European Journal of Agriculture and Food Sciences
Vol 5 | Issue 5 | October 2023
ISSN 2684-1827

RESEARCH ARTICLE

Investigation of the Physiochemical and Microbiological Quality of Fruit Yoghurt Sold in Elazig Province

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ABSTRACT

This study was conducted to determine some quality parameters of 25 fruit yoghurt samples (strawberry, forest fruit, blueberry, apricot, fig, mango, peach) sold in Elazig province. For this purpose, physicochemical (pH, acidity, fat, dry matter, starch, peroxidase, heat treatment) and microbiological [total mesophilic aerobic (TMA) bacteria, psychrotrophic bacteria, *Lactobacillus-Leuconostoc-Pediococcus* (LLP), lactic streptococcus, proteolytic and lipolytic microorganism, coliform, *Enterobacteriaceae*, *Escherichia coli*, *Staphylococcus-Micrococcus*, *Staphylococcus aureus*, *Salmonella* spp. and yeast-mold] analyzes of fruit yoghurt samples were performed. It was determined that 14 samples (8%) did not comply with the Turkish Food Codex Fermented Dairy Products Communiqué and TSE yoghurt standard regarding acidity value (% l.a.). The presence of starch in 91 (52%), peroxidase in 91 (52%) and heat treatment tests in 147 (84%) of the samples were positive. In the 161 (92%) samples coliform, *Enterobacteriaceae* and *Staphylococcus-Micrococcus*; and in the 154 (88%) of yeast and mold microorganisms were observed to be less than <1.0 $\log_{10}$ cfu/g of. Total psychrophilic bacteria, *E. coli*, *Staphylococcus aureus*, and *Salmonella* spp. have not emerged in any of these samples (<1.0 $\log_{10}$ cfu/g). There is only a statistical significance observed in Proteolytic bacteria between fruit yoghurt groups ($P < 0.05$). The lowest number (5.36 ± 0.10 $\log_{10}$ cfu/g) of proteolytic bacteria was observed in forest fruit; the highest (7.02 ± 0.52 $\log_{10}$ cfu/g) was determined in yoghurt with figs. As a result, it was concluded that the microbiological quality of the examined fruit yoghurt samples was not adequate for the hygienic conditions. It is thought that hygienic conditions were not considered during the production process and it could pose a risk to public health.

Keywords: Fruit flavored, microbiological quality, physicochemical quality, yoghurt.

Submitted: June 28, 2023

Published: October 17, 2023

10.24018/ejfood.2023.5.5.709

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1. Introduction

The tribes living as nomads in the Neolithic age kept the milk in containers made of soil or in overalls made of animal skin. With the increases in environmental temperature in milk kept in animal skin, the milk is naturally fermented and as a result, a yoghurt-like product is thought to be formed [1]. Yoghurt was mentioned to be discovered by the Turks and dates back to 800 AD. The first yoghurt was produced by the ancient nomadic Turks living in Asia [2].

Yoghurt is a fermented milk product obtained as a result of the fermentation of milk with *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*. According to the Turkish Food Codex (TFC) Fermented Dairy Products Communiqué [3], yoghurt is defined "as a specific starter culture in fermentation *Streptococcus thermophilus* and *Lactobacillus delbrueckii subsp. bulgaricus* is used together, and obtained in unbroken (set) or broken (stirred) form by mixing the curd after incubation, and containing a sufficient number of live and active starter bacteria at the expiration date".

The consumption of fermented milk products, especially yoghurt, is increasing day by day. Fruit-containing yoghurts have allowed yoghurt to spread to wider consumers [4]. Fruit yoghurt is also defined as in the

Fermented Dairy Products Communiqué; under the name of flavored fermented milk products, sugar and/or sweetener up to 50% by weight, fruits, and vegetables, their juices, purees, pulps, and preparations made from them and canned goods, cereals, honey, chocolate, nuts, coffee, spices composite dairy product containing non-dairy-based ingredients, such as flavoring foods and other counterfeit and non-tarnish flavorings [3]. Fruit yoghurt production involves similar steps to plain yoghurt production; however, the main difference in production is due to the addition of fruit. Yoghurt is a nutrient-rich in carbohydrates, fat, protein, vitamins, and minerals such as calcium and phosphorus [4], [5]. Besides yoghurt has an essential place in the daily diet due to the nutrients it contains, while if consumed regularly, it also has benefits such as cholesterol-lowering, bone development and bone resorption prevention, immune system support, protection against colon and rectum cancer, and tumor formation [6]–[8]. In dairy products, yoghurt constitutes 28% of the production in Turkiye. Turkish Statistical Institute (TSI) stated that yoghurt production in Turkey was 1,136,043 tons in 2019, 1,113,782 tons in 2020, 1,125,959 tons in 2021, and 1,169,280 tons in 2022 [9]–[11].

This study was carried out to examine the physicochemical and microbiological quality of 25 fruit yoghurt samples (strawberry, forest fruit, blueberry, apricot, fig, mango, peach) offered for sale in the province of Elazig.

2. Materials And Methods

Ethical Approvement: This study was conducted in Elazig province with the approval of the Firat University Non-Interventional Research Ethics Committee, dated 20.10.2022 and protocol number 2022/12-20.

2.1. Material

Samples of 25 fruit yoghurts (strawberry, forest fruit, blueberry, apricot, fig, mango, peach) (total of 175 fruit yoghurts) used in the study were obtained from different shops in Elazig. Samples were collected between 1 November 2022 and 31 March 2023. The yoghurt samples were brought to the laboratory in the cold chain (in an ice box) immediately (~20 minutes) and stored at 4 °C ± 1 °C until the samples were analyzed.

2.2. Method

Physicochemical Analyses: The pH values of the fruit yoghurt samples were measured with a pH meter (HI 11310, Hanna Instruments, USA) [12]. Total acidity (in terms of lactic acid), fat, dry matter analyses and peroxidase tests were performed according to TS 1330 [13]. The determination of starch in the samples was made according to the method suggested by Demirci and Gunduz [14], and the heat treatment control was performed according to the method specified by Tekinşen *et al*. [15].

2.2.1. Microbiological Analyses

For microbiological analysis, 10 g yoghurt samples were taken into a sterile stomacher bag. The 90 mL of sterile 0.1% peptone water (Acumedia 7365A, UK) was added and homogenized in a blender (BagMikser 400, France). Thus, a 10:1 (1/10) dilution of the sample was prepared. Other dilutions of the sample were prepared from this dilution, provided that the same diluent was used, and double series culturing was performed using 1 mL of each of these dilutions. At the end of the incubation period, petri dishes containing 30–300 colonies were evaluated [16], [17]. Plate Count Agar (PCA) (Merck 1.05463.0500, Darmstadt/Germany) was used for total mesophilic aerobic bacteria (TMAB) count and the petri dishes were incubated at 35 °C ± 1 °C for 24–48 hours [18]. Plate Count Agar (PCA) (Merck 1.05463.0500, Darmstadt/Germany) was used for total psychrophilic aerobic (TPA) bacteria count and the petri dishes were incubated at 5 °C–7 °C for 10 days [18]. De Man Rogosa and Sharpe (MRS) Agar (Neogen, NCM0190A, UK) was used to enumerate *Lactobacillus-Leuconostoc-Pediococcus* (LLP). Plates were incubated at 30 °C ± 1 °C for 72 hours and colonies that grew after incubation were counted [19]. The M17 Agar (Liofilchem 610192, Italy) was used for the enumeration of lactic streptococci and colonies formed after incubation of the plates at 30 °C ± 1 °C for 48–72 hours were evaluated [20], [21]. Calcium Caseinate (Conda Pronadisa, 1069.00, Madrid/Spain) was used for proteolytic bacteria enumeration and incubated at 30 °C ± 1 °C for 48 hours [20]. Tributyrin Agar (TBA) (Liofilchem, 610192, Italy) was used for the enumeration of lipolytic bacteria and incubated at 30 °C ± 1 °C for 48 hours [20]. Violet Red Bile (VRB) Agar (Merck, 1.01406.0500, Darmstadt/Germany) was used for coliform bacteria enumeration and the plates were incubated at 37 °C ± 1 °C for 24 hours [22]. Violet Red Bile Glucose (VRBG) Agar (LAB 88, UK) medium was used for the enumeration of *Enterobacteriaceae*. Plates were incubated for 24 hours at 37 °C ± 1 °C. At the end of the incubation, the dark red colonies formed on the plates were counted. For biochemical confirmation, the 5 colonies were randomly selected and subjected to the oxidase test (Liofilchem 88023N, Italy) [23]. Tryptone Bile X-Glucuronide (TBX) Medium Agar (Merck, 1.16122.0500, Darmstadt-Germany) was used for *Escherichia coli* enumeration. Petri dishes were incubated at 30 °C ± 1 °C for 4 hours and then at 44 °C ± 1 °C for 18 hours [24]. Baird Parker Agar (BPA) (Biokar, 055HA, France) added Egg Yolk Tellurit Emulsion (Himedia FD046, India) was used for the enumeration of *Staphylococcus-Micrococcus* microorganisms and incubated at 36 °C ± 1 °C for 30 hours. The number of coagulase (+) *Staphylococcus aureus* was determined by applying the coagulase test (Merck 1.13306.0001, Darmstadt/Germany) to gray-black, shiny colonies surrounded by a transparent zone growing in BPA medium [25], [26]. For analysis of *Salmonella* spp. ISO 6579 [27] procedure was followed. The 25 g samples were left to pre-concentration in 225 mL of buffered peptone water (Buffered Peptone Water) (Biokar, BK131HA, Beauvais/France) at 37 °C ± 1 °C for 18 hours. After pre-concentration, the 0.1 mL sample was added into 10 mL Rappaport-Vassiliadis Broth (LAB 86, UK) (24 hours at 41.5 °C ± 1 °C) and 10 mL Muller-Kauffmann Tetrathi-onate-Novobiocin Broth (Condalab, 1214.00, Madrid)-Spain) and incubated for 24 hours at 37 °C

TABLE I: Physicochemical Traits of Fruit Yoghurt Samples (Mean ± SEM) (n: 175)

		Fruits							
		Strawberry	Forest fruit	Blueberries	Apricot	Fig	Mango	Peach	P-value
pH	Min	4.20	3.98	4.02	4.45	4.20	4.15	4.25	0.054
	Max	4.44	4.38	4.48	4.68	4.64	4.27	4.35	
	X ± SEM	4.35 ± 0.05	4.23 ± 0.09	4.27 ± 0.10	4.56 ± 0.05	4.48 ± 0.14	4.21 ± 0.03	4.32 ± 0.03	
Acidity (l.a.%)	Min	0.68	0.77	0.70	0.63	0.72	0.86	0.72	0.813
	Max	1.46	0.97	1.51	1.51	1.13	0.97	0.83	
	X ± SEM	0.89 ± 0.19	0.85 ± 0.05	1.05 ± 0.17	1.05 ± 0.22	0.87 ± 0.13	0.93 ± 0.03	0.76 ± 0.04	
Fat (%)	Min	0.30	2.00	0.00	1.40	1.40	2.40	0.00	0.218
	Max	3.00	2.80	5.50	2.40	2.60	6.60	2.10	
	X ± SEM	2.23 ± 0.65	2.25 ± 0.19	3.30 ± 1.35	1.90 ± 0.24	2.13 ± 0.37	4.53 ± 1.21	1.40 ± 0.70	
Dry matter (%)	Min	16.63	20.45	17.46	14.48	17.80	21.18	18.18	0.104
	Max	23.75	21.46	26.99	23.52	20.37	39.99	20.75	
	X ± SEM	20.67 ± 1.50	20.92 ± 0.21	23.63 ± 2.18	19.17 ± 2.40	19.42 ± 0.81	29.25 ± 5.59	19.84 ± 0.83	

Note: **n:** Number of samples; **X:** Mean; **SEM**: Standard error mean.

± 1 °C. Cultures grown in broth were drawn with the aid of Xylose-Lysine-Deoxycholate (XLD) (Neogen, NCM0021A, UK) and Xylose-Lysine-Tergitol (XLT4; Neogen, NCM0100A, UK) Agar loop and were drawn at 37 °C ± 1 °C for 24–48 hour incubated. Dichloran Rose Bengal Chloramphenicol Agar (DRBC) (LAB 217, UK) was used for yeast and mold enumeration. Petri dishes were evaluated after 5 days of incubation at 25 °C ± 1 °C [28].

2.2.2. *Statistical Analyses*

Statistical analyses of the study were performed using the IBM® SPSS20 package program. Physicochemical and microbiological analysis data were analyzed with the One-Way ANOVA test, and starch, peroxidase, and heat treatment were analyzed with the Chi-Square independence test. Because equal variances are not being assumed, the Tamhane's T2 post-hoc test was used for multiple comparisons of fruit yoghurt groups. Microbiological data were converted to logarithms and expressed as $\log_{10}$ cfu/g. Chemical and microbiological analysis results were presented as mean ± standard error mean. Pearson correlation test was utilized in the correlation analysis of chemical and microbiological data of fruit yoghurt samples. The statistical significance level was accepted when $P \leq 0.05$ [29].

3. Results

The physicochemical analysis findings of the 25 fruit yoghurt samples are presented in Table I. The pH values of fruit yoghurts were 4.35 ± 0.05 in strawberry yoghurts, 4.23 ± 0.09 in forest fruit yoghurts, 4.27 ± 0.10 in blueberry yoghurts, 4.56 ± 0.05 in apricot yoghurts, 4.48 ± 0.14 in fig yoghurts, 4.21 ± 0.03 in mango yoghurts and 4.32 ± 0.03 in peach flavored yoghurt. The acidity value (% l.a.) was determined as 0.89±0.19% in strawberry yoghurts, 0.85±0.05% in forest fruit yoghurts, 1.05±0.17% in blueberry yoghurt, 1.05±0.22% in apricot yoghurt, 0.87±0.13% in fig yoghurt, 0.93±0.03% in mango yoghurt, 0.76±0.04% in the peach yoghurt. Fat (%) in fruit yoghurts analyzed in this study was determined 2.23±0.65% in strawberry yoghurts, 2.25±0.19% in forest fruit yoghurts, 3.30±1.35% in blueberry yoghurts, 1.90±0.24% in apricot yoghurts, 2.13±0.37% in fig yoghurts, 4.53±1.21% mango yoghurts, and 4.53±1.21% in peach-flavored yoghurt samples. Dry Matter was determined to be 20.67±1.5% in strawberry yoghurts, 20.92±0.21% in forest fruit yoghurts, 23.63±2.18% in blueberry yoghurts, 19.17±2.40% in apricot yoghurts, 19.42±0.81% in fig yoghurts, 29.25±5.59%

TABLE II: Chi-Square Table of Starch, Peroxidase and Heat Treatment Presence in Fruit Yoghurt Samples

	Starch				
Fruits	Positive	Negative	df	X^2	P-value
Strawberry	21	4	6	22.44	0.001
Forest fruit	14	11			
Bueberries	14	11			
Apricot	7	18			
Fig	7	18			
Mango	14	11			
Peach	14	11			
	Peroxidase				
Fruits	Positive	Negative	df	X^2	P-value
Strawberry	24	1	6	70.19	<0.001
Forest fruit	25	0			
Blueberries	7	18			
Apricot	7	18			
Fig	7	18			
Mango	7	18			
Peach	7	18			
	Heat treatment				
Fruits	Positive	Negative	df	X^2	P-value
Strawberry	22	3	6	6.55	0.365
Forest fruit	25	0			
Blueberries	20	5			
Apricot	20	5			
Fig	20	5			
Mango	20	5			
Peach	20	5			

Note: **df:** degree of freedom, $\mathbf{X^2}$: Table chi-square value.

TABLE III: Microbiological Analysis Findings of Fruit Yoghurt Samples (log_{10} cfu/g) (n: 175)

Microorganism		Fruits							P-value
		Strawberry	Forest fruit	Blueberries	Apricot	Fig	Mango	Peach	
TMA	Min	6.00	6.00	6.79	8.55	5.18	6.72	5.17	0.364
	Max	9.11	8.46	9.27	9.22	8.95	8.86	8.97	
	X ± SEM	7.75 ± 0.65	6.88 ± 0.54	8.40 ± 0.55	8.92 ± 0.15	6.91 ± 1.10	8.10 ± 0.69	7.69 ± 1.26	
TPA	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.000
	Max	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
LLP	Min	8.01	7.63	7.24	8.32	7.57	7.31	7.30	0.155
	Max	9.11	8.75	9.20	9.18	8.66	7.77	8.35	
	X ± SEM	8.53 ± 0.27	8.36 ± 0.25	8.61 ± 0.46	8.76 ± 0.20	8.15 ± 0.32	7.56 ± 0.13	7.92 ± 0.32	
Lactic streptococcus	Min	8.25	7.77	7.38	8.45	7.67	7.65	7.48	0.181
	Max	9.25	9.15	9.26	9.18	8.67	7.97	8.46	
	X ± SEM	8.85 ± 0.21	8.70 ± 0.32	8.72 ± 0.44	8.70 ± 0.17	8.24 ± 0.30	7.82 ± 0.09	8.06 ± 0.30	
Proteolytic	Min	6.25	5.17	4.48	5.59	6.00	5.00	5.48	0.049
	Max	6.57	5.65	6.20	7.71	7.65	6.35	6.23	
	X ± SEM	6.41 ± 0.07	5.36 ± 0.10	5.67 ± 0.40	6.68 ± 0.57	7.02 ± 0.52	5.68 ± 0.40	5.87 ± 0.22	
Lipolytic	Min	4.60	4.30	4.25	5.20	4.00	4.32	4.59	0.387
	Max	6.56	5.47	5.58	7.47	7.10	6.22	6.19	
	X ± SEM	5.65 ± 0.45	4.97 ± 0.24	4.93 ± 0.33	6.36 ± 0.64	5.99 ± 1.00	4.98 ± 0.62	5.19 ± 0.50	
Coliform	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.633
	Max	<1.0	<1.0	1.95	3.39	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	1.20 ± 0.25	1.56 ± 0.61	<1.0	<1.0	<1.0	
Enterobacteriaceae	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.612
	Max	<1.0	<1.0	1.60	3.28	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	1.11 ± 0.16	1.53 ± 0.58	<1.0	<1.0	<1.0	
E. coli	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.000
	Max	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Staph.-Micro.	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.555
	Max	<1.0	<1.0	1.89	2.0	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	1.19 ± 0.24	1.21 ± 0.26	<1.0	<1.0	<1.0	
Staphylococcus aureus	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.000
	Max	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Salmonella spp.	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.478
	Max	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Yeast-mold	Min	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.000
	Max	<1.0	<1.0	4.71	3.7	<1.0	<1.0	<1.0	
	X ± SEM	<1.0	<1.0	1.89 ± 0.94	1.93 ± 0.65	<1.0	<1.0	<1.0	

Notes: **n:** Number of samples; **X:** Mean; **SEM:** Standard error mean; **TMA:** Total Mesophilic Aerobe; **TPA:** Total Psychrophilic Aerobe; ***LLP*:** *Lactobacillus-Leuconostoc-Pediococcus*; ***Staph.-Micro*.:** *Staphylococcus-Micrococcus*.

in mango yoghurts and 19.84±0.83% in peach yoghurts in this study. There is no statistical significance between the groups regarding physicochemical properties ($P > 0.05$). In Table II, the presence of starch, peroxidase, and heat treatment is shown. The starch and peroxidase were found to be statistically different between the groups ($P \leq 0.05$). There was no statistical difference between the fruit yoghurt groups in terms of heat treatment ($P > 0.05$) (Table II).

The microbiological analysis findings (log_{10} cfu/g) are presented in Table III. The total number of mesophilic aerobic (TMA) bacteria was determined between the 5.18–9.27 log_{10} cfu/g. TMAB counts were in strawberry yogurts 7.75 ± 0.65 log_{10} cfu/g, forest fruit yogurts 6.88 ± 0.54 log_{10} cfu/g, blueberry yogurts 8.40 ± 0.55 log_{10} cfu/g, apricot yogurts 8.92 ± 0.15 log_{10} cfu/g, fig yogurts 6.91 ± 1.10 log_{10} cfu/g, mango yogurts 8.10 ± 0.69 log_{10} cfu/g. It was determined as 7.69 ± 1.26 log_{10} cfu/g in peach-flavored yogurts. There was no statistical significance in TMAB between the groups ($P > 0.05$). There is only a statistical significance observed in proteolytic bacteria between fruit yoghurt groups ($P < 0.05$). The lowest number (5.36 ± 0.10

TABLE IV: Distribution of General and Special Microorganisms in Fruit Yoghurt Samples (log_{10} cfu/g)

	<1.0		1.0–1.99		2.0–2.99		3.0–3.99		4.0–4.99		5.0–5.99		6.0–6.99		7.0–7.99		8.0–8.99		<9.0	
Microorganism	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
TMA	-	-	-	-	-	-	-	-	-	-	14	8	49	28	7	4	77	44	28	16
TPA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LLP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49	28	91	52	28	16
Lactic streptococcus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49	28	84	48	42	24
Proteolytic	-	-	-	-	-	-	-	-	7	4	77	44	63	36	28	16	-	-	-	-
Lipolytic	-	-	-	-	-	-	-	-	56	32	56	32	35	20	21	12	-	-	-	-
Coliform	161	92	7	4	-	-	7	4	-	-	-	-	-	-	-	-	-	-	-	-
Enterobacteriaceae	161	92	7	4	-	-	7	4	-	-	-	-	-	-	-	-	-	-	-	-
Escherichia coli	175	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Staph.-Mic.	161	92	7	4	7	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Staph. aureus	175	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella spp.	175	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yeast-mold	154	88	-	-	7	4	7	4	7	4	-	-	-	-	-	-	-	-	-	-

Note: **n:** Örnek sayısı; **TMA:** Total Mesophilic Aerobe; **TPA:** Total Psychrophilic Aerobe ***LLP:*** *Lactobacillus-Leuconostoc-Pediococcus;* ***Staph. -Mic.:*** *Staphylococcus-Micrococcus*.

log_{10} cfu/g) of proteolytic bacteria was observed in forest fruit; the highest (7.02 ± 0.52 log_{10} cfu/g) was determined in yoghurt with figs. Distribution of general and specific microorganisms in fruit yoghurt samples (log_{10} cfu/g) are presented in Table IV. The distribution ratio of *LLP* and lactic streptococci between 8.00–8.99 log_{10} cfu/g is 52% and 48%, respectively. The distribution ratio of proteolytic and lipolytic bacteria between 5.00–5.99 log_{10} cfu/g is 44% and 32%, respectively. The number of <1.0 log_{10} cfu/g for coliform, *Enterobacteriaceae*, and *Staph.-Mic*. were determined as 92%. *Escherichia coli, Staph. aureus* and *Salmonella* spp. were determined as 100% for <1.0 log_{10} cfu/g. The rate of those with a yeast and mold number <1.0 log_{10} cfu/g is 88%.

Pearson correlation coefficients of chemical and microbiological data of fruit yoghurt samples are presented in Table V. There was a statistically negative correlation between pH and the fat ($r = -0.445$) ($P \leq 0.05$), and a negative correlation between pH and proteolytic and lipolytic microorganisms ($r = -0.735$ and $r = -0.761$) ($P \leq 0.001$). A positive correlation was determined between acidity value and *LLP* bacteria ($r = 0.552$) ($P \leq 0.01$), lactic streptococci ($r = 0.442$) ($P \leq 0.05$) and yeast-mold ($r = 0.681$) ($P \leq 0.001$). Positive correlation between fat and dry matter value ($r = 0.720$) ($P \leq 0.001$) and negative correlation was determined between proteolytic ($r = -0.426$) ($P \leq 0.05$) and lipolytic ($r = -0.528$) ($P \leq 0.01$) microorganisms. In addition, a negative correlation was determined between dry matter value and proteolytic ($r = -0.484$) ($P \leq 0.05$) and lipolytic ($r = -0.567$) ($P \leq 0.01$) microorganism. It was observed that a positive correlation between *LLP* bacteria and lactic streptococci ($r = 0.901$) ($P \leq 0.001$) and yeast-mold bacteria ($r = 0.462$) ($P \leq 0.05$), and a positive correlation between proteolytic and lipolytic microorganism ($r = 0.841$) ($P \leq 0.001$) (Table V).

4. Discussion

Considering the pH value of the samples El-Bakri and El-Zubeir [30] found 4.68 in their study, Koçak [31] 4.32–4.82, Matter *et al*. [32] 4.63–5.42, Ufuk [33] found it to be 4.14–4.57 strawberry forest fruit, peach, and apricot fruit yoghurts. The findings are in agreement with the pH findings (3.98–6.68) that we found in this study. On the other hand, Kamber [34] found pH values as 3.80–4.62 in strawberry, peach, apricot, and banana fruit yoghurts, Karakus *et al*. [35] found it to be 3.85–4.62 in strawberry yoghurts, which is higher than the findings in the current study. The reason for the low pH value may be related to the disruptions in temperature and duration of the yoghurts during storage and transportation.

TABLE V: Pearson Correlation Coefficients of Chemical and Microbiological Data of Fruit Yoghurt Samples

	Acidity	Fat	DM	TMA	*LLP*	Lactic streptococcus	Proteolytic	Lipolytic	Yeast-mold
pH	0.134	−0.445*	−0.454*	0.103	0.238	0.184	−0.735***	−0.761***	0.279
Acidity	–	0.253	0.360	0.368	0.552**	0.442*	0.176	0.044	0.681***
Fat	–	–	0.720***	0.308	0.053	0.034	−0.426*	−0.528**	−0.053
DM	–	–	–	0.298	0.017	−0.032	−0.484*	−0.567**	0.120
TMA	–	–	–	–	0.353	0.204	−0.035	−0.033	0.350
LLP	–	–	–	–	–	0,901***	0.121	0.230	0.462*
Lactic streptococcus	–	–	–	–	–	–	0.112	0.223	0.275
Proteolytic	–	–	–	–	–	–	–	0.841***	−0.074
Lipolytic	–	–	–	–	–	–	–	–	−0.044

Note: *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$, **DM:** Dry matter; **TMA:** Total Mesophilic Aerobe; ***LLP:*** *Lactobacillus-Leuconostoc-Pediococcus*.

Acidity (%l.a) is an important factor in the formation of the unique aroma of yoghurt, preventing the development of pathogenic microorganisms and increasing the durability of yoghurt. Titration acidity comes from components such as albumin, globulin, phosphate, casein, carbon dioxide, and citrate contained in milk [36], [37]. The titration acidity in yoghurt is formed from lactic acid and other organic acids synthesized by lactic acid bacteria (LAB) during the fermentation of milk [38]. The titratable acidity value in terms of lactic acid has been reported as a minimum of 0.6% and a maximum of 1.5% in the Turkish Standards Institute yoghurt standard (2021) and Turkish Food Codex Fermented Dairy Products Communiqué [3]. When the fruit yoghurt samples analyzed in this study were evaluated according to the Turkish Standards Institute [3], it was determined that 161 (92%) samples complied with this standard; however, 14 (8%) samples did not comply with this standard. Kamber [34], Matter *et al*. [32], and Karakuş *et al*. [35] determined 0.79–1.49%, 0.89–1.80%, and 1.01–1.36% acidity values, respectively. These findings were in agreement with this study's findings (0.63–1.51%); however, it was determined to be higher than Ufuk's [33] findings which were 0.41–1.50%. It is thought that the differences in acidity values are due to the pasteurization degrees of fruit yoghurts, the LAB bacteria they contain, and their activation, incubation temperature, and duration.

Yoghurts are described as full-fat yoghurt (milk fat $\geq$ 3.8), half-fat yoghurt (2.0 > milk fat $\geq$ 1.5), and non-fat yoghurt (milk fat $\leq$ 0.5) in the Turkish Standards Institute [3] and in the Turkish Food Codex Fermented Dairy Products Communiqué [3]. The fat values in this study are consistent with studies of El-Bakri and El-Zubeir [30], Matter *et al*. [32], Wulansari and Kusmayadi [39], and Ufuk [33]. The differences in fat in this study are thought to be caused by the breed of the dairy cattle, their management (intensive and extensive), diet, and season.

The dry matter in this study was measured to be between 14.48–39.99%. The dry matter in this study was similar to the findings of Karakus *et al*. [35]; however, higher than the findings of Wulansari and Kusmayadi [39] and Ufuk [33]. The differences in the dry matter are may related to the composition of the raw milk used, the season in which the raw milk is obtained, the type of fruit, and the production (evaporation process, dry matter standardization) technique.

It has been reported that the presence of starch and peroxidase test results should be negative according to the Turkish Standards Institute yoghurt standard [3]. In addition, it was determined that 91 (52%) of the samples were positive for peroxidase and 147 (84%) heat treatment tests were positive in this study. In a similar study [31], the presence of starch was not determined in the yoghurt samples. Among the samples examined, the highest starch content was found in strawberry yoghurt, followed by forest fruit, blueberry, mango, and peach yoghurts, while the lowest starch content was found in apricot and fig yoghurts. In this study, the presence of peroxidase was detected at the highest rate in strawberry and forest fruit yoghurts. A similar rate of positivity was observed in all flavored yoghurt samples related to heat treatment.

Total mesophilic aerobic (TMA) bacterial count in this study was similar to the findings of El-Bakri and El-Zubeir [30]. However, it was found to be lower than the findings of some authors' studies [40], [32].

In this study, the total psychrophilic aerobic (TPA) bacteria count was <1.0 $\log_{10}$ cfu/g in all fruit yoghurt samples.

Lactobacillus-Leuconostoc-Pediococcus (*LLP*) are bacterial groups that play a role in the unique flavor and aroma of milk and dairy products. In the [10] and Turkish Food Codex Communique on Fermented Dairy Products [3], the total number of specific microorganisms is specified as at least 10^7 cfu/g. The findings of the current study differ from Ufuk's [33] study on *LLP* count in fruit yoghurts.

In this study, lactic streptococci counts were determined between 7.24–9.20 $\log_{10}$ cfu/g. The findings obtained from the analysis results in this study are not in agreement with the findings of the study conducted by Ufuk [33] (4.3–9.3 $\log_{10}$ cfu/g).

Coliform bacteria are microorganisms known as the hygiene index. Their presence in foodstuffs indicates that the heat treatment applied in production is insufficient, the water used in the company is contaminated and the hygiene conditions are not followed [41]. In this study, the number of coliform bacteria was found to be at least <1.0 $\log_{10}$ cfu/g and at most 3.39 $\log_{10}$ cfu/g in the yoghurt samples. El-Bakri and El-Zubeir [30] determined the number of coliform bacteria as 3.59 $\log_{10}$ cfu/g. Koçak [31] found coliform bacteria in 4 (20%) of the 20 yoghurt samples examined in his study. Ufuk [33] determined that 3 (3.03%) of 99 fruit yoghurt were not suitable for the Fermented Dairy Products Communiqué. The coliform bacteria in this study were found to be lower than the findings of Matin *et al*. [40] (4.01–4.65 $\log_{10}$ cfu/g).

In this study, *Escherichia coli* (*E. coli*) was detected as <1.0 $\log_{10}$ cfu/g in all fruit yoghurt samples. While Koçak [31] determined the number of *E. coli* at the level of <1.0 $\log_{10}$ cfu/g in his study; Ufuk [33] stated in his study that 2 of 99 fruit yoghurt samples (2.02%) were not suitable for Fermented Dairy Products Communiqué in terms of *E. coli* bacteria. Moreover, it was reported that fruit varieties added to yoghurts had an inhibitory effect of 12.8%–26.4% on *E. coli* and 63.8% on *S. aureus*. Yoghurts with peach and banana added did not adversely affect the growth of *E. coli* bacteria was reported.

Staphylococcus-Micrococcus bacteria counts were determined as at least <1.0 $\log_{10}$ cfu/g and at most 2.0 $\log_{10}$ cfu/g in the fruit yoghurt samples examined in this study. In addition, Staphylococcus aureus bacteria were not observed in these samples.

Salmonella spp. bacteria were also detected as <1.0 $\log_{10}$ cfu/g.

Yeast-mold bacteria consume some amount of the lactic acid in yoghurt, and enabling the growth of spoilage-causing microorganisms [42]. In the TFC Fermented Dairy Products Communiqué, the number of yeast-molds is specified as 2–3 $\log_{10}$ cfu/g [43]. In this study, yeast-mold count in fruit yoghurt samples was found to be minimum <1.0 $\log_{10}$ cfu/g and maximum 4.71 $\log_{10}$ cfu/g. While yeast-mold was not determined in 154 (88%) of the samples, yeast-mold was detected in 21 (12%) samples. The presence

of yeast-mold bacteria in the samples suggests that contamination may have occurred after the incubation stage in production and during packaging [40]. The microbiological analysis findings obtained in this study are in agreement with the study of El-Bakri and El-Zubeir [30] (3.15 $\log_{10}$ cfu/g). In some studies were found to be at a higher level than the findings of this study [40], [33].

5. Conclusion

In according to the current study, fruit or fruit-flavors supplementation did not affect the physicochemical properties of yoghurt. The low-fat content and the detection of hygiene indicator microorganisms (coliform bacteria, *E. coli* and yeast-mold) may indicate that high-quality raw milk is not used in yoghurt production. On the other hand, it is not applied to industrial yoghurt production methods and the hygienic quality of the packaging materials is unsuitable during the product's packaging. For these reasons, it was concluded that the analyzed fruit yoghurt samples may pose a potential risk to public health.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

Statement

This study was presented as an oral and abstract paper at the "European Conferences 1st International Conference on Health, Engineering and Applied Sciences, 5- May 2023, Bucharest-Romania".

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