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THE EFFECT OF CURD COOKING TEMPERATURE AND TIME ON CHEMICAL AND MELTING PROPERTIES IN CHEESE PRODUCED WITH THE TRADITIONAL METHOD

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Abstract: In this study, the yield and melting behavior of traditionally produced cheeses were analyzed by applying different curd cooking temperatures and times. The cheeses produced by using three different curd cooking times (1 minute, 6 minutes and 11 minutes) and two different curd cooking temperatures (55°C and 65°C) were brined for 90 days and were brined on the 1st, 30th, 60th and 90th days. The process, chemical properties and melting behavior of the cheeses were determined. In the study, the chemical and physical properties of the cheeses produced vary depending on the cooking temperature, cooking time and ripening time. The melting behavior of cheeses was determined according to the initial melting point, degree of fluidity and average flow rate obtained from melting profiles. The initial melting point increased with increasing temperature but decreased with decreasing cooking time. The degree of fluidity and average flow rate of cheeses cooked at 55°C were calculated to be higher than those of cheeses cooked at 65°C. Increasing the curd cooking temperature decreased the fluidity of the cheeses and increased the average flow rate. With increasing cooking time, the flowability of the cheeses decreased while the average flow rate increased.

Key Words: Curd cooking time, Curd cooking temperature, Cheese ripening, Melting behavior

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1. Introduction

Cheese has a special importance in human nutrition due to its long shelf life and the fact that it contains a significant part of the nutrients in milk (protein, milk fat, calcium, phosphorus and some vitamins). It is the dairy product with the most variety in the world because it is produced with different techniques almost all over the world (Kwak et al., 2011).

Due to the differences in the type of milk used today and the production methods, there are hundreds of different types of cheese in the world. In Türkiye various local cheeses are produced according to the regional conditions, cultural habits, animal breeds and species, and production differences of each region, mainly in the Aegean, Eastern Anatolia, Black Sea, and Central Anatolia. For example, white cheese produced in and around Sivas province by mixing sheep's milk and cow's milk is one of the local cheeses that is structurally a hard cheese and has similar behavior to Kashar cheese due to its meltability and is preferred by consumers due to its meltability.

There has been a significant increase in cheese production and consumption in Türkiye in recent years. One of the most important factors in this increase is that traditional cheeses have become sought after, especially in big cities, as a result of the production of traditional cheeses by medium or large-scale enterprises outside the region where they are produced. Therefore, the popularity of local cheeses such as Cecil, Dil, Örgü, Otlu and Mihaliç has increased, as well as Beyaz, Kashar and Tulum cheeses (Hayaloglu et al., 2008).

Pizza, various sauces, etc. are prepared with temperature applications that will ensure the melting and flow of the cheese contained in it. The preference or acceptance of these foods by the consumer depends on the quality of the melted cheese. For this reason, the melting and flow properties of cheese are critical in foods containing cheese.

The melting quality of the cheese is often defined in the industry as "meltability". Meltability is one of the most important functional properties of cheese, and it is defined as how easily the cheese melts and spreads when heated. Cheese meltability includes two aspects: ease of melting and flow size. While the ease of melting is directly related to heat transfer and heat process change of cheese; the flow size is related both to the force to cause the flow and to the high-temperature rheological properties of the cheese. For this reason, heat phase change and rheological properties of cheese should be taken into consideration while determining the melting properties of cheese (Gunasekaran and Ak, 2003).

Changes in the protein network structure explain the mechanism of cheese melting. The integrity of the network structure of cheese, which consists of three-dimensional para-caseinate, is provided by cross-links between proteins. The network structure, in which moisture and oil are trapped separately or in combined masses, resembles a sponge (Fox et al., 2000). Fat is the only component that truly melts in cheese, but increasing the temperature loosens the protein-protein bonds, causing the structure to soften and flow. In the cheese gel, which shrinks with energy, fat and water are separated at the macroscopic level, and protein-protein interactions are changed at the molecular level. At temperatures above 40°C, the number and strength of the bonds in the protein network structure decrease, the casein micelles change from an elastic state to a viscous fluid state, and the contact area between the casein particles also decreases. The decrease in the contact areas of the proteins and the decrease in the hydrogen bonds weaken the protein network structure (Udayarajan, and Lucey, 2005)

The melting property of cheese is made by observation-based tests such as Schrebier and Arnott (Arnott et al., 1957). However, in practice, a new objective evaluation was needed because it takes a long time to examine the melting properties of these tests under different temperatures, different sample shapes and sizes, and the objective evaluation is difficult. In line with this need, Gunasekaran and his research team at the University of Wisconsin designed and developed an instrument to objectively measure the melting/flow behavior of cheeses at different temperatures, and they named this device the "Uw Melting Meter".

The melting property of cheese changes according to the processes applied and the ratio of the molecules in its composition. Since the chemical events occurring during cheese ripening affect the composition, cheese ripening has a direct effect on the melting property. As casein-casein and casein-water interactions increase as a result of increased hydrolysis with proteolysis occurring during ripening, the flow of casein aggregates becomes easier and cheese solubility increases. In addition, the increase in cheese fat content increases its meltability. This effect is due to the increased fat content weakening the protein matrix (Everett and Auty, 2008).

In this study, the effects of different curd cooking temperatures (55°C and 65°C) and cooking times (1 min., 6 mins. and 11 mins.) on the melting behavior of the cheeses produced by the method applied in Sivas province and its surroundings were investigated. For this purpose, firstly, the Uw melting device was prepared and the melting properties of the cheese curds produced were evaluated with this device. In addition, the melting behavior and the change in the chemical composition of cheese clots left to ripen in brine after dry salting were observed on the 1st, 30th, 60th and 90th days of ripening.

2. Material and Methods

2.1. Materials

In this research, milk obtained from cows and sheep raised in rural areas about 2 months after the lactation period was used as raw material. The rennet (1:8000 strengths, Yayla Süper Maya) and salt used in cheese making were obtained from local markets.

Cow and sheep milk were mixed in a 1:1 ratio and brought to 45°C. Without calculating the amount of enzyme to be added to the milk, it was added as much (10 ml) as the amount of continuous production by the people who produce at home. After the enzyme-added milk was coagulated at 40°C, the curd was cut and the curd was boiled at two different temperatures (55°C, 65°C) and three different times (1 min, 6 mins and 11 mins). After the cooking process, the bagged clots were left to be suppressed at approximately 40°C. The curds from which the whey was separated were dry salted and kept for 24 hours, then left to mature in the prepared brine (14% salt) at 15°C for 3 months (Figure 1).

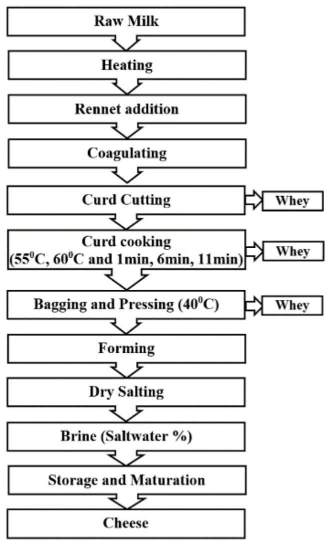

Figure 1. Traditional cheese production flow chart.

2.2. Methods

2.2.1. Physical and chemical analysis of milk and cheese samples used in cheese making

pH, protein, fat, salt, dry matter, water-soluble nitrogen, and water activity analyses were performed on the 1st, 30th, 60th and 90th days following curd and ripening. The dry matter content of curd and cheese was measured gravimetrically (TS, 2006), salt content according to the Mohr method (Hayaloglu et al., 2011) and fat content using Funke-Gerber cheese butyrometers according to the Van Gulik method according to TS 3433. Protein content was measured with Kjeldahl according to the AOAC method (AOAC, 1990). While determining the water-soluble nitrogen content of cheeses and curds, the extract was prepared according to the method of Kuchroo and Fox (1982). The pH of the cheeses was determined potentiometrically by the WTW brand Inlab Level-1 model pH meter with a glass electrode directly. By immersing the electrode directly into the cheese, the average of the values measured from 3 different points was taken. The water activities of the produced curd and cheese were determined at 25°C with an electronic Novasina Labmaster-aw water activity determination device. Color analysis was performed using the Chroma Meter (Minolta, model CR300, Minolta Camera Company, Osaka, Japan). Results are explained according to L*, a* and b* parameters. Before measurements, the instrument was calibrated with a reference white layer (Voss, 1992; Martley and Michel, 2001). All analyses were performed in 2 parallel.

2.2.2. Melting behavior

To determine the melting behavior of the produced curd and cheese, first, a melting profile device, which is like the device that gives the melting profile developed by the University of Wisconsin, can read and monitor the instant level and temperature changes in the heated cheese mass and report the level-temperature relations at desired time intervals has been prepared. In the device, it is ensured that the data collection unit communicates with the personal computer with an appropriate protocol, the data is recorded from the database and monitored on the screen with an interface software. LVDT level sensor, whose frequency changes according to the height change, was used to measure the level, and a T-type thermocouple was used to measure the temperature. Cheese samples were cut with the help of a steel cylinder with a diameter of 3 cm and a height of 0.7 cm and the surfaces of the samples were lubricated with mineral oil (Figure 2). Then, the melting behavior was investigated in the melt analyzer at 70°C. The cheese melting profile (Figure 3) was drawn with the data obtained because of the melting analysis.

Figure 2. The designed melt profile device and the cut cheese sample.

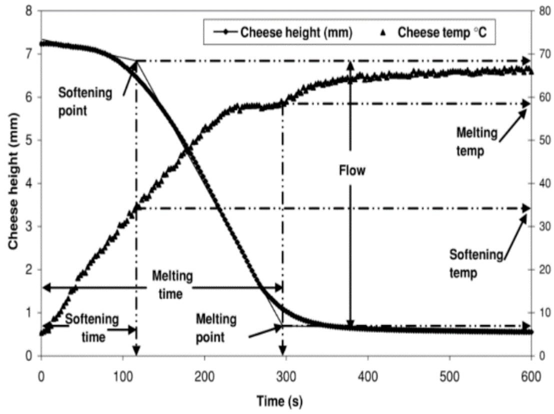

Figure 3. Cheese melting profile (Gunasekaran and Ak., 2003).

Melting initiation temperatures (TEB), flowability and average flow rates (OAO) of cheeses were calculated from the melting profile drawn separately for each cheese. The melting initiation temperature was read from the cheese sample temperature column in the drawn melting profile. The mean flow rate was calculated as the maximum value of the slope of the line connecting the melting temperature (TEB) and the melting termination temperature (TES) in the melting curve. The mean flow rate was calculated as the maximum value of the slope of the line connecting the melting temperature (TEB) and the melting termination temperature (TES) in the melting curve. The average flow rate is an estimate of the meltability of the cheese (Gunasekaran and Ak., 2003). The flowability degrees of the cheeses were calculated according to Chevanan and Muthukumarappan (2007) using the following equation.

$$\text{Flowability (\%)} = \frac{\text{Cheese initial height} - \text{Cheese final height}}{\text{Cheese initial height}} X100 \qquad (1)$$

2.3. Statistical Analysis

The effects of the factors used in the research (ripening time, scalding temperature and scalding time) on the dependent variables were analyzed at P<0.05 level with variance analysis by applying the Statistica package program (1995). If the variance analysis results were found to be significant, the difference between which groups were determined by applying the least significant difference (LSD) test from multiple comparison tests (P<0.05).

3. Results and Discussion

In the study, some chemical properties of the mixture of sheep and cow milk used for cheese production were determined because of the analyzes and the fat content was determined as 5.8 g/100g, protein content 3.88g/100g, dry matter content 13.86 g/100g, pH value 7.8 calculated.

It was found that the dry matter contents of the curds produced by applying two different cooking temperatures and three different cooking times ranged between 50.41-54.55%, respectively, and the effects of cooking time, cooking temperature and the interaction of these factors on the dry matter content of curds were found to be statistically significant (P<0.05) (Table 1).

High-temperature application increases the flocculation of the paracasein micelles and facilitates the removal of water in the structure, that is, it increases syneresis (Metin, 2008). When the cooking temperature of the curds produced increased, the syneresis and thus the amount of water separated from the structure increased, causing the dry matter content of the curds cooked at 65°C to be higher than those cooked at 55°C. The increase in the cooking time at both cooking temperatures also increased the dry matter content. This change in the dry matter content of the curds depending on the cooking time was associated with syneresis and the increase in the applied cooking time led to an increase in the amount of water separated from the structure and thus the amount of dry matter.

It was determined that the dry matter content of the ripened cheeses increased in the 1-30 days of ripening and fluctuated between the 30-90 days. When the dry matter contents of curd and 1st day cheeses were compared, the dry matter contents of 1st day cheeses were higher than that of curds at each cooking temperature and time. This difference in the dry matter content of the 1st-day cheeses stored in curd and brine resulted from the displacement of water and salt in the mass with salting in the 1st day cheeses. The passage of salt into cheese is by diffusion. While salt diffuses into the cheese, the water in the cheese comes out and the cheese loses water (Walstra, 1999; Fox et al., 2000). Therefore, the diffusion of salt into the cheese mass increased the dry matter content in the cheese samples on the 1st day of storage.

Table 1. Average values of the chemical and physicochemical properties of the produced curd and cheese

Ripening time (day)	Cooking time (min)	Cooking temperature (°C)	Dry matter (%)	Fat (%)	Fat in dry matter	Protein (%)	Protein in dry matter	Salt (%)	Salt in dry matter	Water soluble N (%)	pH	a_w	L value
0	1	55	50.41	25.00	49.61	23.41	46.65	0.94	1.86	0.13	5.76	0.98	89.89
0	6	55	51.21	23.00	44.91	23.03	44.97	1.17	2.28	0.23	5.76	0.96	89.16
0	11	55	52.84	25.00	47.31	24.66	46.67	1.17	2.21	0.20	5.82	0.96	88.99
0	1	65	52.92	25.00	47.24	23.97	45.30	0.94	1.77	0.08	5.81	0.97	87.57
0	6	65	50.41	23.00	45.63	23.12	45.87	0.94	1.86	0.27	5.92	0.96	88.74
0	11	65	54.55	26.00	47.67	25.70	47.12	1.17	2.14	0.25	5.91	0.97	87.27
1	1	55	52.34	23.00	43.89	23.92	45.75	3.36	6.63	0.03	5.80	0.87	87.30
1	6	55	56.34	26.05	46.26	23.42	41.59	4.33	7.65	0.24	5.71	0.85	86.78
1	11	55	56.39	26.00	46.10	24.15	42.84	3.98	7.06	0.33	5.67	0.81	87.11
1	1	65	59.83	26.00	43.46	26.43	44.18	5.56	9.29	0.10	5.71	0.85	87.74
1	6	65	53.38	23.00	43.04	22.92	42.96	4.97	9.32	0.27	5.87	0.86	87.08
1	11	65	58.79	24.00	40.89	27.15	46.22	5.41	9.14	0.25	5.90	0.88	86.56
30	1	55	67.45	28.00	41.15	30.98	45.93	6.87	10.19	0.27	6.15	0.85	87.06
30	6	55	66.28	29.50	44.40	27.83	41.99	6.73	10.15	0.26	6.00	0.84	87.94
30	11	55	66.63	29.00	43.52	28.02	42.05	7.31	10.97	0.32	6.06	0.79	86.14
30	1	65	63.93	27.00	42.22	27.37	42.80	7.17	11.21	0.20	6.02	0.84	88.09
30	6	65	67.14	30.00	44.67	27.61	41.14	7.75	11.55	0.39	6.01	0.85	86.74
30	11	65	68.08	29.50	43.33	28.41	41.73	8.04	11.81	0.22	6.09	0.85	86.22
60	1	55	63.28	27.00	42.67	26.81	42.37	7.17	11.32	0.23	5.35	0.94	88.50
60	6	55	67.78	29.50	43.52	28.14	41.52	7.46	11.00	0.22	5.20	0.93	87.33
60	11	55	66.68	30.00	44.94	26.58	39.90	7.90	11.85	0.32	5.18	0.92	86.88
60	1	65	63.27	26.00	41.08	26.72	42.23	8.04	12.72	0.16	5.23	0.91	87.86
60	6	65	65,25	29.00	44.10	26.48	40.28	8.34	12.68	0.23	5.34	0.90	87.00
60	11	65	68.72	30.00	43.66	27.88	40.57	8.92	12.98	0.25	5.52	0.91	86.48
90	1	55	61.95	26.00	41.97	26.93	43.47	7.17	11.57	0.24	5.34	0.92	88.54
90	6	55	61.89	26.00	42.02	27.00	43.63	7.31	11.82	0.26	5.20	0.92	87.27
90	11	55	64.32	28.50	44.31	25.98	40.39	7.90	12.28	0.38	5.11	0.89	86.76
90	1	65	69.18	30.00	43.35	29.32	42.39	7.90	11.41	0.29	5.34	0.92	87.66
90	6	65	66.02	27.50	41.65	28.20	42.71	8.34	12.63	0.32	5.38	0.89	86.98
90	11	65	69.40	29.00	41.69	29.46	42.45	9.07	13.07	0.14	5.19	0.91	87.28

When the effects of cooking time, cooking temperature and ripening time on dry matter content were examined, the effects of single, double, and triple interactions of factors on dry matter were found to be statistically significant (Table 2).

When the storage period increased from the 1st to the 30th day, a sudden increase in the dry matter content of the cheeses was observed at each cooking temperature and time, and on the 30th, 60th and 90th days of storage, the dry matter content of the cheeses increased and decreased depending on the cooking temperature (Table 2). The sudden increase in the dry matter content of cheeses between the 1st and 30th days was associated with the continuation of salt diffusion, 30.-90. It was thought that the increase and decrease between the days were due to the biochemical changes that took place during the ripening of the cheeses (Fox and McSweeney, 2017).

Dagdemir et al. (2003) examined the effect of using different starter cultures on the properties of white cheese and Gursoy (2005) studied the use of some probiotic bacteria as a support culture in the production of white cheese.

Milk fat, which is one of the most important components of milk, is important in terms of nutrition and economy as well as its effect on cheese taste, aroma and texture. When the analysis results of the fat contents of the curd and cheese samples and the fat values calculated over the total dry matter are examined, the fat content of the curds in dry matter varies between 44.91-49.61%, and in general, the fat content of the curds cooked at 55°C is found to be at 65°C. It was observed that it was higher than the cooked curd (Table 1). However, when the effect of the factors on the fat content of the curds in dry matter was analyzed by analysis of variance, it was determined that the effect of cooking temperature alone was not statistically significant, and the cooking temperature x cooking time interaction was significant (Table 2). Therefore, the increase in the boiling time together with the cooking temperature caused some of the fat in the mass to melt and go out of the mass.

Table 2. Effect of factors on chemical and physicochemical properties of curds

Factors	dF	Dry matter		Fat in dry matter		Protein in dry matter		Salt in dry matter	
		MS	F	MS	F	MS	F	MS	F
Cooking temperature (1)	1	5.812	21.705***	0.824	3.511	0.196	0.905	0.171	306.89***
Cooking time (2)	2	13.196	49.280***	15.727	67.028***	3.411	15.765**	0.213	381.12***
1x2	2	4.493	16.778***	4.265	18.176**	1.753	8.101**	0.061	109.22***
Factors	dF	Salt		a_w		Water soluble N		L value	
		MS	F	MS	F	MS	F	MS	F
Cooking temperature (1)	1	0.027	325.28***	0.0000	0.50	0.001	1012.50***	0.46	0.36
Cooking time (2)	2	0.821	975.85***	0.000171	171.50***	0.371	3714.62***	8.28	6.46**
1x2	2	0.027	325.28***	0.000142	141.50***	0.044	4378.79***	0.23	0.18

* P<0.05; ** P<0.01; *** P<0.001; dF= degrees of freedom; MS= mean of squares

When the % fat content of cheeses ripened in brine was examined, it was found that it varied between 23% and 30% (Table 1) and the % fat content of cheeses cooked at 65°C on the 1st day of ripening was lower than those of samples cooked at 55°C. On the 30th and other days of ripening, although there was a difference in the % oil content depending on the cooking time at both cooking temperatures, the effect of the cooking temperature on the % oil content was not observed (Table 1).

Considering the fat content in dry matter of cheese samples ripened in brine, it was observed that there were significant increases and decreases in % fat content during ripening. The fat content in dry matter of cheeses cooked at 65°C on the 1st day of ripening was found to be lower than those cooked at 55°C. This was due to the lower dry matter content of curds cooked at 65°C than those cooked at 55°C.

As a result of the analysis of variance, it was found that the effect of cooking temperature alone on the fat content in dry matter of cheeses was not significant, similar to the one in curd, but the effect of the other factors individually and the double and triple interactions of all factors were significant (Table 3). The significant effect of cooking temperature x cooking time interaction resulted in lower dry matter fat content of cheeses cooked at 65°C than those cooked at 55°C. After the first day of ripening, the fat content of the cheeses showed fluctuations depending on the increase in dry matter content and the biochemical changes in the ripening time.

Protein content, which is one of the dry matter components of cheese, is the most important component in the formation of cheese gel (Chai et al., 2024). While the protein content of the produced curds varied between 23.03-25.70%, the protein content in the dry matter ranged between 44.97-47.12%. It was observed that the protein content of curds in dry matter was generally lower in curds cooked at 55°C than those cooked at 65°C (Table 1). It was determined that the effect of cooking temperature alone on the protein content of curds in dry matter was not statistically significant, but its interaction with time was significant (Table 2). The increase in the cooking time together with the cooking temperature caused some of the fat in the mass to melt and come out, thus increasing the protein content in the dry matter. Considering the protein content of cheeses ripened in brine, it was observed that it varied between 22.92% and 30.98% (Table 1). The % protein content of the cheeses cooked at 65°C on the 1st day of ripening was found to be higher than those of the samples cooked at 55°C. However, increases and decreases were observed in the % protein and dry matter protein content of the ripened cheeses during the ripening period (Table 1). As a result of the analysis of variance, it was found that the effect of cooking temperature on the protein content of cheeses in dry matter was not statistically significant, like the one in curd, but the effect of the double and triple interactions of other factors individually and of all factors was significant (Table 3). After the first day of ripening, the protein content of cheeses in dry matter changed depending on the fluctuation in % fat content, the increase in dry matter content and the biochemical changes in the ripening period.

Cheeses should be matured under certain conditions to provide their unique flavor, color, taste, consistency, and porosity. Water-soluble nitrogen is also evaluated as an indicator of ripening and proteolysis (Oztek, 1994). When Table 1 is examined, the water-soluble nitrogen value for the curds varies between 0.08-0.27%, while the water-soluble nitrogen values of the cheeses ripened in brine are calculated between 0.03-0.39%. The effects of cooking temperature, cooking time and the interaction of these two variables on the water-soluble nitrogen contents of the curds were found to be statistically significant (Table 2). In general, increasing the cooking temperature and time increased the amount of water-soluble nitrogen. Although the water-soluble nitrogen content of the cheeses fluctuated during ripening, the water-soluble nitrogen content of the cheeses increased with the prolongation of the ripening time in both cooking temperatures. In addition, the effects of cooking time, cooking temperature, ripening time and the double and triple interactions of these three factors on the water-soluble nitrogen content were found to be statistically significant (Table 3). As expected, the amount of water-soluble nitrogen in the cheeses increased as the ripening time increased. Akbulut et al. (1996) determined the applicability of some salting methods in white cheese production and their effects on cheese quality and stated that the amount of water-soluble nitrogen increased significantly during storage. In the study, although there was a general increase in the amount of water-soluble nitrogen depending on the ripening time, this increase differed depending on the cooking time and temperature. Oner et al. (2006) in their study on Turkish white cheese determined that the amount of water-soluble nitrogen varied between 0.21-0.36% during ripening and the amount of water-soluble nitrogen increased with the ripening time. The values obtained in the study and the values obtained by the researchers show similarity.

Table 3. Effects of factors on the chemical and physicochemical properties of ripened cheeses

Factors	dF	Dry matter		Fat %		Fat in dry matter		Protein %		Protein in dry matter	
		MS	F	MS	F	MS	F	MS	F	MS	F
Cooking temperature (1)	1	61.52	52.15***	0.75	1.98	17.96	16.62***	8.38	503071***	0.39	0.63
Ripening time (2)	3	436.86	370.27***	66.25	174.92***	6.09	5.63**	48.02	28881117***	23.16	37.81***
Cooking time (3)	2	33.41	28.32***	15.98	42.19***	10.23	9.47***	5.28	316567***	21.60	35.25***
1x2	3	32.81	27.81***	6.82	18.02***	8.49	7.86***	11.72	703521***	4.72	7.70***
1x3	2	15.36	13.02***	4.95	13.07***	8.48	7.85***	8.85	531254***	13.17	21.50***
2x3	6	9.09	7.71	6.46	17.05***	5.16	4.78***	3.13	187546***	5.69	9.29***
1x2x3	6	15.49	13.13***	5.70	15.05***	2.78	2.57*	2.91	174793***	1.85	3.03*
Factors	dF	Salt		Salt in dry matter		Water soluble N		a_w		L value	
		MS	F	MS	F	MS	F	MS	F	MS	F
Cooking temperature (1)	1	18.06	85.88***	29.99	57.84***	0.01	9173.35	0.00	351.13***	0.46	0.30
Ripening time (2)	3	46.06	219.01***	62.95	121.43***	0.02	19919.710***	0.03	28030.79***	0.62	0.41
Cooking time (3)	2	2.68	12.75***	2.37	4.56*	0.06	57459.05***	0.00	1447.63***	8.28	5.43**
1x2	3	0.43	2.04	2.31	4.46**	0.00	3147.70***	0.00	2127.13***	0.24	0.16
1x3	2	0.06	0.29	0.05	0.09	0.05	52536.85***	0.00	5045.38***	0.23	0.15
2x3	6	0.17	0.79	0.56	1.09	0.02	18487.44	0.00	109.29***	0.51	0.34
1x2x3	6	0.38	1.79	0.39	0.76	0.01	9544.36***	0.00	535.38***	0.95	0.62

* P<0.05; ** P<0.01; *** P<0.001; dF= degrees of freedom; MS= mean of squares

Salting is one of the important stages of cheese making. With salting, unique taste, aroma, structure, appearance, etc. qualities are formed (Kosikowski, 1978). The salting process in cheeses is done by adding salt (NaCl) directly to the cheese milk, adding it to the curd or curd, sprinkling the cheese from the outside (dry salting) or keeping the cheese in brine. The brine salting technique is used for the salting of white cheeses (Guven et al., 2003; Ucuncu, 2005). The salting process was applied to the produced curds by combining dry salting and salting in brine. The salt content of the curds varied between 0.94-1.17% and the difference in salt content was due to the difference in the dry matter content of the curds. During the ripening period, the % salt content of the cheeses varied between 3.36% and 9.07%, and the salt content in dry matter ranged between 6.43-13.07% (Table 1). The salting process was applied to the produced curds by combining dry salting and salting in brine. The salt content of the curds varied between 0.94-1.17% and the difference in salt content was due to the difference in the dry matter content of the curds. During the ripening period, the % salt content of the cheeses varied between 3.36% and 9.07%, and the salt content in dry matter ranged between 6.43-13.07% (Table 1). The effects of ripening time, cooking time, cooking temperature and ripening time x cooking temperature on the salt content in dry matter of cheeses were found to be statistically significant (Table 2). In the produced cheeses, the salt % salt and dry matter content of the cheeses boiled at 65°C during ripening were higher than those boiled at 55°C. An increase was observed in the dry matter and salt content of cheeses at both cooking temperatures between the 1st and 30th days of ripening. At each cooking temperature, the dry matter and salt content of cheeses were between 30-90. Although a slight increase was observed between the three days of the week, it was determined that this increase was not statistically significant (P>0.05) with the LSD test performed because of the analysis of variance. Uraz and Gencer (2000) in a study on salt intake in white cheese, stated that the salt content varied between 6.03-7.03 %. In our study, it was thought that this difference in salt content was due to factors such as dry salting, holding in brine, salt in brine and composition of the cheese.

The pH value in milk and dairy products is composed of compounds such as free basic compounds in equilibrium with free and active hydrogen ions, acidic and basic groups attached to protein, free organic acids and free neutral buffer compounds (Gursoy, 2005). The pH value is used as a criterion in explaining the physical, chemical and microbiological changes in cheese technology (Gider, 2006). The pH values of each produced curd and cheese in the 90-day ripening period were measured from three different regions of the curd and cheese, and these values are given in Table 1. While there was no significant difference between the pH values of curd and 1st day of ripening cheeses at each cooking temperature and time, the pH value of cheeses increased from the 1st to the 30th day of ripening, but the pH values of the cheese samples decreased after the 30th day of ripening. Although the pH values of cheeses cooked at 55°C were higher than the pH values of cheeses cooked at 65°C, the change in pH during storage at both cooking temperatures showed parallelism. Similar to the findings of our study by Celikbilek (2010) pH values increased from the first day of ripening to the 15th day and decreased after the 15th day.

Water activity is defined as the ratio of the vapor pressure of water in foods to the vapor pressure of pure water at the same temperature (Rödel, 2001). Although it varies according to the type, the water activity (a_w) in cheese generally varies between 0.87-0.98. The a_w values of curds and cheeses ripened in brine at each cooking temperature and time are given in Table 1. According to the table, the a_w values of the curds varied between 0.96-0.98, while the a_w values of the cheeses varied between 0.81 and 0.94. The salting process has an accelerating effect on the change of water activity, and an increase in salt concentration decreases a_w. When the water activities of the curds and the water activities of the 1st day cheeses are compared, it is seen that the a_w values of the 1st day cheeses are lower than the curds (day 0). It was thought that this situation was caused by the diffusion of salt into the cheese mass with dry salting and brine salting, and the reduction of water activity by binding the water to the salt. With the analysis of variance, the effects of cooking temperature, cooking time, ripening time and the double and triple interactions of these three variables on a_w were found to be statistically significant (Table 3). In general, increasing the cooking time decreased the water activity, while increasing the cooking temperature increased the water activity.

Features such as color, aroma and texture of food are parameters that play an important role in consumer preference and acceptability. Color, which is the first feature to be noticed in all foodstuffs, is closely related to the internal and external quality criteria of the food, and therefore color measurements are important for foods (Yetim and Kesmen 2008). Fat globules and casein micelles in milk play a major role in the white color of cheese because they reflect light in the visible spectrum. While the amount of fat before cooking ensures that the color of the cheese is white, the serum proteins separated by the cooling of the cheese after cooking prevent the reflection of light and reduce the whiteness of the cheese. For this reason, the L* value is important in terms of expressing the whiteness of cheese (Metzger et al., 2000). As seen in Table 1, the L* values of the curds varied between 87.27-89.89, while the L* values of the cheeses ripened in brine for 90 days varied between 86.22-88.54. The effect of the factors on the L* value of cheese was determined by analysis of variance and only the effect of cooking time was found to be statistically significant (Table 3). The increase in the cooking time during the ripening period caused a decrease in the L* value of the cheeses. This was due to the fact that the serum proteins, which separated with the increasing cooking time, prevented the reflection of light and reduced the whiteness of the cheese. Although the effect of cooking temperature on the L value of cheeses is not statistically significant, the L* values of cheeses cooked at 55°C were higher than those cooked at 65°C (Table 1). In many studies, it is stated that the change in the L* value is due to the fat content of the cheeses (Kahyaoglu et al., 2005) but in our study, it was observed that there was no change in the fat content of the cheeses, since the milk used as raw material was the same in all cheese varieties. Therefore, it was determined that the change in L* value changed independently of the oil content.

Since the proteolytic activity of the enzymes continues during the 90-day ripening period in brine after the production stage and because salting causes changes in the cheese structure, as well as in the evaluation of the chemical and physicochemical properties, the evaluation of the cheese ripened in curd and brine is handled separately.

When cheese is heated, many internal changes such as melting, flowing, softening and elongation are observed. As with all other substances, there is a transition from a solid-like state to a liquid-like state in the melting that occurs in cheese. Fat is the only solid that can truly melt in cheese, and milk fats are completely liquid at about 40°C. Proteins do not dissolve, but changes occur in the interactions of proteins with each other and this is called melting. Melting is the cheese's ability to flow and spread, and the cheese softens before it starts to flow. Flowing occurs when sufficient pressure or thermal energy is applied to the softened cheese (Lucey et al., 2003).

The softening of the cheese is expressed by the temperature at the moment of transition to flow (Chevanan and Muthukumarappan, 2007; Ko, and Gunasekaran, 2008) and this temperature is defined as the melting initiation temperature (TEB) in our study. When the melting initiation temperatures obtained from the melting profile of each curd and the ripened cheeses were examined, it was seen that the melting initiation temperatures of the curds varied between 45.66°C and 51.98°C (Table 4).

When the effect of cooking temperature and time on the melting temperature of the curd samples was examined by variance analysis, only the effect of cooking temperature was found to be statistically significant (Table 5). Increasing the cooking temperature increased the melting initiation temperature of the curds. As the high-temperature application increases the rate of water leaving the structure, protein-protein interactions increase. In this case, since the structure of the curds cooked at 65°C becomes tighter than the ones cooked at 55°C, their melting becomes more difficult and therefore their melting start temperature increases. When the melting initiation temperatures of the ripened cheeses are examined in Table 4, it is seen that it varies between 41.80-51.79°C and when the effect of the factors on the melting initiation temperatures of the cheeses is analyzed by analysis of variance, the effects of ripening time, cooking temperature and cooking time are found to be statistically significant (Table 6). With the increase of the applied cooking temperature, the melting initiation temperature increased as in the curds. In addition, the melting temperature of the cheeses decreased with the increase in the ripening time at each cooking temperature and time.

Melting initiation temperatures of the curds were lower at each cooking temperature and time compared to the 1st and 30th day cheeses. This difference between melting initiation temperatures of cheeses ripened in curd and brine is related to salting. Although salt is a secondary component in cheese, it has a primary effect on the properties of meltable and non-meltable cheeses. With the decrease of hydration in paracasein at high salt concentration, salt-out effect; It has been stated that at low salt concentration, the increase in paracasein hydration may result from the salt-in effect (Paulson et al., 1998). Fat is the only solid that can truly melt in cheese, and milk fats are completely liquid at about 40°C. Milk proteins, on the other hand, do not dissolve, but changes occur in the interactions of the proteins with each other and this is called melting.

A firmer cheese structure is formed as a result of the replacement of the Ca^{+2} ion and Na^{+1} ion in the casein structure, called Ca-para-caseinate, in cheese together with salt, and the increase in fat emulsion in the protein matrix (Kindstedt et al., 1992). Thus, the cheese is both harder and harder to melt.

The fact that the melting initiation temperatures of the cheeses were high on the 1st and 30th days of ripening caused an increase in the interaction between paracasein molecules and the thermal energy level that could cause a change in this interaction due to the effect of salting, thus increasing the melting initiation temperature. Whereas, the melting initiation temperatures of the cheeses decreased between 30-90 days. It is thought that this decrease may be due to the increase in the strength of the hydrophobic interactions between the casein molecules, the decrease in the contact area between the casein particles, and therefore the decrease in the durability of the gel structure, as a result of the more homogeneous distribution of the salt in the mass due to the increase in the salt content and salting time.

The degree of flowability is expressed as the percentage decrease in cheese height during melting (Chevanan and Muthukumarappan, 2007). The flowability degrees of the curd and cheese produced by applying different scalding temperatures and scalding times are given in Table 4 and it has been seen from the table that the flowability degrees of the curds vary between 32.78% and 53.35%. The effect of cooking temperature and duration on the flowability of curds was examined by analysis of variance and it was found that the effect of cooking temperature and cooking time was statistically significant (Table 5). With increasing cooking temperature, the degree of flowability also decreased. The effect of cooking temperature on the flowability of curds was associated with the increase of protein-protein interactions due to the increase in the rate of water leaving the structure, at high cooking temperature. The water leaving the structure with high-temperature application causes the structure to become tighter and it becomes difficult to flow (Udayarajan and Lucey, 2005). Therefore, curds cooked at 65°C are harder than those cooked at 55°C, since more water is separated from the structure with the effect of high temperature; thus, their flowability became more difficult. Likewise, increasing the cooking time also increased the amount of water separated from the structure and strengthened the intermolecular bonds, and the flowability of the curds decreased in general due to the increase in the cooking time.

Table 4. Average values of melting properties of curd and cheese produced

RT (day)	CTime (min)	CT (°C)	FD (%)	SP (°C)	AFR (mm/sec)
0	1	55	53.35	45.66	22.45
0	6	55	43.92	45.96	20.55
0	11	55	48.12	47.93	19.85
0	1	65	48.34	48.78	21.60
0	6	65	32.78	49.65	11.95
0	11	65	47.45	51.98	15.25
1	1	55	34.89	48.89	2.80
1	6	55	33.18	41.72	2.60
1	11	55	30.99	49.99	2.15
1	1	65	34.53	50.09	2.70
1	6	65	27.45	46.19	1.90
1	11	65	26.92	51.05	1.75
30	1	55	25.86	48.40	2.20
30	6	55	24.10	40.70	1.65
30	11	55	18.14	44.54	1.25
30	1	65	25.71	42.41	2.00
30	6	65	28.08	49.69	1.90
30	11	65	27.10	50.66	2.70
60	1	55	30.06	41.75	2.15
60	6	55	27.06	44.11	1.85
60	11	55	15.50	42.90	1.20
60	1	65	21.20	43.45	1.65
60	6	65	16.21	47.69	1.15
60	11	65	14.45	46.69	1.05
90	1	55	29.32	41.80	2.05
90	6	55	23.15	42.75	1.60
90	11	55	13.33	48.54	1.35
90	1	65	27.70	43.68	1.85
90	6	65	17.18	47.50	1.00
90	11	65	26.92	40.21	1.60

RT= ripening time, Ctime= cooking time, CT= cooking temperature, FD= flow degree, SP= softening point, AFR= average flow rate

Table 5. Effect of factors on the variables of melting behavior of curds

Factors	dF	Flow degree		Softening point		Average flow rate	
		MS	F	MS	F	MS	F
Cooking temperature (1)	1	94.27	11.75*	39.27	5.85	0.21	0.71
Cooking time (2)	2	169.68	21.16**	8.30	1.23	1.39	4.61*
1x2	2	27.72	3.46	0.22	0.03	0.57	1.88

P<0.05; ** P<0.01; *** P<0.001; dF= degrees of freedom; MS= mean of squares.

The effect of existing factors on the flowability of ripened cheeses was investigated by analysis of variance, the effect of boiling temperature alone was insignificant; The effect of ripening time, cooking time, cooking temperature x cooking time interaction and cooking temperature x ripening time interaction were found to be statistically significant (Table 6). The increase in cooking time and ripening time caused a decrease in the flowability of the cheeses. The decrease in the flowability of the cheeses due to the increase in the ripening time at each cooking temperature was associated with the increase in the salt content of the cheeses, as well as the increase in the melting temperature. In addition, when the flowability degrees of the produced curds were compared with the 1st-day cheeses of ripening, the flowability of the curds was higher than the 1stday cheeses at each cooking temperature and time, as well as the melting initiation temperatures. The decrease in the solubility level of the first-day cheeses was associated with the decrease in the oil level that can be separated from the structure with the increase in the apparent viscosity as a result of the increase in the salt content in the cheese mass, and the decrease in the protein hydration as a result of the pure out effect.

The average flow rate is calculated as the slope in the region where the flow occurs in the melt profile and is expressed in mm/sec. (Gunasekaran and Ak, 2003). The average flow rates of the curds were similar to the flowability degrees and the increase in the cooking temperature caused a decrease in the average flow rates of the curds (Table 4). This showed that the melting behavior of curd cooked at 55°C was better than at 65°C. In addition, the increase in the cooking time in both cooking temperatures caused a decrease in the average flow rate of the curds. Since the increase in cooking temperature and time causes a decrease in the amount of water in the mass of the curds and there is no significant difference between the % oil content of the curds, the flow rates of the curds produced decreased with the increasing cooking temperature and time.

The average flow rates of cheeses produced by applying different cooking temperatures and cooking times during ripening, which is another of the melting parameters, varied between 1.00mm/sec and 2.80mm/sec (Table 4). The effect of factors on the average flow rates of cheeses during ripening was examined by analysis of variance and the effect of the interaction of cooking time, ripening time and cooking temperature x ripening time was found to be statistically significant (Table 5). In both cooking temperatures, the average flow rate of the cheeses decreased with the increase in the cooking time in general. It is thought that this change in the average flow rates of cheeses depending on the ripening time in the applied cooking temperature and durations, as well as in the other melting parameters of the cheeses (melting initiation temperature and flowability degree), is caused by salt diffusion and biochemical changes that occur during ripening. When the produced curd and 1st day cheeses were compared, the average flow rates of the curds were higher than the 1st day cheeses at all cooking temperatures and times. The passage of salt into cheese is by diffusion. As the salt diffuses into the cheese, the water in the cheese also goes out and the cheese loses water (Walstra et al., 1999; Fox et al., 2000). Dry salting of the curd, followed by brine salting, and the salt diffused into the cheese mass caused the interaction between casein molecules to increase. With the increase in the interaction between the casein molecules, the mass became tighter and harder. Therefore, since the mass structures of the 1st day cheeses ripening are firmer and harder than that of the curds, the average flow rates were also lower than that of the curds.

Table 6. Effect of factors on the variables related to the melting behavior of ripened cheeses

Factors	dF	Flow degree		Softening point		Average flow rate	
		Mean of squares	F	Mean of squares	F	Mean of squares	F
Cooking temperature (1)	1	2.03	0.08	82.32	28.53***	0.21	1.27
Ripening time (2)	3	257.01	10.80***	39.32	13.63***	1.68	9.97***
Cooking time (3)	2	156.77	6.59**	31.95	11.07**	1.39	8.25**
1x2	3	107.08	4.50*	20.40	7.07**	0.57	3.42*
1x3	2	147.99	6.22**	25.17	8.72**	0.57	3.36
2x3	6	29.81	1.25	27.19	8.73***	0.14	0.84
1x2x3	6	30.87	1.30	12.89	4.47**	0.17	1.01

4. Conclusion

In Türkiye, various local cheeses are produced according to the local conditions, cultural habits, animal breeds and species and production differences of each region. Examining and developing the production technologies of local cheeses will both increase the production of cheese at the industrial level and contribute to the increase in cheese variety and consumption.

This study aims to standardize the boiling stage of the cheese, which is produced in the province of Sivas and its surroundings in the Central Anatolian region of Türkiye, and which gains importance in consumer preference despite being called white cheese. For this purpose, 6 different clots were prepared by applying the temperature of 55 °C and 65 °C and the cooking time of 1, 6 and 11 minutes during the cooking phase of cheese production. The produced curds were matured for 90 days in dry salting and then in 14% brine, and the effects of cooking temperature and duration on curd, cooking temperature, duration and ripening time on the physical, chemical and melting behavior of cheeses were investigated.

Cooking temperature × cooking time and cooking temperature × ripening time were effective on the melting behavior of cheeses. Although the prolongation of the ripening period affects the melting behavior negatively, it has been observed that the melting behavior of the cheeses produced by cooking the curd at 55°C is better than that of the cheeses cooked at 65°C during the whole ripening process. In addition, the increase in the cooking temperature and the prolongation of the cooking time caused an increase in the salt content of the cheese and thus a decrease in the melting behavior of the cheese. When all the findings obtained in the study are evaluated together, the application of curd cooking temperature of 55°C and cooking time of 6 minutes will improve the melting behavior of cheese and increase consumer preference.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	E.B.B.	N.D.I.
C	50	50
D	80	20
S	50	50
DCP	70	30
L	70	30
W	80	20
CR	50	50
SR	100	
PM	50	50
FA	100	

C= concept, D= design, S= supervision, DCP= data collection and/or processing, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declare that they have no known conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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