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Research Article/Araştırma Makalesi

The effect of packaging material on some quality properties and shelf life of yoğurt

Ambalaj materyalinin yoğurdun raf ömrü ve bazı kalite kriterleri üzerine etkisi

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ABSTRACT

This study was carried out to determine some properties of set type yogurts produced using different packaging materials and stored at 4±1 °C for 28 days and the effect of the packaging material on the viability of yogurt bacteria. Sensory analysis, bacterial counts (*Lactobacillus delbrueckii ssp. bulgaricus* ve *Streptococcus. thermophilus*), and some physicochemical properties (pH, titratable acidity, and released serum amount) of yogurt samples incubated in five different packaging materials (plastic, steel, clay, glass, and porcelain dishes) during the cold storage process were determined. The results found showed that the packaging material was effective on the numbers of viable *L. bulgaricus* and *S. thermophilus* ($p < 0.01$).

Key Words: Yogurt, Microflora, Lactic acid bacteria, Sensory analysis, Packaging

ÖZ

Bu çalışma farklı ambalajlama materyalleri kullanılarak üretilen ve 4±1°C’de 28 gün depolanan set tipi yoğurtların bazı özellikleri ve ambalaj materyalinin yoğurt bakterilerinin canlılıkları üzerindeki etkisini belirlemek amacıyla yapılmıştır. Beş farklı ambalaj materyalinde (plastik, çelik, toprak, cam, porselen) inkübe edilen yoğurt örneklerinin duyusal analizleri ile soğuk muhafaza süreci boyunca bakteri sayıları (*Lactobacillus delbrueckii ssp. bulgaricus* ve *S. thermophilus*) ve bazı fiziko-kimyasal özellikleri (pH, titre edilebilir asitlik ve serum ayrılması) belirlenmiştir. Bulunan sonuçlar ambalaj materyalinin, canlı *L. bulgaricus* ve *S. thermophilus* sayıları üzerinde etkili olduğunu göstermiştir ($p<0.01$).

Anahtar Kelimeler: Yoğurt, Mikroflora, Laktik asit bakterisi, Duyusal analiz, Ambalaj

Introduction

Yogurt, a modern nutrient with a history dating back to ancient times, is a coagulated milk product that is formed by fermenting lactic acid by *Lactobacillus delbrueckii subsp*. *bulgaricus* and *Streptococcus thermophilus* bacteria added to pasteurized cow, sheep, goat, buffalo milk or their mixtures (Tamime and Deeth, 1980). It is thought that for the first time in the Middle East, nomadic tribes discovered yogurt production with the formation of clots as a result of contamination with lactic bacteria during milk storage in animal skins or pots. Yogurt was first introduced to the Middle East and Anatolia and then to Europe in the 16th century by the Turks (Fisberg and Machado, 2015). Today, yogurt production and consumption are increasing all over the world, with the positive effects of yogurt on health being proven after many scientific studies. Thanks to the β-D Galactosidase enzyme during the fermentation, a significant amount of lactose is converted into lactic acid and its amount decreases, while its digestibility increases (Shah, 2007). Thus, yogurt, which is easier to digest than milk, can be easily consumed by lactose-intolerant people (Savaiano, 2014). Furthermore, yogurt plays an active role in the treatment of many different forms of diarrhea, protection of intestinal health, symptomatic treatment of rheumatoid arthritis and osteoarthritis, control of some food allergies and heavy metal poisoning, strengthening the immune system, regulating blood pressure, and controlling diabetes. It is known that the beneficial effects of yogurt on health result from its high calcium concentration and lactic acid bacteria (McKinley, 2005, Weerathilake *et al*. 2014). It is important for yogurt to maintain its microbial flora, sensory and chemical properties to maintain its effectiveness throughout its shelf life. In this context, proper storage conditions and effective packaging are important (Macbean, 2010). The packaging material used in the production of yogurt should not contain microorganisms, there should be no mutual interactions between yogurt and the packaging material, and there should be no odor-taste transition from the packaging material to yogurt. In addition, the packaging material must have high oil resistance and must show an oil-proof property. On the other hand, it should be opaque to prevent oil oxidation (Üçüncü, 2003). It is known that the selection of packaging materials to be used in the yogurt industry is very important both in terms of preserving the natural qualities of the product during storage and marketing and ensuring a high level of food safety. Plastic boxes with polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC) are generally used as packaging material in the yogurt industry (Tamime and Robinson, 1999). Plastics are generally preferred because they have inert properties and do not cause any taste-aroma disorder in yogurt because they do not leave any residue on the surface or inside of the container during production, take the desired shape, are light, easy to transport and store, and their production costs are low (Chandan and Kilara, 2013). However, they are not resistant to heat, cause environmental pollution, and some chemicals added to shape plastic have carcinogenic characteristics, which constitute their negative characteristics (Freeman 2018). Additionally, yogurt bacteria and probiotics are sensitive to oxygen. This is an important problem because plastic containers used in yogurt packaging have high oxygen permeability (da-Cruz *et al.* 2007). Dave-Rajiv and Shah (1997) examined the condition of *L. acidophilus* in yogurts filled in high-density polyethylene (HDPE) containers and glass bottles for 35 days. While dissolved oxygen levels increased significantly in plastic packages, they remained low in glass packages. This can change the microbial flora of yogurt and affect its shelf life.

In this study, the effects of different packaging materials as an alternative to industrially used plastic yogurt packaging materials on the microbial and physicochemical properties of yogurt were investigated during the storage period.

Materials and Methods

Manufacture of experimental yogurts

The cow milk used in the production of the yogurt in this study was obtained from the Kafkas University Veterinary Faculty Farm. First, the chemical analysis of the milk was carried out and the amount of dry matter amount of the milk was determined as 12.4% and the fat content of the milk was 3.4%. The milk was pasteurized at 90 °C for 5 minutes. After the temperature was brought to 45 °C, 3% yogurt starter culture (Chr. Hansen's YC-180) was added to milk. The starter culture was prepared using the method described by Ozcan *et al.* (2008). Fermented milk was added to sterilized dishes which was divided into five groups by taking into plastic (polystyrene), earthenware (glazed inner surface), steel, porcelain and glass (outer surface covered with aluminum foil) dishes of equal volume and size (4 cmx10 cm). After they were covered, they were incubated at 42 °C until pH 4.6 was reached (approximately 3.5 hours). After the incubation, the yogurts were stored at 4 °C for analysis. The manufacture of the experimental yogurts was done in duplicate.

Analytical methods

Physicochemical and microbiological analyzes of yogurts were performed on the 1st, 3rd, 7th, 10th, 14th, 21st and 28th days of the storage period. Sensory analyzes were carried out on the day after yogurt production. All analyzes were done in duplicate.

Physico-chemical analysis

The pH of the yogurt samples was determined by measuring with a digital pH meter (Hanna HI 8521-Romania) after reaching room temperature. The acidity of samples was determined by titration with 0.25 M NaOH in the presence of a phenolphthalein indicator. Titratable acidity was calculated using the Equation (1) below and expressed as a percentage (Meyer *et al.* 2007).

$$Lactic\ acid\ (\%) = \frac{V_{NaOH}x0.09}{m_{sample}} \qquad (Eq. 1)$$

where, V and m are the amount of NAOH spent for titration and the amount of sample used.

While calculating the amount of serum released, 25 g of yogurt sample was taken and filtered through filter paper at 4±1 °C for 2 hours and the amount of serum obtained was determined by measuring volumetrically (Atamer and Sezgin 1986).

Microbiological analysis

To observe the development of microflora, under aseptic conditions at the above-mentioned times, 1 ml of sample was taken from each type of yogurt and mixed with 9 mL of 0.1% peptone water in a sterile tube. Then decimal dilutions were made by taking into account the estimated number of bacteria. M17 Agar (Oxoid CM785) was used to count *S. thermophilus*. The inoculated plates were incubated aerobically at 35-37 °C for 48 h. Typical colonies of 1-2 mm in diameter were counted after being confirmed by microscopic examination. MRS agar pH 5.7 (Oxoid CM 361) was used to count the *L.delbrueckii ssp. bulgaricus.* Again, after inoculation as a spread plate, the petri dishes were incubated at 35 °C for 48 hours under anaerobic conditions (AnaeroGen-Oxoid). Typical colonies of 1–3 mm in diameter were counted after microscopic confirmation (Dave and Shah 1996).

Sensory analysis

In sensory analysis, yogurts were evaluated by 5 panelists in daylight in terms of appearance, consistency, odor and taste. After the panelists first evaluated the appearance, then the consistency, the yogurt was mixed completely and examined in terms of odor and taste. Each panelist evaluated the specified qualities of yogurts with 5 points hedonic scale (1 worst, 5 very good) (Karagül-Yüceer and Drake, 2013).

Statistical analysis

Statistical analyzes were made using the SPSS 18 program. The data obtained from the studies conducted as two independent replicates were analyzed by one-way analysis of variance (ANOVA). Tukey test was used to evaluate the difference between groups ($p < 0.01$) (Pripp, 2012).

Results and Discussion

Physico-chemical analysis

The results of the physicochemical analyses of the samples during the cold storage are given in Figure 1 and Tables 1, 2, 3. The initial mean pH values of the A, B, C, D, E yogurts were 4.07, 4.01, 4.06, 4.12, 4.08 respectively. At the end of 28 d, the pH values were 4.04, 3.93, 4.02, 4.07 and 4.01. During the storage time, the changes in the pH values of B, D, E samples are statistically significant ($p < 0.01$). The pH values of all groups decreased during the cold storage period (Figure 1 and Table 1). Titration acidity differences between the values of B, D, E groups were found significant ($p < 0.01$). The initial titration acidity values of the different yogurt samples were ranged from 0.91 to 1.24 and increased slowly during storage. (Figure 1 and Table 2). During the storage time, the changes in the serum amounts of all sample groups are statistically significant ($p < 0.01$). The initial mean serum amounts of yogurt samples were ranged from 5.06 to 6.00. At the end of the storage period, the serum amount ranged from 4.07 to 6.10 (Figure 1 and Table 3).

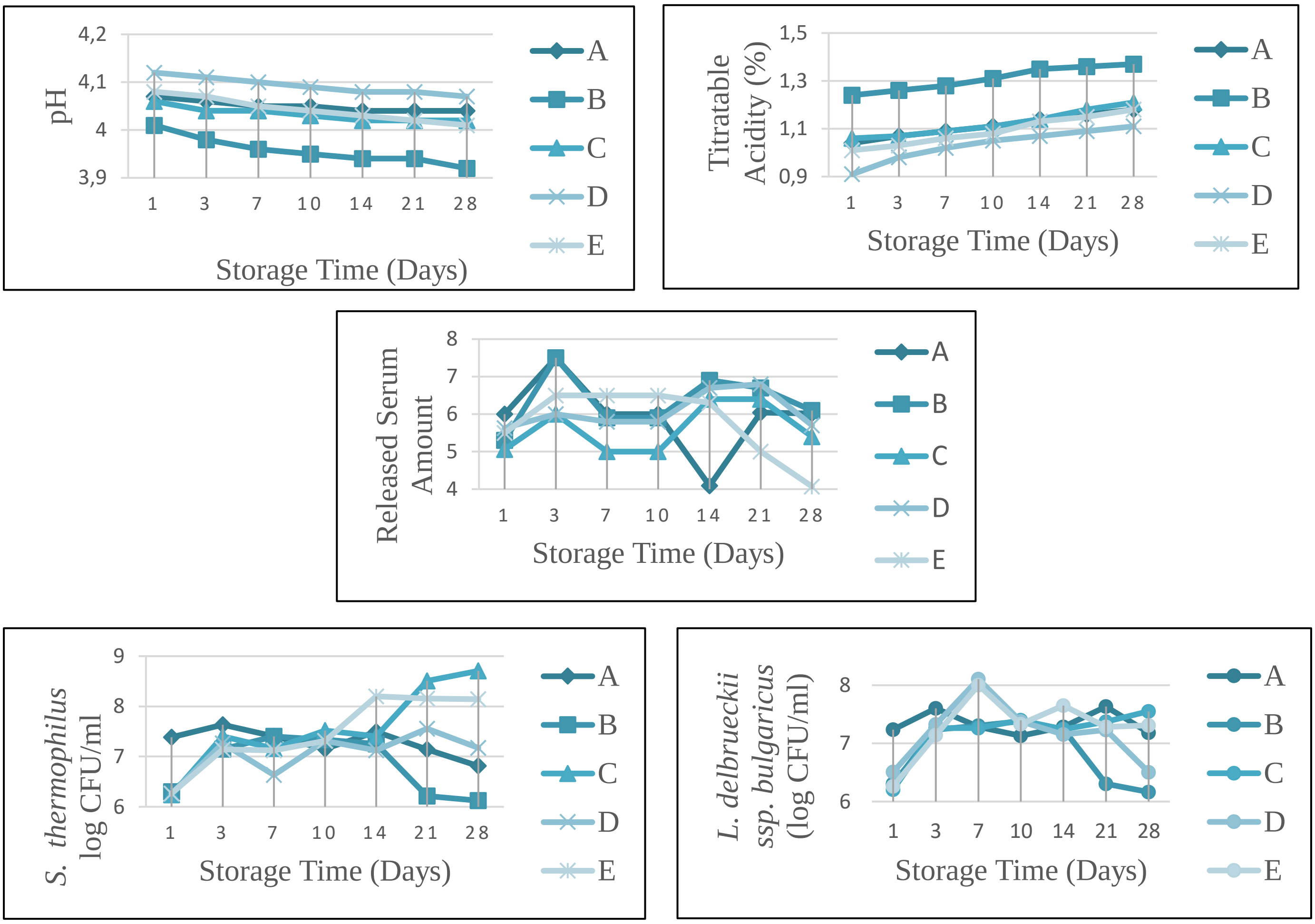

Figure 1. pH, titratable acidity, released serum amount and average numbers of viable *S. thermophiles* and *L. delbrueckii ssp. bulgaricus* values of the yogurt samples during refrigerated storage period (A: PS dish; B: Steel dish; C: Clay dish; D: Glass dish; E Porcelain dish)

Table 1. Mean values of pH traits measured during the incubation and storage periods

	Days	Groups										
		A		B		C		D		E		
		(× ± S×)		(× ± S×)		(× ± S×)		(× ± S×)		(× ± S×)		P
pH	1. day	4.07	0.02^{BCa}	4.01	0.02^{Ac}	4.06	0.00^{Ba}	4.12	0.02^{Dc}	4.08	0.02^{Cd}	**
	3. day	4.06	0.02^{Ca}	3.98	0.02^{Abc}	4.03	0.02^{Ba}	4.11	0.00^{Dbc}	4.07	0.02^{Ccd}	**
	7. day	4.05	0.02^{BCa}	3.96	0.02^{Aab}	4.03	0.02^{Ba}	4.09	0.02^{Dabc}	4.05	0.00^{BCbcd}	**
	10. day	4.05	0.02^{Ca}	3.96	0.02^{Aab}	4.03	0.02^{Ba}	4.09	0.00^{Dabc}	4.04	0.00^{BCabc}	**
	14. day	4.04	0.02^{Ca}	3.94	0.01^{Aab}	4.02	0.02^{Ba}	4.08	0.02^{Dab}	4.03	0.02^{BCab}	**
	21. day	4.04	0.02^{Ca}	3.94	0.00^{Aab}	4.02	0.02^{Ba}	4.08	0.02^{Dab}	4.02	0.02^{Bab}	**
	28. day	4.04	0.02^{Ca}	3.93	0.02^{Aa}	4.02	0.00^{BCa}	4.07	0.02^{Da}	4.01	0.02^{Ba}	**
	P	*		**		*		**		**		

* The statistical difference is not significant. ** 'Significant at 0.01 probability levels. A: Plastic-packaged yogurt, B: Steel-packaged yogurt, C: Clay packaged yogurt, D: Glass-packaged yogurt, E: Porcelain-packaged yogurt, ×: average value, S×: Standard error. Lowercase letters show the statistical difference in the same column, uppercase letters show the statistical difference in the same row.

Table 2. Mean values of titratable acidity traits (%) measured during the incubation and storage periods

		Groups										
		A		B		C		D		E		
	Days	(× ± S×)		(× ± S×)		(× ± S×)		(× ± S×)		(× ± S×)		P
Titratable Acidity (%)	1. day	1.04	0.02^{Ca}	1.24	0.02^{Da}	1.06	0.02^{Ca}	0.91	0.02^{Aa}	1.01	0.02^{Ba}	**
	3. day	1.07	0.03^{Cab}	1.26	0.02^{Da}	1.07	0.02^{Ca}	0.97	0.02^{Ab}	1.03	0.02^{Bab}	**
	7. day	1.08	0.02^{Cab}	1.28	0.02^{Dab}	1.09	0.0^{Cab}	1.02	0.02^{Ac}	1.05	0.02^{Babc}	**
	10. day	1.11	0.03^{Cabc}	1.31	0.02^{Dab}	1.11	0.03^{Cab}	1.05	0.02^{Acd}	1.08	0.03^{Babcd}	**
	14. day	1.13	0.02^{Bbc}	1.35	0.02^{Cbc}	1.14	0.02^{Bbc}	1.07	0.03^{Ade}	1.13	0.02^{Bbcd}	**
	21. day	1.16	0.00^{BCbc}	1.36	0.02^{Dcd}	1.18	0.03^{Ccd}	1.09	0.02^{Ade}	1.15	0.02^{Bcd}	**
	28. day	1.18	0.02^{Bc}	1.37	0.02^{Dd}	1.21	0.02^{Cd}	1.11	0.03^{Ae}	1.18	0.03^{Bd}	**
	P	*		**		*		**		**		

* The statistical difference is not significant. ** 'Significant at 0.01 probability levels. A: Plastic-packaged yogurt, B: Steel-packaged yogurt, C: Clay packaged yogurt, D: Glass-packaged yogurt, E: Porcelain-packaged yogurt, ×: average value, S×: Standard error. Lowercase letters show the statistical difference in the same column, uppercase letters show the statistical difference in the same row.

Table 3. Mean values of released serum amount traits measured during the incubation and storage periods

		Groups										
		A		B		C		D		E		
	Days	(× ± S×)		(× ± S×)		(× ± Sx)		(× ± Sx)		(× ± Sx)		P
Released Serum Amount	1. day	6.00	0.02^{Dc}	5.30	0.03^{Bb}	5.06	0.02^{Aa}	5.63	0.02^{Cab}	5.50	0.03^{BCc}	**
	3. day	7.50	0.02^{Cd}	7.50	0.03^{Cg}	5.06	0.02^{Aa}	6.00	0.02^{Abb}	6.50	0.03^{Be}	**
	7. day	6.00	0.02^{BCc}	5.90	0.03^{Bc}	5.00	0.02^{Aa}	5.80	0.02^{Ba}	6.50	0.03^{Ce}	**
	10. day	6.00	0.02^{Bb}	5.90	0.03^{Aa}	5.00	0.02^{Dab}	5.80	0.02^{Ca}	6.50	0.03^{Ba}	**
	14. day	4.09	0.02^{Aa}	6.90	0.03^{Dg}	6.40	0.02^{Bc}	6.70	0.02^{Cb}	6.30	0.03^{Bd}	**
	21. day	6.04	0.02^{Bc}	6.70	0.03^{De}	6.40	0.02^{Cc}	6.80	0.02^{Db}	5.00	0.03^{Ab}	**
	28. day	6.02	0.02^{Dc}	6.10	0.03^{DEd}	5.40	0.02^{Bab}	5.70	0.02^{Cab}	4.07	0.03^{Aa}	**
	P	*		**		*		**		**		

* The statistical difference is not significant. ** 'Significant at 0.01 probability levels. A: Plastic-packaged yogurt, B: Steel-packaged yogurt, C: Clay packaged yogurt, D: Glass-packaged yogurt, E: Porcelain-packaged yogurt, ×: average value, S×: Standard error. Lowercase letters show the statistical difference in the same column, uppercase letters show the statistical difference in the same row.

Microbiological analysis

The type of packaging material used during the cold storage period affected the numbers of *Lactobacillus delbrueckii ssp. bulgaricus* and *S. thermophilus*. The changes occurring in each group and the differences between the groups during the storage period were found to be statistically significant ($p < 0.01$). The results of microbiological analyses are given in Table 4 and Figure 1.

Sensory analysis

In sensory analyses of the yogurts the appearance, consistency in the spoon, texture in the mouth, flavor, odor and scores of the samples were given in Table 5.

While the group with the lowest pH values was the group in steel dishes, the pH values of samples in glass dishes were the highest. The differences in these groups are statistically significant ($p < 0.01$). This situation is similar to the studies of Turgut, (2016), Kamber and Harmankaya, (2019).

In a study investigating the chemical properties of bio-yogurts made with goat milk packed with glass, HDPE, PS and PP for 21 days, the lowest acidity was reported in yogurts packed with PS (Kudelka, 2005). In this study, during the preservation process, while the highest acidity was in the sample kept in steel dishes, the lowest acidity was in the yogurt samples in glass dishes. The difference that occurred during the cold storage process is significant in all groups ($p < 0.01$). Serum releasing in yogurts caused by the shrivel of the gel and the release of its water can be caused by high-temperature applications or rapidly developing acidity (Aswal *et al.* 2012). The highest serum separation occurred in yogurts in plastic dishes at the beginning of the preservation period and yogurts in steel dishes at the end of the preservation period. While it was found that the serum amount that is released of yogurt samples in plastic, steel, clay, and glass dishes increased during the preservation period, there was a decrease in the serum amount which is released of yogurt samples in porcelain dishes similar to the studies of Kurt *et al.* (1989) and Atasever (2004).

In this study, has been observed that yogurt bacteria are affected by the type of packaging material. Similarly, in a study using different packaging materials in flavored yogurts, it was stated that the shelf life of yogurts was affected by the type of packaging (Saint-Eve *et al.* 2008).

In this study, it was generally observed that the number of alive *S. thermophilus* was more dominant than *L. Bulgaricus* in most of the packaging materials at the end of the storage period as in the study of Nguyen *et al.* (Nguyen *et al.* 2014). This result of the better probiotic activity and lactose using of *S. thermophilus* (Marafon *et al.* 2011, Özer and Kirmaci 2010).

Table 4. Mean values of microbiological traits measured during incubation and storage periods (log10 CFU/ml ± Standard error).

		Groups										
		A		B		C		D		E		
	Days	(× ± S×)		(× ± S×)		(× ± S×)		(× ± S×)		(× ± S×)		P
***Streptococcus thermophilus* (log CFU/g)**	1.gün	7.382	0.07^{Db}	6.302	0.06^{Cb}	6.236	0.07^{Aa}	6.262	0.06^{Ba}	6.265	0.08^{Ba}	**
	3.gün	7.634	0.07^{Dd}	7.150	0.05^{Ac}	7.402	0.06^{Cc}	7.263	0.06^{Bc}	7.140	0.08^{Ab}	**
	7.gün	7.404	0.07^{Cc}	7.400	0.07^{Cf}	7.160	0.06^{Bb}	6.634	0.07^{Aa}	7.123	0.07^{Bb}	**
	10.gün	7.153	0.06^{Aa}	7.336	0.07^{BCe}	7.520	0.07^{Dd}	7.313	0.07^{Bc}	7.313	0.06^{Bc}	**
	14.gün	7.496	0.08^{Dc}	7.252	0.08^{Bd}	7.400	0.06^{Cc}	7.123	0.07^{Ab}	8.200	0.06^{Ef}	**
	21.gün	7.142	0.06^{Ba}	6.212	0.07^{Aab}	8.504	0.08^{Ee}	7.556	0.06^{Cd}	8.152	0.07^{De}	**
	28.gün	6.812	0.05^{Ba}	6.122	0.07^{Aa}	8.706	0.06^{Ef}	7.174	0.06^{Cb}	8.144	0.07^{Dd}	**
	P	**		**		**		**		**		
***L. delbrueckii ssp. bulgaricus* (log CFU/g)**	1.gün	7.234	0.06^{Ec}	6.302	0.06^{Ca}	6.206	0.07^{Aa}	6.508	0.06^{Da}	6.262	0.06^{Ba}	**
	3.gün	7.602	0.06^{De}	7.238	0.06^{Bb}	7.262	0.07^{Bb}	7.324	0.06^{Cd}	7.140	0.06^{Ab}	**
	7.gün	7.282	0.06^{Bd}	7.304	0.06^{Cc}	7.264	0.07^{Ab}	8.104	0.06^{Ef}	8.002	0.06^{De}	**
	10.gün	7.130	0.06^{Aa}	7.380	0.06^{Cd}	7.400	0.07^{Dc}	7.380	0.06^{Ce}	7.330	0.06^{Bc}	**
	14.gün	7.282	0.06^{Cd}	7.246	0.06^{Bb}	7.244	0.07^{Bb}	7.152	0.06^{Ab}	7.650	0.06^{Dd}	**
	21.gün	7.632	0.06^{De}	6.304	0.06^{Aa}	7.374	0.07^{Cc}	7.232	0.06^{Bc}	7.286	0.06^{BCc}	**
	28.gün	7.182	0.06^{Cb}	6.164	0.06^{Aa}	7.552	0.07^{Ed}	6.506	0.06^{Ba}	7.312	0.06^{Dc}	**
	P	**		**		**		**		**		

* The statistical difference is not significant. ** 'Significant at 0.01 probability levels. A: Plastic-packaged yogurt, B: Steel-packaged yogurt, C: Clay packaged yogurt, D: Glass-packaged yogurt, E: Porcelain-packaged yogurt, ×: average value, S×: Standard error. Lowercase letters show the statistical difference in the same column, uppercase letters show the statistical difference in the same row.

Table 5. Sensory characteristics (mean score ± standard deviation)

Groups	Appearance	Consistency in the spoon	Texture in the mouth	Flavour	Odor	Mean
A	3,78 ± 0.17	3.90 ± 0.54	3.78 ± 0.19	3.66 ± 0.29	3.74 ± 0.18	3.77 ± 0.27
B	3.74 ± 0.28	3.78 ± 0.48	3.90 ± 0.42	4.18 ± 0.18	3.74 ± 0.54	3.87 ± 0.38
C	4.18 ± 0.46	3.86 ± 0.21	4.10 ± 0.81	3.82 ± 0.42	4.02 ± 0.32	4.00 ± 0.44
D	4.06 ± 0.56	3.78 ± 0.85	3.78 ± 0.28	3.66 ± 0.24	3.90 ± 0.76	3.84 ± 0.54
E	4.34 ± 0.24	3.98 ± 0.71	3.90 ± 0.36	4.06 ± 0.67	4.06 ± 0.27	4.07 ± 0.45
Mean	4.02 ± 0.34	3.87 ± 0.56	3.90 ± 0.41	3.88 ± 0.36	3.90 ± 0.41	3.91 ± 0.41

A: PS dish; B: Steel dish; C: Clay dish; D: Glass dish; E Porcelain dish

In a study investigating the bacterial load in bio-yogurts made with goat milk packed in glass, HDPE, PS and PP for 21 days, the highest *S. thermophilus* count was observed in HDPE-packaged bio-yogurts (Kudelka, 2005). In this study, while the *S. thermophilus* counts were the highest in the plastic dishes at the beginning of the storage period, the second group had the lowest *S. thermophilus* number at the end of the storage time. Dave-Rajiv and Shah (1997) stated that the number of live probiotic bacteria in yogurts kept in glass dishes is higher than in plastic dishes. Wang *et al.* (2004) also stated that they found the number of alive *S. thermophilus* in dried soy milk preserved in different packaging materials to be higher in samples in glass dishes than in plastic ones. Similarly, in this study, the number of *S. thermophilus* in yogurts in glass dishes increased during the storage period, and at the end of the storage period, a higher number of *S. thermophilus* was found compared to plastic packaged yogurts (7.174 log10 CFU/ml). Casserole pots called Nalbek, which were used for yogurt fermentation in the past, are still used in traditional production today (Sökmen, 2015). In this study, samples in a clay pot with the lowest *S. shermophilus* count at the beginning showed an increase of 2.5 logs at the end of the storage period and became the group with the highest *S. thermophilus* count ($p < 0.01$). The number of *S. thermophilus* in yogurt in porcelain cups increased by 2 logs compared to the initial number ($p < 0.01$), whereas the number of *S. thermophilus* in yogurt in a steel container fell below the initial number at the end of the storage period.

The L. bulgaricus count was found to be the highest in plastic dishes, while the lowest count was found in yogurts kept in clay dishes at the end of the first day. However, during the storage period, the amount of *L. bulgaricus* in yogurts kept in the plastic dishes decreased below the initial number, while the number of *L. bulgaricus* in the yogurt in the pot increased 1 log more and reached the highest number among the groups at the end of the 28th day ($p < 0.01$). Mattila-Sandholm *et al.* (2002) reported that the amount of oxygen in yogurt packaging should be below for probiotic microorganisms to survive during the storage period, while Ishibashi and Shimamura, (1993) reported that the oxygen migration in yogurts stored in polyethylene and polystyrene packaging materials was high during storage. Oxygen has been reported to destroy probiotic bacteria by showing toxic effects in the cells of bacteria (Condon 1987). This situation may explain the decrease in the number of *L. bulgaricus* in yogurts kept in plastic packaging material. In the yogurt samples kept in steel dishes, the number of *L. bulgaricus*, which increased until the end of the 10th day, decreased after the middle of the storage period and reached the lowest number among the groups at the end of the 28th day ($p < 0.01$). The number of *L. bulgaricus* in glass containers increased during the storage period and decreased to the initial number on day 28. The yogurt groups in the porcelain dishes were the second group with the highest *L. bulgaricus* count at the end of the study ($p < 0.01$).

As a result of sensory analysis, the group that received the highest score from the panelists was the yogurt group in porcelain dishes (4.07). The yogurt that was the least liked was the yogurt in plastic dishes (3.77). Yogurts in porcelain dishes have the highest points in terms of appearance, odor, and consistency in the spoon. Consistency is an important property that determines the quality criteria for yogurt. A quality yogurt should have homogeneous viscosity. In addition, there should be no cracks or slits in its structure and there should be no serum breakaway. Generally, factors affecting serum separation in yogurt also affect consistency (Aswal *et al.* 2012). The yogurt group in the plastic dishes in which the highest serum separation was observed also got the lowest score in terms of consistency (3.90/3.78). The flavor characteristics of yogurt are affected by the biochemical reactions and physical reactions of yogurt bacteria, as well as the properties of the milk used in yogurt production and the processes applied to the milk (Mavuş *et al.* 2020). The most admired group in terms of flavor was the yogurt group in steel dishes (4.18), while the least liked yogurt samples were in plastic containers (3.66). This situation is thought to be because there is more lactic acid, which has an effect on the flavor of yogurts in steel dishes. Furthermore, the aroma substances formed during incubation continue to form during the cooling of yogurt (Mavuş *et al.* 2020). In this regard, the ability of the packaging material to retain heat may have affected the sensory properties of yogurt, such as taste and consistency.

Conclusion

As a result of this study, it was seen that the packaging material was effective on yogurt bacteria and affected the shelf life. Taking into account the data obtained from the study, clay, porcelain, and glass packaging materials were more effective for the viability of probiotic cultures due to their low oxygen permeability in yogurt production. On the other hand, their high cost, being heavy and being easily breakable limit their industrial usability. Considering the count of alive bacteria at the end of the storage period, it was concluded that a more effective packaging was provided in pots than in plastic and steel dishes. Although these packaging materials can be preferred to plastic packaging materials in traditional production, they need to be developed when considered on an industrial scale. In this context, studies involving changes in process and production technologies, including reducing oxygen permeability, which is a major problem for plastic packaging materials, must be carried out. However, new studies are needed to choose and develop the most effective packaging material.

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Author Contributions: Sezen HARMANKAYA has designed the study and has collected the data. Sezen HARMANKAYA and Emine Betül AKALIN ÖZAĞDAŞ wrote the article. Sezen HARMANKAYA has conducted the experiment together with Koray İŞBARALI and Emine Betül AKALIN ÖZAĞDAŞ. All authors have read, revised, and approved the manuscript.

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