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ENGINEERING SCIENCES

Effect of blueberry addition on antioxidant activity, textural, microbiological and physicochemical properties of strained yoghurt

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Abstract: In this research, the microbiological, physicochemical, rheological, textural, sensory properties and antioxidant activity of blueberry pulp added (0, 4%, 8% and 12%) strained yoghurt samples were investigated during a 28 day storage period. The *Lactobacillus delbrueckii* spp. *bulgaricus* and *Streptococcus thermophilus* counts in the samples were found to have decreased at the end of the storage period. The lightness, yellowness/blueness and whiteness index values showed a decrease depending on the addition of blueberry, while the redness/greenness values increased. The addition of blueberry had a negative the effects on the fat and protein values, while it had a positive effect on the total solids values. The storage period did not significantly change any of the physicochemical, colorimetric or rheological properties of the strained yoghurt samples. The general acceptability scores of the sample containing 12% blueberry were higher than the other samples. The antioxidant activities and total phenolic content of the strained yoghurt samples increased in accordance with blueberry concentration, while the firmness and work of the shear values decreased. In conclusion, it was determined that the addition of blueberry pulp at a 12% ratio could be used to enhance the nutritional and functional properties of strained yoghurts.

Key words: Antioxidant activity, blueberry, microbiological properties, strained yoghurt, texture profile analysis.

INTRODUCTION

The blueberry, which belongs to the *Vaccinium* L. genus, is a native North American fruit that grows in the wild (Siddiq et al. 2018). Blueberries have many beneficial effects on human health due to their antioxidant content and bioactive components (Çelik et al. 2013). Blueberries are rich in content in terms of bioactive compounds such as vitamins, polyphenol and flavonoid components (Zhou et al. 2020). They are also a good source of vitamin C, iron, calcium and fiber (Mainland & Tucker 2002, Tagliani et al. 2019). Anthocyanin content, in particular, is high among the flavonoids in blueberries. Anthocyanins, which are found in fruit and vegetables, are water-soluble color pigments that have high antioxidant effects (Lin et al. 2016). They are also antibacterial and are protective against cardiovascular diseases, diabetes, cancer and Alzheimer's (Lin et al. 2016, Yousef et al. 2013). Blueberries are used as food additives in desserts, bakery products and dairy products such as ice cream and yoghurt (Ścibisz et al. 2012).

Yoghurt is one of the most consumed fermented milk products in the world. It is produced with lactic acid fermentation by *Lactobacillus delbrueckii* spp. *bulgaricus* (*L. bulgaricus*) and *Streptococcus thermophilus* (*S. thermophilus*) (Brückner-Gühmann et al. 2019). Yogurt has been known to be beneficial on human health for centuries due to its probiotic bacteria content (Ozcan & Kurtuldu 2014). The water of yoghurt is removed with various methods to extend its self-life (Şenel et al. 2009). Strained yoghurt is another fermented dairy product that is derived from yoghurt (Dinkci 2012, Yazici & Akgun 2004). Generally, in the production of strained yoghurt a cloth bag is used to remove the whey (Şenel et al. 2009). Strained yoghurt, which a semisolid food, has many different names such as concentrated yoghurt, labneh (Habib et al. 2017, Saleh et al. 2018), torba, kese or süzme yoghurt (Kesenkaş 2010, Yazici & Akgun 2004).

Full fat or skim cow's milk or goat milk is used in the production of strained yoghurt. But using goat milk is limited. The popularity of strained yoghurt has increased around the world (Serhan et al. 2016). There are various products similar to strained yoghurt such as the Egyptian laban zeer, Bulgarian Besa (Nsabimana et al. 2005), Icelandic skyr, Indian shrikhand and Greek yogurt (Rocha et al. 2015). Strained yoghurt has nutritional and therapeutic properties just like yoghurt. The protein, mineral contents and viable microorganisms count of strained yoghurt is higher according to plain yoghurt and the lactose ratio is lower (Nsabimana et al. 2005). In recent years, the number of studies conducted to improve the functional and nutritional properties of strained yoghurt have increased (Tarakci et al. 2011).

The goals of the present study were: (a) to produce a functional and a new dairy product (b) to determine the usability of blueberry and its most suitable ratio in strained yoghurt (c) to examine the antioxidant capacity of strained yoghurt during storage and (d) to evaluate the effects of the addition of blueberry on the physicochemical, microbiological, rheological, and sensorial properties of the strained yoghurt samples during 28 days of storage.

MATERIALS AND METHODS

Materials

The raw cow's milk was supplied from the ER-HAS Milk and Dairy Products Co. in Erzurum, Turkey. A mix of *L. bulgaricus* and *S. thermophilus* were used as the starter culture in the production of the yoghurt samples (Valiren, Mayasan Gıda Sanayi ve A.Ş İstanbul). The blueberries were purchased from a district in the province of Trabzon, Turkey.

Preparation of the blueberry pulp

The physical and chemical properties of the blueberries were determined as follows: acidity (% citric acid) 1.65%, pH 2.83, water soluble solids 9.00° Brix, total solids 10.70%, L^* 19.53, a^* 5.05 and b^* 2.90. The highbush blueberry fruits (*Vaccinium corymbosum* L.) were obtained and stored frozen. Prior to the preparation of the pulp, the blueberries were kept at 4 °C in a refrigerator for 12 h to melt. The defrosted fruits were blended for 60 s and the pulp was divided into sterile glass jars at concentrations of 4%, 8% and 12%. They were then pasteurized in a hot water bath at 80-85 °C for 3-5 min. Finally, sugar (8%) was added and the pasteurization process was finished. The pasteurized pulps were kept at 4 °C until the production of the yoghurt.

Production of the strained yoghurt

The yoghurt was produced using skim cow's milk. The total solid of the milk was adjusted as 13.4% with skim milk powder. Various properties of the standardized skim milk were determined by using a Milkotester (Master Pro-P2, Milkotester Ltd, Bulgaria). The fat, protein, lactose, total solid and pH values of the raw milk were found as 0.8%, 4.9%, 7.4%, 13.4% and 6.5, respectively. The raw milk was pasteurized at 90 °C for 10 min, then chilled to 43-45 °C and inoculated with a DVS yoghurt starter culture as 2.5%.

Incubation (44 °C) was continued until the pH decreased to 4.6. After incubation, the yoghurt was cooled to 4 °C and kept in a refrigerator for 24 h. Then, the yoghurt clot was cut, transferred into a cloth bag and strained at 4 °C for 46 h. The strained yoghurt was divided into four equal samples: a control sample to which blueberry pulp was not added (C), a sample blended with 4% blueberry pulp (BSY4), a sample blended with 8% blueberry pulp (BSY8) and a sample blended with 12% blueberry pulp (BSY12). All of the strained yoghurt samples were analyzed on the 1st, 14th and 28th days of the storage period. The production of the strained yoghurt was performed as duplicate.

Methods

Microbiological analysis

Samples of 10 g of the strained yoghurt were transferred into 90 mL of sterile NaCl solution (0.85% w/v). Serial dilutions were prepared to 10^{-7} with same saline solution. Man Ragosa Sharpe agar (MRS, Merck, Darmstadt, Germany) was used to determine of the *L. bulgaricus* count. MRS agar was incubated at 37 °C for 72 h under anaerobic conditions, and was counted colonies. Anaerocult A sachets (Merck, Darmstadt, Germany) were used for anaerobic condition (Torriani et al. 1996). *S. thermophilus* colonies were determined on M17 agar (modified Rogosa, Merck, Darmstadt, Germany) at 37 °C for 48 h under aerobic conditions (Torriani et al. 1996). The yeasts and molds were enumerated on acidified (10% tartaric acid) potato dextrose agar, after incubation at 25 °C for 5 days (Frank et al. 1985).

Physicochemical analysis

The pH, acidity (% lactic acid), total solid (%), fat (%) and protein (%) contents of the samples were determined according to methods defined by Association of Official Analytical Chemists (AOAC 2005). A pH-meter (Hanna pH-211) was used to determine the pH values of the samples, while their acidity values were determined using the titration method. The gravimetric method was used to determine total solid content, micro Kjeldahl method was used to determine the protein content and Gerber method was used to determine the fat content of the yoghurt samples.

Water holding capacity (WHC) was determined using centrifuge. 10 g of the strained yoghurt samples were weighted in falcon tubes and centrifuged at 1250x*g* at 4 °C for 10 min. The whey of the samples was removed and weighted. The WHC values were calculated according to equation given below, which was defined by Bensmira & Jiang (2012).

$$WHC = \left(1 - \frac{W1}{W2}\right) x100$$

W1= weight of whey removed from the strained yoghurt, W2= strained yoghurt weight

The water activity (a_w) of the strained yoghurt samples was determined using a LabMaster-aw (Novasina CH-8853, Lachen, Switzerland), which was calibrated with a salted water solution at six different concentrations. The measurements were performed at 25 °C.

The viscosity values of the yoghurt samples were measured with a Brookfield Viscometer, Model DV-II (Brookfield Engineering Laboratories, Stoughton, MA, USA) with a spindle no 7 at a speed of 5, 10, 20, 50 and 100 rpm. The rheological behaviors were calculated using the power law (Ostwald-de-Waele) model and the rheological values were derived from apparent viscosity (η). The flow behavior index (*n*), consistency coefficient (*K*) and shear rate (γ) were obtained from the equation given below (Codină et al. 2016):

$$\eta = K\gamma^{n}$$

The color parameters of the samples were determined using a CR-200 Minolta colorimeter (Minolta Camera Co., Osaka, Japan). The *L** (lightness), *a** (redness/greenness) and *b** (yellowness/blueness) values were determined by instrument. Hue angel (*H°*) values were calculated according to methods described by McLellan et al. (1995). The method described by Cecchini et al. (2011) was used to determine the saturation (*C**) values of yoghurt samples. The whiteness index (WI) values were determined using the method defined by Kurt & Atalar (2018).

The texture analyses of the strained yoghurt samples were performed using a TA-XT.plus Texture Analyzer (Stable Micro Systems Ltd., Godalming, Surrey, U.K). The firmness (N) and work of shear (WoS) (N.s) were measured with a 45° conical probe at 23 °C. The measurements conditions were as follows: 1.00 mm/s pre-test speed, 3.00 mm/s test speed, 5.00 mm/s post-test speed, 0.5 g force and 20.00 mm distance.

Antioxidant activity

-Extraction method

10 mg of the strained yoghurt samples and the blueberry pulp were weighted. The samples were mixed with 10 mL water and blended with an orbital shaker at 600 rpm at room temperature for 2 h. The mixtures were centrifuged at 3900 g for 20 min. The supernatant part was removed and filtered with Whatman No. 1. The extracts were kept at -20 °C until the analyses were carried out. The extracts were used in the analyses of the antioxidant activity and total phenolic content (TPC).

-Determination of 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of the strained yoghurt samples, blackberry pulp and reference antioxidant compounds including BHA, BHT, torolox, α-tocopherol was assayed using a UV–visible spectrophotometer (DU 730 Beckman Coulter Inc., Fullerton, CA, USA). The DPPH radical scavenging activity was performed according to the method defined by Gülçin (2010).

In brief, a DPPH solution was prepared in 0.1 mM ethanol, and 0.5 mL of the DPPH solution was put in a 1.5 mL mixture of ethanol/extracts of different ratios (20-100 μg mL^{-1}). The solutions were mixed with vortex and kept in a dark place for 30 min. The absorption values of the samples were determined at 517 nm with the UV–visible spectrophotometer. The measurements were performed against blank samples. The results were calculated as an IC_{50} (μg mL^{-1}) value that was obtained from a calibration curve by a linear regression. The IC_{50} value is the amount of sample that is necessary to scavenge 50% of the DPPH free radical.

-Determination of TPC

The Folin–Ciocalteau colorimetric method was used to determine the TPCs of the samples (Gülçin et al. 2002). In brief, one mL of extract and 46 mL of distilled water were mixed in a flask. Then, 1 mL Folin–Ciocalteau reagent was added the mixture. After waiting for 3 min, 3 mL of sodium carbonate (2%) was added to the solution, which was then shaken with an orbital shaker at room temperature for 2 h. The absorbance was determined with the UV–visible spectrophotometer (DU 730 Beckman Coulter Inc., Fullerton, CA, USA) at 760 nm. The standard curve, which was determined using different concentrations of gallic acid, was used to calculate the TPC of the samples. The results were reported as µg of gallic acid equivalents (GAE) per mg of sample.

Sensory evaluation

The yoghurt samples were evaluated in terms of color, appearance, texture, acidity, flavor and general acceptability by 10 trained panelists. The panelists consisted of academic staff of the Department of Food Engineering of Atatürk University. All panelists had training at least 40 hours regarding the sensory analysis. The panelists scored the samples from 1 (dislike) to 9 (extremely perfect). Sensory evaluations were carried out on the 1^{st}, 14^{th} and 28^{th} day of the storage period.

Statistical analysis

The empirical design comprised of an completely randomized design in a factorial arrangement: four treatments, three storage periods (1, 14 and 28 days) and two replicates. The replicates were not independent. Statistically analysis of all data were used to SPSS statistical software program version 17 (SPSS Inc., Chicago, IL, USA). Statistical differences in among results were determined with Analysis of variance (ANOVA) and Duncan's multiple range tests.

RESULTS AND DISCUSSION

Microbiological properties

The microbiological properties of the strained yoghurt samples are presented Table I. Not all of the microbiological properties were affected by the addition of the blueberry pulp (P>0.05), however they were significantly (P<0.01) affected by storage time. The *L. bulgaricus* counts of the strained yoghurt samples did not show any significant changes during storage. At the end of the storage period, the *L. bulgaricus* counts of all of the samples, except for sample BSY12, decreased. In their study, Al. Otaibi & El.Demerdash (2008) found that the *L. bulgaricus* counts of essential oil added concentrated yoghurt samples increased at the initial days of storage, and later decreased at the end of storage. Their results were similar to the results of the present study. The *L. bulgaricus* counts recorded in the present study were lower than those obtained by Dinkci (2012), who analyzed various physicochemical and microbiological properties of strained yoghurt samples

Table I. **Microbiological properties of blueberry added strained yoghurt samples during 28 days of storage.**

Parameters	Storage time (days)	Strained yoghurt samples			
		C	BSY4	BSY8	BSY12
L. bulgaricus count (log CFU g^{-1})	1	7.14±0.30a,B	6.42±0.04a,B	6.64±0.57a,B	6.87±0.52a,A
	14	7.54±0.37a,B	7.28±0.13a,C	6.82±0.26a,B	7.24±0.85a,A
	28	5.50±0.39a,A	5.70±0.02a,A	5.13±0.51a,A	5.42±0.18a,A
S. thermophilus count (log CFU g^{-1})	1	5.09±0.04a,A	4.86±0.41a,A	5.56±0.15a,A	5.54±0.24a,A
	14	7.33±0.28a,B	7.00±0.24a,B	7.22±0.56a,B	7.29±0.14a,B
	28	5.38±0.04a,A	5.57±0.42a,A	5.61±0.16a,A	5.58±0.02a,A
Yeast and mould count (log CFU g^{-1})	1	4.35±0.25a,A	4.40±0.05a,A	4.30±0.01a,A	4.26±0.04a,A
	14	6.97±0.37a,B	7.43±0.12ab,B	7.66±0.16b,C	7.60±0.13b,C
	28	6.39±0.22a,B	6.60±0.73a,B	5.97±0.69a,B	6.25±0.19a,B

The different lower case letter in same row and the different upper case letter in same column indicate the significant changes (P<0.05). C: strained yoghurt without bluberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.

containing transglutaminase on the 14th day of storage.

No significant changes were observed in the *S. thermophilus* counts of the samples. The *S. thermophilus* counts of all of the samples increased on the 14th day of storage and then decreased on the 28th day of storage (Table I). These changes were found to be statistically significant (P<0.05). The *S. thermophilus* counts recorded at the beginning of the storage period were statistically similar (P>0.05) to those recorded for all samples at the end of the storage period. The *S. thermophilus* counts of all of the strained yoghurt samples were close to the *L. bulgaricus* counts recorded for all of the samples at the end of the storage. These results were in compliance with those obtained by Liu & Lv (2019), who determined that the *S. thermophilus* counts of blueberry flower pulp added yoghurt samples decreased at the end of storage. However, the counts detected by Liu & Lv (2019) and Dinkci (2012) were higher than those recorded in the present study. The lowest total counts of the *S. thermophilus* and the *L. bulgaricus* in yoghurts must be 10^7 CFU g^{-1} according to legal rules (Anonymous 2018). *S. thermophilus* and the *L. bulgaricus* counts of strained yoghurts were lower than the legal limit at the end of storage.

The yeast and mold counts of samples C and BSY4 increased on the 14th day of storage, and these counts were found to be statistically similar to those recorded on the 28th day of storage. The yeast and mold counts of samples BSY8 and BSY12 increased on the 14th day of storage but decreased at the end of the storage period (Table I). Only a significant change was observed between the strained yoghurt samples on the 14th day of storage. The yeast and mold counts of samples BSY8 and BSY12 were higher than those of the other samples on the 14th day of storage (Table I). These results were higher than those determined by Al.Otaibi & El.Demerdash (2008), Dinkci (2012) and Misirlilar et al. (2012), who studied various physicochemical and microbiological properties of protective culture and bio preservative added strained yoghurt samples.

The yeasts and molds are important problem for fruity yoghurts (Chouchouli et al. 2013), according to legal limits yoghurts must not contain any yeasts and molds. On the other hand, all counts of the microorganisms initially exhibited an increase and then displayed a decrease during the storage period. This may have been caused from the decrease in the growth elements of the microorganism. Additionally, The blueberry has rich bioactive compounds (Çelik et al. 2013, Liu & Lv 2019, Tagliani et al. 2019), and these compounds inhibit microbial activity (Demirkol & Tarakci 2018, Sun-Waterhouse et al. 2013).

Physicochemical properties

The pH and acidity values of the blueberry added strained yoghurt samples were measured during the storage period and it was determined that the pH and acidity values of none of the samples showed a significant change during the storage period (Table II). No significant differences were observed between the pH and acidity values of the samples on the 1st and 14th days of storage. However, on the 28th day of storage the acidity value of the control sample was higher than those of the other samples (P<0.05). The acidity values of all of the samples increased in all samples, however, these changes were not statistically significant (P>0.05) (Table II). The pH and acidity values of the samples at the end of storage ranged between 3.61-3.78 and 2.16%-2.34%, respectively. The pH results obtained in the present study were lower than those observed by Liu & Lv (2019), who determined the pH values of blueberry added

Table II. Physical properties and gross chemical composition of blueberry added strained yoghurt samples during 28 days of storage.

Parameters	Storage time (days)	Strained yoghurt samples			
		C	BSY4	BSY8	BSY12
pH	1	3.77±0.20a,A	3.85±0.08a,A	3.63±0.00a,A	3.69±0.08a,A
	14	3.72±0.11a,A	3.76±0.22a,A	3.69±0.06a,A	3.63±0.11a,A
	28	3.78±0.21a,A	3.69±0.11a,A	3.64±0.04a,A	3.61±0.11a,A
Acidty (% lactic acid)	1	2.17±0.17a,A	1.98±0.15a,A	1.98±0.14a,A	1.94±0.13a,A
	14	2.15±0.08a,A	1.99±0.12a,A	1.98±0.06a,A	2.09±0.17a,A
	28	2.34±0.04b,A	2.16±0.04a,A	2.21±0.02a,A	2.21±0.06a,A
Total solid (%)	1	27.39±1.55a,A	30.45±0.10a,A	29.04±2.12a,A	27.27±1.09a,A
	14	24.41±2.81a,A	31.25±2.09b,A	30.22±2.14b,A	30.68±0.20b,B
	28	22.14±0.86a,A	27.09±1.21b,A	26.69±0.52b,A	26.04±0.69b,A
Fat (%)	1	2.40±0.21b,A	1.95±0.42ab,A	1.65±0.04a,A	1.35±0.00a,A
	14	2.25±0.21c,A	1.80±0.21b,A	1.65±0.02ab,A	1.35±0.00a,A
	28	2.48±0.11c,A	1.95±0.00b,A	1.50±0.02a,A	1.43±0.11a,A
Protein (%)	1	11.96±0.02b,A	10.23±0.08a,A	10.09±0.46a,A	9.67±0.10a,A
	14	11.83±0.78a,A	10.57±1.20a,A	10.34±1.41a,A	9.93±1.29a,A
	28	12.08±0.13c,A	10.89±0.13ab,A	11.14±0.40b,A	10.31±0.15a,A
Water holding capacity (%)	1	98.65±0.67a,A	97.86±0.27a,A	97.84±0.85a,A	97.60±0.28a,A
	14	96.17±4.79a,A	97.64±2.35a,A	97.48±2.43a,A	97.94±1.54a,A
	28	98.15±0.65a,A	98.99±0.42a,A	98.57±0.35a,A	98.67±1.07a,A
Water activity (a_w)	1	0.98±0.01a,A	0.97±0.00a,A	0.97±0.00a,A	0.97±0.00a,A
	14	0.98±0.00a,A	0.98±0.01a,A	0.97±0.00a,A	0.97±0.01a,A
	28	0.98±0.00a,A	0.98±0.01a,A	0.97±0.00a,A	0.98±0.01a,A

The different lower case letter in same row and the different upper case letter in same column indicate the significant changes (*P*<0.05). C: strained yoghurt without bluberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.

yoghurt samples to be between 4.10 and -4.80 and Cinbas & Yazici (2008), who found that the pH values of blueberry added yoghurt samples at end of storage were between 4.11 and 3.97. The acidity results obtained in the present study were higher than those determined by Liu & Lv (2019) and Misirlilar et al. (2012). The changes in the pH and acidity values might have caused by the organic acid content of blueberry and microbial activity.

The effects of the blueberry pulp ratio and storage period on the total solid are displayed in Table II. All samples had a lower total solid at the end of the storage period compared to the beginning, however, the changes were not statistically significant (*P*>0.05). The total solid values of the blueberry supplemented samples were higher (*P*<0.05) compared to those of the control sample on the 14th and 28th days of storage (Table II). Kesenkaş (2010) determined the total solid values of strained yoghurt samples containing probiotic bacteria as being between 19.24%-21.24%. Yazici & Akgun (2004) determined the total solid values of fat replacer added strained yoghurt samples between 18.70% and 26.19% at the end of storage.

As can be seen in Table II, there was no significant difference (*P*>0.05) in the fat values of the samples during the storage period. The control sample had the highest fat value during the storage period. The fat values significantly decreased in accordance with the blueberry concentration of the samples. These results were in compliance with those of Cinbas & Yazici (2008), who studied the various physicochemical and sensory characteristics of blueberry pulp added yoghurt samples. The results of the present study were lower than those obtained by (Çağlar et al. 1997), who determined the fat values of commercial strained yoghurts to be between 5.80% and 9.20%.

No significant difference was observed in the protein values of the yoghurt samples (*P*>0.05) during storage. The control sample had a higher protein content than the other samples on the 1^{st} and 28^{th} days of storage. The protein values reported in the present study were higher than those reported by Kesenkaş (2010) and lower than those determined by Çağlar et al. (1997) and Yazici & Akgun (2004).

No significant changes (*P*>0.05) were observed in the WHC and a_w values of the strained yoghurt samples during storage. There were no significant changes in the WHC and a_w values of any of the samples during storage. The recorded WHC values were higher than those obtained by Saleh et al. (2018), who investigated the physicochemical properties of labneh produced using different hydrocolloids and those obtained by Ranadheera et al. (2012), who studied the physicochemical and sensory characteristics of plain and stirred fruit yogurts.

DPPH radical scavenging activity and TPC of blueberry added strained yoghurt

The DPPH and TPC results of the strained yoghurt samples are shown in Table III. The DPPH radical scavenging activity of all of the samples was expressed as IC_{50} value (μg mL^{-1}). High IC_{50} values indicate low antioxidant activity, while low values show high antioxidant activity. The antioxidant activity of the samples was found to increase in accordance with the increment of the blueberry pulp concentration during the storage period. The highest antioxidant activity during the storage period was determined to be in sample BSY12, while the lowest was determined in the control sample. All of the samples displayed irregular changes during the storage period. However, the antioxidant activity of all of the blueberry added samples at the beginning of storage was lower than at the end of storage. Blueberry pulp had higher antioxidant activity compared to all strained yoghurt samples, while blueberry pulp had lower antioxidant activity than BHA, BHT, torolox and α-tocopherol. The high antioxidant activity of the blueberry added strained yoghurt samples could be the result of the high antioxidant activity and TPC of the blueberry pulp. Liu & Lv (2019) found that the antioxidant activity of set-type yoghurt samples increased in accordance with the increment of blueberry flower pulp concentration. These results were in agreement with the results of the present study. Previous studies in the literature found that the blueberry showed strong antioxidant activity (Çelik et al. 2013, Liu & Lv 2019, Tagliani et al. 2019). On the other hand, phenolic compounds such as anthocyanins decomposed in the beginning of the storage period and later gained stability (Wallace & Giusti 2008).

The highest TPC was determined in sample BSY12 during the storage period, while the lowest was found in the control sample (Table III). The TPC of all of the samples increased in

Table III. DPPH radical scavenging activity and TPC of blueberry added strained yoghurt samples during 28 days of storage.

Parameters		Storage time (days)		
		1	14	28
DPPH (IC_{50}; µg mL^{-1})	BHA	18.57±0.64	18.57±0.64	18.57±0.64
	BHT	22.72±0.98	22.72±0.98	22.72±0.98
	Torolox	17.11±1.02	17.11±1.02	17.11±1.02
	α-tocopherol	16.87±0.43	16.87±0.43	16.87±0.43
	Blueberry	29.04±0.33	29.04±0.33	29.04±0.33
	C	346.65±81.13	269.23±26.99	340.92±60.41
	BSY4	271.23±58.85	210.86±15.11	244.81±41.99
	BSY8	205.44±2.44	155.56±10.64	162.48±0.49
	BSY12	136.03±6.87	115.40±4.34	114.97±12.03
TPC (mg GAE g^{-1})	Blueberry	96.46±1.13	96.46±1.13	96.46±1.13
	C	28.00±2.18	29.79±5.80	29.28±0.36
	BSY4	28.90±0.54	29.92±2.36	30.82±0.00
	BSY8	30.31±0.36	32.62±6.99	31.08±0.36
	BSY12	31.46±0.54	42.62±3.26	35.69±14.14

DPPH: 2,2-diphenyl- 1-picrylhydrazyl, BHA: butylated hydroxyanisole, BHT: butylated hydroxytoluene C: strained yoghurt without bluberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.

accordance with the increment in blueberry ratio. The TPC of samples C, BSY8 and BSY12 increased on the 14th day of storage and then decreased on the 28th day of storage. The blueberry pulp had higher TPC (96.46 mg GAE g^{-1}) compared to the yoghurt samples. The TPCs of the samples were between 29.28 mg GAE g^{-1} and 35.69 mg GAE g^{-1} at the end of storage. The increment in TPC of yoghurts with the addition of different fruits have been observed in many studies (Demirkol & Tarakci 2018). Previous studies in the literature found that the blueberry had strong antioxidant activity (Çelik et al. 2013, Liu & Lv 2019, Saral et al. 2015, Tagliani et al. 2019).

Viscosity and rheological properties of the strained yoghurt samples

No significant differences (P>0.05) were determined between the samples in terms of viscosity values at 50 and 100 rpm during storage, except for sample BSY4, which displayed statistically significant changes at 100 rpm (Table IV). The findings of the present were in contrast with those reported by Liu & Lv (2019) and Cinbas & Yazici (2008).

The Power Law Model was determined as the most suitable rheological model for strained yoghurt by Abu-Jdayil et al. (2000). The K values were affected by storage time (P<0.05), while the addition of blueberry had no significant effect (P>0.05). The K values of all of the samples increased on the 14th day of storage and decreased on the 28th day of storage (Table IV).

Table IV. Viscosity and rheological properties of blueberry added strained yoghurt samples during 28 days of storage.

Parameters	Storage time (days)	Strained yoghurt samples			
		C	BSY4	BSY8	BSY12
Viscosity 50 rpm (cP)	1	27210±16250a,A	34005±5432a,A	27565±10340a,A	26091±4410a,A
	14	43297±9007a,A	37985±4551a,A	32057±332a,A	29507±2502a,A
	28	20139±7337a,A	26756±9037a,A	20911±337a,A	28073±1515a,A
Viscosity 100 rpm (cP)	1	23560±13888a,A	21140±6247a,AB	16153±7165a,A	17161±4377a,A
	14	314516373a,A	32077±1758a,B	22648±3817a,A	23890±8776a,A
	28	18675±1470a,A	17035±3227a,A	14035±3179a,A	18000±2605a,A
Consistency coefficient (*K*) (Pa. s^n)	1	4.94±0.34a,A	4.87±0.13a,A	4.77±0.18a,A	4.76±0.14a,A
	14	5.19±0.09b,A	5.04±0.00ab,A	4.91±0.03a,A	4.87±0.14a,A
	28	4.88±0.14a,A	4.80±0.09a,A	4.75±0.03a,A	4.76±0.09a,A
Flow behavior index (*n*)	1	0.80±0.00a,A	0.83±0.00b,A	0.82±0.01b,A	0.83±0.01b,A
	14	0.80±0.00a,A	0.83±0.01b,A	0.83±0.00b,A	0.83±0.00b,A
	28	0.79±0.02a,A	0.82±0.01a,A	0.80±0.01a,A	0.83±0.01a,A
R^2	1	0.98±0.00	0.97±0.03	0.97±0.01	0.97±0.03
	14	0.99±0.01	0.98±0.02	0.99±0.00	0.97±0.01
	28	0.96±0.04	0.99±0.01	0.98±0.00	0.99±0.01

The different lower case letter in same row and the different upper case letter in same column indicate the significant changes (P<0.05). C: strained yoghurt without bluberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.

However, these differences were not statistically significant (P>0.05). On the 14th day of storage, the *K* value of the control sample (5.19 Pa.s^n) was higher than the other samples (P<0.05). Saleh et al. (2018) found that the *K* values of labneh with the addition of various hydrocolloids were between 0.12 and 0.75 Pa.s^n. Mohameed et al. (2004) found that the *K* values of concentrated yoghurt were between 39.56 and 41.66 Pa.s^n. The values determined by Saleh et al. (2018) and Mohameed et al. (2004) were lower than those determined in the present study. The fiber content of blueberry is high (Saral et al. 2015), and the fiber has an effect on the consistency coefficient (Rajesha et al. 2006, Sudha et al. 2010). In the presented study, the consistency coefficient of strained yoghurt samples was not affected by the addition of blueberry. Because this situation could be caused by the low added blueberry ratio.

The *n* values of the samples were significantly affected by the addition of blueberry (P<0.01), while they were not affected by storage period (P>0.05). The flow behavior index (*n*) in all of the yoghurt samples did not show a significant change during the storage period. The *n* values of the samples containing blueberry were higher than those of the control sample. In addition, the flow behavior indexes of the blueberry added samples were statistically similar to each other (P>0.05). The *n* values of all of the samples were between 0 and 1 during the storage period (Table IV). Thus, all of the strained yoghurt samples demonstrated pseudoplastic behavior. These results were in line of those reported by Saleh et al. (2018), Mohameed et al. (2004), Abu-Jdayil & Mohameed (2002) and Abu-Jdayil et al. (2000). Mohameed et al. (2004) determined that the consistency coefficient and flow behavior index of strained yoghurt correlated with the total solid content.

Table V. Color parameters of blueberry added strained yoghurt samples during 28 days of storage.

Parameters	Storage time (days)	Strained yoghurt samples			
		C	BSY4	BSY8	BSY12
*L**	1	93.44±1.33b,A	85.82±1.91ab,A	81.82±1.10ab,A	72.99±8.95a,A
	14	95.00±1.50b,A	87.20±3.07ab,A	81.28±6.92a,A	79.72±1.40a,A
	28	94.45±0.83c,A	86.79±1.50b,A	85.51±1.48b,A	79.25±0.84a,A
*a**	1	-3.31±0.35a,A	3.95±0.95b,A	7.01±0.71c,A	8.43±0.36c,A
	14	-2.94±0.51a,A	2.74±1.65b,A	5.58±1.91bc,A	8.39±1.24c,A
	28	-2.85±0.25a,A	2.96±0.93b,A	5.18±1.68bc,A	7.88±1.37c,A
*b**	1	10.17±0.76c,A	3.91±0.37b,A	2.02±0.52a,A	0.93±0.78a,A
	14	9.41±0.39b,A	4.71±1.92ab,A	3.19±2.92a,A	1.48±2.11a,A
	28	9.94±0.15b,A	4.69±0.77a,A	3.86±2.05a,A	2.22±1.32a,A
C*	1	10.69±0.84c,A	5.60±0.41a,A	7.31±0.54b,A	7.31±0.44b,A
	14	9.86±0.52b,A	5.71±0.80a,A	6.88±0.20a,A	8.66±0.84b,A
	28	10.34±0.21c,A	5.60±0.16a,A	6.72±0.11a,A	6.72±0.95b,A
H	1	108.01±0.54c,A	45.06±9.55b,A	16.29±5.51a,A	6.13±5.01a,A
	14	107.30±2.15b,A	58.08±24.63ab,A	30.16±29.67a,A	10.85±9.17a,A
	28	106.00±1.12c,A	57.59±12.27b,A	36.92±22.86ab,A	16.40±11.46a,A
WI	1	87.40±0.02b,A	84.75±1.93a,A	80.41±1.22ab,A	71.60±8.38a,A
	14	88.92±1.14b,A	85.92±2.47ab,A	79.99±6.54ab,A	77.94±1.62a,A
	28	88.26±0.58c,A	85.65±1.44bc,A	84.02±1.39b,A	77.65±1.13a,A

The different lower case letter in same row and the different upper case letter in same column indicate the significant changes (*P*<0.05). *L: lightness, *a**: redness/greenness, *b**: yellowness/blueness, *C**: Saturation, *H*: Hue angel, WI: Whiteness index, C: strained yoghurt without bluberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.**

Color parameters of strained yoghurt samples

All of the color parameters, namely the *L**, *a**, *b**, *C**, *H*° and WI values, were significantly affected by the addition of blueberry (*P*<0.01), while they were not significantly affected by the storage period (*P*>0.05). The values of all of the color parameters concerning the strained yoghurt samples are displayed in Table V. The control sample was found to have the highest *L** value on the 1st and 28th days of the storage period, while sample BSY12 had the lowest values on these days. The *L** values of all of the samples significantly decreased in accordance with blueberry concentration during the storage period. The *L** value of the blueberry pulp (19.53) was quite low, thus the samples containing the pulp had lower *L** values compared to the control sample. These results were in compliance with those reported by Cinbas & Yazici (2008) who investigated the color parameters of blueberry pulp added yoghurts.

The *a** and *b**values did not exhibit any significant changes in any of the yoghurt samples during the storage period (Table V). The *a** values of the yoghurt samples significantly increased with the addition of blueberry, while the *b** values decreased ($P<0.05$). The control sample had the lowest *a** value and the highest *b** value throughout the whole storage period. The *a** values of sample BSY12 were higher compared to those of samples C and BSY4 during the storage period, while its *b** values were lower than the those of the two samples. The changes in the color parameters of the samples may have been caused by anthocyanins as blueberries are quiet rich in terms of anthocyanins, which are a natural color pigment (Çelik et al. 2013, Ścibisz et al. 2012, Tagliani et al. 2019). Similar results were obtained by Cinbas & Yazici (2008). However, these results were not agreement with those reported by Ścibisz et al. (2012) who studied the colorimetric measurements of samples containing blueberry.

The *C**, *H°* and WI values of the samples are displayed in Table V. The *C**, *H°* and WI values of none of the samples showed a significant difference during the storage period. They did, however, decrease in accordance with the addition of blueberry. The *C**, *H°* and WI values of the control sample were higher than those of the blueberry added strained yoghurt samples throughout the whole storage period. The sample BSY4 had higher *C**, *H°* and WI values compared to the sample BSY12 during the storage period.

Texture profile of the strained yoghurt samples

The texture profile analysis results of the yogurt samples during the storage period are presented Table VI. The addition of blueberry and storage period had a significant effect on the firmness and WoS of the samples ($P<0.01$). The firmness of all of the yoghurt samples increased at the end of the storage period compared to the beginning, excluding sample BSY4. The addition of blueberry decreased the firmness of the samples. In addition, the control sample was found to have the highest firmness. The firmness of the blueberry added samples was statistically similar on the 14th and 28th days of storage. Similarly, Yazici & Akgun (2004) and Kesenkaş (2010) determined that the firmness of strained yoghurt samples decreased during storage.

Table VI. **TPA of blueberry added strained yoghurt samples during 28 days of storage.**

Parameters	Storage time (days)	Strained yoghurt samples			
		C	BSY4	BSY8	BSY12
Firmness (N)	1	192.13±18.06c,A	138.79±5.83ab,A	146.19±1.51b,A	115.44±1.10a,A
	14	182.78±5.22b,A	152.55±12.23a,AB	145.70±11.84a,A	138.88±3.79a,B
	28	229.61±4.65b,B	166.33±5.53a,B	149.12±16.57a,A	154.41±8.63a,B
Work of shear (N.s)	1	323.45±27.25c,A	230.27±10.34b,A	239.52±7.60b,A	181.47±2.88a,A
	14	307.34±9.22b,A	255.22±21.03a,A	237.77±20.40a,A	227.28±14.34a,B
	28	380.80±3.97b,B	282.92±16.73a,A	246.91±33.33a,A	252.21±16.90a,B

The different lower case letter in same row and the different upper case letter in same column indicate the significant changes (*P*<0.05). C: strained yoghurt without bluberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.

The WoS of the control sample and sample BSY12 were higher on the 28th day of storage compared to the first day of storage. In contrast, the WoS of samples BSY4 and BSY8 showed no significant change during the storage period (Table VI). The WoS of the control sample was the highest throughout the storage period. There were no significant changes in the WoS of the samples containing blueberry on the 14th and 28th days of storage. Sample BSY12 had the lowest WoS on the first day of storage. Narayana & Gupta (2016) investigated the effects of ultrafiltration and inoculum levels on the textural properties of yoghurt and found that the WoS values of the yoghurts was between 39.54 and 59.52. In another study, they determined the WoS values of the mango added yoghurt samples to be between 31.67 and 48.87 (Narayana & Gupta 2013). The results of the present study were lower than those obtained by Narayana & Gupta (2013, 2016).

Sensory properties of the strained yoghurt samples

The sensory scores of the strained yoghurt samples are presented in Figure 1. The appearance and texture scores of the control sample and sample BSY4 significantly decreased at the end of the storage period. The appearance, texture scores of samples BSY8 and BSY12 did not exhibit any significant difference during the storage period. A significant difference was only determined between the samples on the first day of storage (Fig. 1). No significant differences were observed (*P*>0.05) between the yoghurt samples in terms of texture scores during the storage period. The acidity scores of all of the samples decreased on the 28th day of storage, except for sample BSY12. The control sample and sample BSY12 had higher acidity scores than the other samples on the first day of storage. The highest flavor score on the 1st day of storage was

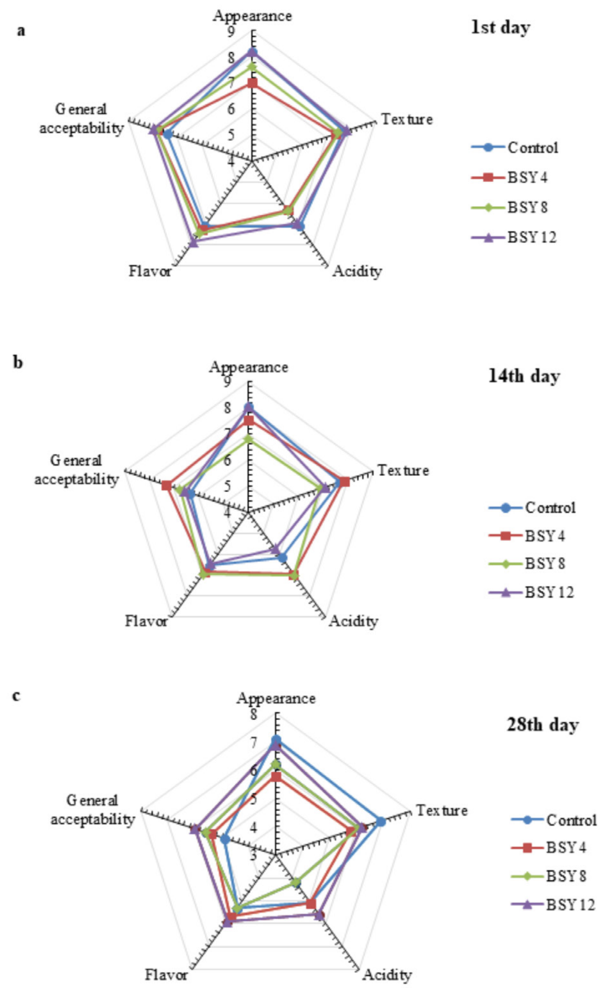

Figure 1. The sensory profiles of strained yoghurt samples at 1st (a), 14th (b) and 28th (c) days of storage C: strained yoghurt without blueberry, BSY4: strained yoghurt containing 4% blueberry, BSY8: strained yoghurt containing 8% blueberry, BSY12: strained yoghurt containing 12% blueberry.

observed in sample BSY12 (Figure 1). The flavor scores of all of the samples were higher at the beginning of the storage period compared to the end. Sample BSY12 was the most accepted by panelists in terms of flavor and general acceptability on the first day of the storage period. All of the yoghurt samples were more desired in terms of flavor and general acceptability at the beginning of the storage period compared to the end. In general, a decrease was observed in all sensory scores in all of the samples at the end of the storage period. Sample BSY12 had higher general acceptability scores compared to the other samples on the 14th and 28th days of storage, however this difference was not statistically significant (P>0.05).

CONCLUSION

The addition of blueberry pulp had statistically significant effects on various physicochemical properties, namely total solids, fat, protein, L*, a*, b*, C*, H° and WI values (P>0.01) syneresis (P<0.05), while, microbiological properties (*L. bulgaricus, S. thermophilus* and yeast and mold counts), pH, acidity, viscosity (at 20 and 100 rpm) and K values were not affected (P>0.05) by the addition of blueberry. The *L. bulgaricus* and *S. thermophilus* counts of the strained yoghurt samples significantly decreased on the 28th day of storage. As expected, all of the strained yoghurt samples displayed pseudoplastic behavior. The DPPH scavenging activity and TPC of the strained yoghurt samples increased with the addition of blueberry pulp and decreased in accordance with the storage period. The addition of blueberry had a negative effect on firmness and WoS, while storage period had a positive effect. The control sample and sample BSY12 had similar scores in terms of all sensory properties. In particular, the general acceptability scores of sample BSY12 were higher than those of the control sample. Consequently, this study indicated that 12% blueberry pulp could be used in strained yoghurt and recommended that strained blueberry added yoghurt samples should storage until 14 days.

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