl ester (apple peel, citrus, fresh) was significantly higher in yogurt samples with fruit sauce ($P<0.05$).

The incorporation of WSA sauce increased the total volatile alcohol content in the yogurt samples. While moderate levels of alcohol contribute to the mild aroma of yogurt, higher ethanol concentrations impart alcoholic, fruity, and grainy flavors (Li et al., 2025). The ethyl alcohol rate detected in Group A, which was relatively lower than in fruit samples, was statistically insignificant. Of the 12 alcohols identified, 1-butyl alcohol (fruit), 1-hexanol (banana, flower, grass, herb), 2-furanmethanol (burnt, caramel, cooked), isoborneol (camphor, fragrant, green, polish), linalool (coriander, floral, lavender, lemon, rose), maltol (fragrant caramel-butterscotch), and α-terpineol (anise, fresh, mint, oil) were detected only in fruit group samples; while 2-butoxy-ethanol (mild, pleasant) and 1-nonanol (fat, floral, green, oil) were determined only in the plain sample. The concentration of 2-ethyl-1-hexanol (green, rose) was higher in stirred yogurt with WSA sauce containing 25% sugar (Sample E) than in other samples ($P<0.01$). No statistically significant difference regarding 1-octanol concentration was found between plain yogurt, set yogurt with 20% sugar WSA sauce, and Sample E. Among the alcohols identified only in the fruit group, the concentrations of 1-butyl alcohol and isoborneol appeared to rise in correlation with increased sugar ratios (Table 4). When comparing set-type samples, the concentration of α-terpineol was found to be significantly higher in stirred samples ($P<0.001$). Linalool and maltol concentrations decreased during storage ($P<0.05$), whereas the effect of storage on other alcohols was found to be insignificant.

Acids are among the important molecular groups that affect the characteristic aroma profile of yogurt (Liu et al., 2022; Han et al., 2024). Within the scope of the present study, acetic (acid, fruit, pungent, sour, vinegar), butanoic (butter, cheese, sour), caproic (cheese, oil, pungent, sour), 3-hexenoic (fruit), 2-ethylhexanoic (mild), benzoic (pungent, sour), caprylic (cheese, fat, grass, oil), and capric (dust, fat, grass) acids were detected in the aroma profile of the yogurt samples. While no significant difference was found among samples in capric acid composition, butanoic and caproic acids were the most abundant acids in plain yogurt, followed by acetic acid ($P<0.001$). 3-Hexenoic acid and 2-ethylhexanoic acid were identified only in fruit group samples; whereas benzoic acid was encountered only in plain yogurt. However, the detectable rate of benzoic acid in plain yogurt was statistically insignificant. The highest concentrations of acetic acid and caprylic acid were determined in Sample E, with significance levels of $P<0.05$ and $P<0.01$, respectively. The lowest acetic acid concentrations were observed in Samples A and D.

Following ketones, terpenes were the compound group with the highest concentration in WSA sauce-supplemented yogurt samples. Various researchers have reported that terpenes are fundamental aroma components in fruits and fruit products (Arslaner and Salık, 2022; Mostafa et al., 2022; Xing et al., 2025). Formed by the bonding of isoprene units, monoterpenes and sesquiterpenes-classified based on the form of this bond-are the dominant volatile aroma compounds in fruits (Xing et al., 2025). Of the 12 terpenes detected, α-pinene (cedarwood, pine, sharp) was the most abundant in plain yogurt samples. The most dominant component of the fruit group was d-limonene (citrus, mint). In plain yogurt samples, α-phellandrene (citrus, fresh, mint, pepper, spice, wood), d-limonene, γ-terpinene (bitter, citrus), and α-farnesene (boiled vegetable, floral, wood) were other identified terpenes.

Compared to the plain sample, the concentration of d-limonene was significantly higher in the fruit group ($P<0.01$ and $P<0.001$); while 3-carene (lemon), β-myrcene (balsamic, fruit, geranium, herb, must), α-terpinene (lemon), p-cymene (citrus, fresh), and 2-carene (rosemary, cedarwood, pine) were identified exclusively in the fruit group. In samples containing fruit sauce, increased sugar concentration decreased the rates of 3-carene, β-myrcene, α-terpinene, d-limonene, and γ-terpinene significantly ($P<0.001$). Comparing the samples containing fruit sauce with the same sugar ratio but produced by different methods (set vs. stirred), no differences were observed in terpenes other than α-phellandrene, p-cymene, and 2-carene (Table 4). Azulene and γ-decalactone (fat, fruit, lactone, peach) were other components detected only in the plain yogurt sample. Furthermore, the proportions of 3,3'-thiobis-1-propene, styrene, p-xylene, and methyl propenyl disulfide identified in plain yogurt samples were significantly higher than those detected in fruit yogurt ($P<0.01$). The milky flavor and aroma were significantly suppressed in fruit-sauce-supplemented yogurt samples due to increased levels of terpene and alcohol compounds resulting from the incorporation of WSA sauce.

Table 4. Volatile compounds of yogurt samples

| | Volatiles | Yogurt Samples | | | | | | Storage (Days) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | Aldehydes | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 5.24 | Acetaldehyde | 14.61±5.63 $^{a}$ | 7.71±1.00 $^{b}$ | 4.08±0.24 $^{c}$ | 7.39±1.11 b | 9.27±1.56 b | *** | 6.92±5.79 | 9.87±5.99 | 9.72±4.38 | ns |
| 18.29 | Hexanal | 1.69±0.20 $^{a}$ | 0.19±0.05 $^{c}$ | 0.29±0.15 $^{bc}$ | 0.28±0.08 bc | 0.53±0.36 b | *** | 0.53±0.72 | 0.68±0.67 | 0.57±0.46 | ns |
| 32.10 | 2-furaldehyde | nd $^{c}$ | 0.16±0.13 $^{b}$ | 0.10±0.08 $^{b}$ | nd $^{c}$ | 0.28±0.09 a | *** | 0.13±0.13 | 0.11±0.15 | 0.07±0.10 | ns |
| 37.75 | Heptanal | 0.32±0.27 $^{b}$ | 0.37±0.03 $^{b}$ | 0.37±0.08 $^{b}$ | 0.48±0.09 a | 0.42±0.08 a | ** | 0.23±0.10 | 0.35±0.12 | 0.40±0.22 | ns |
| 38.37 | 2-Heptenal | nd $^{c}$ | 0.08±0.06 $^{b}$ | nd $^{c}$ | nd $^{c}$ | 0.16±0.01 a | *** | 0.06±0.07 | 0.05±0.09 | 0.03±0.07 | ns |
| 39.00 | Benzaldehyde | nd $^{c}$ | 0.39±0.16 $^{ab}$ | 0.36±0.15 $^{b}$ | 0.51±0.06 $^{a}$ | 0.46±0.05 $^{ab}$ | *** | 0.31±0.21 | 0.40±0.23 | 0.33±0.19 | ns |
| 43.41 | Nonanal | 0.19±0.04 $^{b}$ | 0.23±0.06 $^{b}$ | 0.32±0.29 $^{ab}$ | 0.26±0.11$^{ab}$ | 0.44±0.13 $^{a}$ | * | 0.37±0.24 | 0.26±0.12 | 0.23±0.08 | ns |
| 48.35 | Cuminaldehyde | 0.25±0.04 | 0.28±0.27 | 0.36±0.06 | 0.20±0.06 | 0.18±0.14 | ns | 0.26±0.14 | 0.20±0.09 | 0.30±0.19 | ns |
| | Total aldehydes | 17.06% | 9.41% | 5.88% | 9.12% | 11.74% | - | - | - | - | - |
| | Ketones | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 9.76 | 2-propanone | 7.52±1.38 $^{a}$ | 6.60±1.51 $^{b}$ | 6.73±1.82 $^{b}$ | 5.99±1.55 $^{b}$ | 6.13±1.89 $^{b}$ | * | 7.14±1.18 a | 6.05±1.11 b | 6.28±1.28 b | * |
| 14.70 | 2,3-butanedione | 14.26±2.13 $^{a}$ | 12.02±2.22 $^{b}$ | 12.13±2.48 $^{b}$ | 12.50±2.19 $^{b}$ | 13.31±2.35 $^{ab}$ | *** | 11.47±3.19 | 12.44±3.57 | 13.42±4.10 | ns |
| 21.44 | 2,3-pentanedione | 1.53±0.05 $^{a}$ | nd $^{d}$ | 0.59±0.03 $^{b}$ | 0.46±0.07 c | 0.06±0.14 $^{d}$ | *** | 0.48±0.36 | 0.55±0.39 | 0.56±0.36 | ns |
| 22.00 | 3-hexanone | nd $^{d}$ | 0.29±0.22 $^{c}$ | 0.78±0.25 $^{a}$ | 0.63±0.25 $^{ab}$ | 0.47±0.18 $^{bc}$ | *** | 0.36±0.22 | 0.43±0.24 | 0.51±0.49 | ns |
| 24.55 | Acetoin | 17.06±2.49 $^{a}$ | 13.08±2.63 b | 12.96±2.71 $^{b}$ | 12.23±2.28 $^{c}$ | 11.54±2.43 $^{d}$ | *** | 13.19±1.95 | 13.61±2.42 | 13.33±2.20 | ns |
| 31.99 | n-Nonane | 0.60±0.14 $^{a}$ | 0.12±0.02 $^{b}$ | 0.23±0.14 $^{b}$ | 0.53±0.06 $^{a}$ | 0.21±0.08 $^{b}$ | *** | 0.28±0.27 | 0.33±0.27 | 0.32±0.19 | ns |
| 20.34 | 3 (methylthio)-1-Propene | 1.82±1.22 $^{a}$ | nd $^{b}$ | 0.05±0.07 $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 0.55±1.08 | 0.52±1.10 | 0.06±0.12 | ns |
| 34.10 | 2-Heptanone | 1.73±0.60 $^{a}$ | 0.64±0.28 $^{b}$ | 0.99±0.47 $^{b}$ | 0.75±0.12 $^{b}$ | 0.88±0.34 $^{b}$ | ** | 1.19±0.68 | 0.93±0.51 | 0.86±0.36 | ns |
| 35.31 | 4-methylnonane | 0.52±0.26 $^{a}$ | nd $^{b}$ | 0.35±0.09 $^{a}$ | 0.49±0.20 $^{a}$ | 0.07±0.13 $^{b}$ | *** | 0.35±0.33 | 0.22±0.20 | 0.28±0.25 | ns |
| 39.25 | 6-methyl-5-hepten-2-one | nd $^{c}$ | 0.38±0.18 $^{a}$ | 0.42±0.30 $^{a}$ | 0.16±0.02 $^{bc}$ | 0.24±0.08 $^{ab}$ | ** | 0.20±0.12 | 0.26±0.21 | 0.26±0.29 | ns |
| 43.10 | 2-nonanone | 0.42±0.05 $^{d}$ | 1.22±0.49 $^{c}$ | 2.56±0.24 $^{a}$ | 1.35±0.09 $^{c}$ | 2.18±0.32 $^{b}$ | *** | 1.47±1.00 | 1.30±0.89 | 1.27±1.03 | ns |
| | Total ketones | 45.46% | 34.35% | 37.79% | 35.09% | 35.09% | - | - | - | - | - |
| | Alkanes | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |

Table 4. Continued

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25.58 | n-octane | 0.16±0.36 $^{a}$ | nd $^{c}$ | 0.07±0.07 $^{b}$ | nd $^{c}$ | 0.02±0.04 c | *** | 0.04±0.06 | 0.03±0.07 | 0.07±0.08 | ns |
| 37.50 | n-decane | 2.67±0.38 $^{a}$ | 0.63±0.28 $^{b}$ | 0.87±0.25 $^{b}$ | 0.99±0.29 b | 2.10±1.51 a | *** | 1.61±1.26 | 1.16±0.90 | 1.58±1.02 | ns |
| 38.80 | Octane, 3.3-dimethyl | 0.18±0.03 $^{a}$ | 0.04±0.06 $^{c}$ | 0.15±0.06 $^{ab}$ | 0.09±0.08 $^{bc}$ | 0.20±0.08 a | *** | 0.16±0.04 $^{b}$ | 0.79±0.74 $^{a}$ | 0.16±0.10 $^{b}$ | * |
| 41.76 | n-undecane | nd $^{c}$ | 0.24±0.20 $^{b}$ | 0.17±0.09 $^{bc}$ | 0.15±0.10 $^{bc}$ | 0.54±0.24 $^{a}$ | *** | 0.25±0.18 | 0.23±0.24 | 0.18±0.28 | ns |
| 43.70 | Pentadecane | nd $^{b}$ | 0.03±0.04 $^{b}$ | 0.12±0.02 $^{b}$ | nd $^{b}$ | 0.12±0.05 $^{a}$ | *** | 0.05±0.07 | 0.02±0.04 | 0.03±0.06 | ns |
| | Total alkanes | 3.01% | 0.94% | 1.38% | 1.23% | 2.98% | - | - | - | - | - |
| | Alcohols | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 8.63 | Ethyl alcohol | 1.35±0.32 | 2.10±0.30 | 2.03±0.61 | 1.52±0.94 | 1.65±0.66 | ns | 1.46±0.63 | 1.79±0.75 | 1.93±0.52 | ns |
| 20.09 | 1-butylalcohol | nd $^{d}$ | 0.43±0.09 $^{bc}$ | 0.59±0.15 $^{a}$ | 0.56±0.19 $^{ab}$ | 0.29±0.07 $^{c}$ | *** | 0.36±0.23 | 0.42±0.27 | 0.35±0.26 | ns |
| 30.60 | 2-butoxy-ethanol | 0.51±0.52 $^{a}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | ** | 0.02±0.05 | 0.05±0.11 | 0.23±0.50 | ns |
| 33.10 | 1-hexanol | nd $^{c}$ | 0.72±0.11 $^{a}$ | 0.67±0.13 $^{a}$ | 0.72±0.13 $^{a}$ | 0.46±0.12 $^{b}$ | *** | 0.47±0.27 | 0.52±0.32 | 0.55±0.32 | ns |
| 33.80 | 2-Furanmethanol | nd $^{d}$ | 0.18±0.04 $^{b}$ | 0.12±0.05 $^{c}$ | 0.23±0.04 $^{a}$ | 0.16±0.03 $^{bc}$ | *** | 0.13±0.08 | 0.14±0.09 | 0.14±0.08 | ns |
| 34.50 | 1-nonanol | 0.43±0.04 $^{a}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 0.09±0.20 | 0.08±0.16 | 0.08±0.17 | ns |
| 36.40 | Isoborneol | nd $^{d}$ | 2.03±0.53 $^{bc}$ | 2.49±0.71 $^{b}$ | 1.82±0.06 $^{c}$ | 2.36±0.29 $^{b}$ | *** | 2.10±1.24 | 1.93±1.23 | 1.68±1.15 | ns |
| 39.80 | 1-Octanol | 0.11±0.04 $^{a}$ | 0.09±0.09 $^{a}$ | 0.06±0.00 $^{ab}$ | 0.01±0.03 $^{b}$ | 0.09±0.05 $^{a}$ | * | 0.06±0.05 | 0.09±0.06 | 0.07±0.05 | ns |
| 41.51 | 2-Ethyl-1 hexanol | 0.57±0.13 $^{b}$ | 0.39±0.10 $^{b}$ | 0.50±0.24 $^{b}$ | 0.46±0.19 $^{b}$ | 0.78±0.23 $^{a}$ | ** | 0.30±0.22 | 0.25±0.15 | 0.21±0.36 | ns |
| 43.27 | Linalool | nd $^{b}$ | 0.08±0.06 $^{a}$ | 0.08±0.04 $^{a}$ | 0.07±0.02 $^{a}$ | 0.06±0.09 $^{ab}$ | * | 0.09±0.06 $^{a}$ | 0.05±0.06 $^{ab}$ | 0.03±0.04 $^{b}$ | * |
| 44.90 | Maltol | nd $^{c}$ | 0.10±0.11 $^{b}$ | 0.14±0.06 $^{ab}$ | 0.08±0.08 $^{bc}$ | 0.22±0.08 $^{c}$ | ** | 0.17±0.10 $^{a}$ | 0.08±0.09 b | 0.07±0.09 $^{b}$ | * |
| 45.80 | α-Terpineol | nd $^{c}$ | 0.63±0.18 $^{b}$ | 0.51±0.15 b | 1.42±0.69 $^{a}$ | 1.21±0.54 $^{a}$ | *** | 1.01±0.82 | 0.66±0.35 | 0.60±0.23 | ns |
| | Total alcohols | 2.97% | 6.75% | 7.19% | 6.89% | 7.28% | - | - | - | - | - |
| | Acids | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 18.40 | Acetic acid | 1.14±0.42 $^{b}$ | 1.56±0.37 $^{ab}$ | 1.39±0.41 $^{ab}$ | 1.18±0.21 $^{b}$ | 1.83±0.56 $^{a}$ | * | 1.59±0.65 | 1.28±0.29 | 1.38±0.32 | ns |
| 30.00 | Butanoic acid | 0.84±0.42 $^{a}$ | 0.40±0.08 $^{b}$ | 0.42±0.13 $^{b}$ | 0.14±0.05 $^{c}$ | 0.45±0.06 $^{b}$ | *** | 0.35±0.16 | 0.56±0.43 | 0.44±0.23 | ns |
| 40.12 | Hexanoic (caproic) acid | 2.95±0.71 $^{a}$ | 0.23±0.33 $^{b}$ | 0.18±0.15 $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 0.65±1.05 | 0.52±1.00 | 0.84±1.59 | ns |
| 42.50 | 3-Hexenoic acid | nd $^{d}$ | 0.31±0.24 $^{c}$ | 0.37±0.21 $^{c}$ | 0.88±0.80 $^{a}$ | 0.47±0.07 $^{b}$ | *** | 0.65±0.82 | 0.39±0.23 | 0.17±0.13 | ns |

Table 4. Continued

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44.44 | 2-Ethyl-hexanoic acid | nd $^{b}$ | 0.18±0.14 $^{ab}$ | 0.21±0.16 $^{ab}$ | 0.16±0.15 $^{b}$ | 0.42±0.35 $^{a}$ | * | 0.24±0.31 | 0.24±0.20 | 0.10±0.14 | ns |
| 44.80 | Benzoic acid | 0.12±0.10 | nd | nd | nd | nd | ns | 0.05±0.10 | 0.03±0.06 | nd | ns |
| 45.90 | Octanoic (caprylic) acid | 0.20±0.07 $^{b}$ | 0.36±0.33 $^{b}$ | 0.15±0.14 $^{b}$ | 0.05±0.07 $^{b}$ | 0.76±0.46 $^{a}$ | ** | 0.48±0.51 | 0.24±0.29 | 0.19±0.09 | ns |
| 51.42 | Decanoic (capric) acid | 0.24±0.22 | 0.21±0.16 | 0.23±0.17 | 0.24±0.18 | 0.23±0.06 | ns | 0.23±0.19 | 0.24±0.15 | 0.22±0.14 | ns |
| | Total acids | 5.49% | 3.25% | 2.95% | 2.65% | 4.16% | - | - | - | - | - |
| | Esters | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 15.80 | Ethyl acetate | 4.69±0.58 $^{a}$ | 2.83±0.19 $^{b}$ | 2.71±0.77 $^{b}$ | 2.20±0.31 b | 2.30±0.81 $^{b}$ | *** | 2.28±1.75 | 2.23±1.49 | 2.55±2.35 | ns |
| 38.50 | Butanoic acid. 3 methyl-, butyl ester | 0.22±0.04 $^{a}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 0.05±0.09 | 0.04±0.10 | 0.04±0.09 | ns |
| 38.70 | Butanoic acid. 3-methyl-, hexyl ester | nd $^{c}$ | nd $^{c}$ | 0.10±0.01 $^{b}$ | 0.12±0.11 $^{ab}$ | 0.19±0.09 $^{a}$ | *** | 0.10±0.11 | 0.06±0.09 | 0.09±0.10 | ns |
| 42.00 | Hexanoic acid, butyl ester | nd $^{b}$ | 0.05±0.09 $^{b}$ | 0.83±0.68 $^{a}$ | 0.21±0.33 $^{b}$ | 0.22±0.09 b | ** | 0.42±0.67 | 0.17±0.26 | 0.19±0.25 | ns |
| 42.50 | Hexanoic acid, propyl ester | 0.28±0.12 $^{b}$ | 0.24±0.02 $^{b}$ | 0.57±0.37 $^{a}$ | 0.35±0.12 $^{ab}$ | 0.39±0.22 $^{ab}$ | * | 0.47±0.30 | 0.31±0.11 | 0.32±0.19 | ns |
| 45.23 | Butanoic acid, hexyl ester | 0.32±0.08 $^{d}$ | 0.96±0.78 $^{a}$ | 0.61±0.71 $^{c}$ | 0.41±0.18 $^{c}$ | 0.89±0.16 $^{a}$ | * | 1.01±0.69 a | 0.47±0.29 b | 0.43±0.27 b | * |
| 49.00 | Carbonic acid, dodecyl vinyl ester | 0.37±0.14 $^{b}$ | 0.27±0.18 $^{b}$ | 1.16±0.76 $^{a}$ | 0.77±0.63 $^{ab}$ | 0.66±0.43 $^{ab}$ | * | 0.57±0.60 | 0.73±0.64 | 0.63±0.48 | ns |
| | Total esters | 5.88% | 4.35% | 5.98% | 4.06% | 4.65% | - | - | - | - | - |
| | Terpenes | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 34.94 | ▪ -Pinene | 1.24±0.02 $^{a}$ | 0.62±0.35 $^{b}$ | 0.49±0.06 $^{b}$ | 0.54±0.07 $^{b}$ | 0.46±0.05 $^{b}$ | ** | 0.83±0.09 | 0.52±0.08 | 0.56±0.28 | ns |
| 35.56 | 3-Carene | nd $^{d}$ | 0.24±0.05 $^{a}$ | 0.13±0.02 $^{b}$ | 0.23±0.06 $^{a}$ | 0.07±0.06 $^{c}$ | *** | 0.12±0.09 | 0.13±0.11 | 0.15±0.10 | ns |
| 37.60 | β-Myrcene | nd $^{c}$ | 1.02±0.30 $^{a}$ | 0.44±0.09 $^{b}$ | 0.95±0.28 $^{a}$ | 0.58±0.15 $^{b}$ | *** | 0.69±0.48 | 0.63±0.47 | 0.46±0.30 | ns |
| 38.50 | α-phellandrene | 0.17±0.09 $^{b}$ | 0.22±0.06 $^{b}$ | 0.27±0.04 $^{b}$ | 0.43±0.20 $^{a}$ | 0.19±0.11 $^{b}$ | * | 0.25±0.10 | 0.27±0.21 | 0.26±0.08 | ns |
| 39.50 | α-Terpinene | nd $^{d}$ | 0.25±0.05 $^{a}$ | 0.08±0.06 $^{c}$ | 0.35±0.04 $^{a}$ | 0.13±0.09 b | *** | 0.11±0.10 | 0.15±0.10 | 0.12±0.07 | ns |
| 39.93 | d-Limonene | 0.62±0.10 $^{c}$ | 21.33±2.39 a | 17.25±1.91 $^{b}$ | 23.32±3.34 $^{a}$ | 16.14±2.88 $^{b}$ | *** | 16.06±8.59 | 15.92±9.38 | 13.46±8.11 | ns |
| 40.00 | p-Cymene | nd $^{e}$ | 4.41±0.41 $^{b}$ | 5.93±0.29 $^{a}$ | 2.84±0.54 $^{d}$ | 3.56±0.62 $^{c}$ | *** | 3.36±2.09 | 3.49±2.19 | 3.19±2.03 | ns |
| 41.00 | ɣ-Terpinene | 2.27±0.14 $^{c}$ | 4.28±1.24 $^{a}$ | 3.16±0.68 $^{b}$ | 4.61±0.38 $^{a}$ | 2.25±0.59 $^{c}$ | *** | 3.52±1.21 | 3.50±1.17 | 2.93±1.24 | ns |

Table 4. Continued

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 42.17 | 2-Carene | nd $^{c}$ | 0.44±0.25 $^{a}$ | 0.33±0.16 $^{b}$ | 0.32±0.15 $^{b}$ | 0.34±0.08 $^{b}$ | ** | 0.34±0.21 $^{a}$ | 0.34±0.23 $^{a}$ | 0.17±0.13 $^{b}$ | * |
| 55.00 | α-Farnesene | 0.88±0.54 b | 1.54±1.25 $^{ab}$ | 2.40±0.34 a | 1.34±0.64 $^{ab}$ | 1.31±0.46 $^{ab}$ | * | 2.00±0.77 $^{a}$ | 1.37±0.80 $^{b}$ | 0.69±0.21 $^{c}$ | ** |
| | Total terpenes | 5.63% | 34.85% | 30.62% | 36.28% | 25.30% | - | - | - | - | - |
| | Heterocyclic compounds | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig. |
| 26.81 | Cyclotrisiloxane, hexamethyl- | 2.41±0.63 $^{b}$ | 1.45±1.44 $^{c}$ | 3.65±0.88 $^{b}$ | 1.39±0.28 $^{c}$ | 3.27±0.82 $^{a}$ | *** | 2.35±0.64 | 2.43±0.73 | 2.53±0.74 | ns |
| 46.18 | Azulene | 0.21±0.16 $^{a}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 0.08±0.17 | 0.03±0.06 | 0.02±0.05 | ns |
| 47.62 | Cyclohexasiloxane, dodecamethyl- | 0.15±0.12 $^{b}$ | 0.52±0.10 $^{b}$ | 0.27±0.18 $^{b}$ | 0.17±0.09 $^{b}$ | 1.04±0.69 $^{a}$ | *** | 0.40±0.34 | 0.37±0.26 | 0.52±0.69 | ns |
| 48.00 | Cyclotetrasiloxane, octamethyl- | nd$^{c}$ | 0.24±0.06 $^{bc}$ | 0.94±0.78 $^{ab}$ | 0.33±0.14 $^{bc}$ | 1.51±1.11 $^{a}$ | ** | 0.47±0.94 | 0.33±0.34 | 0.90±0.99 | ns |
| | Total heterocyclics | 2.77% | 2.21% | 4.86% | 1.89% | 5.82% | - | - | - | - | - |
| | Miscellaneous compounds | A | B | C | D | E | Sig. | 1 | 7 | 14 | Sig |
| 25.17 | Toluene | 0.45±0.07 $^{ab}$ | 0.50±0.29 $^{a}$ | 0.14±0.11 $^{c}$ | 0.35±0.03 $^{abc}$ | 0.27±0.21 $^{bc}$ | ** | 0.39±0.28 | 0.30±0.10 | 0.32±0.20 | ns |
| 31.33 | 1-Propene. 3.3'-thiobis- | 2.93±1.17 $^{a}$ | 0.37±0.09 $^{d}$ | 1.23±0.30 $^{b}$ | 0.76±0.64 $^{c}$ | 0.33±0.11 $^{d}$ | *** | 1.41±1.44 | 0.72±0.51 | 0.90±0.70 | ns |
| 33.61 | Styrene | 1.67±0.63 $^{a}$ | 0.48±0.14 b | 0.44±0.24 $^{b}$ | 0.40±0.25 $^{b}$ | 0.51±0.14 $^{b}$ | *** | 1.01±0.91 | 0.86±0.39 | 0.83±0.48 | ns |
| 31.88 | p-Xylene | 0.65±0.30 $^{a}$ | 0.19±0.07 $^{c}$ | 0.14±0.08 $^{c}$ | 0.42±0.08 $^{b}$ | 0.19±0.04 $^{c}$ | *** | 0.36±0.35 | 0.28±0.18 | 0.32±0.15 | ns |
| 36.50 | Methylpropenyl disulfide | 1.90±0.32 $^{a}$ | 0.11±0.08 $^{b}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 1.90±1.18 | 0.49±0.94 | 0.39±0.76 | ns |
| 42.84 | ɣ-Decalactone | 2.62±0.52 $^{a}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | nd $^{b}$ | *** | 0.63±1.32 | 0.49±1.03 | 0.45±0.96 | ns |
| 46.45 | 2-Ethylacridine | nd $^{d}$ | 0.38±0.06 $^{b}$ | 0.27±0.04 $^{c}$ | 0.51±0.17 $^{a}$ | 0.46±0.18 $^{ab}$ | * | 0.04±0.06 $^{a}$ | 0.02±0.04 $^{ab}$ | nd $^{b}$ | * |
| 48.65 | Thiourea, tetramethyl | 1.81±0.74 $^{a}$ | 1.36±0.75 $^{b}$ | 1.20±0.59 $^{b}$ | 1.48±1.23 $^{b}$ | 1.37±0.35 $^{b}$ | ** | 1.41±0.69 $^{b}$ | 1.60±0.66 $^{b}$ | 2.38±1.19 $^{a}$ | * |
| | Total miscallenous | 12.03% | 3.39% | 3.42% | 3.92% | 3.13% | - | - | - | - | - |

*Mean values indicated by different exponential letters in the same line are significantly different from each other (nd: not detected; ns: no significance; *$P<0.05$; **$P<0.01$; *** $P<0.001$).

A: plain yogurt; B: set yogurt+30% WSA with 20% sugar; C: set yogurt+30% WSA with 25% sugar; D: stirred yogurt+30% WSA with 20% sugar; E: stirred yogurt+30% WSA with 25% sugar

## Sensory parameters

Sensory attributes constitute a critical criterion in consumer acceptance or rejection of food products. Furthermore, they play a pivotal role in the market status, sales performance, and competitive positioning of food products (Arslaner et al., 2021). The yogurt samples were comparatively evaluated regarding appearance, consistency by spoon, consistency in the mouth, odor, and taste attributes throughout the 14-day storage period (Figure 3).

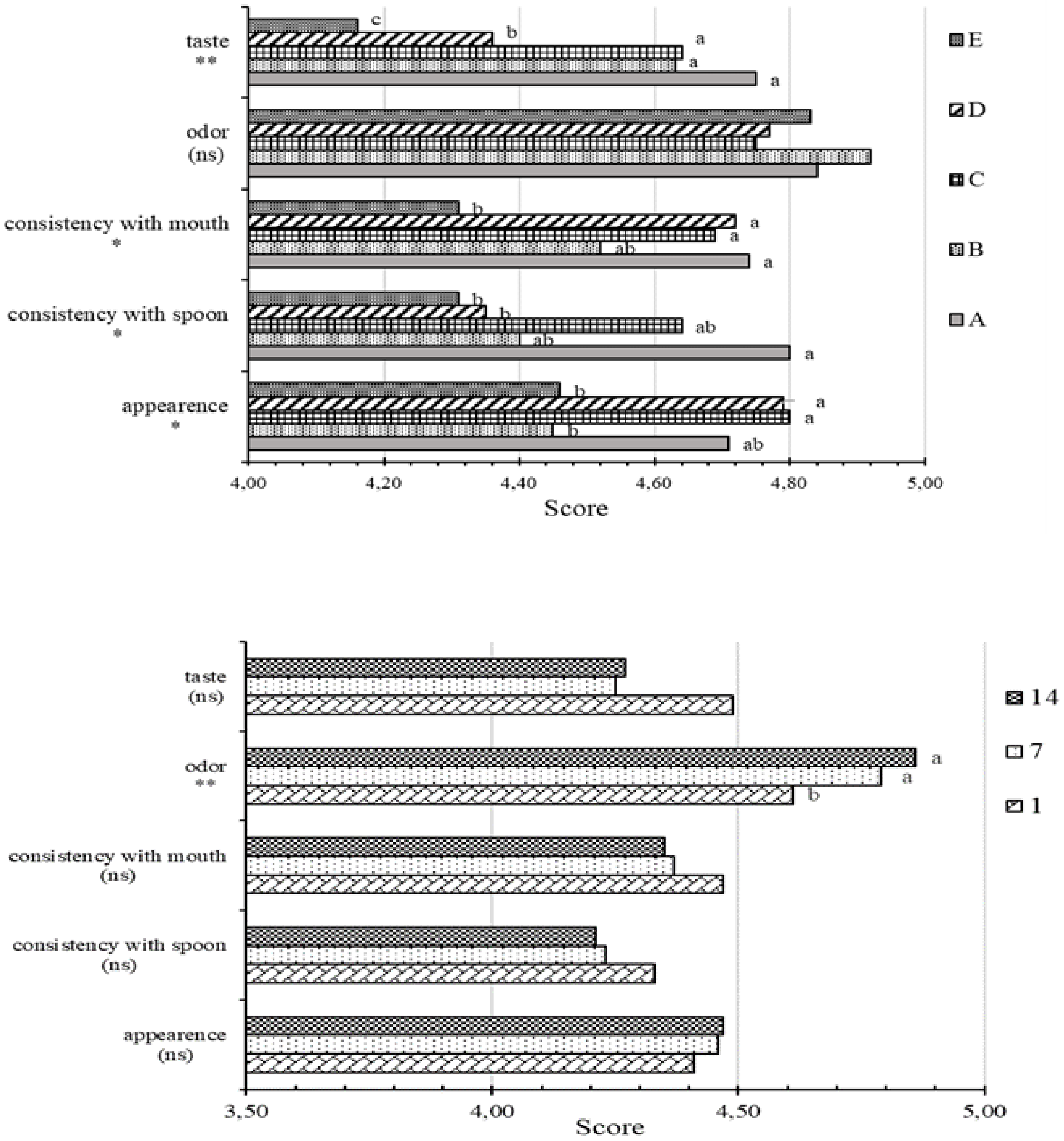

Figure 3. Sensory parameters of yogurt samples

(a) difference between samples (b) difference between storage; Different letters in the data series indicate significant differences (a-d); **: *P*<0.01; *: *P*<0.05; ns: *P*>0.05; A: plain yogurt; B: set yogurt+30% WSA with 20% sugar; C: set yogurt+30% WSA with 25% sugar; D: stirred yogurt+30% WSA with 20% sugar; E: stirred yogurt+30% WSA with 25% sugar

### Sensory parameters

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The incorporation of WSA sauce significantly affected all sensory parameters of the yogurt, except odor ($P<0.01$; $P<0.05$). Regarding appearance scores, Sample C (set yogurt + 30% WSA with 25% sugar) from the fruit-supplemented set group and Sample D (stirred yogurt + 30% WSA with 20% sugar) from the stirred group received significantly higher scores than the plain sample (A) ($P<0.05$). Regarding mouth consistency, Samples A, C, and D showed similar scores. The lowest scores for appearance, consistency in the mouth, and taste were recorded for Sample E (stirred yogurt + 30% WSA with 25% sugar). The highest mean consistency score for the spoon was observed in the plain yogurt sample.

No statistically significant difference in odor scores was found among the samples ($P>0.05$). However, odor was the sole sensory parameter significantly affected by the storage variable ($P<0.01$). The mean scores for the odor attribute increased after the first day of storage.

When evaluating the sensory attributes of fruit yogurt with respect to sugar concentration, Sample C (25% sugar) within the set group received higher scores for appearance, spoon consistency, and mouth consistency than Sample B ($P<0.05$). The taste scores of the fruit-supplemented set samples were statistically indistinguishable from those of plain yogurt but significantly higher than those of the stirred samples ($P<0.01$). When the aroma profile and sensory attributes are evaluated conjointly, it is evident that Sample C is richer in total ketone, alcohol, and ester compounds compared to the other fruit-supplemented samples. In conclusion, based on an overall assessment of all parameters-particularly sensory attributes and aroma composition-the set-type sample containing WSA sauce with 25% sugar (Sample C) can be recommended as the most suitable formulation for industrial yogurt production.

## CONCLUSION

Wild fruits are a valuable yet often underappreciated resource that thrives abundantly in Anatolia. They naturally grow in rural areas away from industrial pollution, which minimizes the risk of harmful chemicals, making them attractive to health-conscious consumers. In addition, wild fruits are cost-effective as they require no agricultural inputs like water, fertilizer, or tilling. Studies show they are rich in essential nutrients. Therefore, preserving and promoting wild fruits is crucial, especially in regions facing diminishing food resources. The results demonstrate that incorporating WSA sauce did not adversely affect the technological or sensory attributes examined in yogurt. Consequently, these findings suggest that using this wild fruit in fruit yogurt production offers a beneficial approach for the dairy industry. Moreover, the richness in volatile compound composition resulting from the use of wild sour apple in fruit yogurt samples may also lead to studies investigating the use of this fruit in the flavor and cosmetics industries.

## CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## AUTHOR CONTRIBUTIONS

AA.: Investigation, Experimental study, Methodology, Writing - original draft. Writing - review & editing, Supervision. B.A.: Investigation, Experimental study. All authors reviewed the manuscript. Competing interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## ETHICAL APPROVAL

The necessary permissions for sensory analyses from the Bayburt University Rectorate Ethics Committee were obtained as per decision number 263354, dated 24 February 2025. A consent-to-participate declaration was obtained from every human participant.

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## REFERENCES

Akal, C., Buran, İ., Albayrak Delialioğlu, R., Yetişemiyen, A. (2018). Farklı şeker oranlarının süt reçelinin kalite özellikleri üzerine etkisi. *Gıda,* 43(5): 865-875. https://doi.org/10.15237/gida.GD18067

Akbari, B., Baghaei-Yazdi, N., Bahmaie, M., Mahdavi Abhari, F. (2022). The role of plant-derived natural antioxidants in reduction of oxidative stress. *BioFactors*, 48(3):611-633.

Amal, A., Eman, A., Nahla, S. Z. (2016). Fruit flavored yogurt: Chemical, functional and rheological properties. *International Journal of Environmental and Agriculture Research*, 2(5):57-66.

Anonymous (2019). Turkish food codex. Notification on fermented dairy products (Notification no: 2022/44). Ministry of Food, Agriculture and Livestock, 30 November 2022, Official Gazette Number: 32029, Ankara.

Arslaner, A. (2020). The effects of adding garlic (*Allium sativum* L.) on the volatile composition and quality properties of yogurt. *Food Science and Technology*, 40(suppl 2): 582-591. https://doi.org/10.1590/fst.31019

Arslaner, A., Salık, M.A. (2020). Some quality properties, mineral and heavy metal composition of wild fruit traditional marmalades. *Turkish Journal of Agriculture - Food Science and Technology*, 8(3):678–687. https://doi.org/10.24925/turjaf.v8i3.678-687.3190

Arslaner, A., Salik, M. A. (2022). Probiotic ice cream with *Malus floribunda* fruit sauce: Quality properties, mineral, and volatile composition. *Journal of Food Processing and Preservation*, 46(5): e16566. https://doi.org/10.1111/jfpp.16566

Arslaner, A., Salik, M.A., Bakirci, İ. (2021). The effects of adding *Hibiscus sabdariffa* L. flowers marmalade on some quality properties, mineral content and antioxidant activities of yogurt. *Journal of Food Science and Technology*, 58:223–233. https://doi.org/10.1007/s13197-020-04533-z

Atamer, M., Sezgin, E. (1986). Yoğurtlarda, kurumadde artırımının pıhtının fiziksel özellikleri üzerine etkisi. *Gıda*, 11(6):327–331.

Bakırcı, İ., Arslaner, A. (2007). The effect of partially-replacing skim milk powder with whey powder in set-type yogurt manufacture. *Milchwissenschaft-Milk Science International*, 62(4):434-438.

Bradley, R.L., Arnold, E., Barbano, D.M., Semerad, R.G., Smith, D.E., Vines, B.K. (1992). Chemical and physical methods. In: *Dairy products: Standard methods for the examination of dairy products*, Marshall RT (ed), 15th edn., American Public Health Association, Washington DC, pp 433–529.

Chouchouli, V., Kalogeropoulos, N., Konteles, S. J., Karvela, E., Makris, D. P., Karathanos, V. T. (2013). Fortification of yoghurts with grape (*Vitis vinifera*) seed extracts. *LWT-Food Science and Technology*, 53(2):522-529. https://doi.org/10.1016/j.lwt.2013.03.008

Dal Konuş, Z., Turgay, Ö. (2023). Kurutulmuş ve taze Trabzon hurması katkılı meyveli yoğurtların bazı özelliklerinin incelenmesi. *Artıbilim: Adana Alparslan Türkeş Bilim ve Teknoloji Üniversitesi Fen Bilimleri Dergisi*, 6(2):16-26. https://doi.org/10.55198/artibilimfen.1387441

Dave, R.I., Shah, N.P. (1996). Evaluation of media for selective enumeration of *Streptococcus thermophilus*, *Lactobacillus delbrueckii ssp. bulgaricus*, *Lactobacillus acidophilus*, and *Bifidobacteria*. *Journal of Dairy Science*, 79(9):1529–1536. https://doi.org/10.3168/jds.S0022-0302(96)76513-X

Demir, H. (2006). Erzurum'da yetişen madımak, yemlik ve kızamık bitkilerinin bazı kimyasal bileşimi. *Bahçe*, 35(1-2): 55-60.

Fatima, S.K., Khan, R.T., Nazir, M., Manzoor, M., Gillani, S. W., Munir, M., ... Ali, M. A. (2025). Exploration of medicinal and nutritional value of Himalayan wild edible fruits: implications for sustainable health and functional foods. *Genetic Resources and Crop Evolution*, 72(8):10071-10091. https://doi.org/10.1007/s10722-025-02557-y

FEMA, 2025. Flavor and Extract Manufacturers Association of the United States, https://www.femaflavor.org/flavor-library (Accessed 27 November 2025).

Forney, C.F., Song, J. (2017). Flavors and aromas: Chemistry and biological functions. E. M. Yahia (Ed.), In: *Fruit and vegetable phytochemicals,* Wiley, pp. 515–540.https://doi.org/10.1002/9781119158042.ch24

Garavand, F., Daly, D.F., Gómez-Mascaraque, L.G. (2023). The consequence of supplementing with synbiotic systems on free amino acids, free fatty acids, organic acids, and some stability indexes of fermented milk. *International Dairy Journal,* 137:105477. https://doi.org/10.1016/j.idairyj.2022.105477

Güldemir, K. (2016). Bayburt ilinde doğal olarak bulunan yabani ekşi elma (*Malus sylvestris* Mill.)'nın farklı yöntemlerle kurutularak antioksidan ve fenolik madde içeriklerinin belirlenmesi, Bayburt Üniversitesi Fen Bilimleri Enstitüsü Gıda Mühendisliği Anabilim Dalı Yüksek Lisans Tezi, Bayburt, Türkiye, 132 s.

Güldemir, K., Çakır, Ö., Çakıroğlu, K. (2020). Yabani-Ekşi elmanın (*Malus sylvestris* Miller) antioksidan aktivite ve fenolik madde içeriği üzerine farklı kurutma yöntemlerinin etkisi. *Fırat Üniversitesi Mühendislik Bilimleri Dergisi*, 32(1):279-285. https://doi.org/10.35234/fumbd.670865

Han, H., Zhang, Z., Yang, Z., Blank, I., Zhong, F., Wang, B., Wang, Y., Zeng, H. (2024). A comparative study to determine the key aroma components of yogurt aroma types based on sensomics and flavoromics. *Food Chemistry*, 460 (2): 140618. https://doi.org/10.1016/j.foodchem.2024.140618

Harrigan, W.F. (1998). Laboratory methods in food microbiology. Gulf Professional Publishing, London, 532 p. ISBN: 978012-326-04-3-7.

Hyson, D.A. (2011). A comprehensive review of apples and apple components and their relationship to human health. *Advances in Nutrition*, *2*(5):408-420. https://doi.org/10.3945/an.111.000513

Köse, Ş., Ocak, E. (2014). Yoğurtta lezzet bileşenlerinin oluşumu ve bu oluşum üzerine etki eden faktörler. *Akademik Gıda*, 12(2):101-107.

Li, B., Ye, L., Zhao, Y., Liu, Y., Chen, Y., Zhang, H. (2025). A comprehensive review of probiotic yogurt: nutritional modulation, flavor improvement, health benefits, and advances in processing techniques. *Agricultural Products Processing and Storage*, 2025(1):17. https://doi.org/10.1007/s44462-025-00023-7

Liu, C., Yang, P., Wang, H., Song, H. (2022). Identification of odor compounds and odor-active compounds of yogurt using DHS, SPME, SAFE, and SBSE/ GC-O-MS. LWT-*Food Science and Technology*, 2022(154):112689. https://doi.org/10.1016/j.lwt.2021.112689

Marco, A. Navarro, J.L. Flores, M. (2004). Volatile compounds of dry- fermented sausages as affected by solid-phase micro extraction (SPME). *Food Chemistry*, 84(2004):633–641. https://doi.org/10.1016/S0308-8146(03)00288-7

Menis-Henrique, M.E.C. (2020). Methodologies to advance the understanding of flavor chemistry. *Current Opinion in Food Science*, 33:131–135. https://doi.org/10.1016/j.cofs.2020.04.005

Mierczak, K., Garus-Pakowska, A. (2024). An overview of apple varieties and the importance of apple consumption in the prevention of non-communicable diseases-A narrative review. *Nutrients*, 16(19):3307. https://doi.org/10.3390/nu16193307

Mostafa, S., Wang, Y., Zeng, W., Jin, B. (2022). Floral scents and fruit aromas: Functions, compositions, biosynthesis, and regulation. *Frontiers in Plant Science*, 13:860157. https://doi.org/10.3389/fpls.2022.860157

O'Shea, N., Ktenioudaki, A., Smyth, T.P., McLoughlin, P., Doran, L., Auty, M.A.E., Arent, E., Gallagher, E. (2015). Physicochemical assessment of two fruit by-products as functional ingredients: Apple and orange pomace. *Journal of Food Engineering*, 153:89–95. https://doi.org/10.1016/j.jfoodeng.2014.12.014

Pal M., Molnár J. (2021). Growing importance of fruits and vegetables in human health. *International Journal of Food Science and Agriculture*, 5(4):567-569. http://dx.doi.org/10.26855/ijfsa.2021.12.001

Remya, P.R., Sharon, C.L., Aneena, E.R., Panjikkaran, S.T., Shahanas, E. (2019). Standardization and quality evaluation of jackfruit based low fat yogurt. *Asian Journal of Dairy & Food Research*, 38(2):93-97. https://doi.org/10.18805/ajdfr.DR-1457

Ścibisz, I., Ziarno, M., Mitek, (2019). M. Color stability of fruit yogurt during storage. *Journal of Food Science and Technol*ogy, 56:1997–2009. https://doi.org/10.1007/s13197-019-03668-y

Sezgin, E., Atamer, M., Gürsel, A. (1988). Yerli ve yabancı starter kullanılarak yapılan yoğurtların kaliteleri üzerinde bir araştırma. *Gıda*, 13(1):5-11.

Simunek, M., Jambrak, A.R., Petrovic, M., Juretic, H., Major, N., Herceg, Z., Hruskar, M., & Vukusic, T. (2013). Aroma profile and sensory properties of ultrasound-treated apple juice and nectar. *Food Technology and Biotechnology*, 51(1):101–111.

Tamime, A.Y., Deeth, H.C. (1980). Yogurt: technology and biochemistry. *Journal of Food Protection*, 43(12):939-977.

Terzioğlu, M.E., Arslaner, A., Bakırcı, İ. (2023). Investigation of strawberry-enriched buffalo yoghurt in terms of quality characteristics and fatty acid composition, ACE inhibitor activity and HMF content. *Gıda*, 48 (2):381-393. DOI: 10.15237/gida.GD22101

Tuorila, H., Sommardahl, C., Hyvönen, L., Leporanta, K., Merimaa, P. (1993). Sensory attributes and acceptance of sucrose and fat in strawberry yoghurts. *International Journal of Food Science & Technology*, 28(4):359-369. https://doi.org/10.1111/j.1365-2621.1993.tb01282.x

Wang, X., Kristo, E., LaPointe, G. (2019). The effect of apple pomace on the texture, rheology and microstructure of set type yogurt. *Food Hydrocolloids*, 91, 83-91. https://doi.org/10.1016/j.foodhyd.2019.01.004

Wu, J., Gao, H., Zhao, L., Liao, X., Chen, F., Wang, Z., Hu, X. (2007). Chemical Compositional Characterization of Some Apple Cultivars. *Food Chemistry*, 103(1):88-93.

Xing, Z., Fu, X., Huang, H., Xu, Y., Wei, L., Shan, C., Du, Y. (2025). Recent advances in *Lactobacillus plantarum* fermentation in modifying fruit‐based products: Flavor property, bioactivity, and practical production applications. *Comprehensive Reviews in Food Science and Food Safety*, 24(2): e70160. https://doi.org/10.1111/1541-4337.70160

Yıldız Küçük, N., Bakırcı, İ. (2025). The effect of using demineralized whey powder and buttermilk powder instead of skimmed milk powder on physicochemical, microbiological, and biochemical properties of yogurt. *Journal of Food Science*, 90: e70296. https://doi.org/10.1111/1750-3841.70296

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