Original scientific paper

UDK: 637.3.07

Effect of different drying methods on the quality attributes of probiotic-enriched cheese chips

DOI: 10.15567/mljekarstvo.2025.0302

Müctebanur Akkaya[1], *Mehmet Çelebi*[2]*, *Ayşe Özçelik*[1] *Bedia Şimşek*[1]

[1]Süleyman Demirel University, Faculty of Engineering and Natural Sciences, Department of Food Engineering,
32260, Isparta, Turkiye
[2]Aydın Adnan Menderes University, Faculty of Engineering Department of Food Engineering, Aydın, Turkiye

Received: 29.12.2024. **Accepted:** 15.06.2025.

---

*Corresponding author: mehmet.celebi@adu.edu.tr

Abstract

In this study, the possibilities of producing probiotic-enriched cheese chips from White cheese (fresh) using various drying methods including natural air drying at 25 °C for 24 hours, microwave drying at 180 W for 120 seconds, and tray drying at 25 °C for 4 hours with an air velocity of 1.3 m/s were investigated. The aim was to examine the effects of different drying systems used in production on the viability of probiotic bacteria (*Lactobacillus acidophilus* (*LA-5*) and *Bifidobacterium animalis* subsp. *lactis* (*BB-12*) and the quality characteristics of probiotic-enriched cheese chips. Physicochemical, textural, volatile aroma components, sensory, and microbiological analyses were conducted on the produced cheese chips. The *LA-5* value nearest to natural air drying was achieved by a tray dryer (7.32 log CFU/g). One of the highest BB12 counts (6.15 log CFU/g) was found in chips samples that were dried with a tray dryer. The closest results to natural air drying in terms of preserving probiotic bacterial viability, overall acceptability scores, and textural properties were obtained using the tray drying method. In the chips produced by the microwave drying method, the total concentrations of volatile aroma components (alcohols, esters, and hydrocarbons) were found to be higher than in the other samples. The tray drying method can be considered an alternative to the natural air drying method in the production of probiotic-enriched chips.

Keywords: natural air drying; tray drying; microwave; probiotic; cheese chips

Introduction

Due to their balanced nutritional content and quick consumption, snacks have grown in production and consumption, making them a nutrient-dense food group. The production of snacks generally uses raw materials such as cheese, fruit, vegetables, and meat, but they can also be produced with the addition of probiotics and prebiotics to impart healthy functional properties (Ciurzyńska et al., 2019; Chudy et al., 2019).

White cheese is one of the most popular semi-hard, fresh, or matured cheeses consumed in the Balkans and Middle Eastern countries (Terzić-Vidojević et al., 2020). Cheese, considering its pH, fat content, oxygen level, and storage conditions, is a product that contributes more to the prolonged viability of probiotic microorganisms during its production and storage (Boylston et al., 2004).

Probiotics are live microorganisms that provide significant health benefits when consumed in certain amounts (Mafaldo et al., 2022). In general, a minimum of 10^6 CFU/g and a daily consumption of at least 100 g are recommended for the application of *Lactobacillus acidophilus*, *Bifidobacteria* spp., and other probiotic microorganisms in the food industry (Boylston et al., 2004). Cheeses, vegetables, grains, and fruits, etc., produced with the addition of probiotics and prebiotics, have started to be used in the production of healthy snacks (Feitoza et al., 2023). Kaan et al. (2024) evaluated the changes in the properties of snack foods by drying cottage cheese enriched with probiotic bacteria (*Lactobacillus acidophilus*) using vacuum dryers at different temperatures.

In the chips production processes, drying, frying, and baking techniques are widely used. In drying technology, there are systems such as microwave drying, sun drying, spray drying, vacuum drying, conventional drying, puff drying, freeze drying, or systems that use these methods in combination (Gurcan, 2023). Drying techniques (vacuum oven dryer, microwave) are used in some products produced in the field of dairy technology (Lor cheese, Kurut, etc.) (Anli, 2020; 2022). However, the high temperature, mechanical processes, dehydration, and osmotic pressure that occur during the drying process can cause the death of probiotics and other cells in fermented products (Akan and Kınık, 2015). The freeze-drying technique is frequently used in the production of probiotic-enriched fruit and vegetable snacks to preserve the viability of probiotics (Feitoza et al., 2023). However, freeze-drying has a high cost, and a slow dehydration rate compared to other drying methods (microwave drying, vacuum drying, etc.) (Ciurzyńska et al., 2020). The drying mechanism varies according to the moisture content of the food, the applied temperature-time relationship, the drying environment, and the type of dryer used. Recently, snack cheeses, cheese bars, and cheese chips have also been frequently studied, and the different drying methods used in their production are being researched (Chudy et al., 2019; Köprüalan, 2019; Gurcan, 2023). Some studies have also been conducted on kefir tarhana chips (Erinç and Çiftçi, 2018) and non-probiotic cheese chips (Albay et al., 2021; Uğur and Şimşek, 2021; Albay et al., 2024).

The subject of this study is to determine how the quality of probiotic-enriched cheese chips (PECC) produced from White cheese (fresh) is affected by using different drying systems (natural air drying, tray dryer, and microwave). For this purpose, PECC samples were examined in chemical, physicochemical, textural, microbiological properties, and also volatile aroma compounds.

Materials and methods

Materials

The full-fat raw cow's milk used in probiotic White cheese chips production was obtained from the Isparta Milk Union-Isparta, Türkiye. Raw cow's milk was transported to Suleyman Demirel University, Food Engineering Department Laboratory (within 1 hour at 4 °C) and used for White cheese production. The constituents of raw cow's milk utilized in chips manufacturing are as follows: Specific gravity 1.029±0.001 g/cm^3, pH 6.66±0.14, titration acidity (% lactic acid) 0.18±0.01 %, dry matter 12.84±0.19 %, ash 0.60±0.01 %, fat 4.15±0.05 %.

In this study, mesophilic starter cultures (*Lactococcus lactis* subsp. *cremoris, Lactococcus lactis* subsp. *lactis;* R-707®, FD-DVS, Chr. Hansen-Denmark) and probiotic starter cultures (*Lactobacillus acidophilus* (LA-5); FD-DVS nu-trish® LA-5®-Chr. Hansen A/S-Denmark) and (*Bifidobacterium animalis* subsp. *lactis* (BB-12); FD-DVS nu-trish® BB-12®-Chr. Hansen A/S-Denmark) were utilised. The coagulating enzyme, liquid cheese rennet manufactured by Chr Hansen A/S-Denmark under the brand "Naturen® Mandra 175" (extracted from calf stomach, including 77-84 % chymosin and 16-23 % pepsin), was used.

Methods

White cheese and probiotic cheese chips production

The raw milk (60 L) obtained for White cheese (fresh) to produce PECC was pasteurized without fat standardization at 72±1 °C for 2 minutes in cooking pots. Thereafter, the milk was cooled to 30-32 °C and 0.02 % $CaCl_2$ was added to the milk. Following this, freeze-dried mesophilic (1 g/100 L) and probiotic (LA-5 and BB-12 1 g/100 L) cultures were directly put into the milk. The milk clotting activity test determined the amount of enzyme to be added to the cheese milk to ensure clotting within 90 minutes (175 IMCU L^{-1}). Then steps of curd cutting, draining, and pressing were performed respectively (Aktosun, 2023). Approximately 12 kg of White cheese (fresh) was produced, and 2 % salt was added to it, and the salty cheese was kneaded by hand. After 35-40 minutes of kneading, the samples were brought to a dough consistency and used to produce chips. The chips doughs were rolled out to the thickness of a thin pastry, cut with a mold, and shaped into round chips. The White cheese and probiotic-enriched cheese chips were produced as shown in Figure 1.

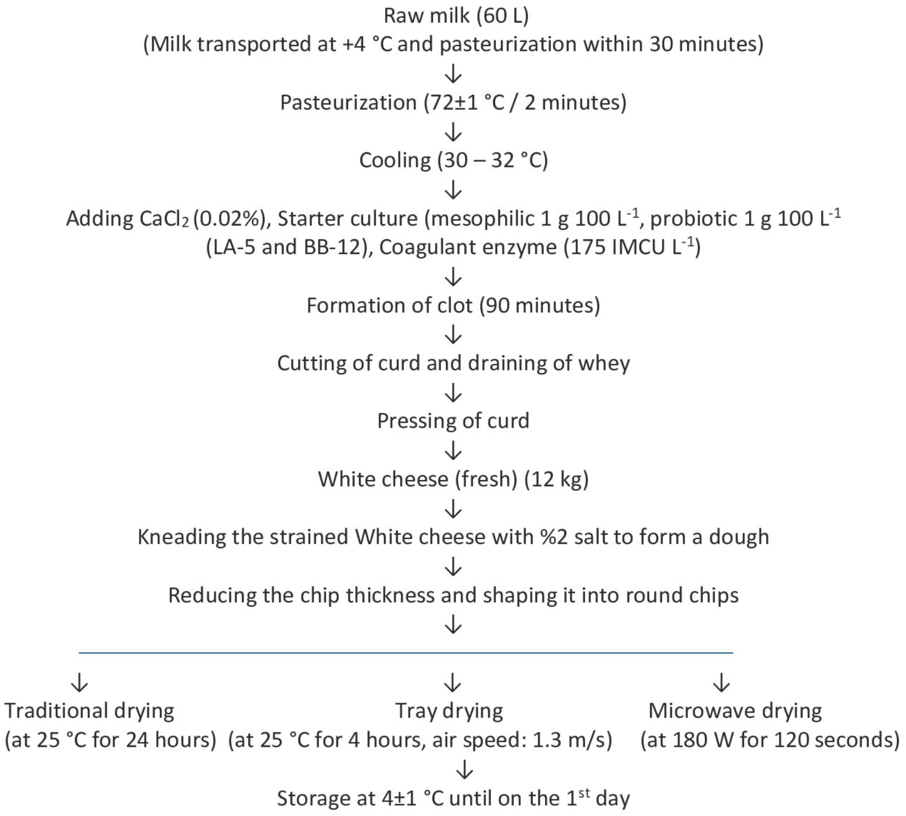

Figure 1. Flow diagram of probiotic-enriched White cheese chips

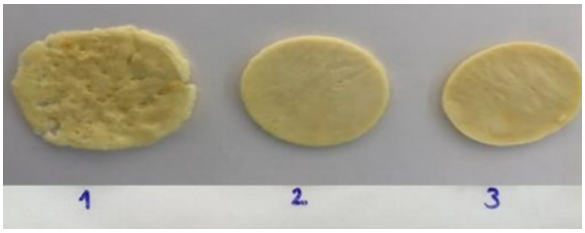

Figure 2. Probiotic cheese chip samples (1: Microwwave Dried Probiotic Cheese Chips (M), 2: Natural Air Dried Probiotic Cheese Chips (G), 3: Tray Dried Probiotic Cheese Chips (T))

Afterwards, the samples shaped were divided into three groups and dried using 3 different drying systems (Figure 2): Microwave (M) drying at 180 W for 120 seconds (Bosch 5870 GH, Germany), Natural air drying (G) at 25 °C for 24 hours, and Tray dryer (T) at 25 °C for 4 hours (1.3 m/s air speed, Microtest MSD2.50.D8-Turkey). Cheese and chips production was performed in triplicate. The chips were stored at 4±1 °C and analysed on the 1st day.

Raw milk and white cheese analyses

The pH (WTW pH 315, Weilheim, Germany), dry matter (%), fat (%), and ash (%) contents were analysed in raw milk and unsalted fresh White cheese, following AOAC (1997) methods. Total aerobic mesophilic bacteria, lactobacilli, lactococcus, and probiotic bacteria *(BB-12*, and *LA-5)* counts were performed in White cheese (Albay, 2022).

Probiotic-enriched cheese chips analyses

Physicochemical analyses

The thickness and diameter measurements of PECC were performed using a digital caliper (0.001 mm, Mitutoyo, Tokyo, Japan)(AACC, 2000). The pH values of the cheese chips were measured with a digital pH meter (WTW pH 315, Weilheim, Germany). The dry matter and ash (%) content was analysed by the gravimetric method, the fat content (%) by the Gerber method. The salt content of the samples was determined using the Mohr titration method (AOAC, 1997).

Color analysis and texture analysis

The *L** (darkness=0/lightness=100), *a** (-green/+red), and *b** (-blue/+yellow) color values of the chips samples were assessed with a Minolta Chroma Meter CR-400, (Japan). The calibration of the color measurement device was performed before each measurement according to the values specified on the calibration plate: C (Y: 92.7, x: 0.3135, y: 0.3193) and D65 (Y: 92.7, x: 0.3160, y: 0.3321). Color measurements were taken from three different points on both surfaces of three randomly selected cheese chips (In particular, care was taken not to take measurements in the porous areas of the microwave chips.).

The texture analysis of the chips samples was performed using the Texture Stable Micro Systems, TA-XT Plus, a texture analysis device from the UK. The three-point bending test was conducted using a Three Point Bend Rig probe (A/3PBT). The maximum force value applied to the chips samples has been correlated with the hardness value, while the deformation value at which the maximum force is applied has been associated with the brittleness value. The hardness (N) and brittleness (mm) values of the chips samples were determined. The probe speed (1 mm/s) and the distance between the probe and the surface of the chips (7 mm distance) were determined, and 3 parallel measurements were performed for each sample.

Microbiological analyses

A 10 g of cheese or cheese chips were mixed with 90 mL of sterile Ringer's (1/10) solution, and 1 mL of this dilution was then transferred into 9 mL of sterile Ringer's solution in aseptic conditions. Afterward, repeated dilutions were formulated. Samples were analysed for bacterial count by using the spread plate procedures. The MRS-NNLP agar medium, comprising nalidixic acid (50 mg/L), neomycin sulphate (100 mg/L), lithium chloride (3000 mg/L), and paromomycin sulphate (200 mg/L), was utilised for the enumeration of *Bifidobacterium* BB12. The previously NNLP mixture was blended with sterile MRS agar medium (de Man, Rogosa, and Sharpe, and Merck, Germany), which was sterilised using a 0.45 µm disposable sterile filter just before being poured into petri plates. Petri plates were incubated for 72 hours at 37 °C within anaerobic jars. MRS-Sorbitol agar was employed to enumerate *LA-5*. Before the incorporation of sorbitol, MRS agar was sterilised, and a 10 % (w/v) D-Sorbitol solution (10 mL) was introduced to 90 mL of MRS agar medium utilising a sterile 0.45 µm filter. Petri plates were incubated for 72 hours at 37 °C in anaerobic jars (Dave and Shah, 1997). Anaerobic kits from Anaerocult (Merck, Germany) were utilised to establish the anaerobic environment. Lactobacilli were enumerated utilising MRS agar. Petri plates were incubated for 72 hours in an anaerobic chamber at 37 °C. Following 48 hours of aerobic incubation at 37 °C, lactococci were enumerated on M17 agar (Gardini et al., 1999). Microbiological count results are presented as log CFU/g following a logarithmic adjustment.

Volatile aroma component analyses

Cheese chips samples were stored at -20 °C until aroma analysis was performed, and then the analysis was applied to the samples brought to room temperature. For the analysis, a 15 mL volume silicone vial (Supelco 27159 mL clear PTFE/Silicone septa Cap) was used, and a 3.0 g chips sample was placed in it and kept at 45 ºC for 15 minutes. (non-fiber). The extraction process was carried out using a 75 µm carboxen®/polydimethylsiloxane (CAR/PDMS) (Fused Silica, Supelco Ltd., Bellefonte, PA, USA) fiber-vial injection. The volatile aroma compounds in the chips samples were performed using a Shimadzu GC-2010 gas chromatography-QP-2010 plus mass spectrometry (GC-MS) system (Shimadzu Corporation, Kyoto, Japan). The detector is the Shimadzu GCMS-QP2010SE (Shimadzu Corporation, Kyoto, Japan). In the separation of compounds, the Rx-5sil MS (30 m x 0.25 mm, i=0.25 µm film thickness; Restek, Bellefonte, catalog No:13623, PA, USA) was used as a column. Initially, the temperature was kept at 40 ºC for 2 minutes and reached 250 ºC with an increase of 4 °C per minute. It was kept at 250 °C for 5 minutes. (Injector and detector temperatures were 250 °C - detector voltage, 70 eV). As a carrier gas, helium was used at a flow rate of 1.61 ml/min. GC-MS analysis was conducted in scan mode set between 40-300 amu. SPME conditions were carried out by holding the fiberless for 15 minutes and the fiber for 30 minutes at 60 °C, followed by desorption at 250 °C (Catalog No: supelco 57318). Volatile compounds were identified by comparing their "Retention Index" (RI) and mass spectra with analytical standards. The identified volatile compounds were verified using the Wiley-NIST (National Institute of Standards and Technology), Tutor, and FFNSC (Flavor and Fragrance Natural and Synthetic) mass spectrum libraries and RI values. RI was calculated using an alkane series for each compound (Frank et al., 2004).

Principal component analysis of sensory properties results and statistical analysis

Sensory analyses were conducted by a panel of 8 experienced assessors (6 women and 2 men) from the Department of Food Engineering at Süleyman Demirel University. Participants were briefed about the sensory evaluation for approximately 2 hours. All samples were presented with a three-digit code. Two different sensory analysis methods were used to evaluate the sensory quality parameters of cheese chips enriched with probiotic bacteria during storage. For the first evaluation, a numerical two-way (bipolar) scale ranging from 1 to 10 was used. Texture (softness-hardness, thickness structure, chewability, and crispiness-brittleness), appearance (whitish-yellow, matte-shiny, and mottled appearance), odor (foreign smell, burnt smell, and cheese smell), and taste (oily taste, grittiness-bland taste, burnt taste, and salty taste) parameters were analyzed. Secondly, a nine-point hedonic scale (1=did not like at all, 9=liked very much) was used to determine general acceptability (Lawless and Heymann, 2010). The samples were stored at 4±1 °C until the sensory analysis was conducted. Cheese chips samples were given to the panelists along with crackers and water.

In the statistical evaluation of the research, the SPSS (Ver. 22.0) statistical program was used for the analysis (DUNCAN, t-test). Analysis of variance was performed with three replications (n:3).

Principal component analysis was applied to the values of hardness, whitish-yellow, matte shiny, mottled appearance, thickness structure, chewability, crispiness-brittleness, foreign smell, burnt smell, cheese smell, oily taste, grittiness-bland taste, burnt taste, salty taste and the Xlstat trial version (XLSTAT 2023.2.1413.1413) was used for statistical data evaluation. As a result of PCA, the classification that emerged in chips samples was explained with scatter plots between the first two principal components PC1 and PC2 in the relevant sections.

Results and discussion

White cheese (fresh) analysis results

The average pH, dry matter (%), fat (%), and ash (%) values of the White cheese were found to be 5.04±0.09, 47.55±0.10 %, 27.50±0.50 %, and 0.91±0.01 %, respectively. Karahançer (2018) found the dry matter (%), pH, and fat (%) analysis results of the White cheese samples stored for 90 days to be 34.08-42.93 %, 4.69-4.86, 11.25-17.75 % on the 1st day, respectively. The findings obtained yielded results within a similar value range as those of Karahançer (2018). The mean analysis results of the White cheese for total mesophilic aerobic bacteria, *LA-5*, and *BB-12* were 8.15, 8.17, and 6.17, respectively (Table 1). In a study, the analysis values of *BB-12*, *LA-5*, and total mesophilic aerobic bacteria (TMAB) in probiotic White cheese samples were observed to be 7.58, 7.59, 8.72 log CFU/g, respectively, on the 7th day of storage (Şaşmazer, 2022).

Probiotic-enriched cheese chips analysis results

Physicochemical analysis results

In the study, when the diameter and thickness values of PECC were examined, it was found that after the drying process, their thickness ranged from 1.25 to 1.90 mm and their diameter ranged from 5.04 to 5.46 cm. (Table 2). It was determined that the sample with the lowest thickness (1.25 mm) and largest diameter (5.46 cm) among the samples was the sample M after drying (p<0.05). During microwave heating, an excessively heated steam formation occurs, which causes expansion due to the moisture in the food's composition and releases the necessary driving pressure (Arimi, 2008). It is thought that this steam formation may have caused the chips to expand in diameter. In a study on cheese chips, the diameter values were reported to be in the range of 4.75-5.10 cm, and the thickness in the range of 0.34-0.23 cm (Aktosun, 2023). The pH values of PECC were examined; the lowest pH value (5.09) was found in natural air drying (p<0.05). The pH values of the chips are consistent with those of other cheese chips studies (Albay et al., 2021; Aktosun, 2023). Probiotic microorganisms, particularly Lactobacillus strains, synthesize acetic, lactic, and propionic acid which decreases the pH (Şaşmazer, 2022). In PECC, the dry matter content was found to be between 79.18 and 81.73 % (Table 2). Albay et al. (2021) emphasized that they found the dry matter content of cheese chips produced from block-type processed cheese to be between 92.77 and 97.24 %. Due to the differences in the drying methods applied and the process (temperature and time) conditions, the dry matter results were found to be low from the Albay's (2022) findings.

The statistical analysis of the fat content in PECC (Table 1) revealed a significant difference between the samples (p<0.05). The fat content of the PECC is aligned with Uğur and Şimşek's (2021) results. However, it is believed that the samples produced from probiotic cheese using the microwave drying technique had significantly low-fat content, and this change is thought to be related to melting and fat leakage due to the heat generated. The difference in ash values between the samples was found to be statistically insignificant. Albay et al. (2021) associated the difference in ash content among the samples with the dry matter content. The lowest salt value was observed in chips produced by the microwave method (3.01 %) (p<0.05). The sample M, having the lowest % salt content, can be associated with visible liquid leakage from the samples during the microwave drying method. In this study, the salt values are aligned with Köprüalan's (2019) results.

Color and texture analysis results

As a result of the color analysis, it was determined that the sample G (82.67) and the sample T (81.58) have similar *L** values (Table 1). However, it has been determined that the microwave drying method significantly reduced lightness (p<0.05) and that sample M was less light (77.47). Albay et al. (2021) determined the *L** value of block-type processed cheese chips obtained from different microwave applications to be in the range from 53.87 to 67.24. The *L** values of chips made from white cheese are higher than the values given by Albay et al. (2021) due to the difference in the cheeses used as raw materials. It is stated that the color of Cheddar cheese puffs produced using microwave and vacuum drying methods is darker yellow due to the reduction in moisture content during drying (Rakcejeva et al., 2009). The *a** and *b** values of block melting cheese chips produced by Albay et al.

Table 1. *Microbiological analysis results of probiotic White cheese chips (log cfu/g) (n=3)*

Microbiological analysis	Raw material and drying methods**			
	W	M	G	T
Total mesophilic aerobic bacteria (TMAB)	8.15±0.05	4.99±0.36^{c*}	7.72±0.02^{a}	6.61±0.18^{b}
Lactobacilli	7.13±0.91	5.12±0.01^{b}	5.69±0.48^{b}	6.89±0.74^{a}
Lactococcus	8.11±0.21	5.09±0.66^{b}	7.47±0.16^{a}	6.96±0.34^{a}
LA-5	8.17±0.04	5.21±0.22^{b}	7.80±0.30^{a}	7.32±0.44^{a}
BB-12	6.17±0.19	3.79±0.14^{b}	6.04±0.10^{a}	6.15±0.24^{a}

**Different lower case letters indicate that the difference between the samples is significant (p<0.05).*
** G: Natural air drying at room temperature; T: Tray drying; M: Microwave drying; W: White cheese.*

(2021) were determined to be 9.77 and 13.36, respectively. In chips, effects such as browning and yellowness in color occur during cooking at high temperatures. In this study, the use of lower cooking parameters compared to other studies, to preserve the viability of probiotic bacteria, has resulted in different color values from those found by the researchers.

Texture, taste, and appearance are important criteria that affect the acceptability of snacks (Chudy et al., 2019). It was determined that among the PECC samples, M was harder (444.12 g) and sample G was more brittle (-2.31 mm) than samples T and M (Table 2). Chudy et al. (2019) reported the hardness value of 2.84-6.82 N and the brittleness value of 3.20-10.00 mm in the puff snacks produced from Harzer cheese. It has been reported that the hardness values of cheese chips produced from block-type processed cheese using a microwave oven dryer range from 384.66 to 520.92 g, and the brittleness values range from 36.60 to 37.28 mm (Albay et al., 2021). The texture values were determined to be different from the researchers' values. It is believed that this difference is due to the varying dry matter ratios in PECC compared to those of the researchers and the differences in drying methods.

Microbiological analysis results

The TMAB counts are accepted as a parameter that determines the storage time that affects the flavor and sensory properties of some freshly consumed cheeses (Irkin and Yalçın, 2017). TMAB count determined in PECC samples ranged between 4.99 log CFU/g and 7.72 log CFU/g ($p<0.05$) (Table 1). Karahançer (2018) found that the counts in the White cheeses produced with different starter culture combinations were between 6.36 and 9.37 log CFU/g, with a continuous decrease in these counts during the ripening period (90 days). In this study, it was observed that the TMAB counts were lower than those seen in White cheese due to the drying process applied. No data reported by researchers on TMAB counts in cheese chips was found. In the samples subjected to the tray drying process, slightly lower TMAB was detected, probably due to the shorter drying time compared to natural air drying ($p<0.05$). The lowest TMAB count in the study was observed in chips produced by microwave drying (4.99 log CFU/g). In a study, it was stated that the fat content in products subjected to microwave processing had a protective effect on bacterial viability, while the water content increased the lethal effect (Fung, 1980). In a study investigating the effect of microwave-vacuum, drying on the properties of curd cheese, it was reported that TMAB counts were 5.03-5.45 log CFU/g on the 15th day at 5 kPa vacuum and 189 and 315 W microwave powers (Anli 2020).

The lactococcal counts of the PECC were determined to be in the range of 5.09-7.47 log CFU/g (Table 1). The lowest value for the lactobacilli counts in cheese chips was observed in microwave-dried samples (5.12 log CFU/g), while the highest values were observed in naturally dried samples (5.69 log CFU/g) ($p<0.05$). In a study conducted by Daglioglu et al. (2002), the lactic acid bacteria count in the tarhana dried with hot air (7×10^3 CFU/g) was found to be higher than the lactic acid bacteria count in the tarhana dried with microwaves (3×10^2 CFU/g). In this study, similarly to this research, it was observed that the microwave drying method resulted in the lowest level of lactobacilli compared to the other two drying methods.

During the storage period of PECC, it was found that the numbers of *BB-12* and *LA-5* were similar between G and T samples, while the microwave drying method showed lower and statistically different values from these two drying methods ($p<0.05$). The *BB-12* counts and *LA-5* counts in PECC were found to be in the ranges of 3.79-6.04 log CFU/g and 5.21-7.80 log CFU/g, respectively. Hammam and Ahmed (2019) reported that the recommended number of active bacteria for probiotic microorganisms to have a positive effect on health should be between 10^5 and 10^7 CFU/g. In the chips samples, the number of *BB-12* was determined to be by these values in tray drying and natural air drying. However, in chips

Table 2. Physicochemical, color and texture analysis results of probiotic White cheese chips (n=3)

Samples		Drying methods***		
		M	G	T
Thickness (mm)	Before drying	1.81±0.08^{a**}	1.95±0.17^{a}	1.87±0.07^{a}
	After drying	1.25±0.14^{b}	1.90±0.21^{a}	1.75±0.25^{a}
Diameter (cm)	Before drying	4.96±0.01^{a}	4.92±0.02^{a}	4.92±0.12^{a}
	After drying	5.46±0.09^{b}	5.10±0.10^{a}	5.04±0.11^{a}
pH		5.17±0.02^{a}	5.09±0.02^{c}	5.14±0.02^{b}
Dry matter (%)		81.73±0.74^{c}	79.18±0.07^{a}	80.74±0.07^{b}
Fat (%)		34.5±0.25^{b}	36.25±0.25^{a}	36.0±0.50^{a}
Ash (%)		5.24±0.12^{a}	5.07±0.01^{a}	5.03±0.13^{a}
Salt (%)		3.01±0.06^{c}	3.81±0.03^{a}	3.55±0.02^{b}
*L**		77.47±0.74^{b}	82.67±0.16^{a}	81.58±0.92^{a}
*a**		-2.77±0.92^{a}	-2.67±0.02^{a}	-2.35±0.20^{a}
*b**		23.75±0.84^{a}	23.93±0.22^{a}	24.38±0.29^{a}
Hardness (N)		444.12±8.25^{a}	332.77±8.06^{b}	346.07±4.52^{b}
Brittleness (mm)		-3.38±0.49^{b}	-2.31±0.24^{a}	-2.44±0.12^{a}

***Different lowercase letters indicate that the difference between the samples is significant ($p<0.05$).*
****M: Microwave drying; G: Natural air drying at room temperature; T: Tray drying.*

dried using the microwave drying method, 3.79 log CFU/g of microorganisms were counted, and the 10^5-10^6 CFU/g range was not reached. *LA-5* counts were detected in all samples within the interval specified by Hammam and Ahmed (2019).

It is known that high microwave power applications in the microwave drying method cause microstructural damage. Additionally, the effect of the inter-molecular friction force generated by microwave heating causes pressure formation within the cell (Cui et al., 2018). It has been reported that osmotic pressure and very high temperature applications can cause probiotic cells to lose their viability (Akan and Kınık, 2015).

Table 3. *Aroma analysis values of probiotic White cheese chips*

Samples	**Drying methods***		
	M	**G**	**T**
Alcohols			
Ethanol (CAS) Ethyl alcohol	1.73	0.58	0.57
7-Etil-2-metil-4-undecanol	0.22	-	-
Total concentration	1.95	0.58	0.57
Esters			
Ethanol, 2-metoksi-, asetat (CAS) 2- Metoksietil asetat	1.16	0.47	0.28
Total concentration	1.16	0.47	0.28
Aldehydes			
Butanal, 3-methyl- (CAS) 3-methylbutanal	-	0.18	-
Nonanal (CAS) n-Nonanal	-	-	0.15
Total concentration	-	0.18	0.15
Carboxylic acids			
2-Propinoic acid	1.27	2.04^{a}	1.35
Acetic acid (CAS) Ethylic acid	68.90	70.79	63.60
Butanoic acid (CAS) n-Butyric acid	0.22	-	-
Total concentration	70.39	72.83	64.95
Hydrocarbons			
Benzene, methyl- (CAS) Toluene	0.24	0.18	-
2-Ethyl-1-hexane	0.53	0.21	-
Octane	3.24	1.53	0.77
Benzene, 1,4-dimethyl- (CAS) p-xilene	-	0.27	0.69
4-Methyl-1-decane	0.82	0.38	-
2-Ethyl-1-octane	0.52	0.27	-
2,2,4,6,6-Pentamethylheptane	5.59	3.74	1.94
1-Decene	0.57	0.36	-
Decane (CAS) n-Decane	3.74	2.09	1.10
2,2,4,4-Tetramethyloctane	0.92	0.64	0.39
3-Methylheptane	0.26	-	-
1-Octene (CAS) Caprilene	0.19	-	-
Dodecane (CAS) n-Dodecane	0.54	0.20	-
2,2,4,4,6,8,8-Heptamethylnonane	0.29	-	-
2,2,11,11-Tetramethyldodecane	0.32	-	-
Total concentration	17.77	9.22	4.89
Ketones			
2,3-Butandion (CAS) Diacetyl	1.20	3.62	14.87
2-Butanone, 3-hidroksi- (CAS) Acetone	1.90	9.95	3.24
3-Methyl-2-pentanone	1.51	-	10.74
2-Pentanone (CAS) Methyl propyl ketone	0.19	-	-
2-Heptanone (CAS) Heptan-2-on	0.50	-	-
Total concentration	5.3	13.57	28.85
Terpenes			
dl-Limonen	0.20	0.28	-
Total concentration	0.20	0.28	-
Other compounds			
Carbon disulfide (CAS) Carbon bisulfid	3.21	2.24	0.32
Toplam konsantrasyon	3.21	2.24	0.32

**G: Natural air drying at room temperature; T: Tray drying; M: Microwave drying*

Volatile aroma component analysis results

The volatile aroma compositions of PECC samples are presented in Table 3. A total of 30 volatile constituents were identified in chips samples. The volatile aroma components identified in the chips samples are as follows: alcohols (2), aldehydes (2), carboxylic acids (3), esters (1), hydrocarbons (15), ketones (5), terpenes (1), other components (1). As seen in Table 3, in sample M, alcohols, hydrocarbons, esters, and other components; in sample T, ketones; and in sample G, aldehydes, carboxylic acids, and terpenes were detected in higher amounts compared to other volatile components. In the production of PECC, starter cultures in the cheese can play a role in the breakdown of lipids and the formation of aroma compounds.

Alcohols

Alcohols, which can contribute to the taste of cheeses and cause the formation of a sweet, fruity, and strong aroma, were found at low levels in the chips samples (G, 0.58 %; T, 0.57 %; M, 1.95 %). In this study, ethanol was detected in all three samples. In samples produced specifically using a microwave, the ethanol content was found to be much higher (1.73 %). 7-Ethyl-2-methyl-4-undecanol was identified only in samples dried by microwave. Ethanol plays a crucial role in the formation of esters. It has been determined that it mostly occurs during the breakdown of lactose and the catabolism of the amino acid alanine (Gursoy et al., 2018). Additionally, the main source of ethanol in cheese is derived from citrate metabolism by *Lactococcus* spp. Aldehydes, which are key aroma components of fermented dairy products, are broken down into ethanol through the enzyme alcohol dehydrogenase. 7-Ethyl-2-methyl-4-undecanol is naturally found in many foods, including fruits (such as apples and bananas) and butter (Karimi et al., 2012). Aktosun (2023) reported that they detected carvacrol, thymol, ethanol, and methanethiol components in cheese chips samples containing wheat fiber.

Esters

Esters are compounds with low sensory perception thresholds that reduce rancidity in cheese and give it a fruity or floral aroma (Shehata et al., 2022). In all PECC samples, ethanol, 2-methoxy-, acetate (CAS) 2-methoxyethyl acetate was detected. This compound was found in the highest concentration in the samples produced by microwave (%1.16). Albay (2024) reported the total ethyl acetate ester concentrations in semi-fat and fat-free chips to be in the range from 0.94 % to 2.13 % and also emphasized that the concentration of ethyl acetate in chips increases with the decrease in fat content.

Aldehydes

Aldehydes are formed by the auto-oxidation of unsaturated fatty acids. It has been noted that most aldehydes give cheese herbaceous, grassy, and malt aromas (Curioni and Bosset, 2002). Octanal, nonanal, and decanal are the most identified aldehydes in the study. They are characterized by green grass and herbaceous aromas (Sgarbi et al., 2013). 3-methylbutanal presents a green malt aroma (bitter and sharp), but at low concentrations, it provides a fruity and quite pleasant scent (Curioni and Bosset, 2002). Components from the aldehyde group have been detected in productions using tray and natural environment drying methods. Aldehydes, which are temporary compounds, do not accumulate in cheese because they quickly convert to alcohols or corresponding acids. Therefore, the aldehyde concentration was found to be quite low in samples G (0.18 %) and T (0.15 %), while it was not detected in sample M. Albay et al. (2024) stated that 3-Methylbutanal was detected as 16.84-21.91 % in cheese chips with different fat contents. This ratio is much higher than the one determined in PECC. 3-Methylbutanal is derived from the amino acid leucine and is formed through oxidative deamination-decarboxylation (Sanches-Silva et al., 2005). Hayaloglu and Özer (2011) stated that aldehydes decrease due to their rapid conversion into alcohols and acids.

Carboxylic acids

Many of the acids found in cheese are formed because of the lipolysis of milk fat. Acetic, propanoic, pentanoic, or octanoic acids are produced as a result of lactose fermentation or lipolysis. It is known that 2-methyl propanoic and 3-methyl propanoic acids are produced as a result of amino acid metabolism (Akarca, 2020). Carboxylic acids constitute the highest concentration in the PECC samples. Acetic acid was found in concentrations of 70.79 %, 63.60 %, and 68.90 % in samples G, T, and M, respectively, while 2-propanoic acid was determined to be present in concentrations of 2.04 %, 1.35 %, and 1.27 %, respectively. Butyric acid, on the other hand, was found at a concentration of 0.22 % in the M sample, while it was not detected in the G and T samples. Albay et al (2024) reported that acetic acid was only detected in fat-free chips (13.24 %). Acetic acid is an important flavor component and plays a significant role in the formation of flavor in cheese. Butanoic acid (n-butyric acid) is the characteristic fatty acid of dairy products. It plays a crucial role in many types of cheese. However, excessive amounts of butanoic acid can also result in bitterness. Butyric acid was detected at a rate of 0.22 % only in products dried using a microwave. Tütüncü (2022) reported that butyric acid was not detected in the samples when a spray dryer was used in a study, and it may have been lost during the applied heat treatment.

Hydrocarbons

Although hydrocarbons do not make a significant contribution to cheese aroma, they play a pioneering role in the formation of other aromatic compounds following different degradation pathways (Bozoudi et al., 2018). Hydrocarbons are formed by the autoxidation of fats. It is known that compounds such as toluene, xylene, and ethylbenzene are formed by the deamination and decarboxylation of phenylalanine, tyrosine, and tryptophan. It has been reported that toluene is detected in high amounts, especially in Domiati cheeses (Barbieri et al., 1994). It has been stated that n-decan is formed because of the decarboxylation of lauric acid (Collin et al., 1993). In this study on PECC, the highest presence of 2,2,4,6,6-pentamethylheptane was detected in microwave-produced samples (5.59 %) and samples produced by natural air drying (3.74 %). The highest number of hydrocarbons was found in the samples produced by microwave (17.77 %), while the lowest amount was found in the samples produced by the tray dryer (4.89 %). The microwave drying process significantly increased the formation of hydrocarbons. Toluene, 2-Ethyl-1-hexane, 4-methyl-1-decan, 2-ethyl-1-octane, n-dodecane, and 1-decan compounds were detected in traditional drying and microwave drying but were not identified in samples dried with a tray dryer. Karahançer (2018) reported that all samples of White cheese contained 2,2,4,6,6-pentamethylheptane and that the highest amount of 2,2,4,6,6-pentamethylheptane during storage (90 days) was found in vacuum-packed White cheese containing *B. bifidum* (1.60-9.23 %).

Ketones

Ketones are presented after the lipid breakdown, which was formed by the ß-oxidation and decarboxylation of fatty acids in the products. They have typical odors and low detection thresholds. They are responsible for the sharp smell that develops in cheeses, especially after ripening. Lactic acid bacteria can produce diacetyl, acetoin, 2,3-butanediol, and acetic acid by using citric acid and the byproduct pyruvate present in milk. Diacetyl is a ketone that contributes to the flavor of dairy products. Diacetyl has a buttery and nutty flavor and is formed in dairy products because of the fermentation of citric acid. Microorganisms that synthesize diacetyl contain diacetyl reductase, which reduces this substance to the tasteless compound's acetoin and 2,3-butanediol. As the product is stored, the intensity and quality of the flavor decrease in proportion to the reduction in the amount of diacetyl (Altuğ and Elmacı, 2017). In the study on probiotic-added White cheese conducted by Karahançer (2018), it was found that in vacuum-packaged White cheeses, on the first day of storage, samples containing *Bifidobacterium bifidum* had 3-hydroxy-2-butanone at a rate of 51.38 %, while samples containing *L. acidophilus* had 3-hydroxy-2-butanone at a rate of 60.46 %.

In PECC (M, G, and T), the lowest levels of 2,3-butanedione diacetyl (1.20 %), and acetone (1.90 %) were observed in sample M. The main reason for this can be attributed to the fact that when the microbiological analysis values of the M samples are examined, the number of lactic acid bacteria is at a lower level compared to the other two samples. In this study, ketones that contribute to the cheese aroma by softening the strength or sharpness of the ketones with fruit and floral notes are found in quite low concentrations in the M samples (5.3 %). Ketones, which are important components in the characterization of cheese aroma, were found in the chips produced with the highest tray dryer (28.85 %). The highest concentration of diacetyl (14.87 %) is found in sample T.

Terpenes

Terpenes are compounds that are naturally found in milk. Akarca (2020) stated that they might have passed into milk through forage plants in pastures. In PECC, limonene was found at the highest level (0.28 %) in chips dried in a natural environment. In the chips produced by microwave, a result close to this ratio (0.20 %) was obtained, while no terpenoid group components were detected in the samples dried with a tray dryer. Terpene compounds are not among the main aroma components of cheeses and are generally associated with the feed content used in animal nutrition. Oliszewski et al. (2013) reported that they detected p-xylene, m-xylene, limonene, and ß-myrcene aromas in Argentine goat cheese, but these aromas did not affect the characteristic property of the cheese.

Other components

Carbon disulfide, which can be included in the organosulfide group and contains a sulphur component, has been identified in all chips samples. It is observed that in chips produced especially by microwave, the highest level (3.21 %) is determined. Albay (2024) reported that as the fat content in cheese chips decreases, the amount of carbon disulfide increases, and this substance was found to be the second dominant component in fat-free chips at a level of 13.5 %.

Principal component analysis of sensory properties results

Sensory parameters (brownish-yellow, whitish-yellow, matte-shiny, mottled appearance, hardness, chewability, grittiness, crispiness, brittleness, thick structure, cheese smell, burnt smell, foreign smell, burnt taste, salty, bland, foreign, and oily taste) were evaluated in the principal component analysis (PCA) of the chips samples. The variance (eigenvalue) of the first principal component (PC1) is 15.98, explaining 94.04 % of the total variance. The variance of the second principal component (PC2) has been determined as 1.013 and explains 5.96 % of the total variance. TB1 and TB2 together explain the entire total variance. The first principal component is ordered based on their same sign (-) and distance from zero; it is observed that the rough structure (-0.250), chewability (0.250), mottled appearance (-0.250), thickness-thinness (-0.250), brittleness (0.250), burnt smell (-0.250), burnt taste (-0.250), crispiness (0.248), oily taste (-0.248), hardness (-0.247), foreign smell (-0.247), oily appearance (-0.246), cheese smell (0.235), salty taste (0.244), and brown-yellow color (0.250) are formed. The second principal component is formed solely by the contrast of matte color (0.77) (Figure 3).

Considering the factor score graph, it was determined that the G and TP samples yielded similar results, while the M sample was different. It has been determined that the chips samples dried with a microwave dryer differ from the other samples in terms of thickness, oiliness, taste and appearance, grainy texture, and mottled appearance, while natural air drying was found to be positive in region at the figure 3 in terms of cheese smell and chewiness but did not have as many positive characteristics in terms of crispiness and brittleness as the samples dried with a tray dryer. As a result of the overall acceptability scores, it was determined that sample G (6.68), sample T (6.38), and sample M (5.38). According to the results, the sample G had the best overall acceptability among the other samples. Panelists reported that sample M was more porous, thinner, and less brittle. This could be explained by the expansion that occurred during evaporation.

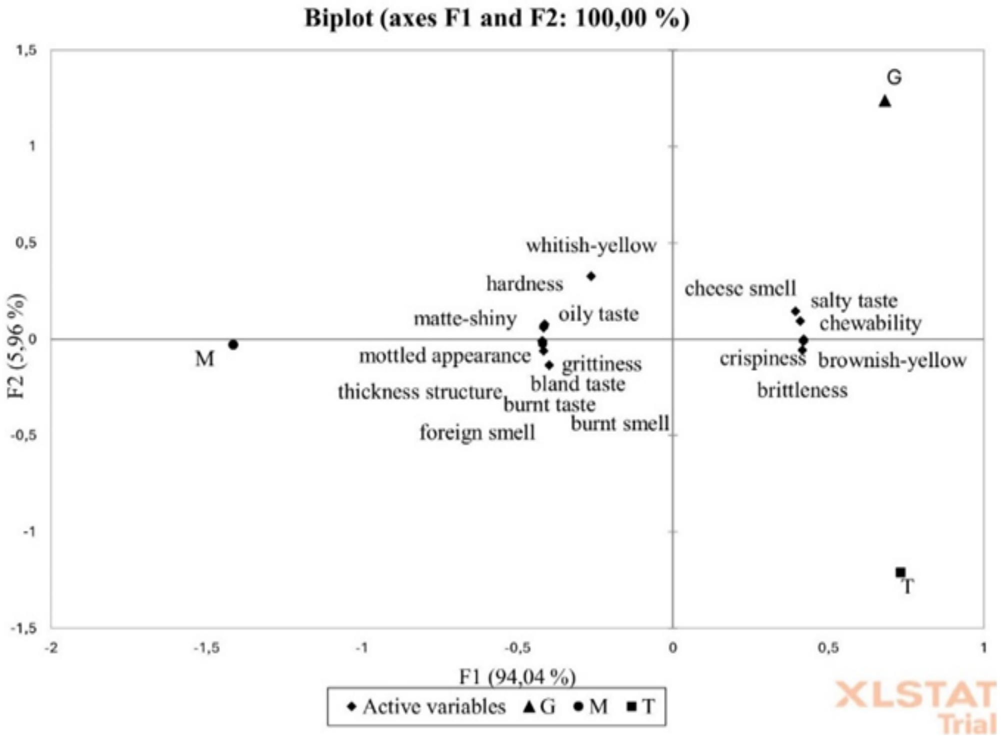

Figure 3. Probiotic cheese chip samples (1: Microwave Dried Probiotic Cheese Chips (M), 2: Natural Air Dried Probiotic Cheese Chips (G), 3: Tray Dried Probiotic Cheese Chips (T))

Conclusion

In the study, traditional drying, tray drying, and microwave drying systems were used for the production of probiotic fresh White cheese curd chips. During the microwave drying process, an expansion (spreading) occurred in the diameters of the samples, and they were observed to have a wider diameter and a thinner structure compared to the other chips. The *BB-12* counts and *LA-5* counts in PECC were found to be in the ranges of 3.79-6.15 log CFU/g and 5.21-7.80 log CFU/g, respectively. In the samples produced by microwave drying (3.79 log CFU/g), *BB-12* counts were found to be below the limit values reported to be necessary for health. However, the count of *LA-5* was determined to be above 10^5 log CFU /g in all samples. In the chips samples, the number of *BB-12* was determined to be these values in tray drying and natural air drying. However, in chips dried using the microwave drying method, 3.79 log CFU/g of microorganisms were counted, and the 10^5-10^6 range was not reached. In all samples, *LA-5* counts were determined to be above the limit values. According to the aroma analysis results, a higher amount of volatile aroma components was detected in sample M compared to the other samples. It was observed that the method that received the most similar sensory scores to the traditional drying method was the tray drying method. Overall, in the production of cheese chips, the microwave drying method stands out due to its short production time, finer texture, degree of hardness, and yellowish color. However, considering the viability of probiotic bacteria, sensory, and overall acceptability scores, a tray dryer could be an alternative to the traditional drying method.

Funding

This study was financially supported by the Chair of Scientific Research Projects' of Süleyman Demirel University (Project number: FYL-2022-8450).

Utjecaj različitih metoda sušenja na svojstva kvalitete sirnog čipsa obogaćenog probioticima

Sažetak

U ovoj studiji razmatrane su mogućnosti proizvodnje sirnog čipsa od bijelog (svježeg) sira obogaćenog probioticima korištenjem različitih metoda sušenja: prirodno sušenje na zraku pri 25 °C tijekom 24 sata, sušenje u mikrovalnoj pećnici na 180 W tijekom 120 sekundi i sušenje na plitici pri 25 °C tijekom 4 sata uz brzinu zraka od 1,3 m/s. Cilj je bio ispitati učinke različitih sustava sušenja korištenih u proizvodnji na održivost probiotičkih bakterija (*Lactobacillus acidophilus* (LA-5) i *Bifidobacterium animalis* subsp. *lactis* (BB-12) te na karakteristike kvalitete sirnog čipsa obogaćenog probioticima. Na proizvedenom sirnom čipsu provedene su fizikalno-kemijske, teksturalne, senzorske i mikrobiološke analize, te analize hlapljivih komponenti arome. Broj živih stanica LA-5 najbliži onom postignutom pri prirodnom sušenju na zraku dobiven je sušenjem na plitici (7,32 log CFU/g) kao i najveći broj živih stanica BB-12 (6,15 log CFU/g). Rezultati najbliži prirodnom sušenju na zraku, u smislu očuvanja vitalnosti probiotičkih bakterija, ukupne ocjene prihvatljivosti i teksturalnih svojstava, dobiveni su metodom sušenja na plitici. U čipsu proizvedenom metodom sušenja u mikrovalnoj pećnici utvrđene su veće ukupne koncentracije hlapljivih komponenti arome (alkohola, estera i ugljikovodika) nego u ostalim uzorcima. Metoda sušenja na plitici može se smatrati alternativom prirodnoj metodi sušenja na zraku u proizvodnji čipsa obogaćenog probioticima.

Ključne riječi: prirodno sušenje na zraku; sušenje na pladnju; mikrovalna pećnica; probiotik; sirni čips

References

1. AACC (American Association of Cereal Chemists) (2000): Approved methods of the American Association of Creal Chemists (10th ed.) Saint Paul, MN.
2. Akan, E., Kınık, Ö. (2015): Factors effecting probiotic viability during processing and storage of food. *Celal Bayar University Journal of Science* 11 (2), 155-166.
3. Akarca, G. (2020): Lipolysis and aroma occurrence in Erzincan Tulum Cheese, which is produced by adding probiotic bacteria and ripened in various packages. *Food Science and Technology, Campinas* 40 (1), 102-116. https://doi.org/10.1590/fst.33818
4. Aktosun, M. (2023): Determination of some properties of cheese chips produced from dietical fiber teleme cheese Master Thesis. Süleyman Demirel University, Isparta, Türkiye.
5. Albay, Z. (2022): The effect of inulin and wheat fiber addition to low-fat milk on some properties of probiotic Tulum cheese. PhD Thesis. Süleyman Demirel University, Isparta, Türkiye.
6. Albay, Z., İşliyen, T., Yıldırım, Y., Şimşek, B. (2021): Some properties of cheese chips produced from block type melting cheese. *Akademik Gıda* 19 (2), 177-184.
7. Albay, Z., Akçay, G., Taplak, G., Şimşek, B. (2024): The effect of cheese fat content on some physico-chemical, textural properties and volatile aroma components of cheese chips. *Mljekarstvo* 74 (4), 285-295. https://doi.org/10.15567/mljekarstvo.2024.0404
8. Altuğ, T., Elmacı, Y. (2017): Flavor compounds found naturally in foods, In: Food Chemistry. İ. Saldamlı (Ed.), Hacettepe University Publ., Ankara, Türkiye, 591-624.
9. Anli, E.A. (2020): Possibilities for using microwave-vacuum drying in Lor cheese production. *International Dairy Journal* 102, 104618. https://doi.org/10.1016/j.idairyj.2019.104618
10. Anli, E.A. (2022): Impact of vacuum assisted oven drying of Kurut on product quality and drying characteristics. *Applied Sciences*, 12 (21), 11228. https://doi.org/10.3390/app122111228
11. AOAC. (1997): Official methods of analysis (16th ed.) Association of Official Analytical Chemists. Washington DC.
12. AOAC. (2005): AOAC official method 996.06, revised 2001. In: Official methods of analysis (18th ed.). AOAC International, Gaithersburg, MD.

13. Arimi, J.M., Duggan, E., O'Riordan, E.D., O'Sullivan, M., Lyng, J.G. (2008): Microwave expansion of imitation cheese containing resistant starch. *Journal of Food Engineering*, 88, 254-262. https://doi.org/10.1016/j.jfoodeng.2008.02.021
14. Barbieri, G., Bolzoni, I., Careri, M., Mangia, A., Paroları, G., Spagnoli, S., Virgili, R. (1994): Study of the volatile fraction of Parmesan Cheese. *Journal of Agricultural and Food Chemistry* 42 (5), 1170-1176.
    https://doi.org/10.1021/jf00041a023
15. Boylston, T.R., Vinderola, C.G., Ghoddusi, H.B., Reinheimer, J.A. (2004): Incorporation of Bifidobacteria into cheeses: challenges and rewards. *International Dairy Journal*, 14 (5), 375-387.
    https://doi.org/10.1016/j.idairyj.2003.08.008
16. Bozoudi, D., Kondyli, E., Claps, S., Hatzikamari, M., Michealidou, A., Biliaderis, C.G., Litopoulou-Tzanetaki, E. (2018): Compositional characteristics and volatile organic compounds of Traditional PDO Feta Cheese made in two different mountainous areas of Greece. *International Journal of Dairy Technology* 71 (3), 673-682.
    https://doi.org/10.1111/1471-0307.12497
17. Chudy, S., Makowska, A., Piatek, M., Krzywdzinska-Bartkowiak, M. (2019): Application of microwave vacuum drying for snack production: characteristics of pure cheese puffs. *International Journal of Dairy Technology* 72 (1), 82-88.
    https://doi.org/10.1111/1471-0307.12562
18. Ciurzyńska, A., Cieśluk, P., Barwińska, M., Marczak, W., Ordyniak, A., Lenart, A., Janowicz, M. (2019): Eating habits and sustainable food production in the development of innovative "healthy" snacks. *Sustainability*, 11 (10), 2800.
    https://doi.org/10.3390/su11102800
19. Collin, S., Osman, M., Delcambre, S., El-Zayat, A.I., Dufour, J.P. (1993): Investigation of volatile Flavor Compounds in fresh and ripened Domiati Cheese. *Journal of Agricultural and Food Chemistry* 41 (10), 1659-1663.
    https://doi.org/10.1021/jf00034a027
20. Cui, L., Nıu, L., Lı, D., Lıu, C., Lıu, Y., Lıu, C., Song, F. (2018): Effects of different drying methods on quality, bacterial viability and storage stability of probiotic enriched apple snacks. *Journal of Integrative Agriculture* 17 (1), 247-255.
    https://doi.org/10.1016/S2095-3119(17)61742-8
21. Curioni, P.M.G., Bosset, J.O. (2002): Key odorants in various cheese types as determined by gas chromatography-olfactometry. *International Dairy Journal* 12 (12), 959-984.
    https://doi.org/10.1016/S0958-6946(02)00124-3
22. Daglioglu, O., Arici, M., Konyali, M., Gumus, T. (2002): Effects of tarhana fermentation and drying methods on the fate of *Escherichia coli* O157: H7 and *Staphylococcus aureus*. *European Food Research and Technology* 215 (6), 515-519.
    https://doi.org/10.1007/s00217-002-0584-0
23. Dave, R.I., Shah, N.P. (1997): Viability of yoghurt and probiotic bacteria in yoghurts made from commercial starter cultures. *International Dairy Journal* 7 (1), 31-41.
    https://doi.org/10.1016/S0958-6946(96)00046-5
24. Erinç, H., Çiftçi, S. (2018): The effects of kefir usage on properties of Tarhana Cips. *The Journal of Food* 43 (1), 114-121.
    https://doi.org/10.15237/gida.GD17105
25. Feitoza, T.G., deLima Ponciano Costa, B., Sampaio, K.B., dos Santos Lima, M., Garcia, E.F., de Albuquerque, T.M.R., de Souza, E.L., Rodrigues, N.P.A. (2025): An in vitro study of the impacts of sweet potato chips with potentially probiotic *Levilactobacillus brevis* and *Lactiplantibacillus plantarum* on human intestinal microbiota. *Probiotics and Antimicrobial Proteins*, 17, 450-465.
    https://doi.org/10.1007/s12602-023-10168-1
26. Frank, D.C., Owen, C.M., Patterson, J. (2004): Solid phase microextraction (SPME) combined with gas-chromatography and olfactometry-mass spectrometry for characterization of cheese aroma compounds. *LWT - Food Science and Technology* 32 (2), 139-154.
    https://doi.org/10.1016/S0023-6438(03)00144-0
27. Fung, D.Y.C., Cunningham, F.E. (1980): Effect of Microwaves on microorganism in foods. *Journal of Food Protection*, 43(8):641-650.
    https://doi.org/10.4315/0362-028X-43.8.641

28. Gardini, F., Lanciotti, R., Guerzoni, M.E., Torriani, S. (1999): Evaluation of aroma production and survival of *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Lactobacillus acidophilus* in fermented milks. *International Dairy Journal* 9 (2), 125-134.
https://doi.org/10.1016/S0958-6946(99)00033-3
29. Gursoy, O., Küçükçetin, A., Gökçe, Ö., Ergin, F., Kocatürk, K. (2018): Physicochemistry, microbiology, fatty acids composition and volatile profile of Traditional Söğle Tulum (goat's skin bag) cheese. *Anais da Academia Brasileira de Ciências* 90 (4), 3661-3674.
https://doi.org/10.1590/0001-3765201820180310
30. Gurcan, A. (2023): The effect of different drying techniques on the properties of Çökelek cheese supplemented with yellow lentil flour. Master Thesis. Pamukkale University, Denizli, Türkiye.
31. Hammam, A.R.A., Ahmed, M.S.I. (2019): Technological aspects, health benefits, and sensory properties of probiotic cheese. *SN Applied Sciences* 1 (9), 1113.
https://doi.org/10.1007/s42452-019-1154-4
32. Hayaloglu, A.A., Özer, B. (2011). Peynir biliminin temelleri. Sidas Medya Yayınları, İzmir, Türkiye.
33. Irkin, R. Yalçın, O. (2017): The potential use of probiotic strains *Lactobacillus acidophilus* NRRL B 4495, *Bifidobacterium bifidum* NRRL B41410 in Lor whey cheese and the effects on sensory properties. *Acta Scientiarum Polonorum Technologia Alimentaria*, 16, 181-189.
https://doi.org/10.17306/J.AFS.2017.0493
34. Kaan, I., Tuna, O., Tepe, A., Zeren, F. E., Küçükçetin, A. (2024): Effect of drying temperatures and using prebiotics on the physicochemical and microbiological properties as well as consumer acceptance of probiotic-enriched Lor cheese snacks produced by vacuum drying. *International Journal of Gastronomy and Food Science*, *36*, 100929.
https://doi.org/10.1002/fsn3.1832
35. Karahançer, H. (2018): Determination of the effects of using Lactobacillus acidophilus and Bifidobacterium bifidum in the production on some properties of White pickled cheese. Master Thesis. Akdeniz University, Antalya, Türkiye.
36. Karimi, R., Sohrabvandi, S., Mortazavian, A.M. (2012): Review article: sensory characteristics of probiotic cheese. *Comprehensive Reviews in Food Science and Food Safety* 11 (5), 437-452.
https://doi.org/10.1111/j.1541-4337.2012.00194.x
37. Köprüalan, Ö. (2019): Production of White cheese snacks having high protein content by explosion-puff drying: Determination of optimum pretreatment conditions, optimization of puff drying process conditions. Master Thesis. Ege University, İzmir, Türkiye.
38. Lawless, H.T., Heymann, H. (2010). Sensory evaluation of food principles and practices. *Springer Science and Business Media.*
https://doi.org/10.1007/978-1-4419-6488-5.
39. Mafaldo, I.M., de Medeiros, V.P.B., da Costa, W.K.A., da Costa Sassi, C.F., da Costa Lima, M., de Souza, E.L., Magnani, M. (2022): Survival during long-term storage, membrane integrity, and ultrastructural aspects of *Lactobacillus acidophilus* 05 and *Lacticaseibacillus casei* 01 freeze-dried with freshwater microalgae biomasses. *Food Research International*, 159, 111620.
https://doi.org/10.1016/j.foodres.2022.111620
40. Oliszewski, R., Wolf, I.V., Bergamini, C.V., Candioti, M., Perotti, M.C. (2013): Influence of autochthonous adjunct cultures on ripening parameters of Argentinean goat's milk cheeses. *Journal of the Science of Food and Agriculture* 93 (11), 2730-2742.
https://doi.org/10.1002/jsfa.609
41. Rakcejeva, T., Zagorska, J., Dukalska, L., Galoburda, R., Eglitis, E. (2009): Physical-chemical and sensory characteristics of Cheddar Cheese snack produced in vacuum microwave dryer. *Cheminė Technologija* 3 (52), 16-20.
42. Sanches-Silva, A., Lopez-Hernández, J., Paseiro-Losada, P. (2005): Profiling flavor compounds of potato crisps during storage using solid-phase microextraction. *Journal of Chromatography A* 1064 (2), 239-245.
https://doi.org/10.1016/j.chroma.2004.05.108
43. Sgarbi, E., Lazzi, C., Tabanelli, G., Gatti, M., Neviani, E., Gardini, F. (2013): Nonstarter lactic acid bacteria volatilomes produced using cheese components. *Journal of Dairy Science* 96 (7), 4223-4234.
https://doi.org/10.3168/jds.2012-6472

44. Shehata, M.G., Abd El-Aziz, N.M., Darwish, A.G., El-Sohaimy, S.A. (2022): *Lacticaseibacillus paracasei* KC39 immobilized on prebiotic wheat bran to manufacture functional soft White cheese. *Fermentation* 8 (10), 496. https://doi.org/10.3390/fermentation8100496
45. Şaşmazer, R. (2022): Investigation of White cheese production opportunities. PhD Thesis. Uludağ University, Bursa, Türkiye.
46. Terzić-Vidojević, A., Veljović, K., Tolinački, M. Živković, M. Lukić, J. Lozo, J. (2020): Diversity of non-starter lactic acid bacteria in autochthonous dairy products from Western Balkan Countries-technological and probiotic properties. *Food Research International*, 136, 109494. https://doi.org/10.1016/j.foodres.2020.109494
47. Tütüncü Ertan, S. (2022): Encapsulation of oil-based cheese aroma by using spray-drying and efficience of microcapsules in model foods. Master Thesis. Istanbul Technical University, İstanbul, Türkiye.
48. Uğur, S., Şimşek, B. (2021): Some physicochemical, textural properties and acrylamide contents of chips produced from the Teleme of white cheese. *Niğde Ömer Halisdemir University Journal of Engineering Sciences* 10 (2), 606-614. https://doi.org/10.28948/ngmuh.932609