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Research Article

Evaluation of The Quality Characteristics of Dried Erzincan Tulum Cheese by Hot Air Circulation Dryer at Different Temperatures

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Abstract

Erzincan Tulum Cheese, a geographically indicated product made from high-fat sheep's milk, is among the most recognized varieties of tulum cheese in Türkiye. This study aimed to explore a novel application area for Erzincan Tulum Cheese by transforming it into a powdered form through drying. The drying process was employed not only to extend the product's shelf life but also to introduce a new traditional dried cheese format to consumers. Drying was conducted using a hot air circulation oven at three different temperatures of 40, 50 and 60°C until the final moisture content reached approximately 10%. The resulting cheese powders were analyzed for their physical, chemical, and microbiological properties. Among the tested conditions, drying at 50°C for 210 minutes yielded the most favorable quality attributes. Based on the findings, this innovative form of Erzincan Tulum Cheese shows potential as a flavoring agent in various food applications, including soups, pizzas, pasta dishes, chips, sauces, and ready-to-eat meals.

Keywords: Erzincan Tulum Cheese, cheese drying, hot air circulation drying, powdered cheese

Farklı Sıcaklıklarda Sıcak Hava Sirkülasyonlu Kurutucu ile Kurutulan Erzincan Tulum Peynirinin Kalite Özelliklerinin Değerlendirilmesi

Öz

Erzincan Tulum Peyniri, yüksek yağ oranına sahip koyun sütünden üretilen ve coğrafi işaret ile korunan bir peynirdir. Türkiye'nin en çok bilinen tulum peynirlerinden biridir. Bu çalışmanın amacı, Erzincan tulum peynirine yeni bir kullanım alanı sağlamaktır. Bu amaçla, kurutma işlemi sadece peynirin raf ömrünü uzatmak için değil, aynı zamanda tüketiciler için toz formda geleneksel kurutulmuş peynir olarak yeni bir ürün geliştirmek için de kullanılmıştır. Erzincan tulum peyniri, son üründeki nem içeriği yaklaşık %10'a ulaşana kadar 40, 50 ve 60°C'lik sıcaklıklarda sıcak hava sirkülasyonlu kurutma fırınında kurutulmuştur. Peynir tozlarının fiziksel, kimyasal ve mikrobiyolojik özellikleri incelenmiştir. 50 °C'de 210 dakika boyunca yapılan kurutmanın en yüksek kaliteyi sağladığı belirlenmiştir. Bu yeni tip Erzincan Tulum Peynirinin çorbalarda, pizzalarda, makarnalarda, cipslerde, soslarda ve yemeklerde baharat olarak kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Erzincan tulum peyniri, peynir kurutma, sıcak hava sirkülasyonlu kurutma, toz peynir

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1. Introduction

Cheese is one of the most widely consumed dairy products globally and plays a significant role in human nutrition. Across different regions of the world, a diverse range of production methods have evolved. While cheese was originally developed as a means of preserving the nutritional components of milk, it has since become a key dietary item valued for both its nutritional profile and sensory characteristics [1]. Among dairy products, cheese stands out for its variety, attracting considerable attention from consumers. It is also a rich source of essential nutrients, including fats, proteins, vitamins, calcium, magnesium, and potassium.

There are approximately 4,000 recognized cheese varieties worldwide, with around 130 of them originating from Türkiye. Among these, white cheese and kashar cheese are the most widely produced in the country, followed by various regional types such as tulum cheese, herb cheese, pot cheese, lor cheese, and cube cheese [2]. According to data from the Turkish Statistical Institute (TÜİK), white cheese constitutes 60% of Türkiye's total cheese production, while kashar cheese accounts for 15%. Another 15% consists of tulum and Mihaliç cheeses, and the remaining 10% comprises various locally produced cheeses [3]. Tulum cheese is produced in several regions and often takes on regional names, including Erzincan Tulum (Şavak) Cheese, Divle Tulum Cheese (Karaman), Çimi Tulum Cheese (Antalya), Isparta Tulum Cheese, Selçuklu Tulum Cheese (Konya), and İzmir Tulum Cheese, which is typically stored in brine [4]. Erzincan Tulum Cheese is distinguished by its white to creamy color, high fat content, buttery aroma, and semi-hard, crumbly texture. It is traditionally made from sheep's milk and was the first tulum cheese in Türkiye to receive geographical indication status, granted by the Turkish Patent and Trademark Office in 2000 [5].

Milk and dairy products are highly perishable due to their rich microbial load and elevated water activity. To mitigate spoilage and extend shelf life, various food processing technologies are applied, with drying being among the most prevalent. The food industry employs a wide array of drying methods, including freeze drying, hot-air drying, fluidized bed drying, spray drying, and microwave-assisted drying. In addition, advanced techniques such as osmotic dehydration and hybrid drying—which integrate multiple drying technologies—are increasingly utilized to optimize processing efficiency and improve product quality. Among these, tray drying is commonly used for dehydrating cheese under controlled conditions, offering notable advantages such as operational simplicity and cost-effectiveness [6].

The development of dehydrated cheese products dates back to World War II, when the U.S. Army utilized cheese powder in industrially produced, cheese-based rations due to its superior stability at elevated storage temperatures compared to natural cheese, which required refrigeration [7,8]. Since that time, dehydrated cheese has evolved into a widely used dairy ingredient, valued both as a flavor enhancer and a nutritional supplement in a variety of food formulations [9].

Cheese can be subjected to drying processes to reduce its moisture content, thereby extending shelf life, improving transportability, and creating value-added derivative products suitable for diverse food applications [10]. Owing to their prolonged shelf stability, ease of use, and reduced transportation and storage costs—particularly the lack of need for refrigeration—cheese powders have become widely utilized additives across the food industry [11,12,13]. Beyond their practicality, cheese powders serve as highly versatile ingredients: they impart intense cheese flavor in snack formulations, function as binding agents in coated nut products, and act as thickeners in instant mixes, ready-to-eat meals, sauces, and dips. In bakery applications, cheese powder may also contribute to leavening and enhance the texture, consistency, and shelf stability of seasoning blends [14,15,16]. The scope of cheese powder applications continues to expand due to these functional advantages. Granulated and dried cheese powders offer key benefits such as enhanced microbiological safety, extended shelf life, and immediate usability. Furthermore, their suitability as seasonings or topping ingredients broadens their potential for incorporation into a wide range of food products.

In this study, preliminary trials were carried out to determine the optimal drying temperature and duration for Erzincan Tulum Cheese. The samples were dried using a hot air circulation tray dryer until a final moisture content of approximately 10% was achieved. The impact of varying drying temperatures and times on the quality characteristics of the cheese was systematically investigated. Upon completion of the drying process, the physical, chemical, and microbiological properties of the resulting cheese powders were analyzed. The temperature condition that produced the most favorable effects on the final product was identified, with the overarching goal of introducing a novel form of Erzincan Tulum Cheese suitable for broader food applications.

2. Materials and Methods

2.1. Materials

Erzincan Tulum Cheese used in the study was sourced from a local producer and stored at −18°C in airtight, sealed jars until further analysis. All chemicals used in the experimental procedures were of analytical grade and were obtained from Sigma-Aldrich. Based on preliminary trials, a final moisture content of approximately 10% was reached after 270, 210, and 180 minutes of drying at temperatures of 40, 50, and 60°C, respectively.

2.2. Methods

2.2.1. Hot air circulation drying process

To establish the appropriate drying conditions for use in a hot air circulation drying oven, Erzincan Tulum cheese samples were subjected to drying at various temperatures and durations (Table 1). In preliminary experiments, the optimum sample amount and thickness, temperature and time were determined to achieve a target moisture content (10%). Prior to drying, the samples were crumbled and spread on sieves to achieve an approximate thickness of 0.5 cm. The moisture content of cheese samples was measured in every 30 minutes during drying. Based on these trials, further drying process was carried out in a hot air circulation dryer at temperatures of 40, 50 and 60°C for durations of 270, 210, and 180 minutes, respectively. The dried samples were then granulated using a blender to create a uniform structure and stored in the refrigerator (+4°C) until further analysis.

Table 1. The change in moisture content (%) of Erzincan Tulum cheese samples during drying

Time (min)	40°C	50°C	60°C
Control	40,85	40,67	40,78
30	38,15	35,88	37,30
60	36,64	30,40	29,80
90	30,40	26,10	22,30
120	27,16	19,69	16,22
150	21,80	14,72	13,81
180	16,51	12,44	10,93
210	15,30	10,26	9,52
240	11,04	9,79	8,93
270	10,01	9,57	7,67

2.2.2. Chemical and physical analyses

Dry matter, protein, and titratable acid were determined according to standard methods of the Association of Official Analytical Chemists (AOAC) [17], fat, salt and ash contents of cheese powders according to the methods defined by Kurt et al. (2007) [18]. Powdered cheese sample (10 g) was mixed with 15 mL of distilled water until a homogeneous mixture was obtained, the pH values of the mixture were measured using a digital pH meter (Hanna HI 2002-02 edge, Hanna Inc., Romania) [19].

The water activity (a_w) of the samples was measured at 25°C using a water activity meter (Testo 650, Testo Inc., NJ, USA). The color parameters $L*$ (lightness), $a*$ (redness), and $b*$ (yellowness) were measured using a Chroma Meter CR-400 (Konica Minolta Business Technologies, Inc., Tokyo, Japan). The chroma (C) value, color change (ΔE) and the Browning Index (BI) were calculated using the $L*$, $a*$, and $b*$ values according to the following equations [20,21].

$$C = \sqrt{a^2 + b^2} \quad (1)$$

$$BI = \frac{100\,\mathrm{x}\left(\frac{a+1{,}75\mathrm{x}L}{5{,}647\mathrm{x}L+a-3{,}012\mathrm{x}b}\right)-0{,}31}{0{,}17} \quad (2)$$

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (3)$$

2.2.3. Microbiological analyses

The microbiological analyses of cheese powder were conducted before and after drying. 10 g of sample was suspended in 90 mL of sterile ¼ Ringer solution (Merck, Darmstadt, Germany) and homogenized for 5 minutes using a magnetic stirrer (Heidolph MR Hei-Tec, Schwabach, Germany). Serial 10-fold dilutions were prepared using 9 mL of sterile Ringer solution for each dilution step. The pour plate technique and aerobic incubation were used to determine the total mesophilic aerobic bacteria (TMAB) and yeast and mold counts. TMAB was enumerated on Plate Count Agar (PCA; Merck) following incubation at 37°C for 2-3 days, while yeast and mold counts were determined on Potato Dextrose Agar (PDA; Merck) after incubation at 25°C for 5-7 days. The results were expressed as the logarithm of the mean colony-forming units per gram of cheese (log cfu g^{-1}).

2.2.4. Statistical analysis

The statistical analysis of the data obtained was analyzed using SPSS statistical package programme at 95% confidence interval. One-way analysis of variance (ANOVA) was used for comparison. In cases where the difference between samples was significant, Duncan Multiple Comparison test was used to determine the difference between means. The significance of differences between treatments was evaluated at a significance level of $p<0.05$.

3. Results and Discussion

Cheese samples were dried at 40, 50, and 60°C temperatures in a hot air circulation dryer. Initial moisture content of the control cheese was approximately 40%. The final moisture contents of the powdered cheese samples dried at 40, 50 and 60°C were 10.01, 9.57, and 7.67%, respectively. During the drying process, samples dried at 50°C exhibited lower agglomeration and more stable drying behavior, whereas those dried at 60°C showed the highest degree of agglomeration along with increased fat loss observed (Figure 1). Research on spray drying conditions in cheese powder production has shown that increasing outlet air temperatures can cause a significant reduction in free fat content, indicating higher fat loss at elevated temperatures [22].

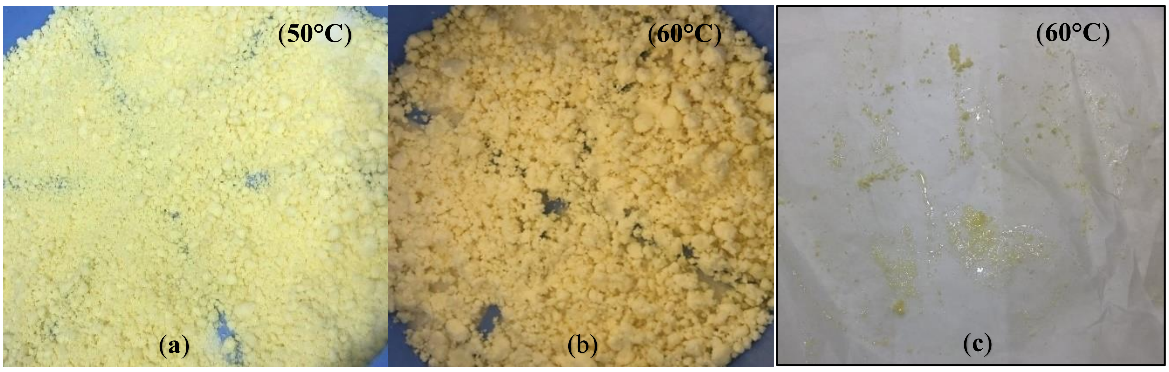

Figure 1. Agglomeration (a, b) and fat leakage (c) during drying.

The variations in cheese samples moisture content with drying time is presented in Figure 2. The drying temperature is an important parameter for the moisture content of the cheese. The moisture content decreased with the increase in drying time. The drying time required to reach the target moisture content (10%) was 270 minutes at 40°C, which decreased to 210 minutes at 50°C and further to 170 minutes at 60°C. It is well established that increasing the drying air temperature enhances both diffusion and mass transfer rates, thereby accelerating moisture removal and significantly reducing the overall drying time [23].

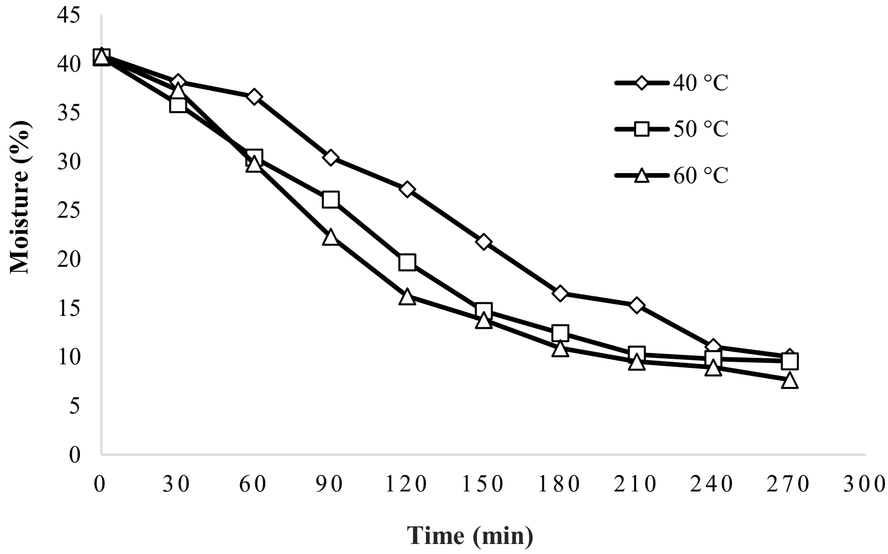

Figure 2. Drying curves of cheese at different drying conditions.

3.1. Physical and chemical characteristics

Drying is a complex operation involving simultaneous physical, chemical, and biochemical transformations that occur during the removal of moisture from a product [24]. The process can significantly influence the compositional and functional properties of food, with outcomes varying based on the drying technique employed, the intensity of thermal exposure, and the specific processing parameters applied [25]. The physical and chemical properties of both the control sample and the powdered forms of Erzincan Tulum Cheese are presented in Table 2.

Table 2. Physical and chemical characteristics of Erzincan Tulum Cheese and powdered cheese samples.

	Control	Powdered cheese		
		40°C	**50°C**	**60°C**
Dry matter (%)	60,40±0,55^{a}	92,80±0,14^{b}	92,60±0,34^{b}	93,01±0,02^{b}
Fat (%)	30,50±0,14^{a}	23,90±0,42^{b}	26,45±0,21^{c}	25,70±0,17^{d}
Protein (%)	20,89±0,09 ^{a}	35,26±2,67^{b}	35,07±0,2^{b}	32,61±0,11^{c}
Ash (%)	3,76±0,056 ^{a}	5,60±0,39^{b}	5,70±0,02^{c}	5,90±0,25^{d}
Salt (%)	2,10±0,14^{a}	3,26±0,014^{b}	3,20±0,015^{b}	3,24±0,014^{b}
pH	5,56±0,28^{a}	4,80±0,28^{b}	4,73±0,14^{bc}	4,69±0,00^{c}
Acidity (Lactic acid %)	1,56±0,014^{a}	2,20±0,00^{c}	2,10±0,070^{bc}	2,00±0,071^{b}
Water activity (a_{w})	0,944±0,02^{a}	0,563±0,03^{b}	0,558±0,03^{b}	0,551±0,01^{b}

Means within a row with different superscripts are significantly different ($p<0.05$).

As presented in Table 2, a substantial increase in dry matter content was observed following the drying process, rising from 60.40% in the control sample to over 92% in all dried cheese samples. This increase is attributed to the substantial moisture evaporation during drying. Although the dry matter values showed slight variations across the temperature range of 40°C to 60°C, the trend suggests an eventual equilibrium point where further moisture loss becomes negligible [26]. A notable reduction in fat content was observed in the dried samples compared to the control. This decrease is likely due to lipid migration or leakage during the drying process, particularly at higher temperatures [27]. When exposed to heat, cheese melts and fat is readily released from the protein matrix, contributing to this loss [28]. While the absolute protein content remains unaffected by the drying process, the reduction in moisture results in a higher relative protein concentration on a dry matter basis in the dried cheese compared to the fresh sample. Therefore, the process does not diminish the total amount of protein but increases its proportion relative to overall weight due to the reduced water content [29,30]. The ash content, which reflects the total mineral composition, also increased with rising drying temperatures. This effect is primarily due to the concentration resulting from moisture loss, as minerals remain stable under thermal treatment. Consequently, the increase in ash content represents relative accumulation rather than an absolute gain—similar to the behavior of salt during drying. Furthermore, a gradual decline in pH was observed with increasing drying temperatures, accompanied by a corresponding rise in titratable acidity.

Moisture content indicates the total water present in a food system, while water activity (a_w) reflects the availability of free water responsible for biochemical reactions. It serves as a critical indicator for predicting the shelf life of the resulting powder product [31]. The water activity (a_w) values of the powdered cheese samples were measured as 0.563, 0.558, and 0.551 at 40, 50, and 60°C, respectively, whereas the a_w of the control sample was 0.944. A significant ($p < 0.05$) reduction in a_w was observed with increasing drying temperatures from 40°C to 60°C. It was stated that at higher drying temperatures, the rate of heat transfer increases, providing greater driving force for moisture evaporation and accelerating the moisture loss. This results in the dried cheese foam with reduced a_w [32]. Given the high nutritional value of dairy products, the a_w value of 0.944 observed in the control sample represents a highly favorable environment for the growth of pathogenic microorganisms since it exceeds the critical threshold of 0.91 required for bacterial proliferation. The results presented in Table 2 reveals that the a_w values of the granulated Erzincan Tulum cheese samples dried at 40, 50, and 60°C are all below $a_w = 0.61$—the critical limit for microbial activity—indicating that the dried products fall within a microbiologically safe range. Although the a_w values of the granulated powder samples were found to be very similar, the effect of drying temperature on a_w was statistically significant ($p < 0.05$).

3.2. Color

Color is a critical quality attribute of powders, significantly affecting their sensory appeal, perceived quality, and market value. It is influenced by various factors, including drying temperature and duration, enzymatic and non-enzymatic browning reactions, moisture content, and surface water levels [33,34]. The changes in the color of the cheese samples dried at different temperatures and the control sample were given in Figure 3. As can be seen from the Figure 3, the color changes in the cheese samples became more pronounced as the temperature increased.

Figure 3. The color changing of control and dried cheese samples.

*L**, *a**, *b**, *C**, *BI* and *ΔE* were significantly influenced ($p < 0.05$) by the drying temperature (Table 3). Compared to control, the powdered cheese samples exhibited dark color resulting in lower lightness (*L**) value, as well as higher redness (*a**) and yellowness (*b**) value. This can be attributed to the pigment degradation associated with Maillard reaction [35,36]. The similar results were obtained in other studies [37,38].

Table 3. Color properties of Erzincan Tulum Cheese and powdered cheese samples.

	Control	Powdered cheese		
		40°C	**50°C**	**60°C**
L	93,76±0,80^{a}	75,37±0,67^{b}	68,88±1,65^{c}	73,75±0,41^{d}
a	-4,36±0,03^{b}	-4,40±0,08^{a}	-4,37±0,01^{b}	-4,48±0,09^{a}
b	17,40±0,65^{a}	21,27±0,32^{b}	21,41±0,19^{b}	24,70±0,08^{c}
C	17,94 ±0,63^{a}	21,72±0,33^{b}	21,85±0,18^{b}	25,10±0,09^{c}
BI	198,84±0,71^{a}	195,98±0,47^{b}	213,55±0,72^{c}	217,16±0,20^{d}
ΔE	-	19,28±1,32^{b}	25,18±2,30^{c}	21,27±0,99^{d}

Means within a row with different superscripts are significantly different ($p<0.05$).

The chroma (*C**) value, which reflects the saturation, purity, or intensity of visual color, increased in all powdered cheese samples compared to the control ($p < 0.05$). At the same time, *BI* also increased with increasing drying temperature. The Maillard reaction is considered one of the key factors influencing the browning index during the food drying process [39]. The total color difference (*ΔE*) between the control and powdered cheese samples ranged from 19.28 (40°C) to 25.18 (50°C). It was stated that the perceivable color differences can be analytically classified as very distinct ($\Delta E > 3$), distinct ($1.5 < \Delta E < 3$), and small ($\Delta E < 1.5$) [40]. Thus, indicates perceptible to very distinct color changes compared to the control.

3.3. Microbiological analyses

TMAB and yeast-moulds were significantly influenced ($p<0.05$) by the drying temperature (Table 4). The microbial composition of cheese can be attributed to three principal sources: the indigenous microbiota of the raw milk, the starter cultures intentionally added during manufacturing, and contamination occurred during processing. Contamination by yeasts and molds often results from post-processing recontamination of the final product. Cheese can become contaminated through exposure to these microorganisms, which may be present on various surfaces and environments within the production facility, including air, equipment, water, and brine [41].

Table 4. Microbiological analysis results of Erzincan Tulum cheese samples (log cfu g^{-1})

Sample	TMAB	Yeast-Moulds
Control	7,62±0,035[a]	5,17±0,063[a]
40°C	6,83±0,049[b]	3,84±0,021[b]
50°C	6,32±0,042[c]	3,36±0,098[c]
60°C	3,36±0,077[d]	2,57±0,042[d]

Means within a row with different superscripts are significantly different ($p<0.05$).

According to the Turkish Codex Regulation on Microbiological Criteria [42], there are no specified limits for TMAB and yeast–moulds counts in cheese. It can be seen that initial counts of TMAB and yeast-moulds were 7.62 and 5.17 log cfu g^{-1}, respectively. In this study, TMAB and yeast-moulds counts exhibited a significant decline with increasing drying temperatures reaching 3.36 and 2.57 log cfu g^{-1} at 60 °C, respectively. Reduction in TMAB count followed same trend as yeast-moulds, at higher drying temperature the inactivation effect was higher. The bactericidal effect of increased temperature is well documented, as higher thermal conditions lead to substantial microbial inactivation [43,44,45]. Drying at this temperature appears to be particularly effective in enhancing microbial safety and may represent a critical threshold for processing. Overall, drying at 60 °C yielded the lowest microbial loads for both TMAB and yeast–moulds, indicating its potential as the optimal temperature for ensuring microbiological safety in powdered cheese production. Nevertheless, this microbial advantage must be weighed against potential compromises in quality attributes such as color, flavor, and functional properties at elevated drying temperatures.

4. Conclusion

The powdering of food products offers notable advantages in terms of storage efficiency, logistical convenience, and extended shelf life. Moreover, this technique, when applied to various types of cheese, enables the development of novel applications. The resulting cheese powders are commonly utilized in products such as chips, soups, sauces, crackers, ready meals, and other food items. It is anticipated that granulating Erzincan Tulum cheese will broaden its range of applications, as its intense flavor allows for effective use in small quantities.

This study demonstrated that hot air circulation drying is an effective method for transforming traditionally produced Erzincan Tulum cheese into a powdered form with extended shelf life and potential for broader culinary applications. Among the tested temperatures, drying at 50 °C for 210 minutes was found to be the most suitable condition, offering a favorable balance between physicochemical quality and microbial safety. While drying at 60 °C resulted in the lowest microbial counts, it also caused negative effect on appearance of powdered cheese.

The drying process significantly reduced moisture content and water activity, placing the powdered cheese in a microbiologically safe range. Additionally, drying led to concentration of protein and minerals due to moisture removal, although a reduction in fat content was observed, particularly at higher temperatures. Color analysis indicated that increasing temperature intensified browning and color changes, likely due to Maillard reactions, potentially affecting consumer perception.

Overall, granulated Erzincan Tulum cheese produced at 50 °C drying temperature holds promise as a functional and flavorful ingredient for incorporation into various food products such as soups, sauces, ready meals, and snacks. The findings highlight the potential for developing novel dairy-based powdered products using traditional cheeses, contributing both to value-added utilization and to regional product innovation.

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Ethics in Publishing

This study does not involve any ethical concerns related to its publication.

Author Contributions

All authors made equal contributions to the preparation and writing of this manuscript.

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