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Research Paper / Araştırma Makalesi

Comparison of Physicochemical, Microbiological, and Sensorial Characteristics of Fermented Probiotic Drinks Produced from Corn and Cow Milks

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ABSTRACT

This study was focused on preparing corn milk by boiling corns, and producing fermented probiotic drinks by adding inulin and sugar into this milk as well as producing a probiotic drink from cow's milk. Milks were fermented by using a yogurt starter culture and *Lactobacillus acidophilus* LA-5. Fermented probiotic drinks were stored at 4°C for 30 days, and the physicochemical, microbiological, and sensorial characteristics of the drinks were compared during storage. The probiotic drink made from cow's milk exhibited the highest protein (2.25%), titratable acidity (0.46%), L* color (84.41) values and general sensory liking score (4.09) while having the lowest pH (4.46), syneresis (4.50 mL/50 mL) and apparent viscosity (0.09 Pa.s) values. The titratable acidity, syneresis, and apparent viscosity values of drinks increased during storage as the counts of *S. thermophilus, L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* decreased. The power-law model showed that the probiotic drinks exhibited a pseudoplastic flow behavior. Notably, the apparent viscosity value of probiotic drinks produced from corn milk was higher than that of the other samples ($p<0.05$). Additionally, the probiotic drink produced from corn milk had the lowest average counts of *S. thermophilus, L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus*. During storage, the highest decrease (%) in the counts of *L. acidophilus* was determined in probiotic drinks produced from corn milk (8.54%), followed by corn milk and sugar (5.50%), corn milk and inulin (5.46%), and cow's milk (4.30%).

Keywords: Corn milk, Cow's milk, Probiotic drink, *Lactobacillus acidophilus,* Physicochemical characteristics

Mısır ve İnek Sütlerinden Üretilen Fermente Probiyotik İçeceklerin Fizikokimyasal, Mikrobiyolojik ve Duyusal Özelliklerinin Karşılaştırması

ÖZ

Bu çalışmada inek sütünden probiyotik içecek üretiminin yanı sıra haşlanmış mısırdan mısır sütü elde edilmiş ve mısır sütüne inülin ve şeker ilave edilerek fermente probiyotik içecek üretimi gerçekleştirilmiştir. Sütler, yoğurt starter kültürü ve *Lactobacillus acidophilus* LA-5 kullanılarak fermente edilmiştir. Fermente probiyotik içecek örnekleri 4°C'de 30 gün süreyle depolanmış ve fizikokimyasal, mikrobiyolojik ve duyusal özellikleri açısından karşılaştırma yapılmıştır. İnek sütünden yapılan probiyotik içeceğin en yüksek protein (%2.25), titrasyon asitliği (%0.46) ve L* renk (84.41) değerleri ile genel beğeni puanına (4.09) ve en düşük pH (4.46), serum ayrılması (4.50 mL/50 mL), görünür viskozite (0.09 Pa.s) değerlerine sahip olduğu belirlenmiştir Depolama süresi boyunca örneklerin titrasyon asitliği, serum ayrılması ve görünür viskozite değerleri artarken, *S. thermophilus, L. delbrueckii* subsp. *bulgaricus* ve *L. acidophilus* sayılarında azalma olmuştur. Power Law modeline göre, probiyotik içecek örnekleri psödoplastik akış davranışı göstermiştir. Özellikle mısır sütünden yapılan probiyotik içeceğin görünür viskozite değeri diğer örneklere göre daha yüksek bulunmuştur ($p<0.05$). Ayrıca, mısır sütünden yapılan probiyotik içeceğin en düşük ortalama *S. thermophilus,* *L. delbrueckii* subsp. *bulgaricus* ve *L. acidophilus* sayılarına sahip olduğu belirlenmiştir. Depolama süresince *L. acidophilus* sayısında en fazla düşüş (%) mısır sütünden yapılan probiyotik içecekte (%8.54), bunu takiben mısır sütü ve şeker (%5.50), mısır sütü ve inülin (%5.46) ve inek (%4.30) sütünden yapılan içeceklerde tespit edilmiştir.

Anahtar Kelimeler: Mısır sütü, İnek sütü, Probiyotik içecek, *Lactobacillus acidophilus*, Fizikokimyasal özellikler

INTRODUCTION

The nutritional value of food and beverages plays a crucial role in meeting consumers' dietary needs and reducing the risk of chronic diseases. In supermarkets worldwide, there is a strong recommendation for chemical-additive-free beverages made from various fruits and vegetables with minimal processing [1]. In developing countries, where milk and its products are expensive and there is a preference for avoiding cow's milk due to vegetarianism or allergies, significant efforts are being directed toward producing yogurt from a variety of food sources [2]. Non-dairy alternatives, particularly cereal-based products, have gained global attention in response to the growing trends of lactose intolerance, vegetarianism, veganism, and low-fat diets [3]. Consequently, the demand for vegetable milk, which serves as a substitute for animal milk and dairy products not suitable for a vegan diet, has been steadily increasing [4]. In line with the rising popularity of vegetarianism, there is also a growing appreciation for the benefits of probiotics [5].

The term "probiotics" is defined as live microorganisms that, when consumed in adequate amounts, provide health benefits to the host [6]. Numerous studies have investigated the dietary and therapeutic properties of *Lactobacillus acidophilus*, which is considered reliable probiotic bacteria used in food production. Fermented milk products produced with *L. acidophilus* undergo a pre-fermentation process, resulting in increased nutritional value and improved digestibility compared to regular milk [7]. While the dairy industry has traditionally played a major role in developing probiotic products, other sectors, such as the nut, cereal, and vegetable milk industries, have also become involved. Vegetable milks, in particular, are noteworthy because they offer nutritional and health benefits, along with the inclusion of prebiotic compounds such as inulin, making them suitable for producing synbiotic products (combining probiotics and prebiotics). Furthermore, prebiotics like inulin not only provides health benefits but also offer technological advantages to fermented products by increasing viscosity and promoting the survival of probiotics during processing and storage [8]. In recent years, functional soft drinks like probiotic-enriched soy milk, germinated rice beverage, and corn milk have gained popularity among health-conscious consumers [9].

Corn, scientifically known as *Zea mays L.*, is a widely cultivated tropical crop that serves as a common staple food. It primarily consists of starch, with low protein content and an inadequate amino acid profile [10]. The isolated corn fiber derived from corn kernels has been identified as a prebiotic suitable for promoting the growth of both *Bifidobacterium* and *L. acidophilus*. With its cultivation spanning over 160 countries, corn plays a significant role in the diets of millions of people [11]. This versatile crop is utilized in the production of various food items, including noodles, porridge, bread, tortillas, and corn drinks. Corn milk, a soft beverage, offers potential health benefits due to its inclusion of several phytonutrients, such as dietary fiber, vitamins, antioxidants, and minerals [9]. However, fermented probiotic corn-based yogurt-like products, particularly corn drinks, remain limited in the market [11].

The objective of this study was to produce probiotic drinks using corn milk and cow's milk and to compare their physicochemical, microbiological, and sensorial properties over a 30-day storage period at 4°C. Inulin and sugar (sucrose) were utilized as additional ingredients in the production of probiotic drinks using corn milk. The study also assessed the acceptability of the samples as preferable carriers for *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* by calculating the reduction (%) of these microorganisms at the end of the storage period.

MATERIALS and METHODS

Materials

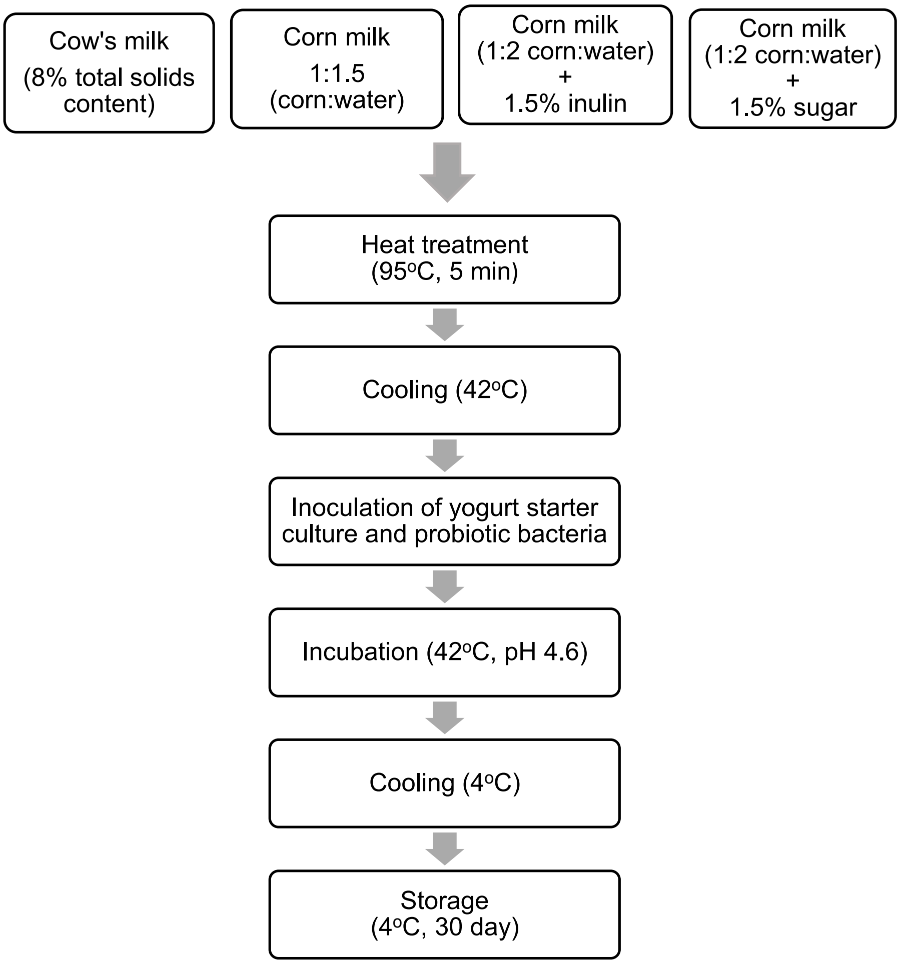
Corn kernels (Superfresh, Kerevitaş Food Industry and Trade Inc., Bursa, Türkiye) were obtained from a local market, while raw cow's milk was bought from Akdeniz University Faculty of Agriculture's Cattle Farm. The yogurt starter culture (CHR M790) and *L. acidophilus* LA-5 were acquired from Chr. Hansen A/S (Horsholm, Denmark). The preparation of corn milk and fermented probiotic drink samples took place at the Department of Food Engineering, Akdeniz University.

Production of Corn Milk

Distilled water was boiled, and corn kernels were added to the boiling water. The mixture was boiled for 10 minutes. After filtering the boiled water, distilled water was added to the boiled corn at corn/water ratios of 1/1.5 (w/w) and 1/2 (w/w). The mixture was then blended for 5 minutes using a Kenwood Thermoresist Glass Blender AT338. The resulting slurry was passed through a 1 mm^2 sieve, and the filtrate was collected in a clean container, yielding corn milk.

Production of Fermented Probiotic Drink from Corn and Cow's Milk

The total solids content of cow milk was adjusted to 8% for use in the production of the probiotic drink. The corn milk, prepared with a corn/water ratio of 1/1.5 (w/w), was used to produce 100% corn milk without the addition of sugar or inulin. For the corn milk prepared with a corn/water ratio of 1/2 (w/w), 1.5% inulin or 1.5% sugar was added. The cow milk and corn milk, with adjusted total solids content of 8%, underwent heat treatment at 95°C for 5 min and then cooled to 42°C. The cooled milk was inoculated with a yogurt starter culture (0.05 g/L) containing *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus*, as well *as L. acidophilus* LA-5 (0.05 g/L). The mixture was incubated at 42°C until the pH reached 4.6. The resulting probiotic drink samples were filled into 200 mL plastic cups with lids and stored at 4°C for 30 days (Schema 1).



Schema 1. Schematic diagram of the production steps of fermented probiotic drinks

Physicochemical Analyses

The protein, total solids, and ash contents of the milk and probiotic drink samples were analyzed using the AOAC standard methods [12] on the first day of storage. The titratable acidity of the milk and probiotic drink samples was determined by titration using 0.1 N NaOH (Merck KGaA, Darmstadt, Germany) following the AOAC standard method [12]. The titratable acidity (TA) value was expressed as a percentage of lactic acid. The pH of the probiotic drink samples was measured at 25°C using a calibrated pH meter (Orion 2 Star, Thermo Scientific, Singapore). To assess the color parameters of the probiotic drink samples, a color measuring device (Minolta Colorimeter CR-400, Konica Minolta, Japan) was employed. The CIE L*, a*, b*, and ∆E color parameters were obtained directly from color measuring device. Before measuring the samples, the device was calibrated using a white calibration plate (L=95.14, a=-0.13, b=2.71, and ∆E=0.57). To analyze syneresis, probiotic drink samples were placed in a volumetric cylinder. The total volume of separated whey was measured during storage and expressed as milliliters of whey per 50 mL of probiotic drink [13].

Rheological Analyses

Rheological measurements of probiotic drink samples prepared from cow milk and corn milk were conducted on the 1st, 15th, and 30th days of storage at 4°C. The rheological parameters of the probiotic drink samples were determined using a Brookfield R/S plus stress-controlled rheometer (Brookfield Engineering, Middleboro, MA, USA) equipped with a concentric cylinder double gap (DG3) measurement system. The measurements were carried out at 10°C in a water bath (Brookfield TC-502). For the measurement, 19 mL of the sample was deposited into the rheometer gap after gently mixing it with ten up-and-down spoon motions in the cup. After allowing 2 min for temperature equilibrium, the measurements were recorded. The samples were subjected to shear by linearly increasing the shear rate from 0.1 to 300 s^{-1} for 5 minutes, followed by reducing it to 0.1 s^{-1} for another 5 minutes. The rheological parameters of the samples were determined using the power-law model and Rheo3000 software (Rheotec Messtechnik GmbH, Berlin, Germany). The apparent viscosity values were calculated at a shear rate of 50 s^{-1} [14].

Microbiological Analyses

Microbiological analyses were performed to determine the counts of *L. acidophilus* LA-5 in the probiotic drink samples. MRS agar with bromocresol green and clindamycin (MRSBC agar) was used for the analysis, while the plates were incubated anaerobically at 37°C for 72 hours. The counts of *L. delbrueckii* subsp. *bulgaricus* were determined using MRS agar, while the plates were incubated at 45°C for 72 hours. The counts of *S. thermophilus* were conducted on M17 agar (Merck KGaA, Darmstadt, Germany) containing 1% (w/v) lactose, followed by incubation at 45°C for 24 hours [15].

The percentage reduction in the counts of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* in the samples stored for 1, 15, and 30 days was calculated using the equation 1 provided by Ergin et al. [16].

$$R = \left[\!\left[1 - \frac{logN\,(cfu)}{logNo\,(cfu)}\right]\!\right] \times 100 \qquad \text{(cfu: colony forming unit)} \qquad (1)$$

where N_0 represents the microbial count in the samples stored for 1 day, while N represents the microbial count in the samples stored for 15 and 30 days.

Sensory Analyses

A group of 40 individuals, consisting of academic staff and graduate students from the Department of Food Engineering and Department of Nutrition and Dietetics at Akdeniz University, participated in the sensory evaluation of the samples. The panelists, ranging in age from 22 to 40, had no known medical conditions that could impact their sense of smell and taste. The sensory evaluation took place on the 1st, 15th, and 30th days of storage and the hedonic scale, which ranges from 1 (very bad) to 5 (very good) was used to evaluate the sensory quality (color and appearance, texture and consistency, taste and smell, and general liking) of samples, The evaluations were conducted at room temperature, approximately 2 hours before or after meals. Transparent plastic cups containing 25 mL of probiotic drink samples at 8°C were presented to the panelists for evaluation. The samples were coded with three-digit numbers and evaluated in a randomized order. Each panelist conducted the evaluation individually in a well-lit environment and was instructed to drink water between samples [17].

Statistical Analysis

The statistical analysis was performed with two replications conducted simultaneously. The average values obtained from the analyses were subjected to variance analysis using the SAS statistical program (SAS System 9.0, SAS Institute Inc., Cary, NC, USA). To determine the significance of the sources of variation, Duncan Multiple Comparison Test was used to assess the levels of effects.

RESULTS and DISCUSSION

Physicochemical Properties

In Table 1, the average contents of total solids, ash, and protein are presented for milk and probiotic drink samples on the 1st day of storage. Additionally, the pH and titratable acidity values of milk samples on the 1st day are included. Among the milk samples with an adjusted total solids content of 8%, cow's milk exhibited the highest levels of ash content, protein content, and pH value (p<0.05). The probiotic drink made from cow's milk also had the highest average ash and protein contents (p<0.05). Figure 1 illustrates the pH and titratable acidity values of the fermented probiotic drink samples throughout the storage period.

Table 1. Composition of milk and probiotic drink samples

Type of sample		Total solids (%)	Ash (%)	Protein (%)	pH	Titratable acidity (%)
Milk	Corn	7.99±0.16 a	0.20±0.02 c	1.62±0.03 b	6.29±0.03 b	0.11±0.01 a
	Cow	7.92±0.01 a	0.31±0.01 a	2.20±0.01 a	6.41±0.03 a	0.12±0.00 a
	Corn + Inulin	7.79±0.23 a	0.23±0.01 b	1.37±0.02 c	6.23±0.02 b	0.09±0.01 b
	Corn + Sugar	8.05±0.05 a	0.21±0.02 bc	1.39±0.01 c	6.29±0.03 b	0.09±0.01 b
Probiotic drink	Corn	8.05±0.01 a	0.20±0.02 b	1.76±0.11 b		
	Cow	8.04±0.11 a	0.34±0.06 a	2.25±0.08 a		
	Corn + Inulin	8.08±0.08 a	0.21±0.01 b	1.39±0.01 c		
	Corn + Sugar	8.07±0.08 a	0.18±0.04 b	1.41±0.01 c		

Values are expressed as mean ± standard deviation. Values with different letters (a-c) show the difference in the same column (p<0.05).

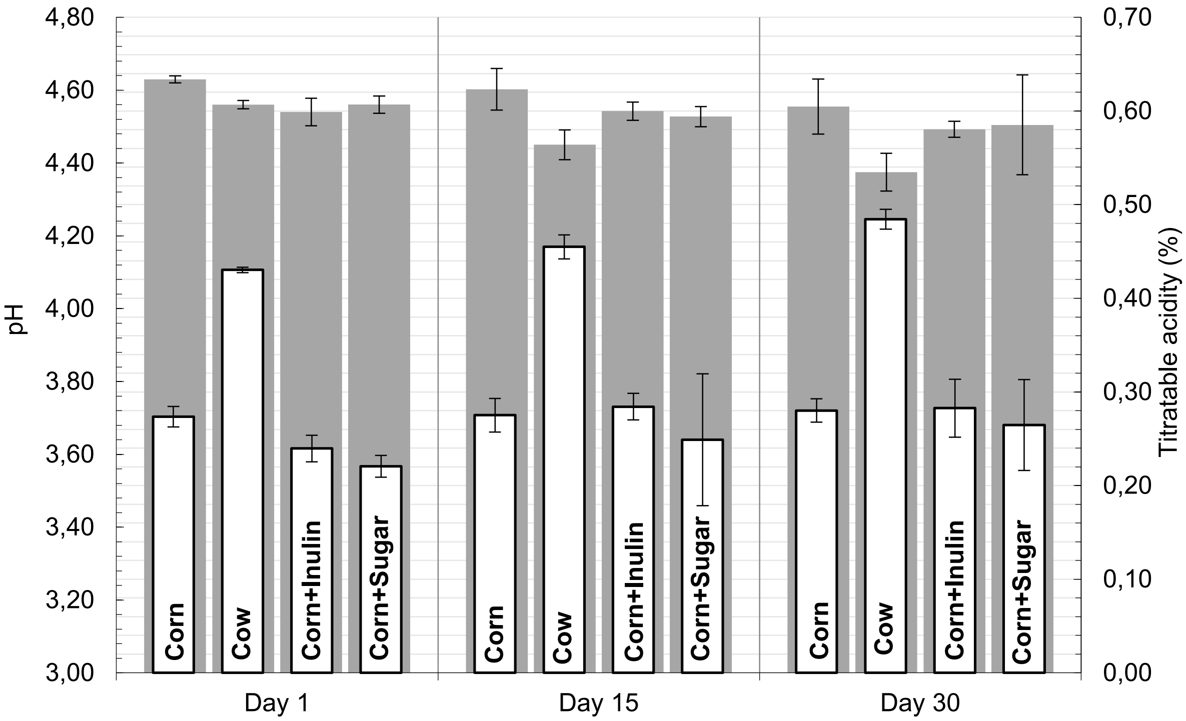


Figure 1. pH ( ) and titratable acidity ( ) values of fermented probiotic drink samples during storage

The impact of sample variety and storage time on the titration acidity values of probiotic drink samples stored at 4°C for 30 days was found to be statistically significant, with a significance level of $p<0.001$ for the sample variety and $p<0.01$ for the storage time (Table 2). Among the probiotic drink samples, the one made from cow's milk exhibited the highest titration acidity value, while the drink made from corn milk and sugar had the lowest titration acidity value ($p<0.05$). Additionally, the probiotic drink made from corn milk had the highest pH value, whereas the drink made from cow's milk had the lowest pH value. This difference between the corn milk and cow's milk samples could be attributed to the lower buffering capacity of cow's milk. It should be noted that *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* can metabolize lactose and fructose, converting them into lactic acid through the Embeden-Meyerhof-Parnas (EMP) pathway. However, *L. delbrueckii* subsp. *bulgaricus* lacks invertase, which prevents it from converting sucrose into lactic acid through the EMP pathway [18]. This could explain the lower titration acidity value observed in the sample containing sucrose. The increase in titratable acidity and decrease in pH during storage is likely attributed to the production of lactic acid from lactose by lactic acid bacteria [15].

Table 2. Effect of the sample type and storage time on titratable acidity and pH values of fermented probiotic drinks

	Titratable acidity (%)	pH
Type of sample	***	***
Corn	0.28±0.01 b	4.60±0.06 a
Cow	0.46±0.02 a	4.46±0.09 c
Corn + Inulin	0.27±0.03 b	4.52±0.03 b
Corn + Sugar	0.24±0.05 c	4.53±0.08 b
Storage time (days)	**	***
1	0.29±0.09 b	4.57±0.04 a
15	0.32±0.02 a	4.53±0.07 b
30	0.33±0.02 a	4.48±0.10 c

Values are expressed as mean ± standard deviation. Values with different letters (a-c) show the difference in the same column $p<0.05$, *$p<0.05$, **$p<0.01$, ***$p<0.001$

The color of food products plays a crucial role in determining their quality and consumer acceptance [1]. The lightness (L*) scale ranges from 0 (black) to 100 (white). The coordinate a* represents reddish colors with positive values and greenish colors with negative values, while the coordinate b* represents yellowish colors with positive values and bluish colors with negative values [17, 19]. Figure 2 displays the L*, a*, b*, and ∆E values of fermented probiotic drink samples throughout the storage period.

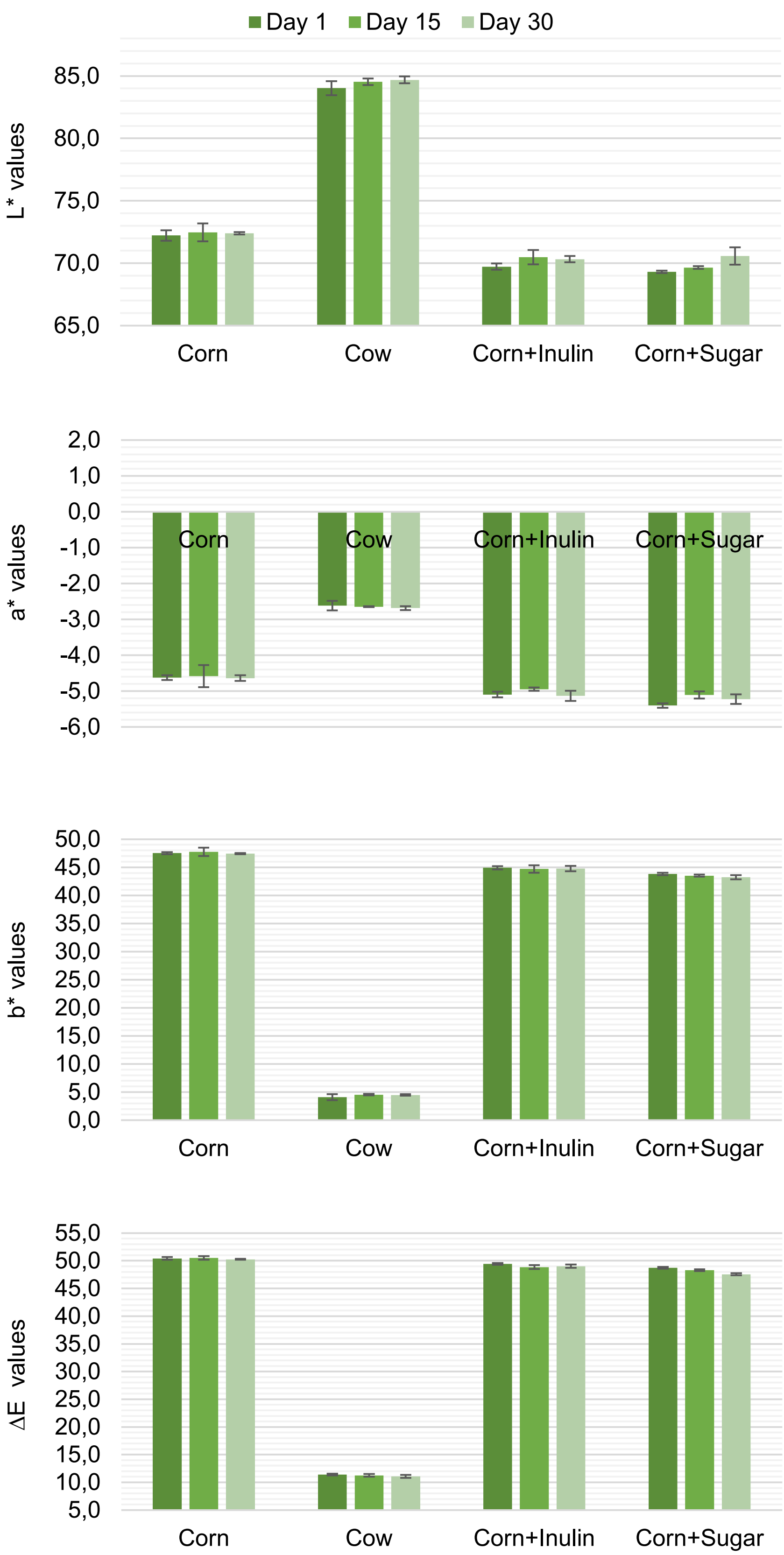


Figure 2. The L*, a*, b* and ΔE values of fermented probiotic drink samples during storage

Probiotic drink samples made from cow's milk exhibited the highest L* and a* values while showing the lowest b* and ΔE values ($p<0.05$). On the other hand, probiotic drink samples made from corn milk had the highest b* and ΔE values. Notably, when considering the b* value, it was observed that the yellowness of the probiotic drink produced from corn milk exceeded that of the other samples. Among the samples, the probiotic drink made from corn milk and sugar displayed the lowest a* value (Table 3). The primary factor influencing the yellow color of the probiotic drink samples made from corn milk was the presence of corn, which is the main ingredient containing carotenoids such as lutein and zeaxanthin [20, 21]. The difference observed between the samples produced from corn milk is likely attributed to the amount and type of pigments present in the milk composition. Additionally, a* statistically significant increase in the mean L* and ΔE values of probiotic drink samples during storage was observed ($p<0.05$).

Table 3. Effect of sample type and storage time on color parameters of fermented probiotic drink samples

	L*	a*	b*	ΔE
Type of sample	***	***	***	***
Corn	72.36±0.45 b	-4.62±0.17 b	47.56±0.44 a	50.40±0.25 a
Cow	84.41±0.46 a	-2.65±0.08 a	4.38±0.36 d	11.25±0.25 d
Corn + Inulin	70.17±0.49 c	-5.06±0.12 c	44.79±0.47 b	49.10±0.36 b
Corn + Sugar	69.85±0.67 c	-5.24±0.16 d	43.51±0.35 c	48.20±0.53 c
Storage time (days)	***	*		***
1	73.82±1.55 b	-4.44±1.12 b	35.09±0.31 a	40.01±0.19 a
15	74.28±6.22 a	-4.32±1.03 a	35.13±0.44 a	39.73±0.27 b
30	74.49±6.15 a	-4.42±1.06 b	34.97±0.27 a	39.48±0.20 c

Values are expressed as mean ± standard deviation. Values with different letters (a-d) show the difference in the same column ($p<0.05$), *$p<0.05$, **$p<0.01$, ***$p<0.001$

Figure 3 illustrates the apparent viscosity and syneresis values during the storage period. In this study, the average apparent viscosity values of probiotic drink samples ranged from 0.08 to 0.55 Pa.s on the 1st day of storage, 0.09 to 0.59 Pa.s on the 15th day of storage, and 0.1 to 0.64 Pa.s on the 30th day of storage, respectively. Additionally, Figure 4 showcases the consistency coefficient and flow behavior index values of the probiotic drink samples throughout the storage period. The consistency coefficient values of probiotic drink samples ranged from 0.99 to 9.68 Pa.sn on the 1st day of storage, 1.08 to 11.60 Pa.s on the 15th day of storage, and 1.36 to 13.51 Pa.s on the 30th day of storage. For the analysis of flow behavior, various models including Newtonian flow, Power-law, Bingham, and Herschel-Bulkley were employed in this study. The Power-law model provided a high correlation coefficient (R^2) ranging from 0.94 to 0.98, accurately describing the rheological properties of the samples. The flow behavior index (n) values, which indicate the tendency of fluids to behave in Newtonian flow, were less than 1 for the probiotic drink samples produced in our study, ranging from 0.13 to 0.34 on the 1st day, 0.11 to 0.33 on the 15th day, and 0.09 to 0.32 on the 30th day of storage, suggesting non-Newtonian pseudoplastic flow behavior.

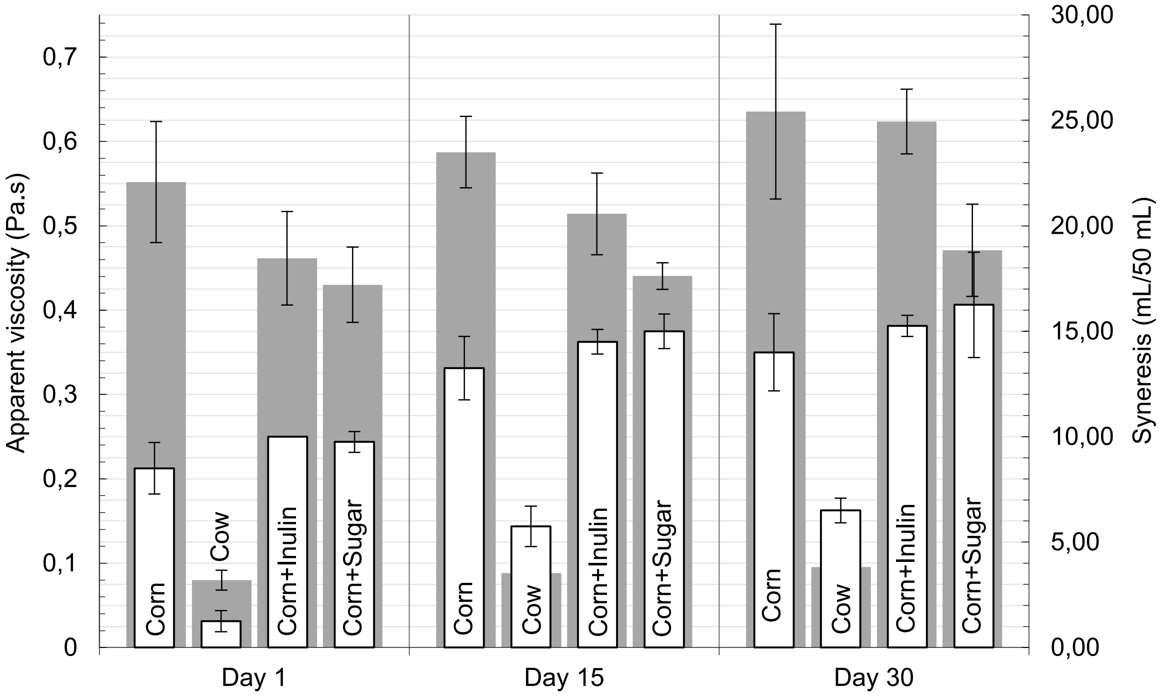


Figure 3. Apparent viscosity ( ) and syneresis ( ) values of the probiotic drink samples obtained during the storage period.

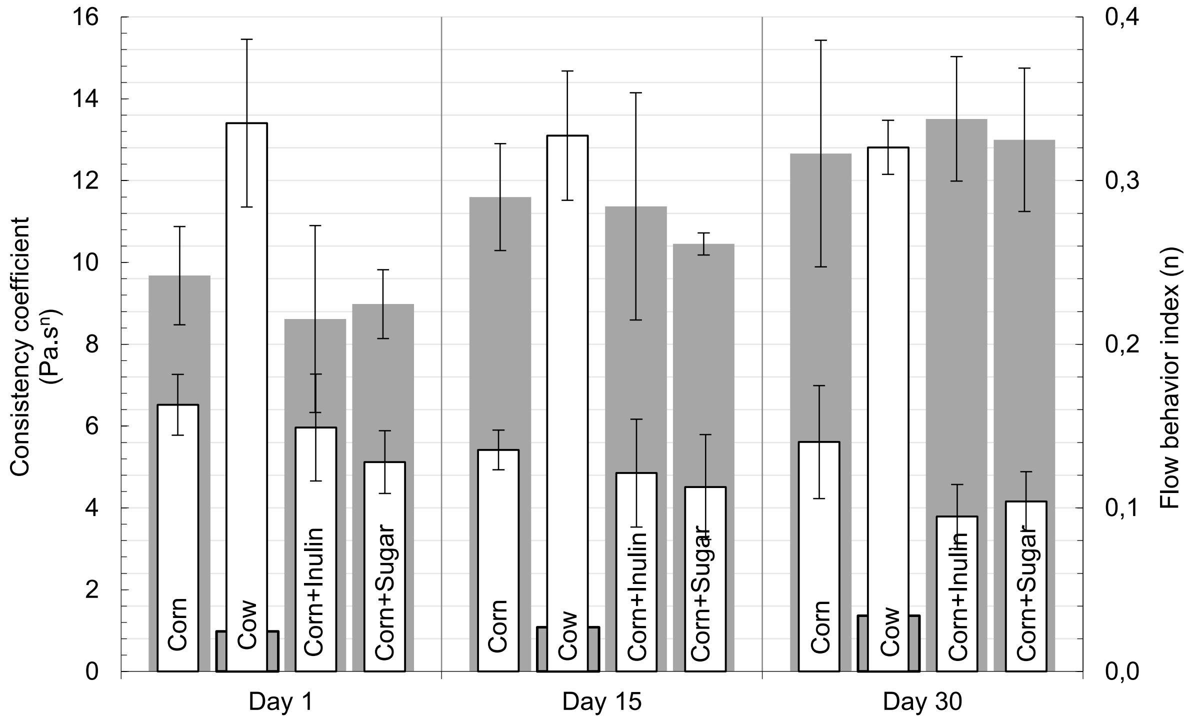


Figure 4. Consistency coefficient (■) and flow behavior index (□) values of the probiotic drink samples during the storage period.

Syneresis, apparent viscosity, consistency coefficient, and flow behavior index values of probiotic drink samples were affected by sample type and storage time at the $p<0.001$. Table 4 presents the effect of sample type and storage time on the syneresis, apparent viscosity, consistency coefficient, and flow behavior index values of fermented probiotic drink samples. It was observed that the average apparent viscosity values of probiotic drink samples made from corn milk were higher compared to the other samples, while the probiotic drink made from cow's milk exhibited the lowest syneresis, apparent viscosity, and consistency coefficient values. Furthermore, the probiotic drink sample made from cow's milk had the highest flow behavior index value ($p<0.05$).

Table 4. Effect of the sample type and storage time on the syneresis, apparent viscosity, consistency coefficient, and flow behavior index values of fermented probiotic drink samples

	Syneresis (mL/50mL)	Apparent viscosity (Pa.s)	Consistency coefficient (Pa.s^n)	Flow behavior index (n)
Type of sample	***	***	***	***
Corn	11.92±1.51 b	0.59±0.07 a	11.31±0.62 a	0.15±0.01 b
Cow	4.50±0.68 c	0.09±0.01 d	1.14±0.30 b	0.33±0.03 a
Corn + Inulin	13.25±0.36 a	0.53±0.05 b	11.17±0.84 a	0.12±0.04 c
Corn + Sugar	13.67±1.27 a	0.45±0.04 c	10.81±0.58 a	0.12±0.02 c
Storage time (days)	***	***	***	*
1	7.38±0.56 c	0.38±0.10 b	7.07±0.96 c	0.20±0.09 a
15	12.13±0.97 b	0.41±0.04 b	8.63±0.18 b	0.18±0.10 ab
30	13.00±1.35 a	0.46±0.05 a	10.13±0.37 a	0.17±0.02 b

Values are expressed as mean ± standard deviation. Values with different letters (a-d) show the difference in the same column ($p<0.05$), *$p<0.05$, **$p<0.01$, ***$p<0.001$

Syneresis, a significant quality defect, occurs when the protein network breaks down during storage, leading to the loss of the gel structure's ability to retain the serum phase [22]. The protein structure membrane surrounding fat globules enhances emulsion stability by reducing interfacial energy and surface tension. Increasing acidity during fermentation disrupts the protein structure membrane, promoting fat globule contact and flocculation. Consequently, emulsions with low protein content may experience increased phase separation [23]. As indicated in Table 1, probiotic drink samples produced from corn milk had lower protein content, which affected the syneresis values. Additionally, bacteria surviving in the probiotic drink hydrolyze proteins during storage, leading to the release of trapped serum within the protein structure [24]. In our study, an increase in syneresis values during storage was observed ($p<0.05$). Various factors, including structural differences, amino acid composition, surface polarity, or hydrophobicity of proteins in milk composition, can influence syneresis [25]. Based on our results, it was inferred that the differences between the samples may be attributed to variations in titration acidity values and protein structures between cow's milk protein and corn milk derived from corn.

The particle diameter of fat globules, casein micelles, and whey proteins in cow's milk ranges between 0.1-10 µm, 20-400 nm, and 3-10 nm, respectively [26]. However, corn milk is obtained by passing corn slurry through a 1 mm^2 sieve. Consequently, the fermented probiotic drink produced from corn milk displayed higher apparent viscosity and consistency coefficient values compared to the drink made from cow's milk. Kucukcetin et al. [27] demonstrated that apparent viscosity and consistency coefficient values of ayran increased while flow behavior index values decreased with increasing particle size. Ergin [28] established a correlation between apparent viscosity values, consistency coefficient values, and particle size of probiotic yogurt samples, suggesting that protein content can also influence apparent viscosity values. Wang et al. [11] similarly found that the viscosity of a product increased with higher soy protein content in a probiotic corn-based yogurt-like product. In our study, the apparent viscosity values of fermented probiotic drinks produced solely from corn milk were higher than those produced from corn milk with inulin and sugar. This might be attributed to the higher protein content of the fermented probiotic drink made solely from corn milk (Table 1). The addition of inulin to corn milk resulted in higher apparent viscosity compared to the addition of sugar in the samples, potentially due to the water-holding and thickening properties of inulin [29]. The apparent viscosity and consistency coefficient values of the samples increased during storage. It is known that protein-protein interactions and slow protein rearrangements in fermented products continue during cold storage, which is associated with a decrease in pH [30].

Microbiological Properties

Figure 5 depicts the logarithmic values of *S. thermophilus, L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* counts in probiotic drink samples during storage, along with the temporal variations in these values.

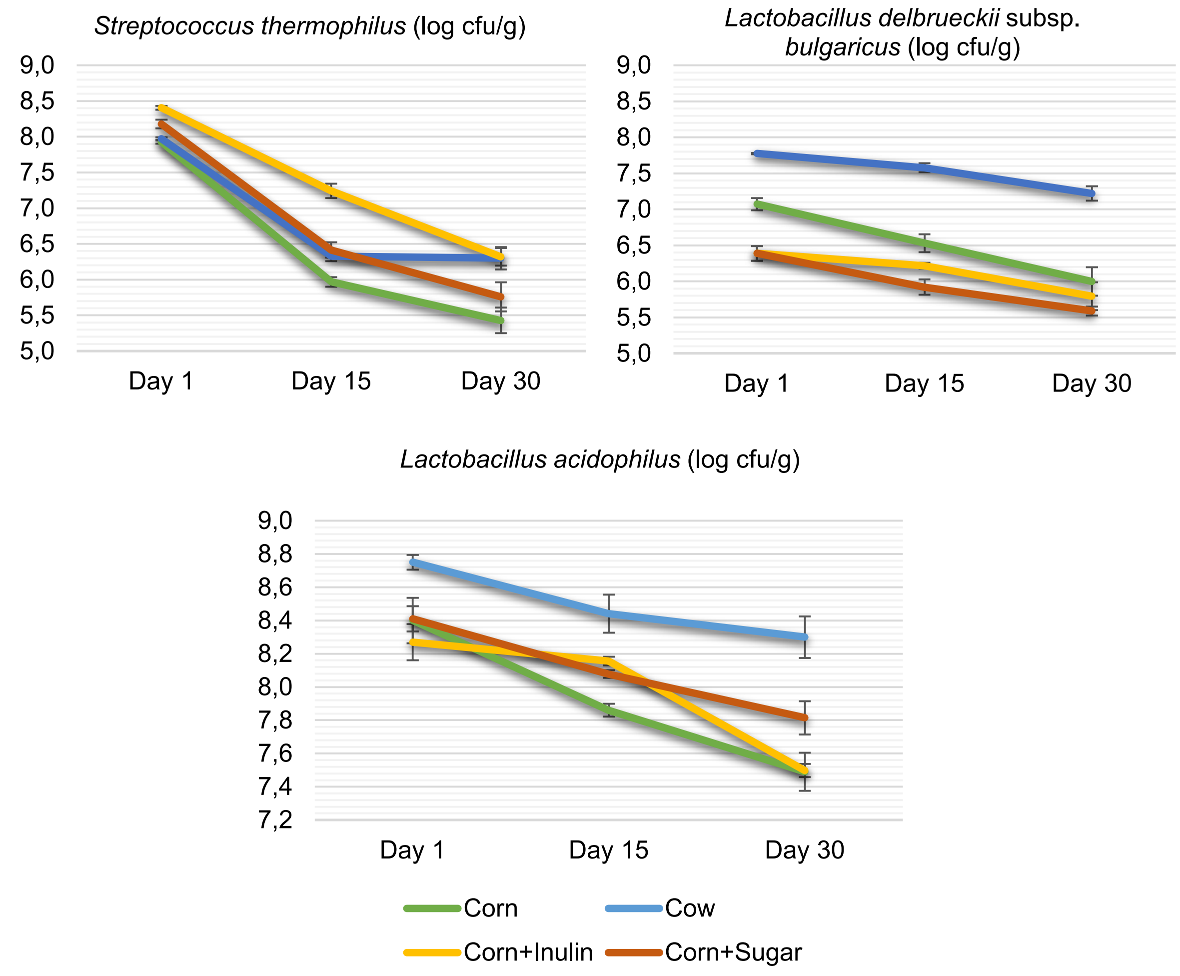


Figure 5. Survival of (a) *Streptococcus thermophilus*, (b) *Lactobacillus delbrueckii* subsp. *bulgaricus,* (c) *L. acidophilus* in probiotic drink samples on 1st, 15th and 30th day of storage.

The counts of *S. thermophilus, L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* in probiotic drink samples were found to be influenced by both the sample type and storage time at a significant level of $p<0.001$. The probiotic drink made from cow's milk exhibited the highest average counts for *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus*, while the probiotic drink made from solely corn milk had the lowest counts for these bacteria ($p<0.05$) (Table 5). Comparing the *L. acidophilus* counts among the samples made from corn milk, the probiotic drink sample made from corn milk and inulin had the highest count. This can be attributed to the fact that inulin acts as a prebiotic substance. In our study, although the counts of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* showed statistically significant differences among the samples, the viability of *L. delbrueckii* subsp. *bulgaricus* and *L. acidophilus* during storage did not differ by more than 1 log cfu/g.

Table 5. Effect of the sample type and storage time on the microbiological properties of fermented probiotic drink samples

	Streptococcus thermophilus (log cfu/g)	*Lactobacillus delbrueckii* subsp. *bulgaricus* (log cfu/g)	*Lactobacillus acidophilus* (log cfu/g)
Type of sample	***	***	***
Corn	6.44±0.32 c	5.97±0.36 d	7.92±0.43 c
Cow	7.32±0.26 a	7.52±0.29 a	8.50±0.22 a
Corn + Inulin	6.87±0.24 b	6.54±0.48 b	8.10±0.27 b
Corn + Sugar	6.78±0.31 b	6.13±0.27 c	7.97±0.36 c
Storage time (days)	***	***	***
1	8.12±0.20 a	6.91±0.60 a	8.46±0.21 a
15	6.49±0.12 b	6.56±0.65 b	8.14±0.22 b
30	5.95±0.42 c	6.15±0.68 c	7.77±0.38 c

Values are expressed as mean ± standard deviation. Values with different letters (a-d) show the difference in the same column ($p<0.05$), *$p<0.05$, **$p<0.01$, ***$p<0.001$

The survival of probiotic microorganisms is crucial for them to exhibit their beneficial properties during food processing, storage, and gastrointestinal transit. To ensure the desired effects of probiotic bacteria, these specific microorganisms must remain viable, active, and abundant in the product until the expiration date, with cell counts ranging from 10^6 to 10^9 cfu/g [31]. The dosage reaching the target site in the body plays a significant role in the manifestation of characteristic effects of probiotic bacteria [32]. In our study, the counts of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* in probiotic drink samples decreased during storage ($p<0.05$) (Table 5). The effects of sample type and storage time on the percentage reduction of microorganism counts in the samples are presented in Table 6. The percentage reduction of microorganism counts increased during storage ($p<0.05$). The probiotic drink sample made from corn milk exhibited the highest decrease in the counts of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus*. The type of milk used can influence the fermentation of milk products, as microorganisms can be stimulated or inhibited by compounds present in milk [33]. Antibacterial and polyphenolic compounds, such as phenolic acids and flavonoids, found in corn milk may hinder the growth of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* in probiotic drink during storage. When comparing the reduction rates (%) of *L. acidophilus*, no significant difference ($p<0.05$) was observed between the reduction rates in the probiotic drink samples made from cow's milk, corn milk and inulin, and corn milk and sugar (Table 6).

Table 6. Effect of the sample type and storage time on the reduction of microorganism counts (%)

	Reduction of *S. thermophilus* counts (%)	Reduction of *L. delbrueckii* subsp. *bulgaricus* counts (%)	Reduction of *L. acidophilus* counts (%)
Type of sample	**	***	***
Corn	28.10±1.39 a	11.41±1.62 a	8.54±1.42 a
Cow	19.34±2.13 c	4.82±1.23 b	4.30±0.61 b
Corn + Inulin	20.82±0.55 c	6.11±1.32 b	5.46±1.50 b
Corn + Sugar	25.55±1.62 b	9.91±1.25 a	5.50±0.97 b
Storage time (days)	***	***	***
15	20.19±4.20 b	5.10±0.68 b	3.84±0.53 b
30	26.72±4.61 a	11.02±1.03 a	8.06±0.86 a

Values are expressed as mean ± standard deviation. Values with different letters (a-d) show the difference in the same column ($p<0.05$), *$p<0.05$, **$p<0.01$, ***$p<0.001$

Sensorial Properties

Figure 5 shows the color & appearance, texture & consistency, taste & smell, and general liking scores of probiotic drink samples during storage.

Table 7 presents the sensory evaluation results of probiotic drink samples, focusing on taste & smell, as well as general liking. The probiotic drink made from corn milk and sugar received the lowest scores in taste & smell and general liking (Table 7). Over the course of 30 days of storage, there was a significant decrease in sensory scores ($p<0.05$). The lower scores in texture and consistency of the fermented products could be attributed to serum separation, as reported by Kizzie-Hayford et al. [23]. In our study, the probiotic drink sample made from cow's milk showed the lowest serum separation value (Table 4) and received the highest scores in texture & consistency. Regarding color & appearance, the probiotic drink sample made from cow's milk, which had the highest L* (brightness) parameter, received the highest score. When considering the general liking and taste and smell scores, it was observed that the probiotic drink sample made from cow's milk was preferred more than the samples made from corn milk.

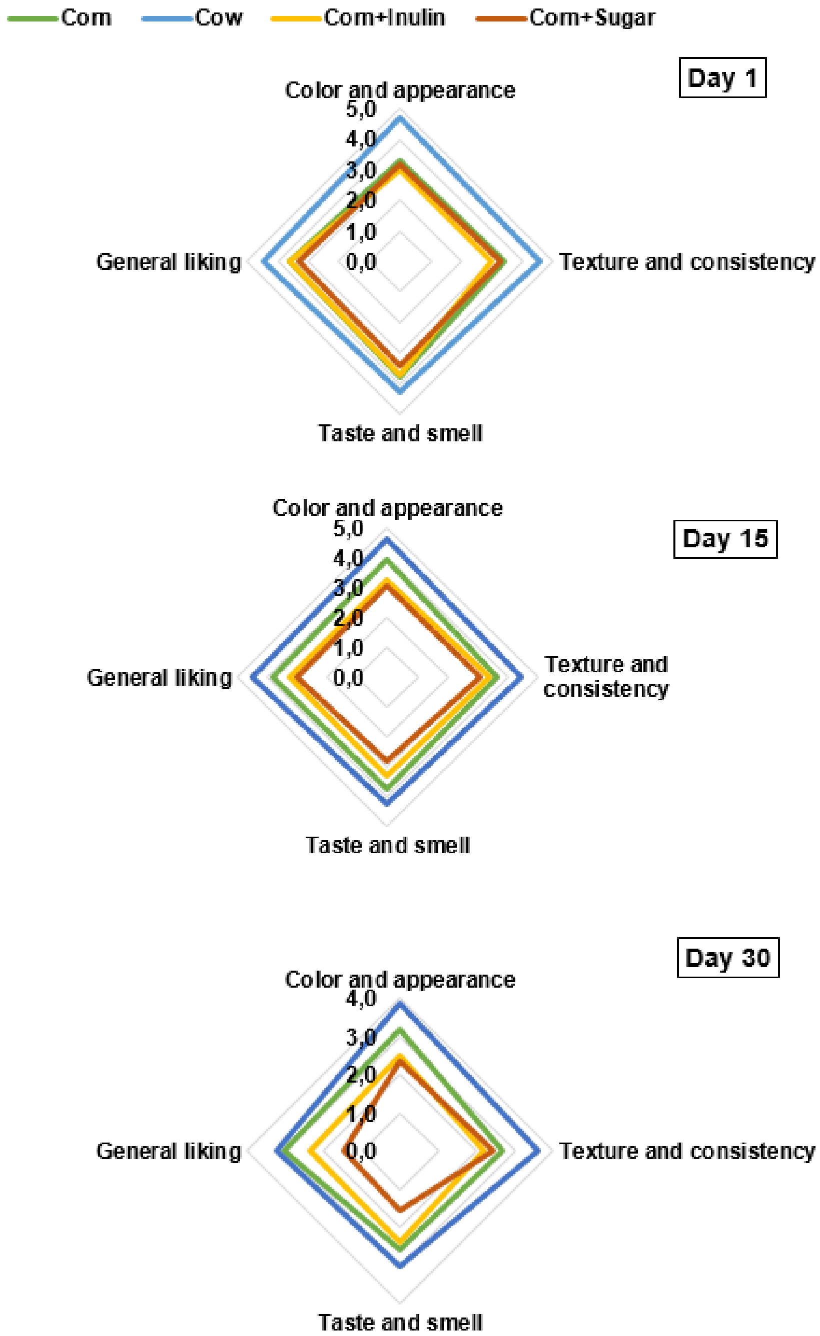


Figure 6. Color & appearance, texture & consistency, taste & smell, and general liking scores of fermented probiotic drink samples during storage (full score = 5; 1 point: very bad, 2 points: bad, 3 points: fair, 4 points: good, 5 points: very good)

Table 7. Effect of the sample type and storage time on the sensory qualities of fermented probiotic drink samples

	Color and appearance	Texture and consistency	Taste and smell	General liking
Type of sample	***	***	**	***
Corn	3.48±0.37 b	3.23±0.46 b	3.38±0.26 ab	3.50±0.20 b
Cow	4.40±0.42 a	4.21±0.48 a	3.84±0.27 a	4.09±0.27 a
Corn + Inulin	2.92±0.41 c	2.86±0.61 b	3.15±0.31 b	3.08±0.26 bc
Corn + Sugar	2.88±0.50 c	2.94±0.53 b	2.61±0.38 c	2.61±0.13 c
Storage time (days)	***	***	***	***
1	3.55±0.77 a	3.56±0.68 a	3.82±0.15 a	3.77±0.18 a
15	3.72±0.68 a	3.63±0.61 a	3.53±0.22 a	3.64±0.22 a
30	2.99±0.65 b	2.74±0.62 b	2.38±0.23 b	2.55±0.30 b

Values are expressed as mean ± standard deviation. Values with different letters (a-d) show the difference in the same column ($p<0.05$), *$p<0.05$, **$p<0.01$, ***$p<0.001$

CONCLUSION

In this study, it was observed that probiotic drink samples made from corn milk exhibited certain distinct characteristics compared to the probiotic drink made from cow's milk. Specifically, probiotic drink samples made from corn milk had higher pH values, a* values, syneresis, apparent viscosity, and consistency coefficient values. The color of the probiotic drinks made from corn milk was noticeably more yellow in comparison to the probiotic drink made from cow's milk. Regarding the microbiological properties, probiotic drink samples produced from cow's milk demonstrated high probiotic viability (>10^8 cfu/g) at the end of the storage period, while the viability of *L. acidophilus* (>10^7 cfu/g) was maintained in all samples (Figure 5). However, the counts of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, and *L. acidophilus* decreased during storage, with the lowest reduction (%) observed in the probiotic drink made from cow's milk. Among the different probiotic drink samples, the probiotic drink made from cow's milk was found to be the most preferred in terms of sensory attributes. On the other hand, fermented probiotic drinks produced from corn milk with inulin can be recommended to vegans, with relatively high apparent viscosity values and probiotic bacteria count.

REFERENCES

[1] Shiekh, K.A., Luanglaor, T., Hanprerakriengkrai, N., Jafari, S., Kijpatanasilp, I., Asadatorn, N., Worobo, R.W., Bekhit, A.E., Assatarakul, K. (2023). Antioxidants and quality changes of thermally processed purple corn (*Zea mays* L.) milk fortified with low sucrose content during cold storage. *Foods,* 12, 277.

[2] Donald, I., Eucharia, C.N. (2018). Nutritional and sensory evaluation of African breadfruit-corn yoghurt. *African Journal of Food Science*, 12(4), 73-79.

[3] Menezes, A.G.T., Ramos, C.L., Dias, D.R., Schwan, R.F. (2018). Combination of probiotic yeast and lactic acid bacteria as starter culture to produce maize-based beverages. *Food Research International*, 111, 187-197.

[4] Çomak Göçer, E.M., Koptagel, E. (2023). Production of milks and kefir beverages from nuts and certain physicochemical analysis. *Food Chemistry*, 402, 134252.

[5] Muncey, L., Hekmat, S. (2021). Development of probiotic almond beverage using *Lacticaseibacillus rhamnosus* GR-1 fortified with short-chain and long-chain inulin fibre. *Fermentation*, 7, 90.

[6] FAO/WHO. (2001). Report on Joint FAO/WHO Expert consultation on evaluation of health and nutritional properties of probiotics in food including powder milk with live lactic acid bacteria. Available at: www.ftp.fao.org/es/esn/ food/probio_report_en.pdf (accessed 11 May 2023).

[7] Çomak Göçer, E.M., Ergin, F., Aşcı Arslan, A., Küçükçetin, A. (2016). Farklı inkübasyon sıcaklığı ile inkübasyon sonlandırma pH'sının probiyotik yoğurdun fizikokimyasal ve mikrobiyolojik özellikleri üzerine etkisi. *Akademik Gıda* 14(4), 341-350.

[8] Bernat, N., Cháfer, M., Chiralt, A., González-Martínez, C. (2015). Development of a non-dairy probiotic fermented product based on almond milk and inulin. *Food Science and Technology International*. 21(6), 440-53.

[9] Sangkam, J., Apichartsrangkoon, A., Baipong, S., Sriwattana, S., Tiampakdee, A., Sintuya, P. (2019). Pre-blanching corn and pressurization effects on the physicochemical and microbiological qualities of corn milk, *Food Bioscience*, 31, 100446.

[10] Ajala, L., Ologunde, M., Adetuyi, F.O. (2013). Physicochemical and sensory qualities of spiced soy-corn milk. *African Journal of Biotechnology*, 12(17), 2262-2265.

[11] Wang, C., Zheng, H., Liu, T., Wang, D., Guo, M. (2017). Physiochemical properties and probiotic survivability of symbiotic corn-based yogurt-like product. *Journal of Food Science*, 82(9), 2142-2150.

[12] AOAC. (2000). Official methods of analysis of AOAC International (17th ed.). Gaithersburg, MD, USA: Association of Official Analytical Communities.

[13] Yalçın, S., Ergin, F., Küçükçetin, A. (2021). Effects of homogenization and heat treatment of milk with different fat content on physical properties of ayran. *Annals of the Brazilian Academy of Sciences*, 93(3), e20200517.

[14] Çomak Göçer, E.M., Koptagel, E. (2023). Production and evaluation of microbiological &

rheological characteristics of kefir beverages made from nuts. *Food Bioscience* 52, 102367.

[15] Çomak Göçer, E.M., Ergin, F., Özen Küçükçetin, İ., Küçükçetin, A. (2021). In vitro gastrointestinal resistance of *Lactobacillus acidophilus* in some dairy products. *Brazilian Journal of Microbiology*, 52(4), 2319-2334

[16] Ergin, F., Atamer, Z., Çomak Göçer E.M., Demir, M., Hinrichs, J., Kucukcetin, A. (2021). Optimization of *Salmonella* bacteriophage microencapsulation in alginate-caseinate formulation using vibrational nozzle technique. *Food Hydrocolloids*, 113, 106456.

[17] Çomak Göçer, E.M., Koptagel, E. (2023). Farklı yağlı tohumlardan elde edilen bitkisel sütlerden üretilen kefirlerin bazı fiziksel ve duyusal özellikleri. *The Journal of Food*, 48(1), 227-241.

[18] Estedez, A.M., Majia, J., Figuerola, F. and Escobar, B. (2008). Effect of solid content and sugar combination on the quality of soymilk yoghurt, *Journal of Food Processing and Preservation,* 34: 87-97.

[19] Paredes, J.L., Escudero-Gilete, M.L., Vicario, I.M. (2022). A new functional kefir fermented beverage obtained from fruit and vegetable juice: Development and characterization. *LWT*, 154, 112728,

[20] Aini, N., Sumarmono, J., Sustriawan, B., Prihananto, V., Priscillia, E. (2020). The quality of corn milk-based cheese analogue made with virgin coconut oil as a fat substitute and with various emulsifiers. IOP Conference Series: Earth and Environmental Science, 443, 012039.

[21] Scott, C.E., Eldridge, A.L. (2005) Comparison of carotenoid content in fresh, frozen and canned corn. *Journal of Food Composition and Analysis*, 18, 6,551-559.

[22] Rasika, D.M.D., Vidanarachchi, J.K., Rocha, R.S., Balthazar, C.F., Cruz, A.G., Sant'Ana, A.S., Ranadheera, C.S. (2021). Plant-based milk substitutes as emerging probiotic carriers. *Current Opinion in Food Science*, 38: 8-20.

[23] Kizzie-Hayford, N., Jaros, D., Zahn, S., Rohm, H. (2016). Effects of protein enrichment on the microbiological, physicochemical and sensory properties of fermented tiger nut milk. *LWT*, 74, 319-324.

[24] Yeniçeri, Ş.A, Çomak Göçer, E.M., Küçükçetin, A. (2021). Probiyotik bakteri içeren ayranın fizikokimyasal ve mikrobiyolojik özellikleri. *Akademik Gıda*, 19(4), 414-423.

[25] Ozturkoglu-Budak, S., Akal, C., Yetisemiyen, A. (2016). Effect of dried nut fortification on functional, physicochemical, textural, and microbiological properties of yogurt. *Journal of Dairy Science*, 99(11), 8511-8523.

[26] Walstra, P., Walstra, P., Wouters, J. T., Geurts, T. J. (2005). Dairy science and technology. (2nd ed.), CRC press, Boca Raton.

[27] Küçükçetin, A., Comak, E.M, Aşcı, A., Demir, M., Şık, B. (2012). Effect of casein to whey protein ratio of skim milk on the physical properties of a yoghurt drink, Ayran. *Milclwissenschaft,* 67(3), 233–248.

[28] Ergin, F. (2022). Süt tozu, peyniraltı suyu izolatı veya inülin ile kurumaddesi arttırılan ve kalsiyum klorür eklenen sütlerden üretilen probiyotik yoğurtların bazı fizikokimyasal, mikrobiyolojik ve duyusal özellikleri. *Akademik Gıda*, *20*(2), 145-160.

[29] Chetachukwu, A. S., Thongraung, C., Yupanqui, C. T. (2018). Effect of short-chain inulin on the rheological and sensory characteristics of reduced fat set coconut milk yoghurt. *Journal of Texture Studies*, *49*(4), 434-447.

[30] Güler-Akın, M., Ferliarslan, I., Serdar Akın, M. (2016) Apricot probiotic drinking yoghurt supplied with inulin and oat fiber. *Advances in Microbiology*, 6, 999-1009.

[31] Casarotti, S.N., Penna, A.L.B. (2015). Acidification profile, probiotic in vitro gastrointestinal tolerance and viability in fermented milk with fruit flours. *International Dairy Journal*, 41, 1-6.

[32] Ascı Arslan, A., Çomak Göçer, E.M., Demir, M., Atamer, Z., Hinrichs, J., Küçükçetin, A. (2016). Viability of *Lactobacillus acidophilus* ATCC 4356 incorporated into ice cream using three different methods. *Dairy Science and Technology*, 96,477-478.

[33] Atalar, İ. (2019). Functional kefir production from high pressure homogenized hazelnut milk. *LWT - Food Science and Technology*, 107, 256-263.