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Research Paper / Araştırma Makalesi

Effect of Different Heat-Treated Ultrafiltration (UF) Retentates with Altered Protein-to-Fat Ratios on Physicochemical and Sensory Properties of UF White Cheese

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ABSTRACT

In this study, ultrafiltration (UF) white cheese samples were manufactured using UF retentate, which had been heat-treated at different temperatures (75°C and 85°C for 15 s) and had altered ratios of protein-to-fat (P/F) (0.8, 0.7, and 0.6). The physicochemical and sensory properties of UF white cheeses during storage (90 days) were determined. White cheese manufactured from UF retentate with a P/F ratio of 0.6 had higher fat and lower protein contents than those with the P/F ratios of 0.7 and 0.8. Treatment temperature significantly influenced the pH and titratable acidity values of UF white cheeses. The highest hardness and chewiness values and the lowest adhesiveness values were determined in UF white cheese with P/F ratios of 0.8 and heat-treated at 85°C. During storage, the L*, a*, b*, and ΔE* values of white cheeses varied between 94.51 and 98.34, -0.77 and -0.06, 7.78 and 10.13, and 10.61 and 13.00, respectively. The use of high-fat-content ultrafiltered retentate subjected to high temperatures in the manufacture of white cheeses had a positive effect on overall acceptability scores.

Keywords: Cheese, Membrane filtration, Texture

Farklı Isıl İşlem Görmüş ve Protein-Yağ Oranları Değiştirilmiş Ultrafiltrasyon (UF) Retentatlarının UF Beyaz Peynirin Fizikokimyasal ve Duyusal Özellikleri Üzerine Etkisi

ÖZ

Bu çalışmada farklı sıcaklıklarda ısıl işlem uygulanan (75°C ve 85°C'de 15 s) ve protein yağ oranı değiştirilmiş ultrafiltrasyon (UF) retentatları kullanılarak beyaz peynir örnekleri üretilmiştir. UF beyaz peynir örneklerinin fizikokimyasal özellikleri ve tüketici kabulü 90 günlük depolama süresince belirlenmiştir. Protein/yağ oranı 0.6 olan UF retentattan üretilen peynirler, protein/yağ oranı 0.7 ve 0.8 olan UF retentatlardan üretilen örneklere göre yüksek yağ ve düşük protein içeriğine sahiptir. Isıl işlem sıcaklığı, beyaz peynirlerin pH ve titrasyon asitliği değerlerini istatistiksel olarak önemli düzeyde etkilemiştir. En yüksek sertlik ve çiğnenebilirlik ile en düşük yapışkanlık değerleri protein/yağ oranı 0.8 olan 85° C'de ısıl işlem görmüş UF retentantlardan üretilen beyaz peynirlerde belirlenmiştir. Depolama süresince, beyaz peynirlerin L*, a*, b* ve ΔE* değerleri sırasıyla 94.51-98.34, -0.77 - -0,06, 7.78-10.13 ve 10.61-13.00 arasında değişmiştir. Beyaz peynirlerin üretiminde yüksek ısıl işlem sıcaklıklarına tabi tutulan yüksek yağ içeren UF retentant kullanımı genel kabul edilebilirlik puanları üzerine olumlu bir etkiye sahiptir.

Anahtar Kelimeler: Peynir, Membran filtrasyon, Tekstür

INTRODUCTION

The use of concentrated milk through ultrafiltration (UF) membranes in its production has created a new production process for white cheese. The use of the UF process for milk concentration enables the selective separation of molecules with a molecular weight ranging from 1 to 200 kDa from the milk serum through cross-flow processing on the membrane surface under pressure [1]. In the UF process, the milk is divided into two parts: the diluted part, known as permeate, and the concentrated part, referred to as retentate. In the production of white cheese by the UF process, the retentate is utilized, and unlike traditional white cheese, whey is not expelled from the curd [2]. The salt, starter culture, and rennet could be added to the UF retentate in the production of white cheese by the UF process [1]. The UF process can increase the cheese yield and textural quality and decrease protein, fat, and total solids loss compared to traditional cheese production [3].

Different strategies, such as full concentration (approximately 7.5 times), 4 to 6 times concentration, a maximum of two-fold concentration, and concentration plus evaporation, can be employed in cheese production by the UF process. In the production of white cheese, as well as feta, mozzarella, havarti, danbo, and cheddar cheeses with the UF process, milk can be concentrated four to six times [4-6]. Alterations in the composition and structure of the UF retentate create differences in casein aggregation compared to milk. Casein micelles move more closely together because of the reduced distance between them, which likely increases the aggregation rate and directly influences the curd structure. The protein network becomes coarser with increasing casein concentration in cheeses produced by the UF process [7, 8]. The fat content, distribution of fat globules, and protein-fat interactions within cheese are important for the textural and structural properties of cheese [9]. The concentration of fat by the UF process appears to enhance the contact surface among fat globules, which causes them to aggregate and then fuse. When the fat globules remain intact within the protein matrix, the plasticizing influence of fat and water restricts the interactions among casein chains. Moreover, the retention of whey proteins in cheeses produced by the UF process results in the entrapment of water within the cheese matrix due to the hydrophilic characteristics of whey proteins [10]. The degree of whey protein denaturation may also impede rennet-induced aggregation of the casein micelles. Consequently, the manufacture of semi-hard and hard cheeses should not be achieved by subjecting milk to severe heat treatment. These lead to textural defects, such as softness and openness in cheeses produced by the UF process [11-13]. The heat treatment temperature and time significantly influence the degree of whey protein denaturation [14]. The milk composition and processing parameters affect the properties of cheeses [15].

Although there are many studies in the literature on the use of the UF process in cheese production, to our knowledge, there is no study evaluating the combined effects of the P/F ratio of UF retentate and the heat treatment applied to UF retentate on the quality and sensory characteristics of white cheese. The aim of this study was to ascertain how three different P/F ratios in UF retentate, along with two different heat treatments, affected the physicochemical and sensory properties of white cheese.

MATERIALS and METHODS

For the manufacture of white cheese by the UF process, raw cow milk was obtained from the Cattle Farms of Antalya, Türkiye. Rennet (600 International Milk Clotting Units mL^{-1}) and starter culture (R-704-DVS, including *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris*) were purchased from Maysa Food (İstanbul, Türkiye) and Peyma-Hansen Cheese Rennet Industry and Trade Inc. (İstanbul, Türkiye), respectively. The commercial salt (NaCl), polyethylene boxes (500 mL), and lids were supplied from local markets of Antalya. All the chemicals were of analytical grade, produced by Sigma Aldrich (Steinheim, Germany).

Manufacture of White Cheese by Ultrafiltration

The raw milk was heat treated at 72°C for 15 s and then standardized to about 3% fat using a separator (Tetra Pak, Alfa Laval Tumba AB, Eskilstuna, Sweden) at 50°C. Standardized milk was concentrated using an UF unit (UF 2000, Teknoproses Engineering Consulting Industry Trade Ltd. Co., Ankara, Türkiye) with a spiral-type membrane module (GR73PP-UF-pHt, Alfa Laval) at a pressure of 4.5 bar and a temperature of 50°C. After concentration, UF retentate was divided into three parts to adjust the protein-to-fat ratios of each differently as 0.6, 0.7, and 0.8 using milk cream (with 65% fat). The UF retentates with different P/F ratios were homogenized at 80 bar with an MG4-140B model homogenizer (BOS Homogenizers BV, Hilversum, Netherlands). The homogenized ultrafiltered retentates were heat treated at 75°C for 15 s and at 85°C for 15 s with a plate heat exchanger (Alfa Laval, PHE, Lund, Sweden) to denature whey proteins, respectively, in 1% and 10% ratios according to the kinetic data of Kessler [16]. After heat treatment, the UF retentates with varying P/F ratios were cooled at 32°C, followed by the addition of salt (1.0% w/v) and inoculation with starter culture (0.1% w/v). Then, the UF retentates were mixed with rennet solution in the filler machine (RPK-SBPD 2000, Ropak Machine Process Automation Industry and Trade Inc., Bursa, Türkiye). Then, the polyethylene boxes were filled immediately with the UF retentates and sent to a coagulation tunnel (Tünel 2000, Teknoproses Engineering Consulting Industry Trade Ltd. Co.). After moving through the tunnel at 32°C for 30 min, boxes were then sealed with aluminum foil and closed with lids. The UF retentates were incubated at 32°C for 24 hours until the pH reached about 4.7 and then cooled to 4°C. The white cheese manufactured by the UF process, named UF white cheese, was stored at 4°C for 90 days.

Physicochemical Analysis

Total solids, fat, and protein contents were determined in the raw milk, UF retentates, and UF white cheeses according to the Association of Official Analytical Chemists (AOAC) methods by the gravimetric, Gerber, and Kjeldahl, respectively [17-19]. The pH values of the raw milk, UF retentates, and UF white cheeses were measured with a pH meter (Thermo Scientific Orion 2 Star, Bremen, Germany). The titratable acidity and salt (NaCl) content of the UF white cheeses were determined by the Soxhlet-Henkel and Volhard methods, respectively [20, 21]. The CIE Lab color parameters (L*, a*, and b*) of each UF white cheese were measured by using a Konica Minolta Chroma Meter CR300 (Minolta Co., Ltd., Osaka, Japan). ΔE* values were calculated using the equation 1 below [22]:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

The device was calibrated using a white calibration plate (L=95.14, a=-0.13, b=2.71, and ΔE=0.57) before use. The TA-XT2 Texture Analyzer (Stable Micro Systems, Haselmere, Surrey, UK), equipped with a cylinder probe (P/2, 25 mm diameter), was used to measure the texture quality attributes (hardness, cohesiveness, resilience, and chewiness) of the UF white cheese samples [23].

Sensory Analysis

For the sensory analysis, 100 participants (59 females and 41 males) between the ages of 20 and 50 who did not have any specific health problems that would have an impact on the sensory evaluation were selected from the Department of Food Engineering at the Akdeniz University (Antalya, Türkiye) and from Yörükoğlu Dairy Product Inc., Co. (Antalya, Türkiye). The selected participants were informed about the sensory evaluation for approximately 1 h to become familiar with the descriptors. All samples were presented with a three-digit code. The hedonic scale ranging from 1 = “dislike extremely” to 7 = “like extremely” was used to evaluate the sensory quality parameters (color, texture, taste, and overall acceptability) for the sensory properties of the UF white cheese samples during the stored period. The participants evaluated a total of six UF white cheeses after 1, 45, and 90 days of storage [24].

Statistical Analysis

Each test was done in triplicate. SAS Statistical Software (release for Windows, SAS Institute Inc., Cary, NC, USA) was used to analyze the data. A three-factor ANOVA was performed to determine the effects of P/F ratio, heat treatment temperature, and storage time on the physicochemical and sensory properties of the UF white cheese samples. To identify differences among treatment means, Duncan's multiple range test was used.

RESULTS

Table 1 presents the chemical composition of the UF retentate with varying P/F ratios alongside raw milk. The total solids and protein contents of the UF retentates increased more than 2.6 and 4.1 times compared to raw cow milk, respectively. The highest fat content was found in the UF retentate with a P/F of 0.6. Similar pH values were observed for the raw cow milk and in UF retentates.

Table 1. The chemical composition of the UF retentate with varying P/F ratios alongside raw cow milk

Components	Raw cow milk	UFR0.8 P/F *	UFR0.7 P/F	UFR0.6 P/F
Total solids (%)	12.02±0.22	31.98±0.72	31.78±0.29	32.01±0.23
Fat (%)	3.76±0.08	16.12±0.11	17.85±0.15	19.81±0.09
Protein (%)	2.95±0.08	12.95±0.12	12.54±0.06	12.10±0.14
pH	6.71±0.06	6.66±0.51	6.71±0.36	6.68±0.44

Values are the means ± standard deviations. * UFR0.8 P/F: UF retentate with a P/F ratio of 0.8, UFR0.7 P/F: UF retentate with a P/F ratio of 0.7, * UFR0.6P/F: UF retentate with a P/F ratio of 0.6.

Total solids, fat, protein, and salt contents as well as pH and titratable acidity of the UF white cheeses are shown in Table 2. The results of ANOVA analysis showed that only storage time significantly ($P<0.05$) affected the total solids content of the UF white cheeses. The total solids content of the UF white cheese samples decreased from day 1 until day 45 and then slightly increased up to day 90 (Table 3). This may be explained by the rearrangement of peptide bonds in cheeses and the osmotic pressure difference between the cheese and the environment during storage [25, 26]. The UF white cheese sample manufactured from the UF retentate with a P/F ratio of 0.6 had a higher fat content and a lower protein content than that of other UF white cheese samples (Table 3). It might be due to the higher fat content and lower protein content of the UF retentate with a P/F ratio of 0.6 comparing the UF retentates with P/F ratios of 0.7 and 0.8. During the storage period, both the fat and protein contents of the UF white cheeses decreased. Gholamhosseinpour et al. [27] also found a notable decrease in fat content in cheese with a prolonged storage period. This phenomenon is attributed to the lipolysis of fats, resulting in the production of glycerol and free fatty acids. Soltani et al. [28] reported that changes in protein contents related to protein proteolysis and diffusion of water-soluble nitrogen into brine in UF Iranian white cheese. In the current study, the P/F ratio and heat treatment temperature did not significantly affect the salt content of the UF white cheeses. Salt content increased at the end of the storage period related to the osmotic pressure difference between the cheese moisture and the brine. This trend was similar to results reported by Al-Otaibi and Wilbey [29] and Guven et al. [30].

Table 2. Some chemical characteristics of the UF white cheese

Parameters	Storage (day)	0.8 P/F-75*	0.7 P/F-75	0.6 P/F-75	0.8 P/F-85	0.7 P/F-85	0.6 P/F-85
Total solids (%)	1	35.95±0.29	35.63±0.39	35.44±0.69	36.02±0.42	35.63±0.32	35.33±0.32
	45	35.24±0.10	35.06±0.22	35.11±0.09	35.48±0.10	35.56±0.48	35.13±0.37
	90	35.43±0.18	35.12±0.08	35.21±0.07	35.56±0.27	35.62±0.10	35.21±0.25
Fat (%)	1	17.00±0.28	19.05±0.35	20.65±0.14	17.25±0.07	18.75±1.06	20.20±0.99
	45	16.40±0.57	18.75±0.35	20.25±0.21	16.90±0.42	18.00±0.28	19.50±0.71
	90	16.15±0.21	18.70±0.28	19.77±0.32	16.81±0.84	17.52±0.11	19.29±0.34
Protein (%)	1	13.43±0.46	12.96±0.13	12.46±0.18	13.51±0.25	12.98±0.06	12.56±0.19
	45	13.00±0.30	12.88±0.20	12.37±0.35	13.16±0.11	12.87±0.04	12.43±0.11
	90	12.64±0.21	12.32±0.28	12.18±0.18	12.84±0.08	12.65±0.25	12.21±0.49
Salt (%)	1	1.79±0.03	1.85±0.09	1.86±0.12	1.82±0.04	1.83±0.11	1.85±0.08
	45	1.88±0.03	1.87±0.05	1.86±0.09	1.89±0.07	1.96±0.09	1.88±0.06
	90	1.93±0.12	1.89±0.04	1.94±0.02	1.89±0.03	1.99±0.07	1.95±0.09
pH	1	4.74±0.04	4.78±0.03	4.75±0.03	4.65±0.04	4.66±0.02	4.66±0.01
	45	4.63±0.03	4.65±0.04	4.68±0.04	4.58±0.02	4.55±0.01	4.57±0.03
	90	4.68±0.01	4.72±0.03	4.71±0.04	4.69±0.03	4.69±0.04	4.69±0.03
Titratable acidity (SH)	1	74.05±2.47	68.15±1.91	72.90±3.82	80.95±1.63	71.10±3.54	74.85±3.46
	45	79.75±2.19	79.05±2.05	82.10±0.42	89.25±1.91	80.15±3.61	84.95±1.91
	90	90.75±2.05	82.95±1.91	85.00±0.99	82.00±0.42	85.95±1.91	86.85±2.19

Values are the means ± standard deviations. * 0.8 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.8, 0.7 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.7, 0.6 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.6, 0.8 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.8, 0.7 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.7, 0.6 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.6

The pH and titratable acidity values of the UF white cheeses were determined to be 4.55-4.78 and 68.15-90.75 SH, respectively. The effect of the P/F ratio of the UF retentate on pH and titratable acidity values of the UF white cheese was not significant. The UF white cheeses manufactured from the UF retentate heat-treated at 85°C had lower pH and higher titratable acidity than those manufactured from the UF retentate heat-treated at 75°C. Because of their increased moisture content and consequent lactic acid, as well as their lower protein content (casein as a proportion of total protein) and buffering capacity, high-temperature cheeses have a lower pH [31, 32]. An increasing heating temperature leads to the denaturation of whey proteins, and the insolubilization of calcium phosphate causes changes in buffering capacity [33]. The pH values of all UF white cheese samples decreased during the first 45 days, after which a significant increase was observed. The increase in pH at the end of the storage is ascribed to the utilization of lactic acid, the formation of non-acidic decomposition by-products, and the release of alkaline substances resulting from the hydrolysis of proteins [34].

Table 3. The effects of the P/F ratio, heat treatment temperature, and storage time on some chemical and physicochemical characteristics of the UF white cheese

Experimental factors	Total solids (%)	Fat (%)	Protein (%)	Salt (%)	pH	Titratable acidity (SH)
P/F ratio	ns	***	***	ns	ns	ns
0.8	35.61±0.38 a*	16.75±0.50 c	13.09 ±0.38 a	1.87±0.08 a	4.66±0.06 a	82.79±6.11 a
0.7	35.44±0.40 a	18.46±0.67 b	12.78±0.28 b	1.90±0.10 a	4.68±0.08 a	81.75±6.85 a
0.6	35.24±0.40 a	19.94±0.63 a	12.37±0.25 c	1.89±0.10 a	4.68±0.06 a	81.11±5.85 a
Heat treatment temperature (°C)	ns	ns	ns	ns	***	***
75	35.50±0.42 a	18.53±1.62 a	12.69±0.44 a	1.88±0.09 a	4.70±0.05 a	78.77±5.96 b
85	35.35±0.39 a	18.25±1.28 a	12.80±0.41 a	1.90±0.10 a	4.64±0.06 b	84.99±6.55 a
Storage time (day)	*	**	***	*	***	***
1	35.67±0.53 a	18.82±1.49 a	12.98±0.45 a	1.83±0.09 b	4.71±0.06 a	75.32±4.63 c
45	35.26±0.36 b	18.30±1.46 b	12.78±0.34 a	1.89±0.08 ba	4.61±0.05 b	83.61±4.08 b
90	35.36±0.27 ba	18.04±1.41 b	12.47±0.33 b	1.93±0.08 a	4.70±0.03 a	86.71±3.23 a

Values are the means ± standard deviations; different letters for each parameter in a column show significant differences using Duncan's multiple range test (P<0.05). Significant effects at * P<0.05, ** P<0.01, ***P<0.001. ns; not significant.

The textural properties of the UF white cheese samples are shown in Table 4. The UF retentate with a P/F ratio of 0.8 resulted in the UF white cheese having significantly (P<0.05) higher hardness and lower adhesiveness compared to those samples manufactured from the UF retentates with P/F ratios of 0.6 and 0.7. However, non-significant effects of the P/F ratio of the UF retentate were recorded on the springiness and chewiness of the UF white cheese samples (Table 5). Similar to our results, Lepesioti et al.

[35] determined higher hardness and lower adhesiveness in fat-reduced Quark-type cheese. When the P/F ratio decreased, the fat content of the UF white cheese increased, and its hardness decreased. This may be explained by the effect of fat, which disrupts the protein matrix and acts as a lubricant, resulting in smoothness and a softer texture [36]. Moreover, the UF white cheeses manufactured from the UF retentate with a P/F of 0.8 had the highest protein content, which may be related to adhesiveness [35].

Table 4. Some textural properties of the UF white cheese

Parameters	Storage (day)	0.8 P/F-75	0.7 P/F-75	0.6 P/F-75	0.8 P/F-85	0.7 P/F-85	0.6 P/F-85
Hardness (g)	1	795.13±90.31	745.51±90.23	640.07±70.08	874.78±66.63	821.63±41.81	769.21±55.05
	45	682.64±51.53	544.34±62.67	599.31±86.78	837.06±64.39	756.21±64.24	719.82±80.09
	90	606.72±82.05	435.17±79.57	486.60±63.04	627.94±51.08	615.64±16.78	647.29±64.54
Adhesiveness (g.mm)	1	-113.09±33.25	-77.79±24.80	-60.57±19.88	-121.01±48.83	-82.73±6.56	-79.67±11.89
	45	-71.15±9.98	-64.79±6.34	-53.66±18.03	-86.31±19.90	-69.65±7.71	-60.27±18.04
	90	-48.50±11.57	-46.57±8.44	-40.91±7.75	-64.87±9.04	-56.04±15.97	-54.51±21.19
Springiness (mm)	1	0.69±0.15	0.75±0.13	1.16±0.48	0.59±0.20	0.71±0.15	1.08±0.59
	45	0.78±0.10	0.75±0.09	0.72±0.15	0.94±0.36	1.08±0.58	0.81±0.11
	90	0.88±0.40	0.82±0.41	0.69±0.18	1.13±0.65	0.92±0.46	0.74±0.23
Chewiness (g.mm)	1	122.86±14.88	109.90±22.71	105.80±35.73	140.06±33.79	130.66±13.92	125.82±35.74
	45	106.02±16.45	100.90±22.14	99.49±15.00	111.89±41.27	108.92±17.35	107.67±31.78
	90	97.07±30.76	94.72±26.23	91.27±23.15	102.99±4.39	96.71±31.90	86.68±15.17

Values are the means ± standard deviations. * 0.8 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.8, 0.7 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.7, 0.6 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.6, 0.8 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.8, 0.7 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.7, 0.6 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.6.

The increasing heat treatment temperature increased the hardness and chewiness values of the UF white cheese samples. Aydemir and Kurt [37] observed that the highest hardness value was determined in white cheeses produced from milk heated at 85°C for 5 min, followed by white cheeses made from milk at 75°C for 5 min and at 65°C for 20 min, respectively. The authors attributed this to the fact that intramolecular and intermolecular interactions of casein occur more intensely with higher heat treatment temperatures. Moreover, the percentage of denatured protein in cheese increases with temperature, which leads to an improvement in the overall cheese structure. In the UF white cheese samples, chewiness demonstrated a similar trend to hardness, which was in accordance with the study of Jia et al. [38]. The results of the ANOVA analysis showed that heat treatment temperature and storage time had no significant effect on the springiness of the UF white cheeses (Table 5), which may be because of the constant and high moisture content of the samples [39]. The hardness and chewiness of the UF white cheeses decreased during storage. Aydemir and Kurt [37] and Fathollahi et al. [40] explained the decrease in hardness value caused by protein proteolysis in white cheeses during storage.

Table 5. The effects of the P/F ratio, heat treatment temperature, and storage time on some textural properties of the UF white cheese

Experimental factors	Hardness (g)	Adhesiveness (g.mm)	Springiness (mm)	Chewiness (g.mm)
P/F ratio	***	***	ns	ns
0.8	737.36±122.74 a*	-84.16±37.00 b	0.85±0.42 a	113.48±30.37 a
0.7	653.06±147.21 b	-66.27±18.23 a	0.83±0.36 a	106.97±26.05 a
0.6	644.89±114.00 b	-58.27±20.22 a	0.87±0.35 a	102.79±30.34 a
Heat-treatment temperature (°C)	***	**	ns	*
75	615.05±131.81 b	-64.12±27.17 a	0.82±0.30 a	103.11±25.58 b
85	741.82±166.49 a	-75.01±29.04 b	0.89±0.36 a	112.38±31.98 a
Storage time (day)	***	***	ns	***
1	773.49±98.01 a	-89.15±35.00 c	0.83±0.36 a	122.52±30.14 a
45	691.93±118.48 b	-67.64±17.46 b	0.85±0.31 a	105.82±26.19 b
90	569.89±101.64 c	-51.90±15.26 a	0.88±0.44 a	94.91±24.47 b

Values are the means ± standard deviations; different letters for each parameter in a column show significant differences using Duncan's multiple range test (P<0.05). Significant effects at * P<0.05, ** P<0.01, ***P<0.001. ns; not significant.

The color parameters, such as L* (lightness), a* (+redness/-greenness), and b* (+yellowness/-blueness), and ΔE* (total color differences) values [41] are shown in Table 6. The highest L*, a*, b*, and ΔE* values were found in the UF white cheeses manufactured from the UF retentate with a P/F of 0.6. Sánchez-Macías et al. [42] also determined that during 28 days of ripening, the L*, a*, and b* values of the full-fat goat cheeses were higher than those of reduced-fat and low-fat goat cheeses. An increasing fat content leads to lightness due to the high light scattering ability of fat globules [43]. In cheese, light penetrates the outer layers and is dispersed by milk fat globules and the boundaries of whey pockets [44]. According to the ΔE value ranges,

the color difference between samples can be estimated as recognizable (1.5-3.0) and well visible (3.0-6.0) [22]. In the current study, ΔE* values were found above 6.0 in all UF white cheeses, which is noticeable to the consumer.

Table 6. Color characteristics of the UF white cheese

Parameters	Storage (day)	0.8 P/F-75	0.7 P/F-75	0.6 P/F-75	0.8 P/F-85	0.7 P/F-85	0.6 P/F-85
L*	1	96.54±0.45	96.07±0.80	97.15±1.20	97.20±0.48	97.46±0.80	98.34±0.52
	45	95.45±0.37	95.02±1.25	95.80±0.66	96.45±0.27	96.52±0.38	96.56±0.41
	90	94.71±0.78	94.87±0.24	94.94±0.66	94.57±2.09	94.51±2.16	94.64±2.04
a*	1	-0.35±0.19	-0.35±0.16	-0.30±0.11	-0.77±0.20	-0.64±0.05	-0.51±0.05
	45	-0.29±0.11	-0.20±0.12	-0.18±0.10	-0.68±0.12	-0.64±0.09	-0.54±0.06
	90	-0.19±0.14	-0.10±0.13	-0.06±0.05	-0.60±0.23	-0.43±0.13	-0.41±0.08
b*	1	8.02±0.20	8.30±0.29	8.45±0.19	7.81±0.41	8.19±0.35	8.23±0.05
	45	8.69±0.27	8.84±0.27	8.84±0.19	7.78±0.36	8.23±0.26	9.44±0.72
	90	8.97±0.57	9.97±0.87	10.00±0.38	8.25±0.15	9.21±0.42	10.13±0.91
ΔE*	1	10.84±0.20	11.08±0.25	11.41±0.32	10.76±0.35	11.20±0.20	11.43±0.13
	45	11.42±0.26	11.52±0.34	11.59±0.18	10.61±0.37	11.06±0.24	12.25±0.71
	90	11.71±0.61	12.68±0.17	12.74±0.40	11.19±0.15	12.14±0.58	13.00±1.05

Values are the means ± standard deviations. * 0.8 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.8, 0.7 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.7, 0.6 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.6, 0.8 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.8, 0.7 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.7, 0.6 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.6.

As seen in Table 7, high heat treatment temperatures caused an increase in L* values and a decrease in the a* and b* values of the UF white cheeses. Darnay et al. [22] compared the color parameters of cheese made from raw or pasteurized (72°C, 15 s) buffalo milk and observed higher L* values and lighter yellow color in buffalo cheese made from pasteurized milk. The color properties of cheeses may be related to the changes in milk during heat treatment. As an example, the larger size of casein micelles during heat treatment results in milk whitening, which subsequently influences reflectance and reduces the yellow index [45]. The storage time was found to be significantly effective on the L*, a*, b*, and ΔE* values of the UF white cheese samples (P<0.001). Although lipolysis and amounts of carotenoid compounds were not measured in this study, alteration of color parameters in cheeses during storage may be due to lipolysis of fats and oxidation of carotenoids. Sabbagh et al. [46] also noticed a decrease in the L* value, probably due to the degree of lipolysis during the storage period. Moreover, Sabetsolat et al. [2] explained that the color alterations in the cheese samples are likely attributable to the oxidation of the carotenoid compounds that contribute to red color during storage.

Table 7. The effects of the P/F ratio, heat treatment temperature, and storage time on color parameters of the UF white cheese

Experimental factors	L*	a*	b*	ΔE*
P/F ratio	*	***	***	***
0.8	95.81±1.38 ba	-0.48±0.27 c	8.25±0.57 c	11.09±0.53 c
0.7	95.73±1.54 b	-0.39±0.24 b	8.79±0.79 b	11.63±0.77 b
0.6	96.23±1.67 a	-0.33±0.19 a	9.18±0.89 a	12.07±0.85 a
Heat treatment temperature (°C)	*	***	***	ns
75	95.61±1.11 b	-0.22±0.16 a	8.89±0.77 a	11.68±0.75 a
85	96.24±1.83 a	-0.57±0.17 b	8.54±0.90 b	11.52±0.90 a
Storage time (day)	***	***	***	***
1	97.12±1.04 a	-0.48±0.22 c	8.16±0.34 c	11.12±0.36 c
45	95.96±0.88 b	-0.42±0.23 b	8.63±0.65 b	11.43±0.64 b
90	94.70±1.55 c	-0.29±0.24 a	9.42±0.91 a	12.25±0.93 a

Values are the means ± standard deviations; different letters for each parameter in a column show significant differences using Duncan's multiple range test (P<0.05). Significant effects at * P<0.05, ** P<0.01, ***P<0.001. ns; not significant.

Table 8 shows the scores of panelists for the UF white cheeses during 90 days of storage. Farah et al. [47] reported that acceptance of food depends mostly on three attributes: appearance, taste, and texture, and is independent of the nutritional content of the food. The effect of the P/F ratio and heat treatment temperature on the appearance, texture, and taste scores of the UF white cheese samples was not significant (P>0.05), whereas the lowest overall acceptability scores were found in the samples manufactured from the UF retentate with a P/F of 0.8 (Table 9). Sánchez-Macías et al. [42] demonstrated that most of the 50 untrained consumers were not accepting of lower-fat goat cheese because of its hard, dry, and rough texture. Besides,

Kaczyński et al. [48] showed that the fat content, which affects the texture and color of cheeses, determines its acceptability.

Table 8. Sensory properties of the UF white cheese

Parameters	Storage (day)	0.8 P/F-75*	0.7 P/F-75	0.6 P/F-75	0.8 P/F-85	0.7 P/F-85	0.6 P/F-85
Appearance	1	3.79±1.40	3.77±1.30	3.63±1.43	3.78±1.50	3.73±1.55	3.67±1.54
	45	3.20±0.94	3.33±1.34	3.34±1.27	3.23±0.95	2.69±0.85	3.03±0.96
	90	3.92±1.54	4.00±1.25	3.87±1.50	4.65±1.36	4.14±1.36	3.81±1.20
Texture	1	3.36±0.98	3.55±0.81	3.37±0.78	3.38±0.80	3.15±0.80	3.51±0.70
	45	3.29±0.98	3.69±0.70	3.79±0.84	3.64±0.81	3.45±0.76	3.31±0.80
	90	3.51±0.82	3.34±0.84	3.70±0.72	3.74±0.86	3.70±0.81	3.68±0.92
Taste	1	2.73±0.71	3.03±0.84	3.31±0.82	2.99±0.85	3.06±0.83	3.33±0.61
	45	2.53±0.61	2.78±0.63	2.99±0.55	2.98±0.85	2.71±0.64	2.78±0.70
	90	3.52±0.96	3.44±0.78	3.59±0.85	3.35±0.80	3.22±0.62	3.22±0.69
Overall acceptability	1	3.97±1.45	3.63±1.83	4.40±1.72	3.73±1.98	3.83±1.73	4.23±1.78
	45	4.50±1.37	3.88±1.80	4.13±1.22	3.94±1.71	4.06±1.43	4.25±1.25
	90	2.44±1.79	3.24±1.82	3.40±2.00	3.32±1.67	4.80±1.55	4.32±1.62

Values are the means ± standard deviations. * 0.8 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.8, 0.7 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.7, 0.6 P/F-75: UF white cheese manufactured from UF retentate heat treated at 75°C and having a P/F ratio of 0.6, 0.8 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.8, 0.7 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.7, 0.6 P/F-85: UF white cheese manufactured from UF retentate heat treated at 85°C and having a P/F ratio of 0.6.

Overall acceptability scores increased when the heat treatment temperature was increased from 75 to 85°C (Table 9). Similar to our results, Frau et al. [49] demonstrated that spreadable cheese obtained from milk pasteurized at 75°C had higher general acceptance scores than those obtained from milk pasteurized at 65°C because of the change in the water-holding capacity of protein. Miloradoviç et al. [50] found that as the heat treatment temperature of milk increased, the sensory acceptability in cheeses increased and reported that after high heat treatment, components of the milk fat globule membrane engaging with milk proteins, which resulted in the microstructure of cheese produced from milk subjected to high heat treatment having fewer spherical voids. The storage time significantly affected the appearance, taste, and overall acceptability scores of the UF white cheeses. The appearance and taste scores of the UF white cheese samples decreased from day 1 to day 45 and then increased until day 90. The overall acceptability scores increased on the 45th day and then decreased at the end of the storage period (Table 9). The research conducted by Soltani et al. [28] demonstrated no correlation among appearance scores, texture scores, and total scores noted in UF cheeses during storage time. Al-Otaibi and Wilbey [39] reported that consumers' appreciation of UF cheeses on a hedonic scale did not change during 12 weeks of storage and explained that the breakdown of proteins and release of proteolysis products at moderate levels may cause the formation of an acceptable taste in cheeses.

Table 9. The effects of the P/F ratio, heat treatment temperature, and storage time on sensory properties of the UF white cheese

Experimental factors	Appearance scores	Texture scores	Taste scores	Overall acceptability scores
P/F ratio	ns	ns	ns	*
0.8	3.87±1.45 a*	3.54±0.87 a	3.20±0.94 a	3.35±1.93 b
0.7	3.69±1.38 a	3.46±0.82 a	3.07±0.78 a	3.88±1.78 a
0.6	3.61±1.39 a	3.56±0.80 a	3.25±0.76 a	4.14±1.69 a
Heat-treatment temperature (°C)	ns	ns	ns	***
75	3.73±1.40 a	3.54±0.83 a	3.24±0.89 a	3.54±1.90 b
85	3.72±1.43 a	3.50±0.83 a	3.10±0.76 a	4.04±1.73 a
Storage time (day)	***	ns	***	**
1	3.75±1.47 a	3.43±0.82 a	3.20±0.85 a	3.77±1.91 ba
45	3.13±1.08 b	3.52±0.84 a	2.79±0.68 b	4.12±1.49 a
90	4.08±1.40 a	3.63±0.83 a	3.39±0.80 a	3.60±1.90 b

Values are the means ± standard deviations; different letters for each parameter in a column show significant differences using Duncan's multiple range test (P<0.05). Significant effects at * P<0.05, ** P<0.01, ***P<0.001. ns; not significant.

CONCLUSION

The findings of this study indicated that the P/F ratio of UF retentate and the temperature of applied heat treatment to UF retentate led to substantial differences in the physicochemical and sensory properties of the UF white cheese. The decreasing P/F ratio and heat treatment temperature decreased the hardness value

and increased the adhesiveness, a*, and b* values in the UF white cheese. The overall acceptability scores were lower for the UF white cheeses, which were manufactured from the UF retentate heat-treated at 75°C for 15 s and had a P/F of 0.8. In conclusion, when the physicochemical and sensory properties of the UF white cheese are taken into account, experiments conducted within the scope of this study showed that the UF retentate, which was heat treated at 85°C for 15 s and has a P/F ratio of 0.7, is more suitable for use in the manufacture of UF white cheese.

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