

A Comparative Study on Some Quality Properties and Mineral Contents of Yoghurts Produced From Different Type of Milks ^[1]

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Summary

The objective of this study was to determine and compare the some quality properties and mineral contents of yoghurts made from different types of milks. For this purpose; physical, chemical, microbiological and sensory properties of yoghurts produced from cows', buffaloes', ewes' and goats' milks were examined during 28 day storage at 4°C. Some major and minor mineral contents of yoghurts were also determined. Total solids, protein, ash, Ca and P contents of ewes' yoghurt were significantly higher compared with the other yoghurts. An increase in viscosity was observed with increasing total solids and protein contents of yoghurts. Zn and Fe contents of cows' yoghurt were higher than the other yoghurts. *L. bulgaricus* and *S. thermophilus* counts of all yoghurts showed an increasing until day 7 of storage then a decreasing until the end of storage. Although cows' and ewes' yoghurts were the most acceptable during storage, goats' yoghurt was the lowest scored by panelists.

Keywords: Yoghurt, Milk type, Quality properties, Mineral content

Farklı Tür Sütlerden Üretilen Yoğurtların Bazı Kalite Özellikleri ve Mineral İçerikleri Üzerine Karşılaştırmalı Bir Araştırma

Özet

Bu çalışmanın amacı; farklı tür sütlerden üretilen yoğurtların bazı kalite özellikleri ile mineral içeriklerini tespit etmek ve karşılaştırmaktır. Bu amaçla, inek, manda, koyun ve keçi sütlerinden üretilen yoğurtların 4°C'de 28 günlük muhafaza süresince fiziksel, kimyasal, mikrobiyolojik ve duyuşsal özellikleri incelenmiştir. Ayrıca, yoğurtların bazı major ve minör mineralleri de araştırılmıştır. Diğer yoğurtlarla karşılaştırıldığında koyun yoğurdunun toplam kuru madde, protein, kül, Ca ve P içeriklerinin daha yüksek olduğu görülmüştür. Yoğurtların toplam kuru madde ve protein içeriklerinin artışına bağlı olarak viskozite değerleri de artmıştır. İnek yoğurdunun Zn ve Fe içerikleri diğer yoğurtlara nazaran daha yüksek bulunmuştur. Yoğurtların *L. bulgaricus* ve *S. thermophilus* sayıları muhafazanın 7. gününe kadar artmış, daha sonra muhafaza süresinin sonuna kadar azalmıştır. İnek ve koyun yoğurtları duyuşsal açıdan muhafaza süresince en kabul edilebilir olmalarına rağmen, keçi yoğurdu panelistler tarafından en düşük puanları almıştır.

Anahtar sözcükler: Yoğurt, Süt çeşidi, Kalite özellikleri, Mineral içeriği

INTRODUCTION

An increase interest in the production and consumption of fermented dairy products has been observed due to their flavourful and healthful properties. Yoghurt, obtained by the lactic acid fermentation of milk by addition of homofermentative yoghurt starter bacteria, is the most well known fermented dairy product around the world. Although the origin of yoghurt is not known precisely it is thought that it might be as the Middle East according to the historical records ¹. Yoghurt is rich in calcium,

phosphorus, magnesium, vitamin A and riboflavin ². It also contains high levels of viable yoghurt bacteria and their metabolites which are beneficial for health; so that many undesired microorganisms couldn't grow up in yoghurt. Thus, it is accepted to be a safety product ³.

The milk used for production of yoghurt is important in terms of quality parameters of yoghurt including flavour textural and compositional characteristics. Although milks



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from other animal species, such as ewes, goats and buffaloes are utilized to the human diet in various parts of the world, a great number of studies have focused on cows' milk. Yoghurt is mostly made from cows' milk and a very limited extent from ewes', goats' or buffaloes' milks in Turkey. However, for home-made yoghurt, cows', buffaloes', goats' and ewes' milks or their mixture are frequently used in different regions of Turkey. On the other hand, these milks are very popular in countries around the world, especially Mediterranean region¹. Buffaloes' milk has an important nutritional value because of its high level of fat content particularly, which is responsible for its high energetic and nutritive properties⁴. Furthermore, buffaloes' milk is the second most produced milk in the world with 82 billion liters produced each year (12.5% of milk produced in the world), after cows' milk (84% with 551 billion liters)⁵, although it is the least produced milk in Turkey. Ewes' milk, the other milk type, contains higher amount of proteins than cows' milk (58 g/kg and 33 g/kg, respectively) and does not require fortification of the milk in the production of yoghurt⁶. Besides, ewes' yoghurt has a pleasant creamy-sour flavour, considered by many to be better than cows' yoghurt⁷. On the other hand, goats' milk and its products, such as yoghurt and cheese, are becoming increasingly popular in the world for its high nutritional value, easy assimilation of components, therapeutic, antioxidative and antiallergenic properties, but it is a possible problem of musky, rancid and goatly flavour and aroma in goats' milk products⁸.

Yoghurt can be a good dietary source of essential minerals. It could contribute importantly to the recommended daily intake of calcium and magnesium to maintain the physiological processes in the body⁹. Moreover, bioavailability of calcium from yoghurt is higher than from milk. The acidic pH of yoghurt ionizes calcium and hence facilitates intestinal calcium absorption¹⁰. Phosphorus, magnesium and zinc are also in an available form in yoghurt for absorption and utilization by the body¹¹. In addition, yoghurt contains noticeable quantities of sodium and potassium¹. The levels of essential minerals present in dairy products depend on the technological treatments, type of milk used and accuracy of analysis¹².

The traditional fermented milk products made from the milks of cows, ewes and goats are still competitive with newer products. There have been a number of separate studies on physicochemical, rheological, microbiological, sensory properties and mineral contents of yoghurts made from these milks. However, only a few comparative research data have been documented on some quality properties^{13,14} and mineral contents of yoghurts made from different types of milks¹⁵. Furthermore, information about the chemical composition and physical characteristics of buffaloes' yoghurt is scarce, compared to cows', ewes' and goats' yoghurts. The comparison of physicochemical, rheological, microbiological, sensory properties and mineral

contents in yoghurts made from these four milks has not been reported in the literature. Therefore, the aims of this study were to determine the some quality properties and mineral contents of the yoghurts made from cows', ewes', goats' and buffaloes' milks and to contribute to the literatures comparing the differences among these yoghurts.

MATERIAL and METHODS

Milks and Starter Cultures

Cows' milk was supplied by dairy farm of Atatürk University in Erzurum province of Turkey. Ewes', goats' and buffaloes' milks were obtained from different villages in Erzurum province. Direct-to-vat system yoghurt starter culture (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* spp. *bulgaricus*) coded YC350 was used in yoghurt-manufacturing supplied from Chr.Hansen-Peyma, Istanbul, Turkey.

Manufacture of Yoghurts

The yoghurts were manufactured according to the protocol proposed by Tamime and Robinson¹ in duplicate. The raw cows', ewes', goats' and buffaloes' milks were separately strained using a cloth filter. Each milk was held to 85°C for 25 min using batch pasteurization and cooled down to 44±1°C. The heat treated milk was inoculated with thermophilic starter culture (*S. thermophilus* and *L. bulgaricus*). The inoculation rate was 20 g/100 L milk for all samples. Then, each inoculated milk was distributed into 200-mL sterile glass cups and incubated at 44±1°C until it reached pH 4.6. After fermentation, yoghurt samples removed and stored at 4±1°C for 28 days and analyzed 1, 7, 14, 21 and 28 d of cold storage.

Chemical Analyses

Total solids, fat, ash, titratable acidity¹⁶ and protein contents¹⁷ of milks and yoghurt samples were determined. The pH was measured with a pH meter (model WTW pH-340-A, Weilheim, Germany) fitted with a combined glass electrode.

Syneresis

The yoghurt samples were analyzed for syneresis throughout storage according to the method described by Atamer and Sezgin¹⁸ Twenty-five grams of yoghurt samples were weighed and filtered. After 120 min of drainage at 4±1°C, the amount of collected whey (mL) in a flask was recorded and expressed as an index of syneresis.

Apparent Viscosity

The apparent viscosities of yoghurt samples were measured during storage using Visco Star-L Fungilab viscometer equipped with a number 6 spindle and operated

at a speed of 20 rpm. All of the measurements were performed in duplicate and sample temperature was $4\pm 1^\circ\text{C}$. The yoghurt samples were stirred gently for 10 s before the viscosity measurement. The readings were taken from instrument directly at the point of 30th s and were recorded in centipoise¹⁹.

Mineral Analysis

Mineral contents (Ca, Mg, Na, P, K, Fe, Mn, Ni, S and Zn) of yoghurt samples were determined using an Inductively Coupled Plasma Optical Emission Spectrometry (ICP/OES (Perkin-Elmer, Optima 2100 DV, Shelton, CT, USA)) and following the method described by Güler²⁰. Decomposition of samples was performed in a microwave oven (Berghof speed wave, Germany). For this purpose, about 0.5 g yoghurt sample was weighed into the digestion vessels. Concentrated nitric acid (10 mL) was added and after that, digestion was carried out to each sample at 210°C and 176 psi pressure for 10 min. After cooling, the carousels were removed from the oven, 30% hydrogen peroxide (2 mL) was added to samples and then second digestion was applied at 195°C and 95 psi pressure for 5 min. The vessels were immediately closed after the addition of oxidants. At the end of the digestion process, the samples were diluted with distilled water to a suitable concentration, and were filtered through Whatman no. 42 filter paper. All diluted digests were eventually analyzed by an ICP-OES.

Microbiological Analysis

For each yoghurt sample, 11 g were weighted and diluted aseptically in 99 mL of sterile peptone water (0.1% w/v). Serial dilutions were made in 0.1% sterile peptone water and appropriate dilutions were poured plated in duplicate. The counts of *S. thermophilus* were enumerated on M17 agar (Oxoid Ltd, Basingstoke, Hampshire, UK) by incubating the plates aerobically at 37°C for 48 h²¹. For enumeration of *L. bulgaricus* MRS agar (Oxoid Ltd) was used and the plates were incubated anaerobically at 37°C for 72 h. Anaerobic conditions were provided using Anaerocult A sachets (Merck). Plates containing 20-200 colonies were enumerated and the results are expressed as colony-forming units per gram (cfu/g) of yoghurt sample.

Sensory Analysis

Sensory analysis was carried out in yoghurt samples by a group of six panelists from the academic staff working in the Dairy Department. Taste and aroma, odor, mouth-feel, texture, acidity and general acceptability of samples were scored on a scale of 1-9 on days 1, 7, 14, 21 and 28 of storage. Samples were left at the room temperature for 10-15 min and they served with a glass of water a slice of bread²².

Statistical Analysis of Data

The data were analyzed statistically using SPSS statistical

software programme version 13 (SPSS Inc., Chicago, IL, USA). Analysis of variance (ANOVA) and Duncan's Multiple Range Test was used to determine significant differences among results.

RESULTS

Milk Composition

The compositions of raw cows', ewes', goats' and buffaloes' milks were total solids contents 12.06%, 17.40%, 14.15%, 16.56%; fat contents 3.80%, 5.90%, 4.70%, 7.40% and ash contents 0.70%, 0.91%, 0.78%, 0.77%, respectively. The respective pH and titratable acidity of cows' milk were 6.49 and 0.20%; those of ewes' milk were 6.64 and 0.24%, those of goats' milk were 6.55, 0.19% and those of buffaloes' milk were 6.78 and 0.15%. Mineral contents of milks used in yoghurt production are shown in Table 1.

Physical and Chemical Characteristics of Yoghurts

The results of the chemical and physical analyses of the yoghurt samples during storage are presented in Table 2. Ewes' yoghurt had the highest total solids (18.59%), protein (7.02%) and ash (0.97%) contents whereas buffaloes' yoghurt had the highest fat (8.26%) content ($P<0.05$).

The mean pH values of ewes' and goats' yoghurts were higher than cows' and buffaloes' yoghurts (Table 2). Milk type and storage time affected significantly ($P<0.05$) titratable acidity of yoghurt samples. As shown in Table 2, ewes' yoghurt had the highest mean titratable acidity value but cows' yoghurt had the lowest mean value of titratable acidity. The lowest mean value of titratable acidity was found on day 1st of storage, but the highest value was found on day 28th of storage, and these differences were

Table 1. Mineral contents (mg/kg) of milks used in yoghurt production
Tablo 1. Yoğurt üretiminde kullanılan sütlerin mineral içerikleri (mg/kg)

Minerals	Milk Types			
	Cow	Buffalo	Ewe	Goat
<i>Major Elements</i>				
Ca	1137	1509	1512	1312
K	1359	1065	1077	1496
Mg	97	145	148	152
Na	335	334	457	469
S	497	684	948	817
P	869	1146	1209	1051
<i>Minor Elements</i>				
Fe	35.03	13.59	35.29	33.57
Mn	0.15	0.18	0.19	0.12
Ni	0.62	0.99	1.11	0.92
Zn	43	49	81	113

statistically ($P < 0.05$) significant.

The syneresis values of yoghurt samples were affected significantly ($P < 0.05$) by milk type and storage time and the changes were shown in *Table 2*. The mean syneresis values of yoghurts decreased ($P < 0.05$) on day 7 but showed an increase ($P < 0.05$) at day 14 followed by a decrease ($P < 0.05$) until day 28 of storage. Concerning the rheological properties of yoghurts, there were significant ($P < 0.05$) differences between yoghurt samples for apparent viscosities. The results showed that ewes' yoghurt had higher viscosity than the other yoghurts.

Mineral Composition

Table 3 shows the mean values of major and minor

elements in yoghurts and their changes during storage. Most of the major and minor mineral contents were in accordance with the ash contents of each yoghurt with a few exceptions (*Tables 2* and *3*). There were significant differences among the yoghurt samples in terms of major element contents such as Ca, K, Mg, Na, S and P (*Table 3*). The mean values of Ca in all the yoghurt samples were found to be higher than those of P values. However, the mean Ca and P contents were 1879 ppm and 1441 ppm in ewes' yoghurt as the maximum content, respectively. When examined the data presented in *Table 3*, it was observed that the mean values of major elements in yoghurts generally increased ($P < 0.05$) on day 7 but showed a decrease ($P < 0.05$) at day 14 followed by an increase ($P < 0.05$) until day 28 of storage. The highest mean value

Table 2. The mean values of some physical and chemical characteristics of yoghurts made from different milks and their statistical evaluations in terms of milk source and storage time

Tablo 2. Farklı sütlerden üretilen yoğurtların fiziksel ve kimyasal özelliklerine ait ortalama değerler ve süt çeşidi ile depolama süresi bakımından istatistiksel değerlendirmesi

Yoghurt Samples	Physical and Chemical Characteristics							
	Total Solids (%)	Ash (%)	Fat (%)	Protein (%)	Titrateable Acidity (%)	pH	Whey Separation (ml/25g)	Viscosity (cP)
Cow	12.12±0.14 ^a	0.72±0.02 ^a	3.91±0.13 ^a	3.56±0.14 ^a	1.01±0.08 ^a	4.05±0.11 ^a	8.32±1.54 ^d	3254±476 ^a
Buffalo	17.87±0.35 ^c	0.86±0.02 ^c	8.26±0.28 ^d	4.72±0.06 ^b	1.17±0.12 ^b	4.09±0.08 ^a	3.39±0.83 ^b	13302±1558 ^c
Ewe	18.59±0.20 ^d	0.97±0.03 ^d	6.66±0.21 ^c	7.02±0.19 ^d	1.52±0.15 ^c	4.16±0.11 ^b	1.51±0.51 ^a	21380±1077 ^d
Goat	15.06±0.11 ^b	0.84±0.02 ^b	5.35±0.22 ^b	4.81±0.12 ^c	1.14±0.08 ^b	4.17±0.11 ^b	6.48±0.52 ^c	6412±934 ^b
Storage Time (days)								
1	15.91±2.76 ^a	0.840±0.08 ^a	5.95±1.74 ^a	4.94±1.25 ^a	1.09±0.18 ^a	4.26±0.07 ^c	4.77±2.45 ^b	10033±7221 ^a
7	16.12±2.78 ^b	0.853±0.08 ^b	6.26±1.88 ^c	5.03±1.31 ^{ab}	1.15±0.20 ^b	4.16±0.08 ^b	4.31±2.47 ^a	10817±7169 ^b
14	15.84±2.76 ^a	0.846±0.09 ^{ab}	6.05±1.69 ^b	4.96±1.33 ^a	1.18±0.19 ^b	4.12±0.07 ^b	5.68±3.41 ^c	10948±7651 ^{bc}
21	15.83±2.70 ^a	0.854±0.12 ^b	6.07±1.61 ^b	5.11±1.47 ^b	1.27±0.21 ^c	4.03±0.08 ^a	5.02±3.35 ^b	12533±7905 ^d
28	15.84±2.69 ^a	0.850±0.11 ^b	5.88±1.70 ^a	5.09±1.33 ^b	1.36±0.24 ^d	4.02±0.03 ^a	4.85±2.93 ^b	11104±7409 ^c

¹ Means are average of two trials. Different letters indicate ($P < 0.05$) between yoghurt samples and days of storage

Table 3. Mineral contents (mg/kg) of yoghurts made from different milks and their statistical evaluations in terms of milk source and storage time

Tablo 3. Farklı sütlerden üretilen yoğurtların mineral içerikleri(mg/kg) ve süt çeşidi ile depolama süresi bakımından istatistiksel değerlendirmesi

Yoghurt Samples	Mineral Substances									
	Major Elements				Minor Elements					
	Ca	K	Mg	Na	S	P	Fe	Mn	Ni	Zn
Cow	1268±232 ^a	1571±295 ^b	114±16.80 ^a	390±58.30 ^a	683±110 ^a	921±181 ^a	18.84±5.75	0.16±0.11	0.97±0.49	60.68±24
Buffalo	1697±152 ^{bc}	1164±101 ^a	156±15.14 ^b	344±27.08 ^a	866±153 ^b	1175±69 ^b	13.57±8.34	0.15±0.06	1.11±0.47	63.95±22
Ewe	1879±378 ^b	1133±206 ^a	186±32.63 ^b	567±95.70 ^b	1229±286 ^c	1441±300 ^c	12.79±10.44	0.19±0.07	1.16±0.43	72.99±21
Goat	1643±438 ^b	1800±524 ^b	187±42.38 ^b	568±133.8 ^b	1014±274 ^b	1188±281 ^b	16.79±12.38	0.14±0.07	0.97±0.49	75.03±38
Storage Time (days)										
1	1403±252 ^a	1211±295 ^a	135±29.84 ^a	399±81.09 ^a	737±188 ^a	108±166	27.67±12.86 ^b	0.23±0.07 ^b	1.07±0.42	71.46±37
7	1701±397 ^{bc}	1752±685 ^b	177±54.22 ^b	530±199.9 ^b	923±284 ^b	1249±313	15.98±11.43 ^a	0.17±0.08 ^{ab}	0.89±0.55	111.13±36
14	1490±325 ^{ab}	1363±303 ^a	153±29.35 ^{ab}	445±101.1 ^{ab}	900±249 ^{ab}	1093±242	11.54±9.53 ^a	0.12±0.06 ^a	0.92±0.27	60.48±22
21	1678±493 ^{abc}	1407±223 ^a	167±43.49 ^b	473±129.5 ^{ab}	1029±331 ^{bc}	1193±387	8.58±3.69 ^a	0.13±0.07 ^a	1.00±0.42	73.26±28
28	1836±320 ^c	1353±318 ^a	169±39.88 ^b	488±120.8 ^b	1152±283 ^c	1283±297	13.72±9.73 ^a	0.17±0.08 ^{ab}	1.38±0.54	69.57±29

¹ Means are average of two trials. Different letters indicate ($P < 0.05$) between yoghurt samples and days of storage

of K (1800 ppm) was found in goats' yoghurt whereas the highest Na contents were determined in ewes' (567 ppm) and goats' (568 ppm) yoghurts. Of the minor elements, Mn and Ni were found at higher in ewes' yoghurt. No significant differences ($P>0.05$) were observed among Fe, Mn, Ni and Zn contents in all yoghurts.

Counts of Yoghurt Bacteria

The mean viable counts of *S. thermophilus* and *L. delbrueckii* spp. *bulgaricus* in the yoghurt samples and the changes during storage are shown in Table 4. The effect of milk type on *S. thermophilus* counts was found to be significant ($P<0.05$).

Sensory Results

Results of the sensory evaluation of cows', ewes', goats' and buffaloes' yoghurts on a scale from 1 (very bad) to 9 (excellent) are shown in a radar plot in Figs. 1a, b, c and d, respectively. In general, cows' and ewes' yoghurts received similar scores by panelists for odor, taste and aroma and general acceptability characteristics. Goats' yoghurt was the least acceptable for its non-typical yoghurt taste and liquid texture. Ewes' yoghurt received the highest texture scores and it was parallel to its viscosity values.

Table 4. The mean counts (log cfu/g) of yoghurt bacteria counts of yoghurts made from different milks and their statistical evaluations in terms of milk source and storage time

Table 4. Farklı sütlerden üretilen yoğurtların ortalama yoğurt bakterisi sayıları (log kob/g) ve süt çeşidi ile depolama süresi bakımından istatistiksel değerlendirmesi

Yoghurt Samples	Yoghurt Bacteria	
	<i>L. bulgaricus</i>	<i>S. thermophilus</i>
Cow	8.10±0.52 ^a	8.18±0.36 ^c
Buffalo	8.17±0.30 ^a	8.49±0.32 ^d
Ewe	7.99±0.36 ^a	7.20±0.50 ^a
Goat	8.19±0.30 ^a	7.66±0.43 ^b
Storage Time (days)		
1	8.29±0.22 ^{bc}	7.77±0.28 ^a
7	8.44±0.35 ^c	8.15±0.61 ^b
14	8.06±0.23 ^b	8.11±0.62 ^b
21	8.04±0.32 ^{ab}	7.84±0.65 ^{ab}
28	7.73±0.35 ^a	7.54±0.82 ^a

¹ Means are average of two trials. Different letters indicate ($P<0.05$) between yoghurt samples and days of storage

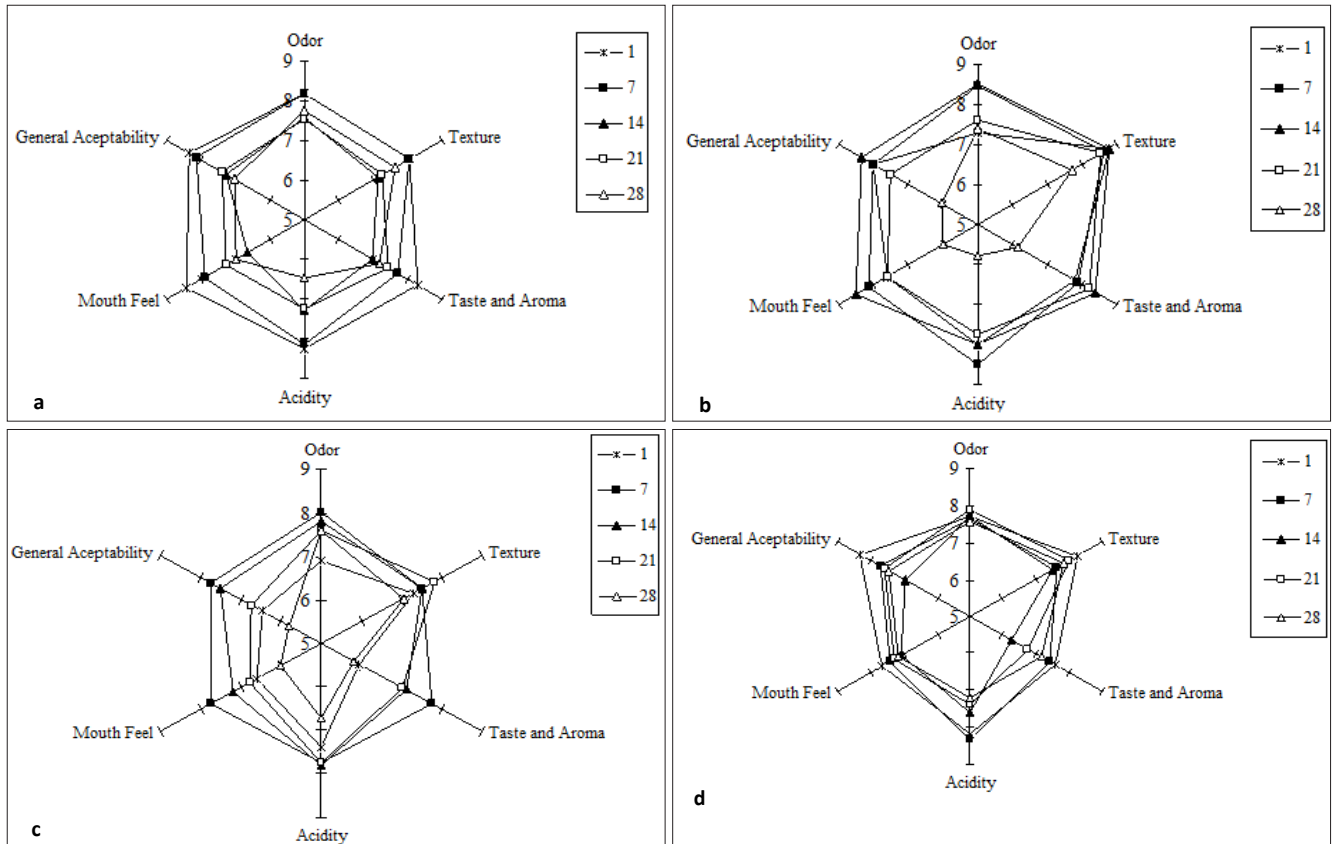


Fig 1. (a) Sensory profile of yoghurt made from cows' milk during storage (b) Sensory profile of yoghurt made from ewes' milk during storage (c) Sensory profile of yoghurt made from goats' milk during storage (d) Sensory profile of yoghurt made from buffaloes' milk during storage

Şekil 1. (a) İnek sütünden üretilen yoğurdun depolama süresince duyuşal deęerlendirmesi (b) Koyun sütünden üretilen yoğurdun depolama süresince duyuşal deęerlendirmesi (c) Keçi sütünden üretilen yoğurdun depolama süresince duyuşal deęerlendirmesi (d) Manda sütünden üretilen yoğurdun depolama süresince duyuşal deęerlendirmesi

DISCUSSION

Gross Chemical Composition of Yoghurt Samples

There were significant differences ($P < 0.05$) in the gross chemical composition of yoghurts due to source of milk used. The chemical composition of cows' yoghurt was lower than the others. The gross chemical values of yoghurts were similar to that found by Güler and Sanal¹⁵ in cows', ewes' and goats yoghurts.

Titrateable Acidity and pH

The pH values of all yoghurts significantly decreased from 4.26 to 4.02 throughout storage ($P < 0.05$). This could be attributed to further metabolic activity of starter cultures during storage²³. Although ewes' yoghurt had the highest mean pH value, it also had the highest titrateable acidity. This can be due to higher buffering capacity from increasing protein content in the milk²⁴. So, in this study a decrease in pH of yoghurts with increasing protein contents and an increase in acidity of yoghurts with increasing total solids were observed. The changes of pH and titrateable acidity values for yoghurts during storage were similar to those indicated in the literatures^{24,25}.

Syneresis and Viscosity

Syneresis, which defined as shrinkage of a gel occurs with expulsion of liquid, is a common defect in fermented milk products²⁶. The highest mean value of syneresis (8.32 mL/25g) was in cows' yoghurt and the lowest mean value (1.51 mL/25g) was in ewes' yoghurt. This could be related to total solids of the samples. It was reported that common reasons for the occurrence of syneresis include the use of a high incubation temperature, excessive whey protein to casein ratio, low solids content and physical mishandling of the product during storage and retail distribution²⁷. Vargas et al.²⁸ found that similar result in yoghurts made from mixtures cows' and goats' milks, suggesting that the addition of goats' milk led to lower syneresis.

The mean viscosity values of yoghurts increased up to 21st day but decreased at 28th day of storage (Table 2). This increase could be also depended on protein contents of yoghurts as well as total solids. On the contrary, Tarakçı²⁹ found that the viscosity values of yogurt samples decreased during storage period. The effect of different types of milks on viscosity and incubation time was studied by Jumah et al.³⁰. They found that sheep milk reached the highest viscosity value, followed by caprine and bovine milk. The differences in viscosity among types of milk appeared to be due to the differences in total solids contents of the milks. Because, the viscosity value of yoghurt rise with the increase of its total solid content.

Mineral Composition

Mineral analyses are essential for determining the

quality and safety of milk and milk products²⁰. Ewes' yoghurt showed higher mineral contents, mainly Ca, S and P than cows', goats' and buffaloes' yoghurt. As known, milk and milk products, especially ewes' milk and its products, are excellent dietary sources of Ca, P and Mg and they can provide a significant amount of calcium in a bioavailable form^{2,10,15}. Mg, is related to Ca and P function, may bind to the non-phosphorylated binding sites in the caseins¹¹. It has been reported that Mg absorption was faster with diets based on caseins, mainly β -casein, compared to those based on lactoserum proteins³¹. In this study, Mg contents in ewes' (186 ppm), goats' (187 ppm) and buffaloes' yoghurts (156 ppm) were determined similar, with cows' yoghurt (114 ppm) being the lowest. According to this, it can be recommended that commercial yoghurts manufactured from mostly cows' milk should be mixed with ewes', goats' and buffaloes' milks for providing enhancement of Mg absorption. The highest mean value of K was found in goats' yoghurt. These findings were similar to that reported by Güler and Şanal¹⁵. Raynal-Ljtovac et al.³² also reported that goats' milk was distinguished by its high K content. The levels of major elements obtained in this study were higher than values found by Stelios and Emmanuel³³ for goats' and ewes' yoghurts. In general, the results obtained in this study were accordance with the changes of ash contents of the yoghurts during storage.

The essential minor elements have four major functions as stabilizers, as essential elements for hormonal function, as elements of structure and as cofactors in enzymes³⁴. Of the minor elements, Fe and Zn were found at higher levels in cows' yoghurt (Table 3). Güler and Sanal¹⁵ also reported 0.72 ppm as the maximum content of Fe in cows' yoghurt. The mean minor element contents of yoghurt samples determined in this study were higher than reported by some researchers^{15,20}. This may be due to possibility of contamination from metal containers³⁵.

Counts of Yoghurt Bacteria

The viable counts of *S. thermophilus* were higher in buffaloes' yoghurt (8.49 log cfu/g) than in the other samples. This could be due to its high fat and fat soluble vitamins stimulate growth of microorganisms. The number of *S. thermophilus* and *L. delbrueckii* spp. *bulgaricus* significantly increased up to day 7 and decreased up to end of storage ($P < 0.05$). Similar results were reported by Güler-Akın and Akın³⁶. There were no significant ($P > 0.05$) differences between yoghurt samples in terms of the viable counts of *L. delbrueckii* spp. *bulgaricus*.

Sensory Evaluation

From Figs. 1 a, b, c and d it can be seen that the total scores of yoghurts decreased at 28th day of storage because of development of acidity and loss of structure. Although at the beginning of storage (1st and 7th days of storage) cows' and buffaloes' yoghurts received high scores for odor, taste

and aroma, mouth feel and general acceptability, ewes' and goats' yoghurts received lower scores. This could be related to more intensive favorable or unfavorable flavour of yoghurts at the beginning of storage. The yoghurt samples received similar scores for acidity characteristic and the scores decreased during storage. This result was accordance with the instrumental measurements.

In conclusion, the highest mean values of total solid, protein, and ash contents were found in ewes' yoghurt. However, the highest fat content was determined in buffaloes' yoghurt. The viscosity values of yoghurt samples were affected during storage by total solids, protein, pH and syneresis values. The highest Ca and P contents were determined in ewes' yoghurt. Therefore, ewes' yoghurt may be considered as an important source in respect to these elements. While cows' and ewes' yoghurts were received the highest scores, goats' yoghurt was the lowest scored by panelists due to its musky, rancid and goatly flavour.

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