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Article

Enrichment in Bioactive, Techno-Functional and Health Benefits of Yogurt Fortified with Cranberry (*Cornus mas* L.)

Mete Deniz Mutlu, Hilal Kanmaz, Büşra Kaya and Ali Adnan Hayaloğlu *

Department of Food Engineering, Inonu University, 44280 Malatya, Türkiye; mete.mutlu@lezita.com.tr (M.D.M.); hilal.kanmaz@inonu.edu.tr (H.K.); 36223620002@ogr.inonu.edu.tr (B.K.)
* Correspondence: adnan.hayaloglu@inonu.edu.tr

Abstract: In this study, the total phenolic and anthocyanin contents, antioxidant activity, color, pH, serum separation, water holding capacity (WHC), rheology, texture and viscosity of cranberry (*Cornus mas* L.)-enriched yogurt were determined. The addition of cranberries (5–15%) to yogurt resulted in a proportional increase in antioxidant activity, total anthocyanin and phenolic contents. In yogurt samples to which cranberries were added, the WHC increased, while the serum separation values decreased. Due to the red color of the cranberry fruits, the L* (lightness) and b* (yellowness) values decreased, and the a* (redness) values increased ($p < 0.05$). The sensory evaluation showed that the 10% (*w*/*w*) cranberry-added yogurt had the highest general acceptability score when compared to the other samples. Also, it was found that the addition of 10% (*w*/*w*) cranberries to the yogurt samples contributed positively to the physicochemical (textural properties, rheological behavior, color and serum separation) and biochemical (antioxidant activity, phenolics and anthocyanins) properties of the samples. The addition of cranberries to yogurt influenced the growth of microbial populations. The number of starter bacteria (counts for *Lactobacillus delbrueckii* subsp. *bulgaricus*) in the yogurt samples with cranberries was slightly lower than in the control sample; but was at an acceptable level. *E. coli* and coliform bacteria were not detected in either the control yogurt sample or the samples with added cranberries. In conclusion, the addition of 10% (*w*/*w*) cranberries to yogurt can be recommended in order to achieve acceptable physical and sensory properties as well as the enrichment of yogurt with nutritional and functional aspects.

Keywords: cranberry; yogurt; antioxidant activity; total phenolic; anthocyanin; stirred-type yogurt

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1. Introduction

Yogurt is a nutritious fermented milk product that contains health-promoting substances, such as vitamins and minerals, and is one of the most widely consumed products in the world [1,2]. Fermented dairy products, such as yogurt, are more easily tolerated by lactose-intolerant individuals compared to fresh milk with the same amount of lactose. This is because yogurt fermentation converts lactose into glucose and galactose, enhancing digestibility for individuals with lactose intolerance. Additionally, yogurt contains probiotics, live bacteria that offer important health benefits to the host [3]. Although there are many fermented dairy products, yogurt is known for its health-promoting effects and can be appropriately used as a probiotic carrier, as the milk proteins in yogurt provide important protection for the probiotic bacteria during gastric passage [4]. The growing health awareness of consumers plays an important role in the development of functional foods. With the emergence of epidemics such as COVID-19, infectious diseases still pose a major threat to human life, and people consider it necessary to strengthen their immunity to resist diseases [5]. People's increasing interest in functional milk and dairy products for a healthy diet is due to their bioavailability and health benefits [6,7]. Yogurt and other dairy products do not contain fiber. An adequate intake of dietary fiber in the human body has been reported to have positive effects on the regulation of bowel function and on the prevention and treatment of diseases such as cardiovascular disease, diabetes and colon cancer [8]. Polysaccharides in plant fibers, such as inulin and fructooligosaccharides, serve as prebiotic supporters for probiotic development in yogurt by enhancing the gut microbiota, stimulating the growth and activity of probiotic bacteria, thereby supporting the host's health [9]. Fiber in fruit can alter/improve the fatty acid profile of probiotic yogurts, and the use of fiber-containing by-products from fruit processing can lead to the development of new value-added fermented dairy products [10]. The beneficial synergistic relationship between fruits and probiotic bacteria has resulted in their inclusion in dairy products and a new era of functional food innovation [11].

Yogurt with fruit contains both the refreshing taste of fruit and the beneficial effects of yogurt. Fruit yogurt tastes better and more pleasant than regular yogurt [12]. It has been shown that the survival of probiotic cultures in dairy products can be improved by the addition of fruits rich in phenolic compounds [13]. The sensory properties of yogurt can change with the addition of fruit. In addition, pectin and sugars from fruit can increase the consistency and viscosity of yogurt and have a positive effect on the mouthfeel [14]. Ingredients added to yogurt during production can also have a positive effect on the quality of the yogurt, as they can influence the microflora of the yogurt [14]. Pereira et al. [15] reported that exotic fruits added to yogurt after fermentation increase the total phenol content. Jaster et al. [16] reported that strawberry pulp added to yogurt at 15% and 30% increased the total anthocyanin content threefold compared to the control yogurt. The addition of strawberries was also reported to increase the antioxidant activity of yogurt. Sahingil and Hayaloglu [7] reported that the addition of rosehip fruits, which are rich in phenolic substances, to yogurt increased the total phenolic content and antioxidant activity of rosehip-containing yogurt. In another study, the addition of blueberry powder was reported to increase the antioxidant activity and total phenolic and flavonoid contents of yogurt [17]. Kim et al. [18] found that yogurt samples prepared with cranberry extract had higher antioxidant activity compared to yogurt from the control group. Varnaite et al. [19] reported an increase in the total phenolic content and antioxidant activity of yogurt to which cranberry pulp had been added.

Cranberry (*Cornus mas* L.) is a wild plant that grows in Asia and Europe and has recently also been cultivated in Turkey. Its ripe red fruits have a sour taste [20]. The cranberry fruit is rich in anthocyanins, flavonoids, natural antioxidants, iridoids, essential minerals, carotenoids, tannins, vitamins, pectin and sugars, which can be used on an industrial scale as food supplements [21]. The preservation of foods with products containing natural antimicrobial, antioxidant and phenolic compounds is a good alternative to reduce health risks and economic losses and to extend the shelf life of processed foods [22]. The organic compounds commonly found in cranberries can be categorized into five chemical groups. These are anthocyanins, monoterpenes, phenolic acids, flavonoids and tannins [23]. Anthocyanins are specific compounds with health-promoting effects that are found in functional foods and are abundant in the cranberry fruit [24].

The aim of this study was to investigate the use of cranberry fruit, which is rich in phenolic compounds with high antioxidant activity and known health-promoting effects, to improve the overall quality of yogurt and increase its nutritional value. Cranberry fruits were used in yogurt production and analyzed at weekly intervals during the 21-day storage period.

2. Material and Methods

2.1. Material

Pasteurized cow's milk (6.70 for pH, 3.40% for fat, 4.70% for lactose and 2.47% for protein) was supplied from a local dairy plant (Dutpınar A.Ş., Malatya, Türkiye). Cranberries (2.89 for pH, 0.11% for fat and 1.49% for protein) were purchased from a local fruit and vegetable store (Malatya, Türkiye). A commercial yogurt starter culture (YF-L903), consisting of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*, was purchased from Chr. Hansen (Istanbul, Türkiye) for the preparation of yogurt.

2.2. Preparation of Yogurt Samples

For the preparation of yogurt samples, cranberries were pureed with a domestic blender (Bosch ErgoMixx, Istanbul, Türkiye) and used to prepare the fruit yogurt. For the production, 20 L of cow's milk was used, and the flowchart is presented in Figure 1. For the four different storage days, seven jars of each yogurt sample were prepared. In total, 28 jars of yogurt were produced for each sample. The yogurts were made in 180 mL glass jars. A total of 5.04 L of milk was used for each sample. The total ingredients for each sample were as follows:

CY0: 5 L of cow's milk
CY5: 5. L of cow's milk, 252 g cranberries
CY10: 5. L of cow's milk, 504 g cranberries
CY15: 5. L of cow's milk, 756 g cranberries.

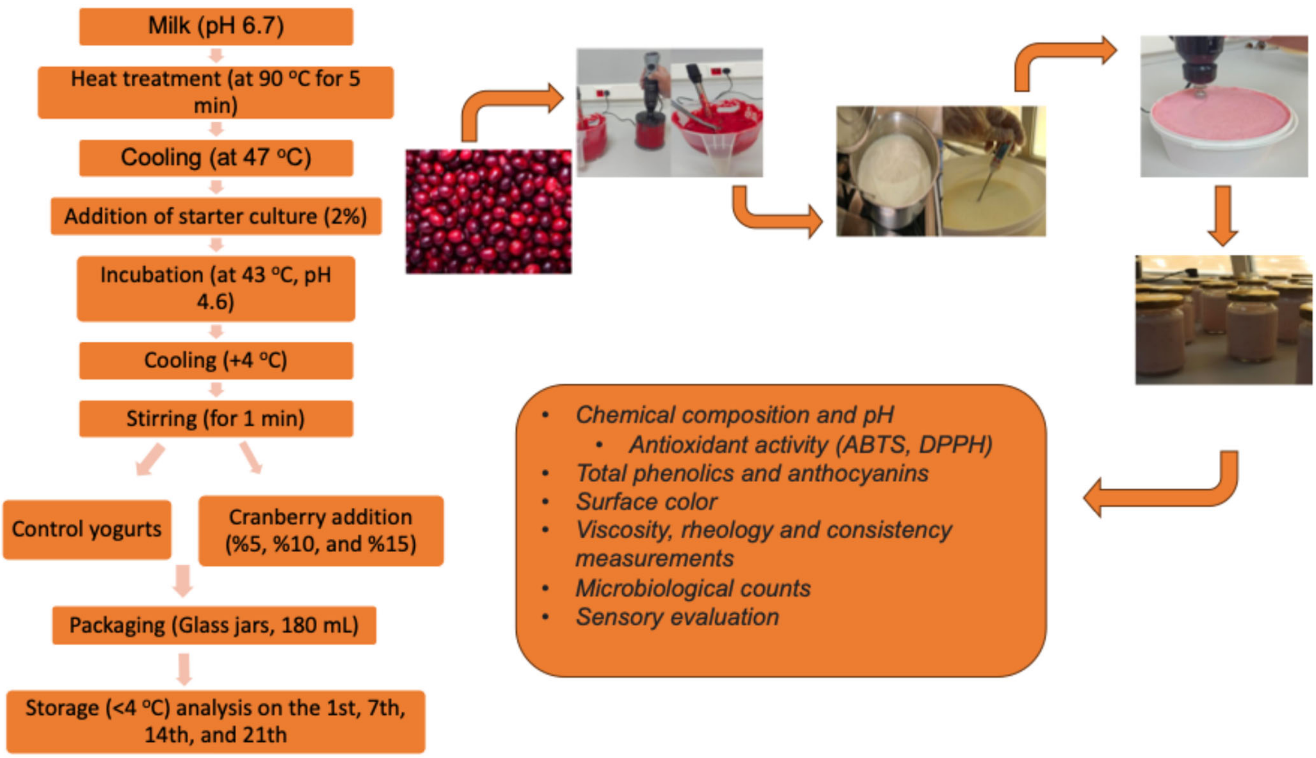


Figure 1. Flowchart for experimental yogurt production process and experimental design.

In 180 mL glass vials, 2% starter cultures were added to pasteurized (90 °C for 5 min) and warmed to 45 °C cow's milk with an initial pH of 6.7, measured using a pH meter

(Mettler Toledo, SevenCompact, S220, Schwerzenbach, Switzerland), and incubated at 43 °C until a final pH of 4.6 was reached. At the end of the incubation, the yogurt samples were cooled at room temperature (20–22 °C) for 30 min. The cooled samples were stored overnight at +4 °C. Subsequently, the pureed cranberry fruits were added to the yogurt in the cups at the ratios of control (CY0), 5% (CY5), 10% (CY10) and 15% (CY15), and the samples were stored at +4 °C during analysis, on the 1st, 7th, 14th and 21st day of storage. The yogurt production was repeated two times with a week interval.

2.3. Chemical Composition and pH

The total solids, fat, protein and ash contents as well as the pH of the samples were determined as described in detail in Sahingil and Hayaloglu [7]. The titratable acidity was determined using the alkali titration method. From homogeneously mixed (Ultra Turrax model T25, IKA Werke, Staufen, Germany) yogurt samples, 10 ± 0.5 g was weighed, and 10 mL of distilled water cooled to 40 °C was added and mixed. Subsequently, 0.5 mL of 1% phenolphthalein indicator was added, followed by titration with 0.1 N NaOH solution until a pink color, persisting for at least 30 s, was observed. The results were determined in terms of the acidity percentage [25].

2.4. Antioxidant Activity

2.4.1. ABTS Determination

First, a 7 mM 2,2-azinobis(3-ethlybenzthiazoline-6-sulfonic acid) diammonium salt (ABTS) solution was prepared as described in [26]. Then, 0.1 g of yogurt sample was weighed, and 0.9 mL of ethanol was added and then centrifuged (Hettich UNIVERSAL 320 R, Tuttlingen, Germany) at +4 °C at 13,500 rpm for 10 min. After centrifugation, 100 µL of the supernatant was mixed with 2.4 mL of the ABTS solution previously adjusted to 0.70 nm. The tubes were mixed homogeneously with the vortex and kept in the dark for 10 min. At the end of the time, the absorbance was read at 734 nm using a spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) against ethanol and the results were expressed as mg Trolox equivalent/g fresh weight [27].

2.4.2. DPPH Determination

To prepare 2,2-diphenyl-1-picrylhy-drazyl (DPPH) solution, 2.5 mg of DPPH reagent was dissolved in 100 mL of methanol. The yogurt samples were diluted 50 times with methanol, then 100 µL of the diluted sample was mixed with 3.9 mL of DPPH solution in a tube and mixed using a vortex. The tubes were kept in the dark for 45 min and the absorbance was read at 517 nm against methanol. The results were expressed as mg Trolox equivalent/g fresh weight [25].

2.5. Total Phenolics and Anthocyanins

For the analysis, 2% (*w*/*v*) Na_2CO_3 in water and Folin–Ciocalteu's reagents (Merck, Darmstadt, Germany) were used. An amount of 5 g of yogurt samples were prepared by methanolic extraction as described in Singleton et al. (1999). Then, 40 µL of the prepared mixture was mixed with 3.16 mL of water and 200 µL of Folin reagent. This mixture was vortexed for 1 min and kept in the dark for 5 min. After the addition of 600 µL of 2% Na_2CO_3 to the mixture, the samples were measured at 765 nm in a UV-1800 spectrophotometer (Shimadzu, Kyoto, Japan). The results were expressed as mg GAE/100g [28].

For the determination of total anthocyanins, the extraction was performed by adding 50 mL of methanol containing 0.1% HCl into 10 g of homogenate and kept at −18 °C for 24 h. Then, measurements were read at 520 nm using the same spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) and the results were calculated as mg cyanidin-3-O-rutinoside/100 g fresh weight [29].

2.6. Serum Separation and Determination of Water Binding Capacity

For the serum separation analysis, a funnel and coarse filter paper were first placed in a measuring cylinder and the tare was recorded. An amount of 25 g of yogurt was weighed at 4 °C and placed in the funnel. The serum was collected in the graduated cylinder for 2 h. The amount of serum in the measuring cylinder was then determined volumetrically. The results were multiplied by 4 and expressed as a percentage [29].

For the analysis of water holding capacity, 5 g of yogurt was weighed into tubes. Centrifugation was performed at 4500 rpm, 10 °C and for 30 min. After centrifugation, the supernatant was removed and the weight of the pellet was weighed. The results were calculated according to the following formula and expressed as a percentage [30].

Pellet: solid part (sediment) remaining at the bottom of the centrifuge tubes. Supernatant: liquid part remaining at the top of the centrifuge tubes.

$$\%WBC = \frac{Pellet\ (g)}{The\ initial\ sample\ amount\ (g)} \times 100$$

2.7. Surface Color

Color measurements of the yogurt samples were performed using a colorimeter (Konica Minolta, model CR-5, Osaka, Japan). The CIE color values (L*, a*, b*) of the samples were read using the colorimeter. The instrument was set as illuminant D65 and observer angle 10°. A total of seven measurements were performed using 3 mm diameter Petri dishes and the results were reported as an average [31].

2.8. Viscosity, Rheology and Consistency Measurements

The viscosity measurement of the samples was performed using a Brookfeld viscometer (model DV-II+, Middleboro, MA, USA), using the spindle number 4. Viscosity measurements were performed on samples brought to room temperature (20–22 °C). For each yogurt sample, four measurements were performed after 10 s of rotation, and the averaged values were expressed in Pa.s [32]. The rheological properties of the samples were monitored by a dynamic oscillating shear test using a rheometer (Anton Paar, MCR 301, Graz, Austria). The temperature was set to 20 ± 0.01 °C before the rheological experiments and the elastic (G') and viscous (G'') modulus were performed. A frequency sweep test was monitored with frequency range of 0.01 to 100 Hz with a constant strain of 0.5%. The consistency of yogurt samples was measured using a 30 mm disc probe using a TPA apparatus (TA, XT2 plus C, Stable Micro Systems, Surrey, UK) by the modified method [33]. The test was performed by inserting the instrument probe into the sample in a 180 mL glass vial at a rate of 1 mm/sec, penetrating up to 75% of the sample height and then exiting at a rate of 10 mm/second.

2.9. Microbiological Counts

The microbiological analyses of the yogurt samples were performed using microbiological media including MRS agar (incubation at 37 °C for 72 h under anaerobic conditions, ISO 7889:2003) for lactobacilli, M17 agar (incubation at 37 °C for 48 h [34]) for lactococci, Plate Count Agar (PCA) (incubation at 30 °C for 72 h [35]) for the total number of aerobic mesophilic bacteria, Tryptone Bile X-glucon for *E. coli*, Tryptone Bile X-glucuronide Agar (TBX Agar) (24 h incubation at 44 °C [36]) and Violet Red Bile Agar (VRBA) (24 h incubation at 37 °C [37]) for the number of coliform bacteria. Dichloran-Rosenbengal-Chloramphenicol Agar (DRBC Agar) (5-day incubation at 25 °C [38]) was used for yeasts and molds using the smear method. At the end of the incubation period, the counts were expressed as mean values ($\log_{10}$ CFU mL^{-1}) of at least three petri dishes.

2.10. Sensory Evaluation

The form provided in Hayaloglu et al. [39] was modified to create the sensory evaluation form. The sensory analysis was conducted by eight panelists. Each yogurt sample was presented to the panelists in transparent sample containers. The created sensory evaluation form was assessed based on the ratings provided by eight educated panelists and covered the following criteria: taste, odor, consistency, appearance, color and general acceptability. Before the evaluation, panelists received a free and informed consent form of agreement to participate in this research. This work has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Panelists were familiar with the general sensory testing procedure and plain and fruit yogurt in their daily consumption.

2.11. Statistical Evaluation

The statistical analysis of the results of the fruit yogurt samples prepared by adding cranberries in different proportions was carried out using the software SPSS 25.0 for Windows. The differences between the fruit yogurt samples were determined using ANOVA and Duncan's test for multiple comparison at the $p < 0.05$ level of significance. The sensory evaluation data were tested with a non-parametric Kruskal–Wallis's test using the same software.

3. Results and Discussion

3.1. Chemical Composition and pH

The pH of all the yogurt samples decreased during the 21-day storage period ($p < 0.05$). In yogurt samples prepared with cranberry, it was observed that the pH values of the samples decreased with an increasing amount of cranberry (Table 1), and the results were consistent with our study [17]. Rahman et al. [40] reported that in the yogurt samples prepared by adding strawberry juice, the pH values of the yogurt samples with added fruit decreased and the titration acidity values increased compared to the yogurt of the control group. It is assumed that the decrease in the pH values of the yogurt with added cranberries is due to the organic acids in the cranberries and the acidification by the lactic acid bacteria. The titratable acidity values of the control group and the yogurt with added cranberries varied between 1.096% and 1.460%. The titratable acidity values of the samples increased as the amount of cranberries added to the yogurt increased ($p < 0.05$). Alzamara et al. [41] reported that the titratable acidity of the yogurt samples prepared by adding rosehip marmalade varied between 0.83% and 1.05% and the acidity increased with increasing amount of rosehip and reported results compatible with the present study. The total solid content in yogurt varied between 10.34% and 12.31%. The amount of total solid content increased as a consequence of the cranberry addition. While the total solid content of yogurt samples increased until the 14th day, it was observed to decrease after the 14th day. It was found that the change in the yogurt samples during the 21-day storage period was statistically significant ($p < 0.05$). On the 21st day, serum separation increased in all the yogurt samples (Figure 4a). This may have led to the loss of some dissolved solids along with water, resulting in a decrease in the total solid content. It was reported that the total solids content of yogurt prepared with the addition of cranberry pulp varied between 13.84% and 17.92% and that the total solids content of the samples increased with increasing addition of cranberry pulp and results consistent with our study were reported [19].

Table 1. pH, titratable acidity, total solid, color (L*, a* and b*) values of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples.

	Day	CY0	CY5	CY10	CY15
pH	1	$4.22 \pm 0.07^{c,C}$	$4.11 \pm 0.06^{b,C}$	$4.07 \pm 0.13^{b,B}$	$3.94 \pm 0.03^{a,B}$
	7	$3.74 \pm 0.08^{c,B}$	$3.69 \pm 0.11^{bc,B}$	$3.62 \pm 0.06^{b,A}$	$3.51 \pm 0.08^{a,A}$
	14	$3.73 \pm 0.03^{b,AB}$	$3.68 \pm 0.10^{b,B}$	$3.61 \pm 0.29^{ab,A}$	$3.47 \pm 0.04^{a,A}$
	21	$3.66 \pm 0.03^{b,A}$	$3.56 \pm 0.24^{a,A}$	$3.47 \pm 0.04^{a,A}$	$3.44 \pm 0.03^{a,A}$
Titratable acidity, % of lactic acid	1	$1.129 \pm 0.047^{a,B}$	$1.187 \pm 0.01^{b,A}$	$1.346 \pm 0.002^{c,C}$	$1.460 \pm 0.006^{d,C}$
	7	$1.168 \pm 0.004^{a,C}$	$1.282 \pm 0.009^{b,D}$	$1.340 \pm 0.007^{c,C}$	$1.427 \pm 0.012^{d,B}$
	14	$1.096 \pm 0.006^{a,A}$	$1.200 \pm 0.007^{b,B}$	$1.275 \pm 0.009^{c,A}$	$1.355 \pm 0.004^{d,A}$
	21	$1.121 \pm 0.004^{a,AB}$	$1.263 \pm 0.004^{b,C}$	$1.313 \pm 0.007^{c,B}$	$1.432 \pm 0.005^{d,B}$
Total solid, %	1	$11.31 \pm 0.07^{a,B}$	$11.56 \pm 0.07^{b,B}$	$11.90 \pm 0.06^{c,B}$	$12.21 \pm 0.03^{d,B}$
	7	$11.38 \pm 0.05^{a,B}$	$11.65 \pm 0.07^{b,B}$	$12.18 \pm 0.07^{c,C}$	$12.26 \pm 0.04^{d,B}$
	14	$11.43 \pm 0.09^{a,C}$	$11.83 \pm 0.10^{b,C}$	$12.31 \pm 0.03^{c,D}$	$12.29 \pm 0.03^{c,B}$
	21	$10.34 \pm 0.06^{a,A}$	$10.41 \pm 0.07^{a,A}$	$11.65 \pm 0.07^{b,A}$	$11.71 \pm 0.12^{b,A}$
L*	1	$80.23 \pm 0.50^{d,A}$	$75.31 \pm 0.10^{c,AB}$	$71.91 \pm 0.36^{b,B}$	$68.57 \pm 0.43^{a,B}$
	7	$80.41 \pm 0.56^{d,A}$	$75.45 \pm 0.19^{c,B}$	$71.25 \pm 0.81^{b,A}$	$68.31 \pm 0.17^{a,B}$
	14	$80.50 \pm 0.40^{d,A}$	$75.22 \pm 0.15^{c,AB}$	$71.16 \pm 0.33^{b,A}$	$68.41 \pm 0.31^{a,B}$
	21	$79.81 \pm 0.65^{d,A}$	$75.08 \pm 0.37^{c,A}$	$71.04 \pm 0.56^{b,A}$	$67.86 \pm 0.47^{a,A}$
a*	1	$-2.01 \pm 0.17^{a,A}$	$4.80 \pm 0.32^{b,B}$	$9.23 \pm 0.18^{c,A}$	$13.00 \pm 0.21^{d,B}$
	7	$-1.96 \pm 0.11^{a,AB}$	$4.29 \pm 0.22^{b,A}$	$10.93 \pm 0.22^{c,D}$	$12.48 \pm 0.34^{d,A}$
	14	$-1.90 \pm 0.18^{a,AB}$	$5.22 \pm 0.25^{b,C}$	$10.17 \pm 0.33^{c,C}$	$13.27 \pm 0.38^{d,B}$
	21	$-1.78 \pm 0.15^{a,B}$	$4.74 \pm 0.38^{b,B}$	$9.78 \pm 0.32^{c,B}$	$12.97 \pm 0.35^{d,B}$
b*	1	$5.62 \pm 0.36^{d,A}$	$3.86 \pm 0.15^{c,A}$	$3.48 \pm 0.31^{b,A}$	$3.16 \pm 0.12^{a,A}$
	7	$5.65 \pm 0.31^{c,A}$	$3.98 \pm 0.16^{a,AB}$	$5.16 \pm 0.13^{b,C}$	$4.11 \pm 0.10^{a,C}$
	14	$5.87 \pm 0.22^{b,A}$	$4.06 \pm 0.13^{a,B}$	$4.01 \pm 0.22^{a,B}$	$3.98 \pm 0.13^{a,B}$
	21	$5.91 \pm 0.16^{b,A}$	$4.11 \pm 0.13^{a,B}$	$4.25 \pm 0.29^{a,B}$	$4.36 \pm 0.24^{a,B}$

$^{A–D}$ Means followed by different letters in the same column are significantly different, $p < 0.05$. $^{a–d}$ Means followed by different letters in the same row are significantly different, $p < 0.05$.

The protein, ash and fat values of the yogurt samples are shown in Table 2. Since the protein content of cranberry fruit is lower than that of milk, the protein values of yogurt decreased with increasing fruit content, and this decrease was statistically significant ($p < 0.05$). The same was valid for ash and fat values. The highest values in terms of protein, ash and fat content were obtained for CY0 yogurt. In agreement with the present study, Rahman et al. [40] reported that the ash and fat values of fruit yogurt prepared with strawberry juice decreased compared to the yogurt of the control group. In yogurt samples prepared with persimmon, cranberry, rosehip, carrot, black persimmon and medlar fruit jam, it was found that the protein value decreased proportionally in yogurt samples with fruits other than rosehip. This was explained by the fact that the fruits examined in the study contained protein in lower concentrations than milk [42].

Table 2. The protein, ash and fat values of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples.

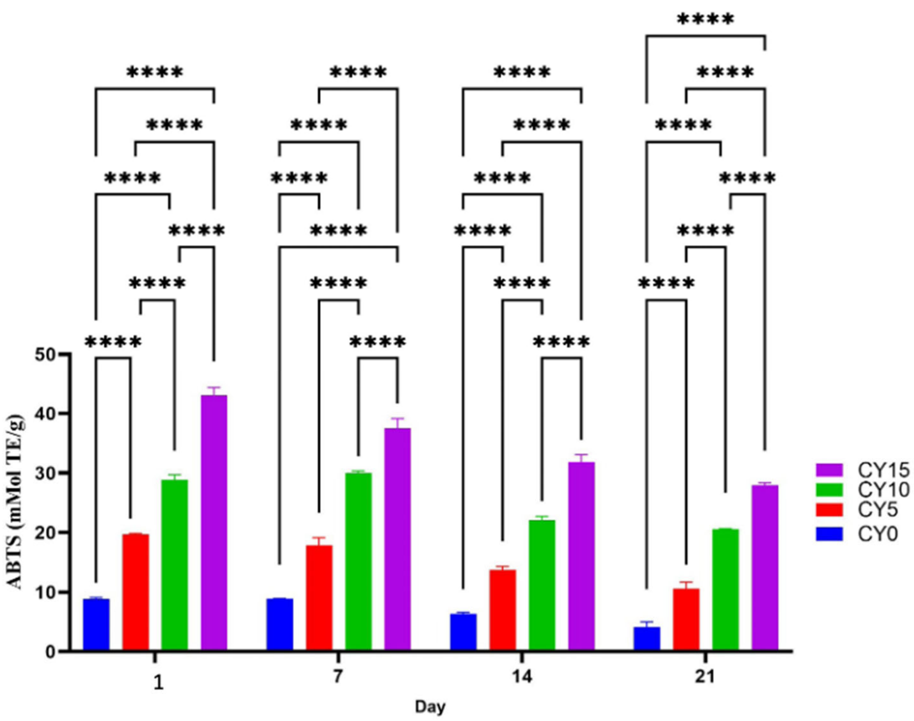
Sample	Protein, %	Ash, %	Fat, %
CY0	3.90 ± 0.11^{c}	0.845 ± 0.012^{d}	3.84 ± 0.05^{d}
CY5	3.40 ± 0.19^{b}	0.825 ± 0.009^{c}	3.00 ± 0.15^{c}
CY10	3.28 ± 0.17^{ab}	0.801 ± 0.019^{b}	2.67 ± 0.12^{b}
CY15	3.19 ± 0.13^{a}	0.735 ± 0.005^{a}	2.17 ± 0.12^{a}

$^{a–d}$ Means followed by different letters in the same column are significantly different, $p < 0.05$.

3.2. Antioxidant Activity

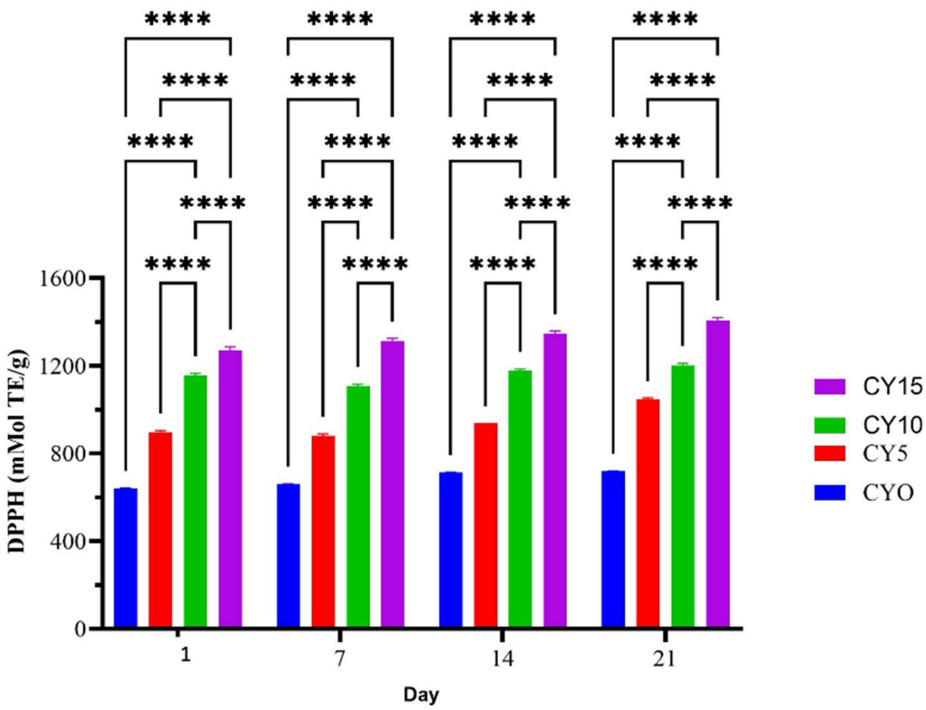
The ABTS assay ranged from 4.12 to 43.01 mmol TE/g (Figure 2). The highest value for ABTS antioxidant activity was obtained from CY15 yogurt, while the lowest ABTS antioxidant activity was obtained from CY0 yogurt. It was found that the ABTS antioxidant activity values of the samples increased significantly with increasing levels of cranberries in the yogurt samples ($p < 0.0001$). The levels of ABTS antioxidant activity of both the control and fruit yogurt samples decreased during storage ($p < 0.05$). Alzamara [43] reported similar results by stating that the levels of the ABTS antioxidant activity of yogurt prepared with cranberry and cherry marmalade increased with the increasing amount of marmalade and the levels of ABTS antioxidant activity of the samples decreased during 21 days of storage. Durmuş et al. [44] reported that the levels of ABTS antioxidant activity of yogurt prepared by adding black mulberry increased with the increase in the concentration of black mulberry. The levels of the ABTS and DPPH antioxidant activity of yogurt samples increased with the increasing concentration of cranberry pulp and results in the present study are consistent with the study by Varnaitė et al. [19].

Our results are in line with the studies on yogurt enriched with apple pulp or black mulberry puree [44,45]. Hayaloglu and Sahingil [7] reported similar results to our study by finding that the addition of rosehips significantly increased the levels of antioxidant activity (ABTS and DPPH) of all the yogurt samples prepared with rosehips. The DPPH antioxidant activity values of the yogurt samples varied between 640.57–1407.89 mmol TE/g. The DPPH antioxidant activity values of the samples increased with the increase in the proportion of cranberries added to the yogurt samples ($p < 0.0001$). Similar observations (increase in DPPH values by adding some fruits in yogurt) were observed for blueberry powder [17], orange pulp [46], cranberries [47], rosehip seed powder [48] and rosehip marmalade [7].



(**a**)

Figure 2. *Cont.*



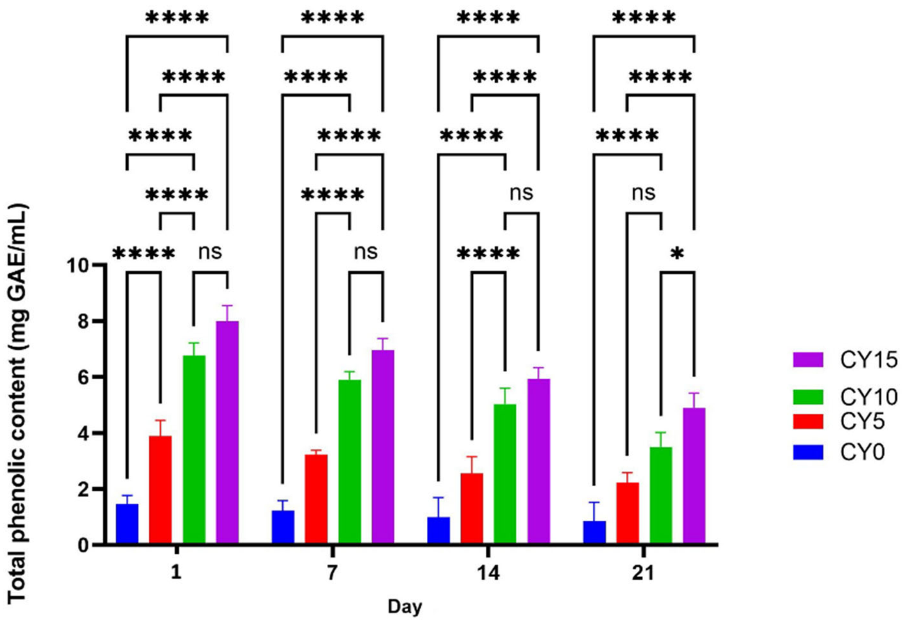
(**b**)

Figure 2. The antioxidants activity (ABTS and DPPH) values of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples. ****: $p < 0.0001$.

3.3. Total Phenolics and Anthocyanin Contents

The yogurt sample with the lowest number of total phenols was determined as CY0 with 0.87 mg GAE/mL, while the highest amount was determined in CY15 yogurt samples with 8.00 mg GAE/mL (Figure 3). Compared to the CY0 yogurt samples, the CY5, CY10 and CY15 samples showed a significant increase in total phenolic content with increasing levels of cranberry puree ($p < 0.0001$). As observed in the antioxidant activity results, the total phenolic content of the samples decreased significantly during storage ($p < 0.05$). The decrease in phenolic content during storage may be due to the probiotic or other microorganisms in the yogurt metabolizing the phenolic compounds, leading to a reduction in their content. This can also be associated with a decrease in antioxidant activity [49]. Şahingil and Hayaloglu [7] reported that the total phenolic content of yogurt samples prepared with rosehip fruit varied between 107.2–213.8 mg GAE/100 g and these authors reported that the addition of rosehip fruit to yogurt samples caused a significant increase ($p < 0.05$) in the total phenolic content. Shori [50] reported a significant increase ($p < 0.05$) in the total phenolic content of yogurt samples prepared with rosemary, dill, thyme and ginger juice extracts compared to control yogurt samples. Also, Alzamara [43] reported that the total phenolic content of yogurt samples prepared with cranberry and cherry jam increased statistically significantly ($p < 0.01$) with the amount of jam added to the yogurt.

The lowest and highest anthocyanin contents were determined in yogurt sample CY0 with 0.353 mg cyanidin-3-O-rutinositide/mL yogurt on the 21st day of storage and CY15 sample with 1.600 mg cyanidin-3-O-rutinositide/mL yogurt on the first day of storage, respectively. During the 21-day storage period, there was a significant decrease in the amount of anthocyanin in the yogurt samples ($p < 0.05$). Uğur et al. [51] reported that the total anthocyanin content of the samples in 27 different cranberry genotypes varied between 0.67–49.30 mg cynadine-3-glycoside/100 g and that this difference was due to the different genotypes having different colors. Ścibisz et al. [52] reported that the total anthocyanin content in fruit yogurt samples prepared with the addition of blueberries increased proportionally to the fruit content. Szoltysik et al. [53] reported that in yogurt samples prepared with honeysuckle fruit (*Lonicera ciliosa*), the total anthocyanin content increased with the increasing fruit content and the total anthocyanin content of all samples decreased during the 21-day storage period.



(**a**)

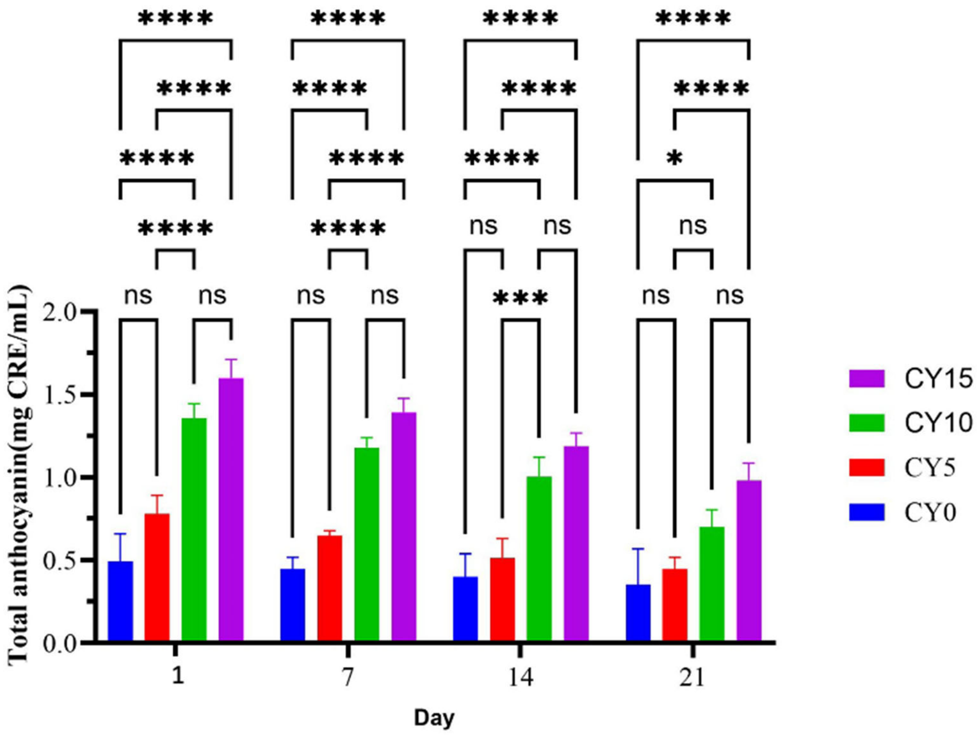


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Figure 3. Total phenolic and anthocyanin values of control (CY0) and 5% (w/w) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples. ns: not significant, *: $p < 0.05$, ***: $p < 0.001$, ****: $p < 0.0001$.

3.4. Water Holding Capacity and Serum Separation

Water holding capacity is an important quality parameter for yogurt. In the present study, the lowest water holding capacity was found on the first day of storage for the control group, while the highest water holding capacity was found for CY15 with 15% cranberry on the 21st day of storage. The water holding capacity of the samples decreased after 21 days of storage ($p < 0.05$). It is hypothesized that the higher water holding capacity of the yogurt samples to which fruit was added compared to the control group is related to the pectin content of the fruit. Sahingil and Hayaloglu [7] reported that the control yogurt had the lowest water-holding capacity and the yogurt samples to which 20% rose hips were added had the highest water-holding capacity and reported results consistent with our study.

Serum separation (syneresis) is caused by the inability of the yogurt gel to maintain the serum phase due to the weakening of the casein network and is an undesirable condition that leads to the accumulation of whey on the product surface. The addition of cranberries increases the total solids content of the yogurt, which has a positive effect on the density of the casein network and reduces syneresis [54]. The serum separation values of the samples increased during the storage period (Figure 4). As a result of this study, both fruit content and storage time were found to affect the serum separation of yogurt, with the serum separation value decreasing with the increasing fruit content and inversely with storage time ($p < 0.05$). In the yogurt samples prepared with the addition of 1%, 2% and 3% apple pulp, the lowest and highest serum separation values were observed in the control and 3% apple pulp-containing yogurt samples, respectively. This is thought to be due to the soluble and insoluble fiber content of apple pulp [45]. Çelik et al. [20] reported that the serum separation value was higher in fruit yogurt samples prepared with cranberry paste compared to the control yogurt and that the serum separation value increased rapidly during the one-week storage period. In another study, orange fiber-containing yogurt containing pectin caused a reduction in serum separation [55].

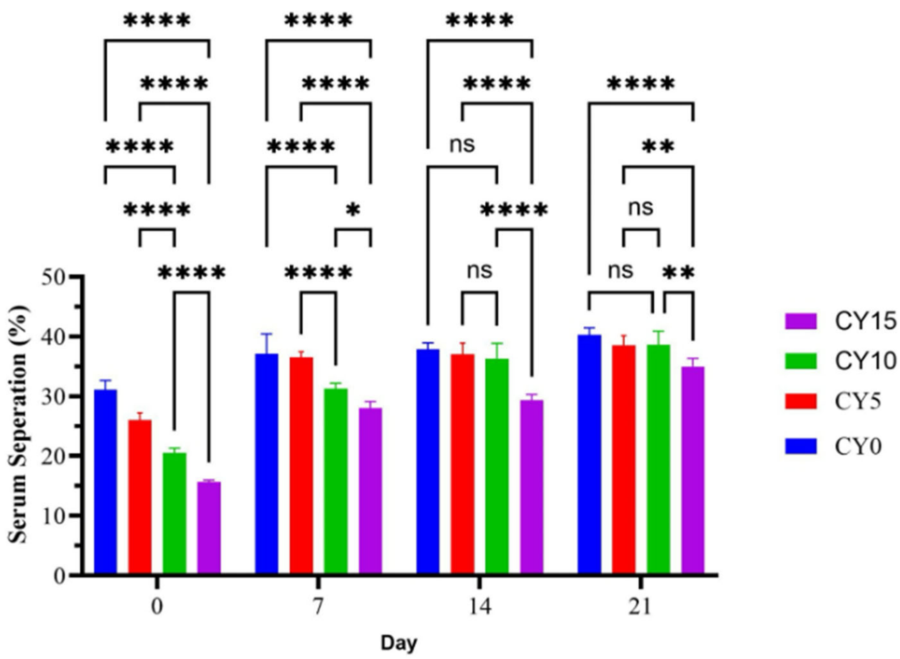

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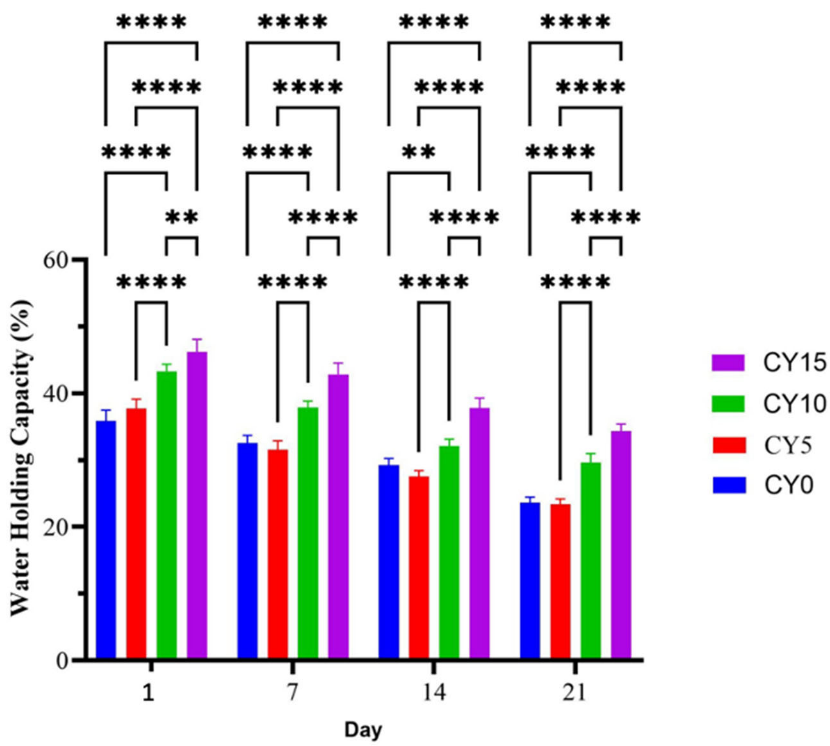
Figure 4. *Cont.*



(**b**)

Figure 4. The serum separation and water holding capacity values of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples. ns: not significant, *: $p < 0.05$, **: $p < 0.01$, ****: $p < 0.0001$.

3.5. Surface Color

The highest L* value was found in CY0 yogurt (80.50) and the lowest L* value in CY15 yogurt (67.86; Table 1). L* values were found to decrease with the increasing cranberry content in the yogurt samples ($p < 0.05$). The present results are consistent with the results of other studies conducted with the addition of black mulberry puree [45], rosehip [7] and cherry–cranberry jam [43]. The CY0 yogurt samples had a negative a* value, while the samples with cranberry had a positive value. It was found that the a* values increased with the increase in cranberry content in the yogurt samples ($p < 0.05$). Açıkgözoğlu [56] reported an increase in the a* values of the samples with the increasing concentration in yogurt to which pomegranate and cherry concentrates were added. Durmuş et al. [44] reported an increase in a* values of the samples with the increasing concentration of black mulberry puree added to yogurt. The b* values decreased with the increasing percentage of cranberry ($p < 0.05$), which can be attributed to the positive contribution of cranberry to b* value. Sahingil and Hayaloglu [7] reported that as the concentration of rosehip pulp in yogurt increased, the a* value increased significantly due to the presence of anthocyanins, so the addition of rosehip gave the experimental yogurt samples a red color. Durmuş et al. [44] reported similar results to the present study by finding that the b* value decreased with the increasing proportion of black mulberry puree in fruit yogurt samples.

3.6. Viscosity, Consistency and Rheology

The viscosity values increased proportionally with the amount of fruit added to the samples (Table 3). While the highest viscosity value was observed in CY15 yogurt samples, the lowest viscosity value was observed in CY0 yogurt samples ($p < 0.05$). The viscosity values of yogurt samples increased rapidly until day 7 and then began to decrease ($p < 0.05$).

Fermented milk, including stirred yogurt, is usually stored at +4 °C for about 24 h until consumption. This causes the gel structure of the yogurt to recover after breaking, new gel structures are formed, and the phenomenon of reassembly (aggregation) occurs in the gel-like product. Reassembly leads to an increase in the viscosity values of yogurt samples during storage. It is also assumed that the phenomenon of reassembly in the damaged gel structure of the yogurt is due to the swelling of the microgels during cooling. It has been hypothesized that the hydrophobic interactions become weaker during storage at low temperatures, leading to an increase in microgel volume [57–59]. Wang et al. [50] reported that the viscosity of yogurt to which they added 3% apple pulp increased significantly compared to control yogurt and reported results consistent with the present study. In yogurt samples prepared with an extract of *Cornus officinalis*, also known as American cranberry, the viscosity of the samples increased significantly with the increasing concentration of the cranberry extract [18], and the results are consistent with the present study.

Table 3. The viscosity values of control (CY0) and 5% (w/w) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples.

	Day	CY0	CY5	CY10	Cy15
Viscosity (Pa.s)	1	0.61 ± 0.01 ^{a,A}	0.63 ± 0.01 ^{b,A}	0.94 ± 0.01 ^{c,B}	1.12 ± 0.01 ^{d,C}
	7	1.15 ± 0.02 ^{a,D}	1.13 ± 0.03 ^{a,D}	1.23 ± 0.02 ^{b,C}	1.49 ± 0.02 ^{c,D}
	14	0.85 ± 0.03 ^{a,C}	0.90 ± 0.02 ^{b,C}	0.95 ± 0.03 ^{c,B}	1.03 ± 0.03 ^{d,B}
	21	0.76 ± 0.02 ^{a,B}	0.82 ± 0.01 ^{b,B}	0.85 ± 0.02 ^{c,A}	0.97 ± 0.01 ^{d,A}

$^{A–D}$ Means followed by different letters in the same column are significantly different $p < 0.05$. $^{a–d}$ Means followed by different letters in the same row are significantly different $p < 0.05$.

In our study, the firmness values of the fruity yogurt samples increased with the increase in the proportion of cranberries added to the yogurt samples (CY5, 23.56 g vs. CY15 4059), as shown in Figure 5. It was found that the effect of cranberry concentration on the firmness values of the tested yogurt samples was statistically significant ($p < 0.05$). The increase in firmness value in CY15 yogurt samples with the highest cranberry content compared to CY0 yogurt samples is consistent with the study by Özdemir [60]. Sodini et al. [61] reported that long-term storage affects some textural properties (firmness) and explained that this could be due to an increase in acidity and casein hydration. High consistency values indicate a viscous product with high density [62]. Considering the results as functions of cranberry concentration and storage time, the influence of cranberry content and storage time on the consistency values of the yogurt samples was statistically significant ($p < 0.05$). Cohesiveness is an indicator of strong binding and influences the structural integrity of the yogurt, which ensures the structural integrity of the product by forming a strong bond [63]. The cohesiveness of the tested yogurt samples varied between −16.03 and −37.01 g. On the first day of storage, it was observed that the cohesiveness values of the yogurt samples decreased with the increasing cranberry content. A higher viscosity index is associated with a stronger gel structure [64]. In this case, the CY15 samples had a lower viscosity index than the CY0 sample on the first day of storage, indicating that the viscosity of the samples decreased with the addition of cranberries. It was found that the change with cranberry concentration in the yogurt samples was statistically significant ($p < 0.05$). The viscosity index is defined as the negative area formed at the return of the probe. The viscosity index values of the yogurt samples tested varied between −12.95 and −78.32 gs. In the yogurt samples to which cranberries were added, the viscosity index values decreased with the increasing cranberry concentration ($p < 0.05$).

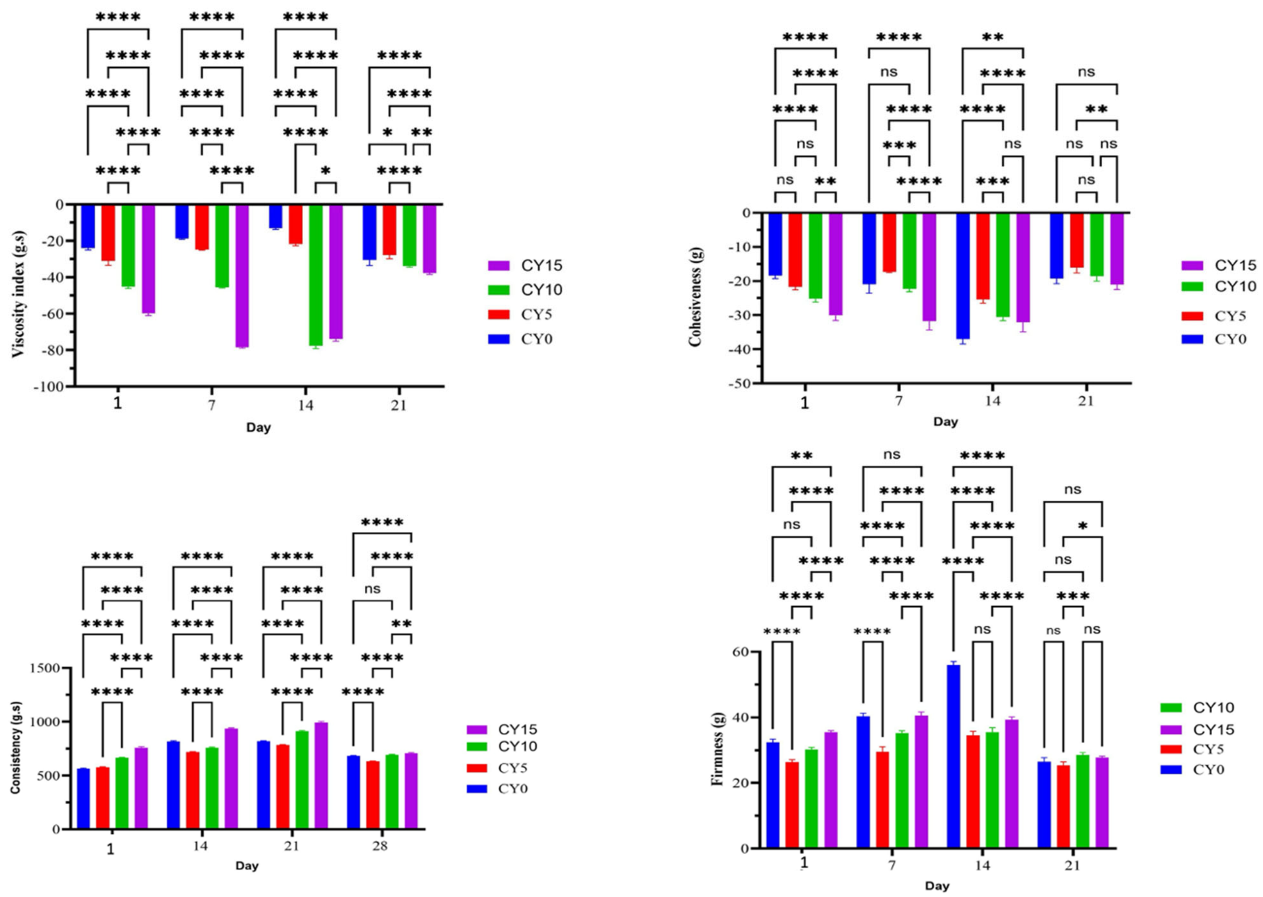


Figure 5. The texture profile analysis of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples. ns: not significant, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$.

The samples were analyzed on the 1st, 7th, 14th and 21st storage days, and the results are shown in Figure 6, with the elastic (G′) and viscous (G″) modulus as a function of the frequency values. The frequency range was scanned between 0.01 and 100 Hz. After the frequency point 29.2 Hz, the G′ values of the samples began to fluctuate. In all the samples, G′ was consistently higher than G″ throughout the storage period. On the first day of storage, the highest G′ value was observed in CY0 yogurt, while the lowest value was observed in CY10 yogurt. When the G″ values were analyzed, the highest and lowest values were observed in the CY15 and CY5 yogurt samples, respectively. This indicates that the addition of cranberries to the yogurt increased the viscosity values of the samples. The G′ and G″ values of the samples were close to each other and the G′ values were higher than the G″ values. The highest G′ value was determined in CY15 yogurt on the 7th day of storage. The high G″ values of the CY15 yogurt samples indicate that the added cranberry fruit led to an increase in the viscosity of the yogurt. On the 14th and 21st days of storage, the highest and lowest G′ value was observed in CY15 and CY5 yogurt samples, respectively.

The G′ value, i.e., the storage modulus, indicates the energy stored in the structure of the sample and subsequently released as a function of the applied voltage. The G″ variable is the viscous response of the sample under investigation and corresponds to the energy lost by the applied voltage and is also referred to as the loss modulus [64]. Throughout the frequency sweep in the samples, G′ > G″ indicates that the viscoelastic gel property is predominant in the samples, and G′ < G″ indicates that the viscous property is predominant in the sample [65]. In stirred yogurts, the stirring process breaks down the gel structure and reduces the viscosity. The presence of fruit particles in yogurt improves its viscoelastic properties and thus the gel structure by increasing the G′ value [66]. In our study, the high G″ values of the CY15 samples indicate that the added cranberry fruits increase the viscosity of the yogurt. It has been observed that the addition of cranberries increases the viscosity values of yogurts. Varnaite et al. [19] reported that the G′ values of all yogurt samples made with added cranberry were higher than the G′ values in our study, the more cranberry pulp was added to the yogurt. Du et al. [67] reported that the G″ values were higher than the G″ values in all yogurt samples prepared with the addition of mulberry pulp and reported results consistent with our study.

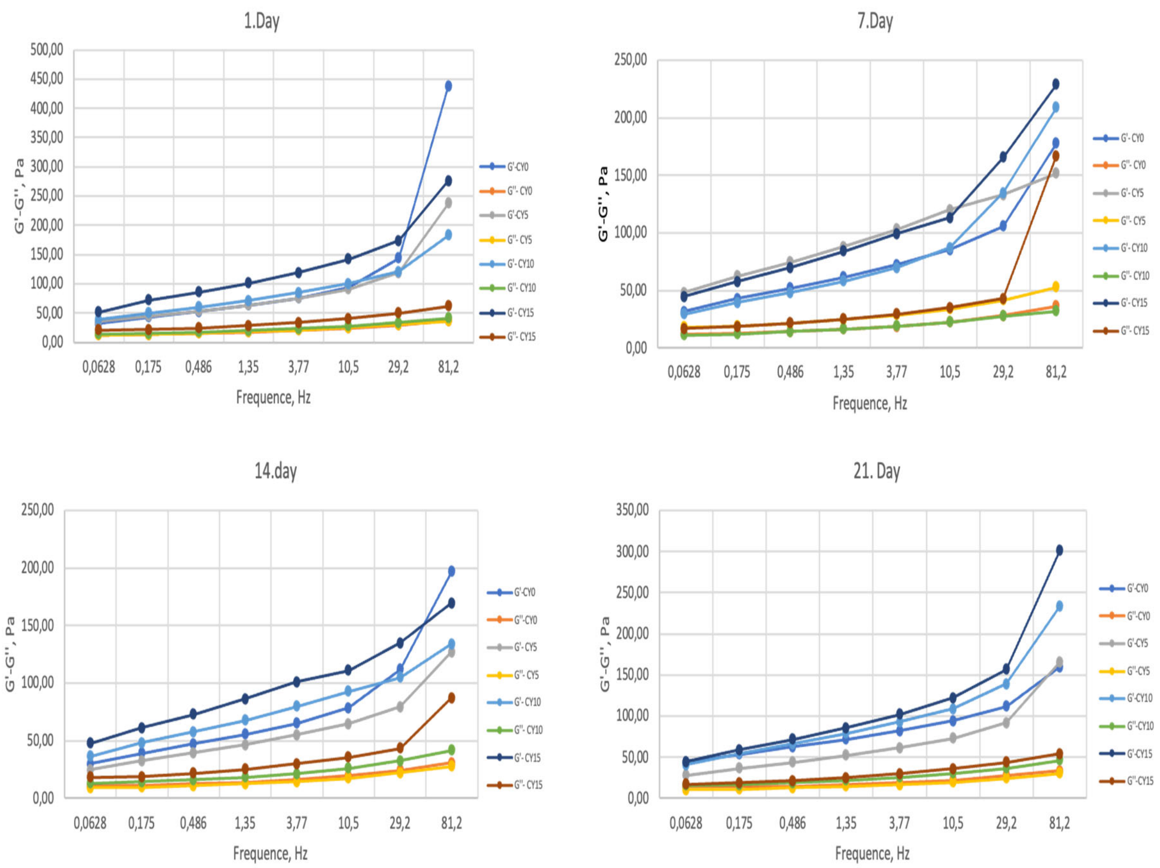


Figure 6. Rheological data of control (CY0) and *Cornus mas*. L containing (CY5: 5% *Cornus mas*. L. CY10: 10% *Cornus mas*. L., CY15: 15% *Cornus mas*. L) yogurt samples.

3.7. Microbiological Counts

The total number of aerobic mesophilic bacteria in the yogurt samples ranged from 4.11 $\log_{10}$ cfu/g to 5.97 $\log_{10}$ cfu/g (Table 4). Açıkgözoğlu [57] reported the total number of viable bacteria in fruit yogurt with added pomegranate and sour cherry as 5.87 $\log_{10}$ cfu/g–6.16 log10 cfu/g for yogurt with added pomegranate and 5.81 $\log_{10}$ cfu/g–5.96 $\log_{10}$ cfu/g for yogurt with added sour cherry.

In the yogurt samples, the total number of aerobic mesophilic bacteria increased with the increase in cranberry content ($p < 0.05$). The number of yeasts and molds also increased in the yogurt samples with cranberry added compared to the control group ($p < 0.05$). Mold and yeast counts decreased in all the yogurt samples during the 21-day storage period, and this decrease was significant in all the samples between the first and seventh day ($p < 0.05$), while the decrease between the 14th and 21st days was not significant ($p > 0.05$). The highest and lowest levels of *Streptococcus thermophilus* were found in yogurt samples CY0 and CY15 at 8.18 and 6.47 $\log_{10}$ cfu/g, respectively. The number of *Streptococcus thermophilus* in the tested yogurt samples decreased with the increasing proportion of cranberries in the yogurt ($p < 0.05$) and with increasing storage time ($p < 0.01$). The number of *Lactobacillus delbrueckii* subsp. *bulgaricus* also increased with the increasing cranberry content (Table 4) and the proportional changes were significant ($p < 0.05$). The highest and lowest numbers of *Lactobacillus delbrueckii* subsp. *bulgaricus* were found in CY15 (8.92 $\log_{10}$ cfu/g) and CY0 (7.82 $\log_{10}$ cfu/g), respectively. It is assumed that this increase is due to the better growth of *Lactobacillus delbrueckii* subsp. *bulgaricus* at low pH values. The number of *Lactobacillus delbrueckii* subsp. *bulgaricus* decreased during the 21-day storage period ($p < 0.05$).

Table 4. The microbiological counts ($\log_{10}$ CFU/g) of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples.

	Day	CY0	CY5	CY10	CY15
Total mesophilic aerobic bacteria	1	5.64 ± 0.04 ^{a,C}	5.66 ± 0.04 ^{a,B}	5.95 ± 0.02 ^{b,C}	5.97 ± 0.01 ^{c,C}
	7	5.34 ± 0.06 ^{a,B}	5.56 ± 0.05 ^{a,A}	5.56 ± 0.08 ^{b,B}	5.38 ± 0.06 ^{b,B}
	14	4.28 ± 0.06 ^{a,A}	4.60 ± 0.05 ^{b,A}	4.91 ± 0.03 ^{c,A}	4.73 ± 0.02 ^{b,A}
	21	4.20 ± 0.06 ^{a,A}	4.11 ± 0.03 ^{b,A}	4.22 ± 0.02 ^{c,A}	4.17 ± 0.07 ^{c,A}
Yeasts and molds	1	4.60 ± 0.08 ^{a,C}	4.65 ± 0.04 ^{a,B}	4.87 ± 0.04 ^{b,C}	4.94 ± 0.03 ^{c,C}
	7	4.48 ± 0.09 ^{a,B}	4.53 ± 0.07 ^{a,A}	4.77 ± 0.05 ^{b,B}	4.79 ± 0.06 ^{b,B}
	14	4.28 ± 0.06 ^{a,A}	4.46 ± 0.10 ^{b,A}	4.64 ± 0.03 ^{c,A}	4.54 ± 0.09 ^{b,A}
	21	4.22 ± 0.10 ^{a,A}	4.44 ± 0.06 ^{b,A}	4.61 ± 0.06 ^{c,A}	4.53 ± 0.06 ^{c,A}
Streptococcus thermophilus	1	8.18 ± 0.03 ^{c,D}	8.15 ± 0.04 ^{bc,D}	8.11 ± 0.05 ^{ab,D}	8.09 ± 0.05 ^{a,D}
	7	8.14 ± 0.04 ^{c,C}	8.02 ± 0.05 ^{b,C}	7.96 ± 0.05 ^{b,C}	7.89 ± 0.06 ^{a,C}
	14	8.08 ± 0.02 ^{c,B}	7.23 ± 0.04 ^{b,B}	7.20 ± 0.03 ^{b,B}	6.95 ± 0.07 ^{a,B}
	21	8.00 ± 0.03 ^{c,A}	7.11 ± 0.03 ^{b,A}	7.08 ± 0.03 ^{b,A}	6.47 ± 0.07 ^{a,A}
Lactobacillus delbrueckii subsp. *bulgaricus*	1	8.70 ± 0.02 ^{b,C}	8.78 ± 0.01 ^{c,D}	8.88 ± 0.02 ^{a,C}	8.92 ± 0.02 ^{a,D}
	7	8.68 ± 0.01 ^{c,C}	8.72 ± 0.02 ^{d,C}	8.32 ± 0.05 ^{b,B}	8.52 ± 0.02 ^{a,C}
	14	8.22 ± 0.03 ^{c,A}	8.24 ± 0.02 ^{c,B}	8.31 ± 0.04 ^{b,B}	8.42 ± 0.02 ^{a,B}
	21	7.82 ± 0.02 ^{d,B}	7.96 ± 0.03 ^{c,A}	8.04 ± 0.03 ^{b,A}	8.14 ± 0.02 ^{a,A}

$^{A–D}$ Means followed by different letters in the same column are significantly different, $p < 0.05$. $^{a–d}$ Means followed by different letters in the same row are significantly different, $p < 0.05$.

E. coli and coliform bacteria were not detected in any of the yogurt samples during the 21-day storage period. Coliform bacteria ferment lactose at about 44 °C, but at this stage they compete with the growth of lactic acid bacteria in the environment, and it becomes difficult for them to survive because the pH and storage temperature are unfavorable for these two groups of bacteria [68]. At the same time, *E. coli* and coliform bacteria are sensitive to low pH values, which is why they are difficult to find at pH values of 4.6 and below, unless there is external contamination.

3.8. Sensory Evaluation

In the sensory analysis of the samples, taste, odor, consistency, appearance, color and overall acceptability were evaluated during storage (Table 5 and Figure 7). In terms of taste scores, CY10 yogurt was the most favorable among the control and fruit yogurt samples that were sensory evaluated by the panelists during the storage period. In terms of taste, however, CY15 yogurt performed the lowest. The addition of 15% cranberries made the yogurt taste slightly sour and sweet. The lower acidity and fat content of CY15 compared to the other samples could be the reason why it received the lowest score. On the 21st day, all the samples showed a statistical difference in taste parameters ($p < 0.05$) and a decrease compared to the first day of storage. On the first day of storage, the highest odor score was obtained by CY0 yogurt, while the lowest scores were obtained by CY10 and CY15 yogurt. As the amount of fruit added to the yogurt increased, the odor score decreased. During the storage period, with the exception of the 21st day, the consistency score was higher for fruit yogurts than for the control yogurt (CY0). On day 21, the consistency score was not statistically different for all the samples. The preferred yogurt with the highest score in terms of appearance was CY10 yogurt ($p < 0.05$). On the first day of storage, CY15 yogurt was selected as the best in terms of color, while panelists' scores decreased with the decreasing fruit content. CY0 and CY10 yogurts were the most popular yogurts in terms of overall acceptability. During the storage period, overall acceptability scores decreased for the other yogurts except C15 ($p < 0.05$). At the end of the storage period, no statistical difference was found between the yogurts in terms of overall acceptability. As a result, the yogurts with added cranberry were appreciated in terms of taste, texture, appearance and color and showed high overall consumer acceptance. Studies on sensory evaluations indicate that the overall acceptability of adding fruit to yogurt is high as it improves sensory properties and increases consumer acceptance [7,69,70].

Table 5. The sensory evaluation of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples.

	Day	CY0	CY5	CY10	CY15	*p*
Taste	1	4.50 ± 0.53	4.88 ± 0.35	5.00 ± 0.00	2.63 ± 0.52	<0.001 ***
	7	3.88 ± 0.83	3.88 ± 0.64	4.13 ± 0.64	1.50 ± 0.53	<0.001 ***
	14	3.13 ± 0.83	2.63 ± 0.52	2.13 ± 0.64	1.25 ± 0.46	<0.001 ***
	21	3.00 ± 0.76	1.38 ± 0.52	1.25 ± 0.46	1.00 ± 0.00	<0.001 ***
p		0.004 ***	0.001 ***	0.001 ***	0.001 ***	
Odor	1	4.38 ± 0.74	3.88 ± 0.83	3.00 ± 0.76	3.13 ± 0.64	0.008 **
	7	3.63 ± 0.52	3.50 ± 0.53	2.63 ± 0.74	2.00 ± 0.76	0.001 ***
	14	2.13 ± 0.64	3.13 ± 0.64	2.38 ± 0.92	1.50 ± 0.53	0.002 ***
	21	1.75 ± 0.71	1.63 ± 0.74	1.50 ± 0.53	1.13 ± 0.35	0.203
p		<0.001 ***	<0.001 ***	0.006 ***	<0.001 ***	
Consistency	1	3.13 ± 0.83	3.75 ± 0.71	4.00 ± 0.53	4.38 ± 0.52	0.015 *
	7	3.25 ± 0.46	4.25 ± 0.71	4.63 ± 0.52	4.63 ± 0.52	0.001 ***
	14	2.38 ± 0.74	3.38 ± 0.74	3.50 ± 1.20	3.75 ± 0.71	0.029 *
	21	1.75 ± 0.89	1.88 ± 0.83	2.13 ± 0.83	2.25 ± 0.71	0.585
p		0.005 ***	<0.001 ***	<0.001 ***	<0.001 ***	
Appearance	1	4.75 ± 0.46	4.63 ± 0.52	4.63 ± 0.52	4.50 ± 0.53	0.793
	7	4.63 ± 0.52	4.50 ± 0.53	4.38 ± 0.52	4.25 ± 0.71	0.642
	14	3.50 ± 0.76	3.50 ± 0.53	4.13 ± 0.64	4.00 ± 0.76	0.176
	21	3.13 ± 0.64	3.38 ± 0.52	4.00 ± 0.93	3.88 ± 0.83	0.131
p		<0.001***	0.001***	0.329	0.349	
Color	1	3.13 ± 0.83	3.75 ± 0.71	4.00 ± 0.53	4.63 ± 0.52	0.04 *
	7	3.50 ± 0.76	4.25 ± 0.71	4.63 ± 0.52	4.38 ± 0.52	0.025 *
	14	2.88 ± 0.64	4.00 ± 0.76	4.13 ± 0.64	3.38 ± 0.92	0.11
	21	2.25 ± 0.89	2.88 ± 0.83	3.00 ± 0.76	2.75 ± 0.71	0.399
p		0.052	0.019 *	0.002 *	<0.001 ***	
Overall acceptability	1	4.75 ± 0.46	4.63 ± 0.52	4.75 ± 0.46	4.13 ± 0.64	0.107
	7	4.63 ± 0.52	4.50 ± 0.53	4.63 ± 0.52	4.00 ± 0.76	0.213
	14	4.50 ± 0.53	3.50 ± 0.53	3.88 ± 0.64	3.50 ± 0.53	0.110
	21	3.50 ± 0.76	3.38 ± 0.52	3.75 ± 0.89	3.88 ± 0.83	0.586
p		0.008 ***	0.001 ***	0.015 *	0.321	

*, ** and *** significant differences at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively.

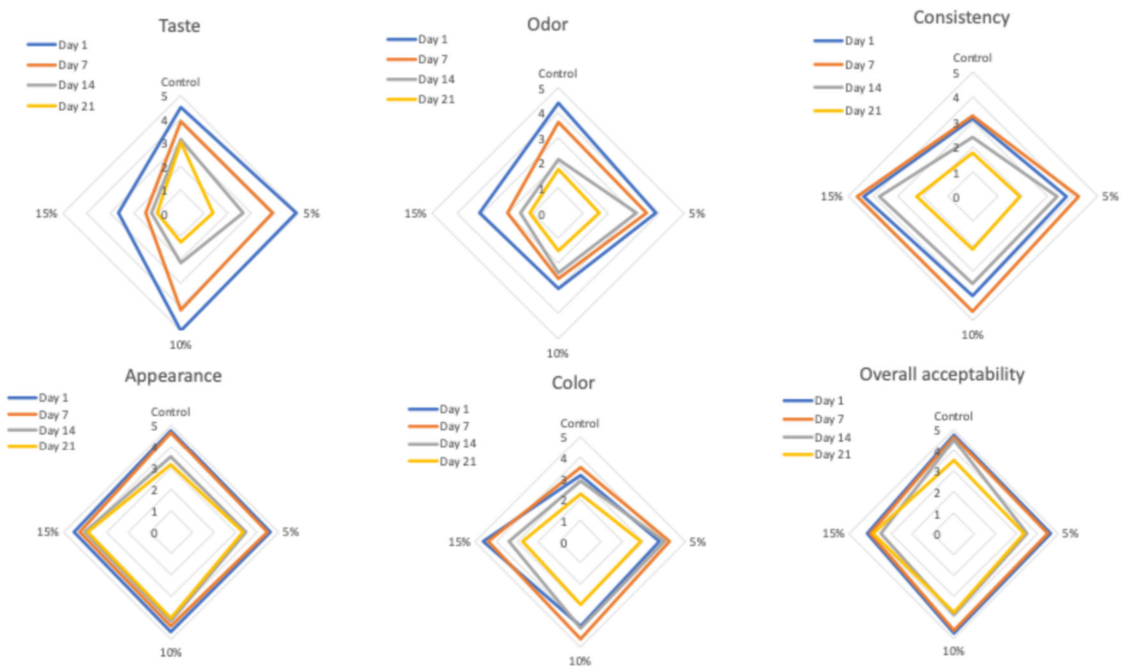


Figure 7. The sensory evaluation of control (CY0) and 5% (*w*/*w*) *Cornus mas* L. (CY5), 10% *Cornus mas* L. (CY10) and 15% *Cornus mas* L. (CY15) yogurt samples.

4. Conclusions

Based on the positive contribution of cranberry addition to the physicochemical properties of yogurt, as well as the results of the antioxidant activity, total phenolic and total anthocyanin contents, and sensory analysis, it has been shown that cranberry-enriched yogurt has improved functional properties. It was found that the antioxidant activity, total phenolic content and total anthocyanin content in yogurt samples to which cranberries were added at a level of 10% increased significantly compared to the control yogurt. At the same time, the best results for serum separation and water holding capacity, which are important quality indicators for stirred-type yogurt, were obtained from yogurt prepared with 15% cranberries. In the sensory analyses for the color parameter, which is an important criterion for the consumer, the highest values for color and consistency were obtained from yogurt samples to which 10% cranberries were added. However, to avoid the formation of a sour and astringent taste due to the tannins contained in the cranberries, it is recommended not to add more than 10% cranberries to the food. In addition, further in vivo and clinical studies are needed to confirm the health effects of such products.

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