

## Characteristics of apricot yogurt fermented with different culture strains and stevia

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### Abstract

This study evaluated the effects of exopolysaccharide (EPS)-producing and non-EPS-producing culture varieties and the enriching of apricot pulp to the post-acidification process and microbiological, viscosity, antioxidant, and sensory properties of yogurt. Two groups of yogurts were produced in terms of culture variety. One of the yogurts in both groups was enriched with apricot pulp at a ratio of 10%. The natural sweetener, stevia, was added at a ratio of 0.1% to all yogurts. The lowest pH and highest acidity values were determined for the non-EPS sample produced without apricot pulp. The dry matter content of the yogurts was increased with whey protein powder. Between the yogurts produced with EPS-producing strains, the bacteria counts were higher for those enriched with apricot pulp. The highest *Streptococcus thermophilus* counts were determined for the sample produced with EPS-producing culture and apricot pulp at the beginning and end of the storage. Total phenolic content (TPC) was higher for the samples produced with conventional culture and enriched with apricot pulp. Similar results were observed in the antioxidant activity. Sensory attributes were considered taste, odor, appearance, texture, and overall acceptability. The yogurts produced with EPS-producing culture were preferred regarding taste, texture, and overall acceptability.

**Keywords:** antioxidant activity, apricot pulp, EPS-producing culture, fruit yogurt

### Introduction

Yogurt is one of the most popular foods in the world. Its popularity has increased because of its healthy properties and nutritional value (Gu *et al.*, 2020). The global yogurt market is set to be worth 106.6 billion dollars in 2024, which shows the product's popularity among consumers (Pereira *et al.*, 2021). Yogurt is a functional food that can be added to some fruits or fruit pulps. Thus, the diversification of functional yogurt products has gained commercial interest, drawing the attention of researchers.

In the dairy industry, exopolysaccharide (EPS)-producing culture is relevant for improving the body and the texture of yogurt, especially in countries where various stabilizers are prohibited (Malaka *et al.*, 2019). In fermented dairy products like yogurt, EPSs from lactic acid bacteria

increase viscosity, reduce syneresis, and bind excess water (Mende *et al.*, 2016). Furthermore, EPS positively affects other properties, such as antioxidant activity and prebiotic potential (Twari *et al.*, 2021). Exopolysaccharides have prebiotic potential because of their longer staying time in the gastrointestinal tract, so it is suitable to use EPSs with functional foods and dairy products such as yogurt (Patel *et al.*, 2012; Tiwari *et al.*, 2021).

Recently, there has been an increasing demand for functional dairy products containing fruit or fruit pulp. Adding value-added products, such as fruits in pure forms, to yogurt enhances its functional properties, especially antioxidant properties, and consumer acceptance (Sobti *et al.*, 2023). Apricot belongs to the Rosaceae family (Tang *et al.*, 2023). Türkiye produces 800.000 tonnes of apricot, almost 22% of total production (Faostat, 2023). It is well known

that apricot has many phenolic compounds that positively affect human health through their antioxidant activity and immune-system-improving capabilities (Saridas *et al.*, 2024). Many studies have investigated the characteristics and antioxidant properties of fermented milk products enriched with fruits such as apricots, blueberries, mangos, peaches, and strawberries (Nikmaram *et al.*, 2015; Sadaghar *et al.*, 2012; Sobti *et al.*, 2023). This fruit has a unique aroma and nutritional value. Based on the physical and chemical aspects of apricot fruit, they are rich in vitamins, carotenes, reductive sugars, dietary fibers, pectins, polyphenols, and minerals (Saadi *et al.*, 2022). Also, in recent years, there has been an increasing demand for more functional, low-calorie products because of nutrition, weight control, and health. Sweeteners are used as sugar substitutes for this purpose. Stevia is one of the natural sugar substitutes, and its major sweetener components are Stevioside, Rebaudioside A, Rebaudioside C, and Dulcoside A. (Furlan & Campderros, 2012). Stevia is 200–300 times sweeter than sucrose and has been used as a sweetener in dairy products such as yogurt (Guggisberg *et al.*, 2011). Natural sweeteners such as stevia can assist the dairy industry in developing yogurt products without adding sucrose or sacrificing flavor (Guggisberg *et al.*, 2011; Pereira *et al.*, 2021). In yogurt production, whey protein fortification can ensure yogurt's desired textural and rheological properties. Yogurts enriched with protein is becoming more popular with customers; hence, protein is connected to weight wellness (Mitra *et al.*, 2022). Milk whey is also a source of valuable nutrients such as whey proteins, calcium, lactose, and vitamins (Sady *et al.*, 2009).

This study aims to investigate the quality parameters and differences between the yogurts produced by using EPS-producing and non-EPS-producing cultures. Apricot fruit pulp was added to two groups of samples, one manufactured with the EPS-producing strain and one manufactured with the non-EPS-producing strain. Whey protein was added to increase non-fat milk solids. Apricot pulp was added to enhance antioxidant and functional properties and microbiological counts. Stevia was added to all yogurt samples, increasing functionality and health properties and as a sugar replacer. So, this study will help to investigate microbiological characteristics, viscosity, sensory evaluation, and antioxidant activity of the yogurt samples produced with different cultures and enriched with a natural sugar substitute stevia, whey protein powder, and apricot pulp.

## Materials and Methods

### Preparation of the apricot fruit pulp

Apricot fruits were purchased from the local market. They were washed and de-shelled into halves. The apricot

pulp was made by stirring thoroughly. The pulp was heat-treated at 72°C for 15 seconds.

### Preparation of starter cultures

The commercial EPS-producing starter culture (Calza Clemente, CYDFH, CR Italy) and non-EPS-producing starter culture (Calza Clemente, CYGH, CR Italy) containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* were used according to the manufacturer's recommendation. CYGH contains an EPS-producing strain of *S. thermophilus*. Ingredients used included whey powder (Pinar Dairy Products, İzmir, Turkey) and natural Stevia leaf powder (Eren International Dış Tic.Ltd.Şti., İstanbul, Turkey).

### Preparation of set yogurt

Yogurt samples were manufactured in the laboratory of the Ege University Dairy Technology Department. A raw milk solution was used for the production. The acidity value of the milk was 0.135%. The milk was divided into four lots. Set-type yogurts were prepared by adding whey protein powder to get 120 g/L of non-fat milk solids. All the samples were supplemented with natural stevia leaf powder at a ratio of 0.01%. After mixing the ingredients, the samples were pasteurized at 85°C for 30 min by circulation in a hot water bath. Then, the samples were cooled to 43°C. The inoculated samples with non-EPS-producing cultures (CYGH, Calza Clemente, Italy) were named K and KK. The inoculated EPS-producing culture samples (CYDFH, Calza Clemente, Italy) were named E and EK. The cultures were added according to the manufacturer's instructions. The samples KK and EK were enriched with apricot pulp at a ratio of 10%. The milk bases for each sample were put in sterile plastic cups, and the cups were incubated at 42°C until a pH of 4.7 was reached and the coagulation process occurred. After cooling, the yogurt samples were stored at 4°C for 21 days. The experimental design of yogurt production is given in Table 1. Also, a graphical abstract of yogurt production is given in Figure 1.

### Determination of physicochemical properties

AOAC International (2004) determined the chemical composition of the yogurt samples according to its methodologies. The pH of the samples was determined by a pH meter (Hanna Instruments Model pH:211, USA). Titratable acidity was given as 1 g lactic acid/100 g. For this purpose, the yogurt samples were mixed with 10 mL of hot distilled water and titrated with 0.1 N sodium hydroxide using a 2% phenolphthalein indicator (AOAC, 2000).

Table 1. Experimental design of yogurt production.

Yogurt	Starter culture		Whey protein powder (%4)	Stevia (%0.01)	Apricot pulp (%10)
	EPS producing	Non-EPS producing			
K		X	X	X	
KK		X	X	X	X
E	X		X	X	
EK	X		X	X	X

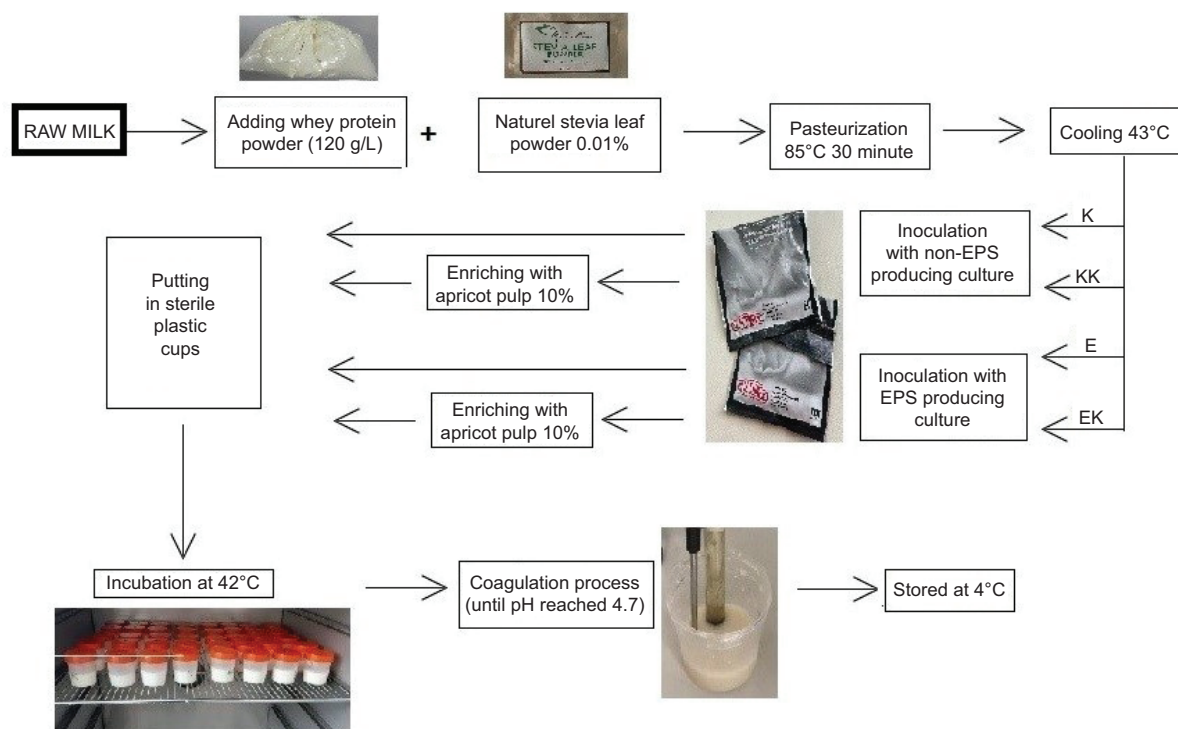


Figure 1. Graphical abstract of yogurt production.

### Microbiological properties

Yogurt starter bacteria were counted per week during storage. M17 Agar (Merck, Darmstadt, Germany) was used to enumerate *S. thermophilus*. The plates were incubated aerobically at 37°C for 48 h. MRS Agar (Merck, Darmstadt, Germany) was used to enumerate *L. bulgaricus* anaerobically at 42°C for 72 h (Dave & Shah, 1996).

### Viscosity properties

The yogurts' viscosity was determined using a Brookfield Viscometer Model DVII at 10°C. Samples were tested using the LV4 spindle after stirring for 60 s. The data were taken in duplicate at a spindle rotation of 20 rpm.

The viscosity properties of yogurt samples were determined on the 1st and 21st days of storage.

### Total phenolic content (TPC) and antioxidant activity

The total phenolic content (TPC) in the yogurt extracts was estimated according to the Folin-Ciocalteu (FC) method with some modifications (Singleton *et al.*, 1999). TPC was compared to a standard curve for gallic acid, and the TPC content of the yogurt samples was expressed as mg gallic acid equivalents (GAE) per liter of yogurt samples. The absorbance was recorded at 760 nm UV/Vis spectrophotometer. The gallic acid calibration curve equation was  $0.0011x + 0.0803$ , and the correlation coefficient was  $R^2 = 0.999$ .

To evaluate the scavenging rate of the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical, 100 µL was taken from diluted yogurt samples and mixed with DPPH reagent (0.0277 g DPPH L<sup>-1</sup> methanol). The mixtures were kept at room temperature in the dark for 2 h. With a ClarioSTAR multiple plate reader, the absorbance was measured at 515 nm. The solution prepared with methanol (100 µL) and DPPH reagent (3.9 mL) was used as a control. The DPPH scavenging activity was calculated using Equation 1.

$$\% = \frac{A_B - A_A}{A_B} \times 100$$

A<sub>B</sub>: Absorbance of DPPH reagent (control)

A<sub>A</sub>: Absorbance of yogurt samples

Sensory properties

Sensory evaluation of yogurt samples consisting of flavor, odor, texture, appearance, and overall acceptability was based on a five-point hedonic scale. Yogurts were coded

with three digits. Experienced academicians from the Department of Dairy Technology (Ege University, İzmir) evaluated the samples weekly at 4°C (Martin-Diana *et al.*, 2003).

In Figure 2, graphical abstract of yogurt analyses is given.

Statistical analyses

The differences between the samples and the effects of ripening were calculated using one-way analyses of variance using SPSS 15.0 (SPSS Inc., Chicago, USA), and the means were compared using Duncan’s multiple range test at *p*<0.05 level.

Results and Discussion

General composition

The general composition of the yogurt samples on the first storage day is given in Table 2. Samples K, KK, and E

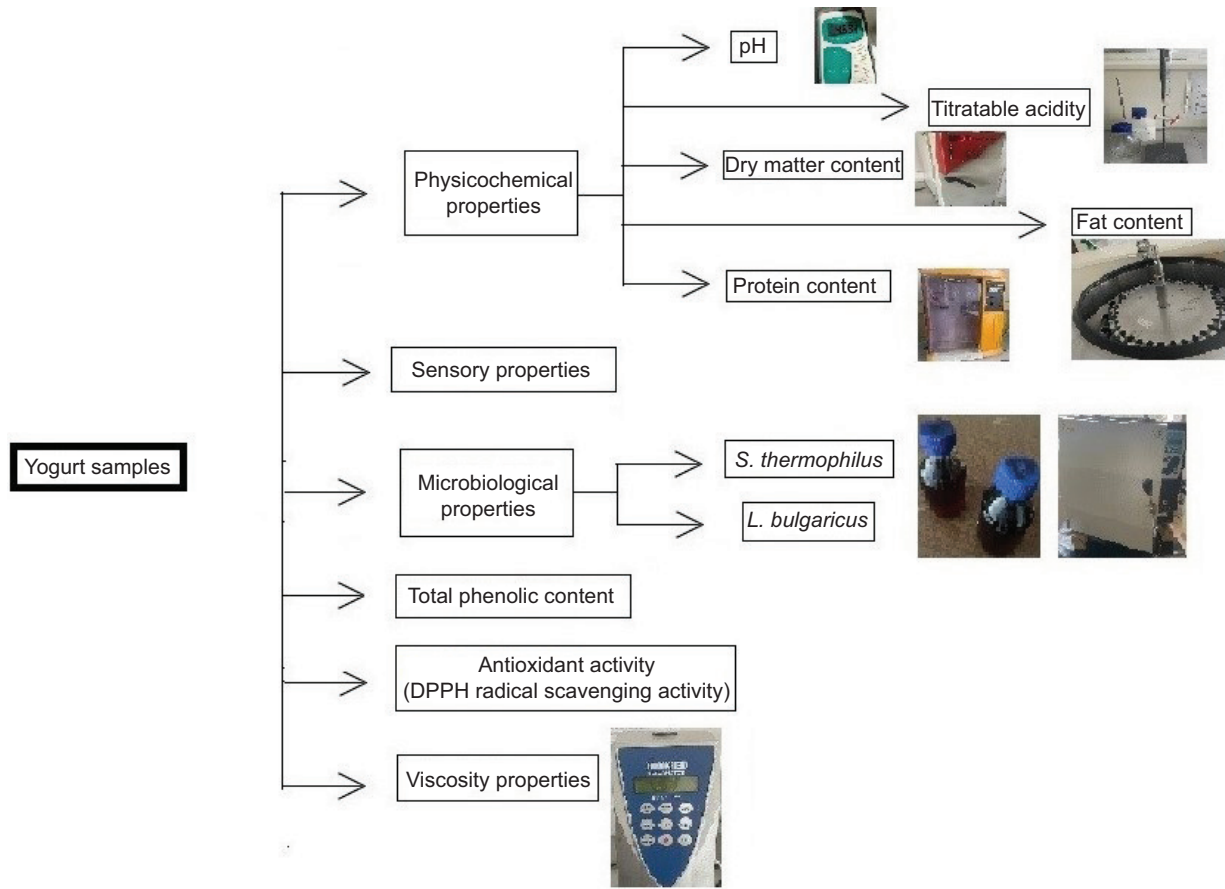


Figure 2. Graphical abstract of analyses.



Table 2. General composition of yogurt samples.

General comp. (%)	K	KK	E	EK
Non-fat dry matter content	11 <sup>B</sup>	11.18 <sup>B</sup>	10.84 <sup>B</sup>	11.78 <sup>A</sup>
Fat	3.2	3.2	3.2	3.2
Protein	2.70 <sup>C</sup>	2.74 <sup>C</sup>	3.21 <sup>B</sup>	3.87 <sup>A</sup>

K: yogurt produced with conventional yogurt culture; KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp; E: yogurt produced with EPS-producing yogurt culture; EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp; A, B Means  $\pm$  standard deviations in the same row with different superscript lowercase letters are significantly different ( $P < 0.05$ ).

were in the same group regarding non-fat dry matter content. Apricot addition increased dry matter content, which was only significant for the samples produced with an EPS-producing starter culture ( $p < 0.05$ ). A study determined that fruit addition significantly affected the dry matter content of yogurt samples (Cuşmenco & Bulgaru, 2020). The fat content of the samples was all the same, with a value of 3.2%. The highest protein content was 3.87% for the sample EK, 3.21 %, 2.74 %, and 2.70 % for the samples E, KK, and K, respectively. The culture variety significantly affected the samples' protein content ( $p < 0.05$ ). This may be due to the culture containing exopolysaccharide-producing strains that enable smooth and thick texture.

## Post acidification

The pH and acidity (% lactic acid) values of yogurt samples are given in Figure 3. The storage period significantly affected the pH of all the yogurt samples except KK ( $p < 0.05$ ). The initial pH of the samples was higher according to the pH determined at the end of the storage. This reduction, called post-acidification, might be because of how the carbohydrates were broken down to organic acids by lactic acid bacteria present in the product (Yapa *et al.*, 2023). The post-acidification process of fermented foods is affected by many factors, such as the type of starter culture, milk composition, storage temperature and pH, homogenization, pre- and pro-biotics, or packaging material (Deshwal *et al.*, 2021). This study determined the lowest pH value for sample K during storage, whereas the highest pH was measured for sample KK. The yogurts produced with EPS-producing strains were grouped at the beginning and 7<sup>th</sup> day of storage. Cartasev and Rudic (2017) produced yogurt with EPS-producing and non-EPS-producing cultures in their study. They specified that pH value and titratable acidity were similar for the two yogurt samples during fermentation.

The storage period significantly affected the acidity of the yogurt samples. The values determined at the end of storage were higher according to the initial acidities, such as pH values. The acidity value of sample K was significantly higher than other samples ( $p < 0.05$ ). Enriching with apricot pulp did not significantly affect the acidity

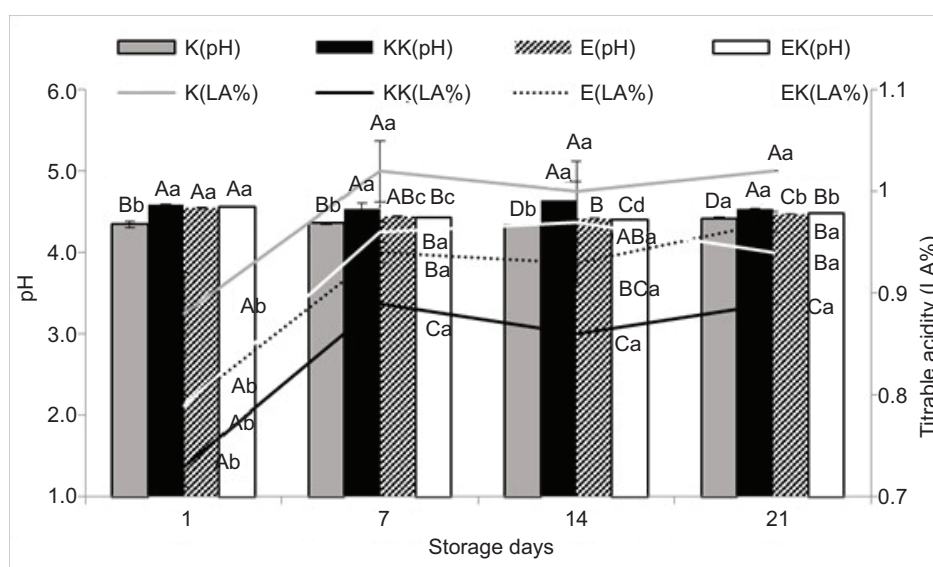


Figure 3. pH and acidity values (% LA) of yogurt samples. K: yogurt produced with conventional yogurt culture (grey bar); KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp (black bar); E: yogurt produced with EPS-producing yogurt culture (hashed bar); EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp (white bar); a-d Means  $\pm$  standard deviations with different superscript lowercase letters are significantly different ( $P < 0.05$ ); A-C Means  $\pm$  standard deviations with different superscript uppercase letters are significantly different ( $P < 0.05$ ).

values of the samples. Dimitrellou *et al.* (2020) indicated that adding fruit juices did not affect the acidity of yogurt samples after the 14<sup>th</sup> day and end of storage. The yogurt samples produced with EPS-producing strains, E and EK, were grouped in terms of acidity values during the storage period. Their titratable acidity was higher than that of the sample KK. Costa *et al.* (2013) reported that the acidity of fermented products must range between 0.6% and 1.5% in terms of consumer acceptance. In the study, both yogurts were produced with a conventional yogurt culture and an EPS-producing yogurt culture between the recommended acidity values.

Microbiological properties

The viable counts of *S. thermophilus* and *L. bulgaricus* are given in Tables 3 and 4, respectively. The highest *S. thermophilus* counts were determined in the EK yogurt sample at the beginning and end of storage. Akalın and Gönç (1999) produced yogurts using a non-viscous culture strain (A) and two viscous culture strains (B and C), both separately and in combination. They found more growth in starter bacteria in yogurts containing viscous culture C. Enriching with apricot pulp significantly affected *S. thermophilus* counts for yogurts produced with an EPS-producing culture in our study. Higher bacteria counts were determined for sample EK than sample E. Dimitrellou *et al.* (2020) indicated that *S. thermophilus* retained high viable counts during storage, especially in yogurts with fruit juices. The storage period significantly affected *S. thermophilus* counts for all samples. On the 14<sup>th</sup> day of the storage, the *S. thermophilus* counts were decreased for all samples. The counts were increased on the last storage day, except in sample KK. Purwandari *et al.* (2007) determined that in yogurt samples, an increase in the number of viable cells was initially observed for the ropy and capsular strain of *S. thermophilus*, and the number of viable cells decreased slightly towards the end of the storage.

The counts of *L. bulgaricus* were significantly lower in the samples produced with the EPS-producing strains ( $p<0.05$ ) because of the ratios of yogurt bacteria in the culture. In yogurt, both *L. bulgaricus* and *S. thermophilus* can produce EPS. However, *S. thermophilus* is more frequently used for producing EPS because *S. thermophilus* counts start to increase earlier during fermentation (Mende *et al.*, 2016). Dan *et al.* (2019) specified that different ratios of *Lb. bulgaricus* and *S. thermophilus* had different viable cell counts, and this ratio plays a critical role in the properties of the final product. Dimitrellou *et al.* (2020) specified that the starter culture contained increased numbers of *S. thermophilus* and a low content of *L. bulgaricus*. It was also confirmed for microbiological analyses in yogurt samples, and the viable count of *L. bulgaricus* was 2.50 log cfu/g at the beginning. In our study, the *L. bulgaricus* counts ranged between 1.91 and 3.19 log cfu/g for the yogurts with EPS-producing culture. For the EK sample, which was enriched with apricot pulp, there were generally higher *L. bulgaricus* counts, like *S. thermophilus* counts. The yogurt samples K and KK, produced by conventional yogurt cultures, were grouped in terms of *L. bulgaricus* counts during storage. The storage period significantly affected all samples' viable counts of *L. bulgaricus* ( $p<0.05$ ). The viable counts of *L. bulgaricus* were lower at the end of storage according to the initial values of the yogurts produced with an EPS-producing culture. Dimitrellou *et al.* (2020) specified that the viable counts of *L. bulgaricus* decreased during the storage period in the yogurts produced with an EPS-producing culture. Ranadheera *et al.* (2012) also reported that the counts of *L. bulgaricus* decreased significantly in the last week of storage, especially for fruit yogurts. The counts of *L. bulgaricus* for other groups were significantly higher at the end ( $p<0.05$ ).

Viscosity properties

In Figure 4, the viscosity properties of yogurt samples are given. The viscosity of the samples produced with an

Table 3. Changes in the viable counts of *Streptococcus thermophilus* during storage (log cfu/g).

Sample	Storage days			
	1	7	14	21
K	9.02±0.01 <sup>Bb</sup>	9.15±0.00 <sup>Aa</sup>	9.14±0.04 <sup>Aa</sup>	9.18±0.01 <sup>Ba</sup>
KK	8.82±0.00 <sup>Cb</sup>	9.03±0.04 <sup>Ba</sup>	9.02±0.04 <sup>Ba</sup>	8.68±0.02 <sup>Dd</sup>
E	8.75±0.07 <sup>Ca</sup>	8.62±0.01 <sup>Cb</sup>	8.18±0.01 <sup>Dc</sup>	8.78±0.04 <sup>Ca</sup>
EK	9.31±0.02 <sup>Aa</sup>	9.14±0.05 <sup>Ab</sup>	8.64±0.06 <sup>Cc</sup>	9.28±0.01 <sup>Aa</sup>

K: yogurt produced with conventional yogurt culture; KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp; E: yogurt produced with EPS-producing yogurt culture; EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp.; a–d Means ± standard deviations in the same row with different superscript lowercase letters are significantly different ( $P<0.05$ ); A–D Means ± standard deviations in the same column with different superscript uppercase letters are significantly different ( $P<0.05$ ).

Table 4. Changes in the viable counts of *Lactobacillus bulgaricus* during storage (logkob/g).

Sample	Storage days			
	1	7	14	21
K	7.51±0.03 <sup>Ab</sup>	7.39±0.00 <sup>Ab</sup>	8.94±0.06 <sup>Aa</sup>	8.99±0.01 <sup>Aa</sup>
KK	7.50±0.01 <sup>Ab</sup>	7.36±0.01 <sup>Ac</sup>	9.06±0.01 <sup>Aa</sup>	9.07±0.01 <sup>Aa</sup>
E	2.88±0.04 <sup>Ca</sup>	1.91±0.01 <sup>Cb</sup>	2.04±0.12 <sup>Bb</sup>	2.24±0.04 <sup>Ba</sup>
EK	3.19±0.03 <sup>Ba</sup>	3.19±0.04 <sup>Ba</sup>	2.18±0.11 <sup>Bb</sup>	2.24±0.06 <sup>Bb</sup>

K: yogurt produced with conventional yogurt culture; KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp; E: yogurt produced with EPS-producing yogurt culture; EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp; a–c Means ± standard deviations in the same row with different superscript lowercase letters are significantly different ( $P<0.05$ ); A–C Means ± standard deviations in the same column with different superscript uppercase letters are significantly different ( $P<0.05$ ).

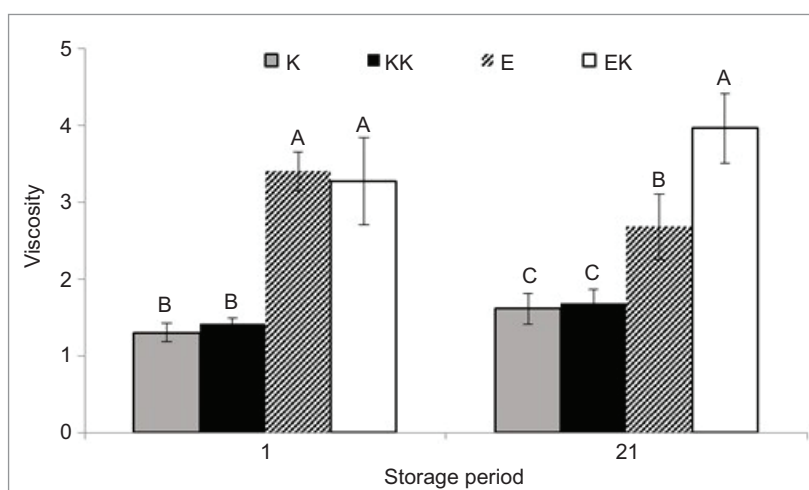


Figure 4. Viscosity of yogurt samples at 1<sup>st</sup> and 21<sup>st</sup> days of the storage. K: yogurt produced with conventional yogurt culture (grey bar); KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp (black bar); E: yogurt produced with EPS-producing yogurt culture (hashed bar); EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp (White bar); A–C Means ± standard deviations with different superscript uppercase letters are significantly different ( $P<0.05$ ).

EPS-producing starter culture was significantly higher than that of a conventional yogurt starter ( $p<0.05$ ). This was because of the impact of the strain's capability to synthesize EPS. Exopolysaccharide-producing strains produce a smooth and thick texture. Cartasev and Rudic (2017) investigated the impact of EPS-producing starter cultures on the physicochemical properties of yogurt, and they specified that the use of EPS-producing starter cultures for yogurt can increase viscosity and improve the mechanical properties of yogurt. Cui *et al.* (2021) reported that *Lb. rhamnosus*-producing EPSs improved the texture of yogurt by interacting with the free water. Yapa *et al.* (2023) reported that the hardness values for probiotic yogurts produced with EPS-producing strains were higher than the control yogurt. Changes caused by EPS included a firmer body and changes in syneresis,

viscosity, and stiffness of fermented milk. This can be due to the interactions between EPSs and the protein network (Folkenberg *et al.*, 2005). The previous study used different origins of yogurt bacteria to produce set-type yogurt. They emphasized that using starter cultures with different origins affected the viscosity of yogurts. The increase in viscosity was thought to be caused by the EPS-production ability of the *S. thermophilus* strain (Yerlikaya *et al.*, 2013). In addition, in a previous study, the application of *S. thermophilus* S3 was studied, and the structural properties of the generated EPS-S3 were characterized. They determined that EPS-S3 contained a high ratio of N-acetyl-galactosamine, leading to higher apparent viscosity (Xu *et al.*, 2023). In addition, the previous study determined higher viscosity in yogurts containing viscous culture (Akalin & Gönç, 1999). In this

study, enriching with apricot pulp had no significant effect on the viscosity properties of yogurt samples. Sun-Waterhouse *et al.* (2013) reported that viscosity can be affected by factors such as formulation composition, starter culture type, heat treatment, and processing method. Şengül *et al.* (2014) reported that the viscosity of strawberry pulp-added yogurts was not influenced significantly by the concentration rates.

#### Total phenolic content (TPC)

Phenolics are major compounds in fruits and vegetables. They have gained much attention recently because of their free radical scavenging capacity and antioxidant power. So, the enrichment of food with phenolics is a promising strategy for higher antioxidant activity (Karaaslan *et al.*, 2011). In our study's TPC of yogurt samples is given in Figure 5. According to the results, culture variety and apricot addition were statistically significant regarding TPC content ( $p < 0.05$ ). The samples produced with a conventional yogurt starter had higher TPC than those produced with an EPS-producing starter culture. Also, the yogurts with an apricot pulp had significantly higher TPC than those with the same culture. This observation is based on the previous study on fruit juices in yogurt; the fortification of grape, Aronia, and blueberry juices increased TPC. In a previous study, the TPC content at a certain level was obtained in control yogurt since ruminant milk usually has a considerable amount of phenolic compounds, which is in accordance with our study (Dimitrellou *et al.*, 2020). In addition, Najgebauer Lejko (2021) obtained higher TPC

content in all yogurts with sweetened different fruit purees than in plain yogurt; they indicated that TPC content was strongly dependent on the type of fruit puree added. According to the results we obtained, the sample that had the highest TPC was KK, with a value of 106.71 mg/L on the first day of the storage, and the same sample had the highest TPC with a value of 109.63 mg/L on the 21st day of the storage period. The TPC of our yogurt samples didn't change significantly on the 21st day of storage compared to the first day. A slight and insignificant increase was determined for the yogurts produced with conventional starter culture. In contrast, a slight and insignificant decrease was determined with the yogurts produced with EPS-producing culture. In their study, Dimitrellou *et al.* (2020) observed a slight and non-significant decrease for fruit yogurts, whereas TPC remained stable for control yogurt. These results may be relevant to the formation of complexes between phenolic compounds and proteins, which can affect phenolic recovery and activity. Several studies have observed that phenolic compounds may interact with proteins in some ways, both reversibly and irreversibly (Ozdal *et al.*, 2013; Vital *et al.*, 2015).

#### Antioxidant activity

Antioxidants are bioactive substances that prevent oxidation reactions. Fruits are natural and effective substances that protect cells against oxidative stress, as demonstrated by many researchers (Karaaslan *et al.*, 2011; Cuşmenço & Bulgaru, 2020; Dimitrellou *et al.*, 2020). The scavenging rate of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical of

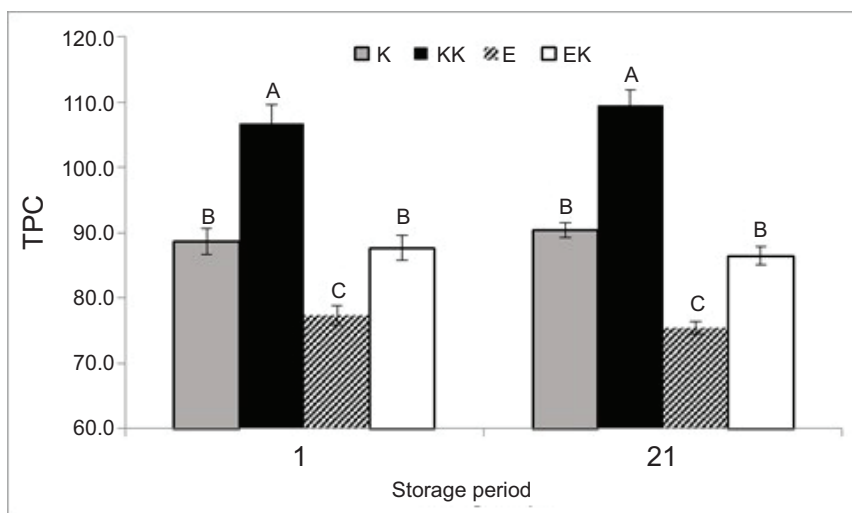


Figure 5. Total phenolic content of yogurt samples at 1st and 21st days of the storage. K: yogurt produced with conventional yogurt culture (grey bar); KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp (black bar); E: yogurt produced with EPS-producing yogurt culture (hashed bar); EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp (white bar); A–C Means  $\pm$  standard deviations with different superscript uppercase letters are significantly different ( $P < 0.05$ ).



fruit and plain yogurt samples was evaluated according to the Najgebauer-Lejko *et al.* (2011) and was given in Figure 6. The DPPH scavenging activity of yogurt samples was higher for the yogurts, which had higher TPC. According to this result, there is a correlation between TPC and antioxidant activity. Apricot addition increased radical scavenging activity, and KK had the highest DPPH value than other samples on the first and 21<sup>st</sup> day of storage. In a study, it was observed that TPC content increased in yogurts with fruit addition, and similar results were observed in antioxidant activity (Dimitrellou *et al.*, 2020). Per their study, Ünal *et al.* (2016) observed that the superiority of green tea infusion on the TPC of yogurts is parallel to those DPPH in the drinking yogurt samples. Antioxidant activity decreased for all samples in the study, but this decrement was crucial for the yogurts produced with EPS-producing starter culture. Like our study, a decrease was observed in the antioxidant activity of the yogurt samples enriched with blueberry, aronia, and grape juices by storage. A study indicated that the interactions of proteins and phenolic compounds affect antioxidant capacity (Dimitrellou *et al.*, 2020). Also, Pan *et al.* (2019) observed a significant decrease in the antioxidant capacity of set yogurts enriched with pomegranate juice powder.

### Sensory properties

The sensory properties of dairy products are important for consumer acceptability and preference. The distinctive

flavor of yogurt comes from lactic acid and the complex mixture of aroma compounds present in milk and produced during milk fermentation (Dan *et al.*, 2023). In Figure 7, sensory scores are given on the 1<sup>st</sup>, 7<sup>th</sup>, 14<sup>th</sup>, and 21<sup>st</sup> days of yogurt samples, respectively. The storage period significantly affected the taste scores of the samples produced with an EPS-producing culture. The scores increased during storage, except on the 14<sup>th</sup> day. The panelists gave the highest scores to samples E and EK during storage except for the first day. The culture variety significantly affected the taste scores of the yogurt samples in this study ( $p < 0.05$ ). However, enriching with apricot pulp had no significant effect. There were no significant differences in the odor scores of the yogurt samples. In addition, the storage period did not significantly affect the odor scores. There were significant differences in the texture scores of samples ( $p < 0.05$ ). Sample E had the highest score during storage, except for the first day. At the end of the storage, samples K and KK had the lowest scores. This was because of the properties of strains that can produce EPSs. Liu *et al.* (2017) and Amatayakul *et al.* (2006) specified that yogurts produced with EPS-producing strains presented higher water-holding capacities and improved viscosities, textures, and mouthfeel. The storage period did not significantly affect the texture scores of the yogurt samples. The storage period significantly affected the appearance scores ( $p < 0.05$ ). At the end of the storage period, all samples had higher scores according to their initial values, except sample KK. There were significant differences between the samples regarding appearance

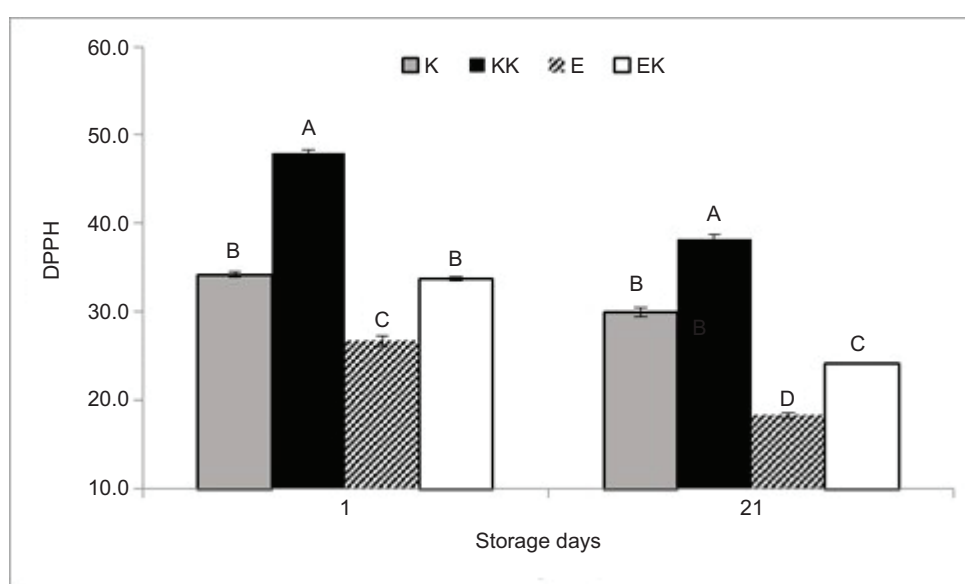
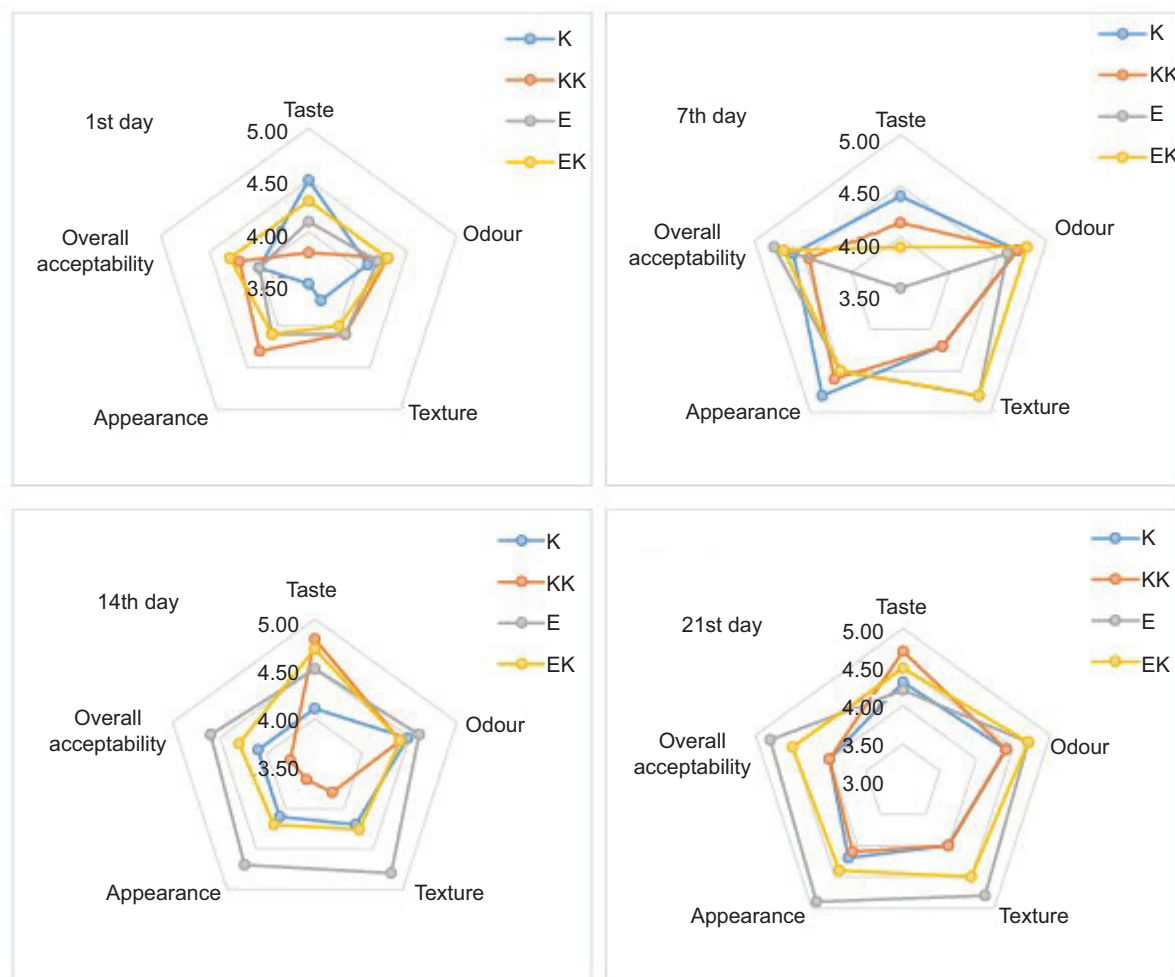


Figure 6. DPPH scavenging activity of yogurt samples at 1<sup>st</sup> and 21<sup>st</sup> days of the storage. K: yogurt produced with conventional yogurt culture (grey bar); KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp (black bar); E: yogurt produced with EPS-producing yogurt culture (hashed bar); EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp (white bar); A–D Means  $\pm$  standard deviations with different superscript uppercase letters are significantly different ( $P < 0.05$ ).



**Figure 7. Sensory scores of yogurt samples during storage. K: yogurt produced with conventional yogurt culture; KK: yogurt produced with conventional yogurt culture and enriched with apricot pulp; E: yogurt produced with EPS-producing yogurt culture; EK: yogurt produced with EPS-producing yogurt culture and enriched with apricot pulp.**

scores on the 14th and 21st days of storage. The panelists gave the highest scores to sample E on these days. Enriching with apricot pulp had no significant effect on odor, texture, and appearance scores. Dorota *et al.* (2015) specified no significant differences between plain yogurt and yogurts enriched with vegetables regarding taste and odor properties. Najgebauer-Lejko *et al.* (2021) enriched yogurt samples with kinds of fruits. The researchers specified that there were no significant differences in terms of taste and odor scores between the control and fruit-enriched yogurts. As with appearance scores, there were significant differences between the samples regarding the overall acceptability scores on the 14th and 21st days of storage. Samples E and EK had the highest overall acceptability scores, respectively. The storage period only significantly affected sample K in terms of overall acceptability. The scores of the sample decreased from the 14th day of the storage. This might be because of the higher acidity of sample K during storage.

## Conclusion

This study determined the highest post-acidification values for sample K during storage. Enriching with apricot pulp positively affected the viability of starter bacteria for the yogurts produced with an EPS-producing strain. Because of the inoculation ratios, the *L. bulgaricus* counts were lower for the yogurts produced with an EPS-producing strain. The viscosity of the samples produced with an EPS-producing strain was higher than the yogurts produced with a conventional starter culture. Both culture variety and apricot addition affected the samples' TPC content and antioxidant activity. Stevia as a sugar substitute had no adverse effect on the characteristics of the yogurt. All yogurt samples assayed had recommended acidity levels, and they all had high sensory scores. Samples K and KK had higher TPC content and antioxidant activity than the other group. Enriching apricot pulp increased the

TPC content and antioxidant activity for both groups. KK had the highest TPC content, so antioxidant activity was observed on storage's first and last days. The culture variety affected the yogurt samples' taste, texture, and overall acceptability scores. The yogurts produced with an EPS-producing strain were preferred to those produced with a conventional starter. Cultures with EPS-producing strains can be used for yogurt in terms of viscosity properties and sensorial acceptance. The apricot pulp can enrich yogurt with an EPS-producing culture in terms of bacterial viability and antioxidant properties. Using the conventional starter for yogurt production with apricot pulp seems like the best option for antioxidant properties.

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