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Optimization of stretching process for improve the textural characteristics of Kashar cheese

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ABSTRACT: This study was aimed to optimize the stretching process (temperature, titration acidity, and NaCl concentration) and to determine the subsequent effects over the quality characteristics of Kashar cheese. The textural and meltability properties were studied in the optimization. Whey was used to set the acidity of stretching water. Textural, meltability, and sensory evaluation scores of matured Kashar cheese obtained from the marketplaces were used for target values to optimize the stretching process. The response surface methodology was used to optimize conditions for stretching process, the arrangement of experimental design and evaluation of analysis results. The optimum conditions were found as follows: 80.20 °C for stretching temperature; 0.61 °SH for stretching water acidity; and 12.00 % for NaCl concentration. Under these conditions: 79.53 N for hardness, -292.24 g.sec for adhesiveness, 0.74 for cohesiveness, 51.20 N for gumminess, and 19.05 mm for meltability values were found in Kashar cheese that was produced for validation. The validation production results were within 95 % confidence intervals for each response obtained at optimal conditions. Thus, this model is successful to predict the textural and meltability values of sample.

Keywords: Kashar cheese; optimization; meltability; textural properties

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INTRODUCTION

Kashar cheese is a semi-hard cheese that is produced by the fermentation of curd. After fermentation of the curd, it is stretched in hot brine. Acidic curd elasticizes after being stretched, which is molded and shaped. It is second mostly consumed cheese in Turkey (Kavak and Karabıyık,2020;Topcu et al., 2020).

Stretching is one of the most important processes in Kashar cheese production that significantly influence quality characteristics. There are rare studies on the acidity of stretching water (TA) used in cheese production. Low TA results in sensory defects (soft texture, bitter taste, etc.) in the cheese. Therefore, importance was given to set suitable TA (Say and Guzeler, 2008, Ucuncu, 2013).

Salting of stretching water is one of the salting methods. With this salting method, salt transition to cheese is more uniform. This method brings ease to hold an amount of NaCl in the cheese at the desired range. In fact, the amount of NaCl in the cheese affects the quality of cheese. Low NaCl content results to excessive degradation of proteins, decrease pH value, and the development of undesirable aroma compounds. The hydration capability of proteins increases when the amount of NaCl is high in cheese and decreases the hardness of the cheese. This situation brings about the sensory defects and promotes the oxidation tendencies in the cheese (Say and Guzeler, 2008; Bähler et al., 2016). There is less knowledge existing about the effect of stretching water temperature on the physical and chemical properties of cheese and quoted a few influences on the degradation of proteins (Hayaloglu et al., 2010).

The stretching process in Kashar cheese is a thermomechanical process involving the application of mechanical energy in the form of shear stress and temperature to the curd. Stretching promotes protein interactions that support the formation of para-casein fibers by changing the fat and protein structures.Some of the whey is separated from the para-casein matrix and accumulates together with the fat as free whey in the cavities or channels (Goncalves and Cardarelli, 2020). During the ripening period of cheese, complex biochemical reactions produce characteristic flavor and alter the texture (Fox et al., 2015). Cheese texture is affected by hydrolysis of proteins, pH increase, water retention increase by amino and carboxyl groups that consisted during the breakdown of protein, NaCl content, and dry matter during ripening (Yasar and Guzeler, 2011). It has been reported that the heat transfer from the surface to the center is hindered, particularly in cheeses made by extending the curd in hot whey or water (Hayaloglu et al., 2014).

Almost no studies are showing the effects of parameters such as the temperature of stretching water (ST), titration acidity of stretching water (TA), and salt concentration of stretching water (SC) on the stretching process on the cheese texture. However, it is quite significant for researchers, producers, and consumers due to its effects on the characteristics of cheese. Thus, this study was purposed to produce Kashar cheese with the desired texture and meltability by optimizing the ST, TA (with whey), and SC using the response surface method (RSM).

MATERIALS AND METHODS

Materials

Raw cow milk required to produce cheese was obtained from Isparta Ünsüt Plant, Turkey. In cheese production, calf rennet (Renna®, 100 % natural veal sirden) was got from Mayasan Gıda Sanayii & Ticaret A. Co. (Istanbul, Turkey) was used. Starter culture (RST - 743®50 U Chr Hansen, Denmark) was added and TA was tuned with the whey obtained in the cheese production.

Methods

Kashar cheese production with respect to the experimental design is presented in Table 2.In the first step, stretching process was optimized. Celebi and Simsek (2020) obtained textural and meltability values to use as goal values to optimize the stretching process.The last step is the validation production under the optimal conditions. In validation production, stretching water parameters determined for the stretching process in Kashar cheese production, have been tested as the specified values (Say and Guzeler, 2008; Hayaloglu et al., 2010).

In the present study, the acidity of the stretching water was adjusted using whey in the production of Kashar cheese. The whey properties used in adjusting TA were as follows: pH 6.33; titration acidity 0.27 %;dry matter 6.27 %; fat 0.68 %; total nitrogen 0.45 % and specific gravity of 1.021 g/mL, respectively.

Experimental design

Kashar cheese and validation production were performed with respect to the production flow chart as presented in Figure 1 (Say and Guzeller, 2008; Cetinkaya, 2012). The factors and actual values (with code values) in the stretching process are shown in Table 1. Fifteen Kashar cheeses were produced (same day,same milk) with respect to the experimental design given in Table 2. The amount of milk used in the production of Kashar cheese was 700 liters. Cheeses produced were ripened for 90 days followed by the textural and meltability analyses.

Raw milk
↓
Pasteurization (72 ±2 °C 2 minutes)
↓
Starter Culture (0.5 %) (35±1 °C) and Calcium Chloride Addition (0.02 %)
↓
Addition of calf rennet(by enzyme activity test)
↓
Cut of clot (1 cm^3 sized) and floating (10 minutes)
↓
Heating the curd (40 °C)
↓
Whey off (1/3 of whey)
↓
Pre-fermentation (up to pH 5.40 - 5.45)
↓
Draining
↓
Fermentation (75 °SH)
↓
Chopping curd (0.5 cm wide and 5 cm long)
↓
Strecthing (5 minutes)
(the coding and trial pattern specified in Tables 1 and 2 was applied)
↓
Moulding
↓
Pre-ripening (12 - 24 hours at 8 ± 2 °C)
↓
Vacuum packaging

Figure 1. Kashar cheese production flow chart

RSM was used to optimize stretching water parameters. A Box-Behnken design (BBD)was employed for the experimental design. Independent factors for stretching water such as ST °C (X1), TA °SH (X2), and SC % (X3) were determined. The influence of these factors on textural and meltability properties of sample was studied. In the study, the three independent factors were examined at three different levels (-1, 0, and +1) and actual values for the independent factors are presented in Table 1.

Table 1. The corresponding real values of the coded one for each independent factor

Codes			
Factors	-1	0	+1
X_1: ST (°C)	72	79	86
X_2: TA (°SH)	0	6	12
X_3: SC (%)	6	9	12

A BBD includes total of 15 runs with different combination of three independent variables which include 3 replicates at the central point are designed (Table 2). Test results were determined with Minitab (18.1). Data were placed in a linear (linear), quadratic and quadratic polynomial regression model with two factor interaction coefficients. The model equation of the responses (Z) and three independent variables (X1, X2 and X3) is given below:

$$Z = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j$$

Where Z is the response (texture and meltability values)of the equation, β_0 is the model intercept, β_i is the linear coefficient (main effect), β_{ii} is the quadratic coefficient, and β_{ij} is the two factors interaction coefficient. R^2 and adjusted R^2 (R_{adj}) values were evaluated to control the model adequacy. For optimal stretching water parameters, the data given by Çelebi and Şimşek (2020) were used as a reference (target value). Researchers have found the most popular sample by conducting numerous sensory tests on Kashar cheeses purchased from the market. The reported texture data of the most admired Kashar cheese were also used as optimization parameters in this study. To find out the optimal stretching water parameters, 103.67 N for hardness, -241.43 g. sec for adhesiveness, 0.79 for cohesiveness, 78.77 N for gumminess, and 18.08 mm for meltability of the Kashar cheese were utilized as target values (Celebi and Simsek,2020).

Production of Kashar cheese for validation

Validation production was performed in 3 parallels with respect to flow chart presented in Figure 1.In this process, optimum values, obtained from the optimization process, were used.After ripening for 90 days, the texture and meltability of the produced Kashar cheeses were analyzed. Analyses results of the Kashar cheeses produced for the validation production were within the 95% prediction range.

Table 2. The results of response surface analysis of the variation of responses as a function of independent factors

Run order	X_1	X_2	X_3	Z_1^*	Z_2	Z_3	Z_4	Z_5
1	86 (1)	6 (0)	6 (-1)	137.32	-248.38	0.37	79.39	18.75
2	86 (1)	12 (1)	9 (0)	158.01	-111.15	0.70	120.95	17.84
3	79 (0)	0 (-1)	12 (1)	89.45	-257.77	0.74	62.61	19.13
4	79 (0)	6 (0)	9 (0)	99.54	-403.79	0.74	73.19	20.33
5	79 (0)	6 (0)	9 (0)	100.14	-313.24	0.73	71.30	20.11
6	79 (0)	0 (-1)	6 (-1)	56.67	-823.35	0.71	38.46	21.11
7	72 (-1)	12 (1)	9 (0)	79.55	-81.33	0.72	56.60	23.86
8	86 (1)	6 (0)	12 (1)	298.17	-99.48	0.66	180.41	16.33
9	72 (-1)	6 (0)	6 (-1)	135.75	-120.77	0.54	66.47	24.66
10	79 (0)	12 (1)	6 (-1)	42.27	-112.81	0.68	29.69	22.33
11	79 (0)	6 (0)	9 (0)	95.71	-519.57	0.73	71.68	20.00
12	86 (1)	0 (-1)	9 (0)	108.76	-607.21	0.61	77.93	17.41
13	79 (0)	12 (1)	12 (1)	115.10	-379.17	0.84	93.09	19.66
14	72 (-1)	0 (-1)	9 (0)	83.59	-283.58	0.78	65.53	22.94
15	72 (-1)	6 (0)	12 (1)	147.29	-43.11	0.77	107.48	22.40

* 95 % in the confidence interval;Hardness (Z_1), Adhesiveness (Z_2), Cohesiveness (Z_3), Gumminess (Z_4), Meltability (Z_5) with ST (X_1), TA (X_2), SC (X_3).

Analysis of whey used to adjust the TA of stretching water

pH values were determined with a digital pH meter (WTW pH 3110, Weilheim, Germany). Acidity was determined according to the alkali titration method. The result is expressed in % lactic acid (AOAC, 1997). Specific gravity was determined using lactodensimeter (AOAC, 1997). Gravimetry was performed by drying a sample of approx. 3-5 g at 104±1 °C until the difference between the two weighing was stabilized. The result was evaluated as percent (AOAC, 1997). Percent fat ratio was determined according to Gerber method with special Gerber milk butyrometer (Marshall, 1992). Total nitrogen ratios were determined by the determination of nitrogen amounts using micro-Kjeldahl method of wet-burned samples (AOAC, 1997).

Kashar cheese analysis

Textural profile analyses (TPA)

TPA of Kashar cheeses produced in optimization and validation stages were performed using the TA-XT2 (Stable Micro Systems, Surrey, UK) texture analyzer. During the analysis, a cylindrical aluminum probe with a diameter of 50 mm (Stable Micro System 50 mm Cyl. Aluminum P/50) was utilized. Test speed was adjusted to 5 mm/sec. with 50 %strain. The pre-test speed was 1 mm/s. Before TPA, the samples were cut into 10x10x2 cm pieces and kept at 25 °C (30 minutes).Test was carried out at 25 °C (Eroglu et al., 2015).

Meltability measurements

Meltability measurement of sample was made with respect to the method following by Koca and Metin (2004). Kashar cheese were cut into a cylindrical shape (41 mm in diameter and 4 mm in height) and laid in the middle of a dish. It was kept for 5 minutes at 230 °C in the electrical oven. After waiting 30 minutes for cooling (at 25 ºC), the specimen expansion of the sample was measured using a scale having 6 different lines. The meltability value was determined as the mean of six readings (Koca and Metin (2004).

RESULTS AND DISCUSSION

Effect of independent variables on textural and meltability properties

The main effects of independent variables such as TA, ST, and SC on the textural and meltability characteristics of Kashar sample, which are independent of each other, are presented in Figure 2. When the hardness and gumminess of Kashar cheese produced by adjusting the TA with whey are examined (Figure 2), the temperature graph representing the process variables tends to decrease up to 75 - 80 °C, followed by an increase after 80 °C. The trend showing the effect of TA on hardness and gumminess values shows a curve in which maximum hardness and gumminess values are obtained around 5 °SH. Salt concentration graph shows that an increase in SCalso increased the hardness and gumminess. At72 - 80 °C of ST, the adhesiveness decreased while the adhesiveness value increased again in the range of 80 to 86 °C (Figure

2). Adhesiveness increased with increasing TA. While the SC showed a decreasing effect on the adhesiveness by 6 - 9 %, the SC had an increasing effect on the adhesiveness above 9 %. Maximum cohesiveness reached at 75 °C of ST while above that, it decreased (Figure 2). While the TA, which is one of the stretchingprocess variables, has a decreasing effect on the cohesiveness value up to about 5 °SH, it has an increasing influence on the cohesiveness value after 5 °SH approx. In other words, the cohesiveness value takes its minimum value when the TA is about 5 °SH. With the increase in the SC, the cohesiveness value also increases, reaching the maximum level when the SCis 12% approx.

ST has a strong influence on the meltability. Generally, meltability decreases linearly with increasing ST. Although the TA weakly effects on the meltability; the meltability value increase slightly with increasing TA. Similarly, the SC also slightly affects the melting properties of cheesethan the ST, still it shows similar behavior. Meltability decreased linearly with the increase in SC.

Modelling and optimization of stretching process

Texture parameters and meltability were the investigated responses under effects of independent factors (ST, TA, and SC). The regression coefficientsand analysis of variance are presented in Table 3. The

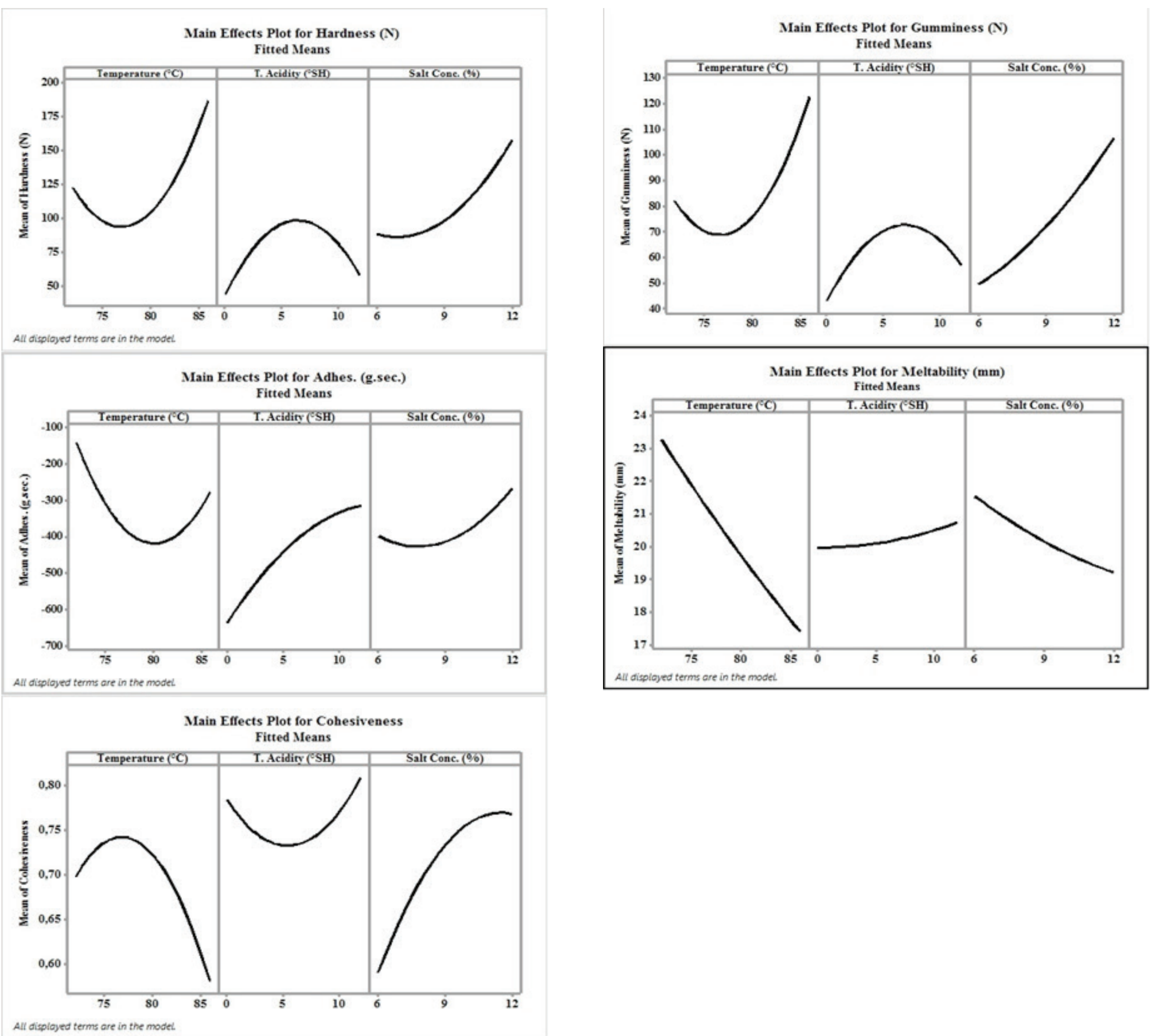

Figure 2. Main effects of independent factors of stretching process on textural and meltability modeling and optimization of stretching process

Table 3. Regression coefficients of the predicted models for the investigated responses of Kashar cheese and independent effects of factors

Coefficients	Z_1	Z_2	Z_3	Z_4	Z_5
β_0: constant	8428^{***}	27097^{***}	-10.40^{***}	4329^{***}	77.21^{***}
β_1: ST	-195.2^{***}	-673^{*}	0.2856^{*}	-103.2^{***}	-0.939^{***}
β_2: TA	-13.1^{ns}	11.8^{***}	-0.1053^{ns}	-20.79^{ns}	0.317^{***}
β_3: SC	-181.7^{***}	-161^{*}	0.081^{**}	-62.2^{***}	-0.614^{***}
β_{11}: STxST	1.151^{***}	4.058^{**}	-0.001933^{**}	0.6191^{***}	0.00350^{ns}
β_{22}: TAxTA	-1.316^{***}	-1.60^{ns}	0.0017^{ns}	-0.615^{**}	0.00539^{*}
β_{33}: SCxSC	2.754^{*}	8.49^{ns}	-0.00639^{ns}	0.672^{ns}	0.02407^{*}
β_{12}: STxTA	0.317^{ns}	1.749^{ns}	0.000887^{ns}	0.309^{*}	-0.00292^{ns}
β_{13}: STxSC	1.777^{**}	1.28^{ns}	0.00067^{ns}	0.714^{*}	-0.00190^{ns}
β_{23}: TAxSC	0.556^{ns}	-11.55^{**}	0.00186^{ns}	0.545^{ns}	-0.00958^{ns}
Significance of regression	***	**	*	***	***
Variability explained *(R^2)*	97.97	96.35	91.21	97.81	99.88

$^*p\leq0.05$; $^{**}p\leq0.01$; $^{***}p\leq0.001$; ^{ns}nonsignificant; Z_1, Hardness (N); Z_2,adhesiveness (g.sec.); Z_3, cohesiveness; Z_4, gumminess (N); Z_5, meltability (mm); β: constant coefficient.

correlation coefficients states more than 96 % of the variance in the test data, except for that cohesiveness value which is less than 96 %, related the independent factors of the fitted models.Models were determined significantly to account for the change of related responses with a function of independent factors ($p\leq0.05$).

Effect of independent variables on hardness

For hardness, the model could account for more than 97 % of the variance in the test data. Except for TA, other first order terms were found to have a remarkable influence on the hardness of sample($p\leq0.001$). The second order terms were found to have an influence on hardness at least $p\leq0.05$statistically. There was a significant interaction between ST and SC on hardness at the $p\leq0.01$ level. Figures 3 - 5 are given for clearly shows the interactions terms influence on the hardness. When the curd was exposed to high ST, the hardness increased with an increase in the TA(Figure 3a). In the stretching process, higher SC increased the hardness of Kashar sample. This effect was intensified with the increase of ST (Figure 4a). The hardness value increased when the TA between 4 °SH and 8 °SH at lower SC while it decreased in other TA ranges (Figure 5a). High SC and TA increased the hardness value of Kashar sample. The hardness values of cheese samples at high salt concentrations were higher than those with low salt concentrations as reported earlier (Kaminarides et al., 1999;Kaya, 2002). Hardness value of cheese increases with the rises of soaking whey temperature. At high ST, lower non-fat dry matter content results in less protein hydration. This means less freedom of movement for protein molecules. As a result, a larger amount of solid and tighter casein matrix is obtained (Kahyaoglu et al., 2005; Tunick et al.,1993). In our study the data which determined for the hardness, are like the relationships reported by the researchers between hardness value and stretching water parameters (TA,SC, and ST).

Effect of independent variables on adhesiveness

The adhesiveness model as can be seen in Table 3,more than 96% of the variance between experimental data was explained. Adhesiveness of Kashar sample was significantly affected by first order terms at the $p\leq0.05$ level. On the other hand, at second-order level, adhesiveness was affected only by ST term ($p\leq0.01$). The interaction term of TA and SC only showed a significant influence on the adhesiveness ($p\leq0.01$). Figures 3 - 5 clearly shows an influence on the adhesiveness by the interaction terms.The adhesiveness of sample decreased as the ST increased and the TA decreased (Figure 3b). The adhesiveness value of Kashar cheese tends to decrease as the ST decreases from 86°C to about 80 °C in the presence of high SC. When the ST diminished from 80 °C to 72 °C, the value of adhesiveness increased again (Figure 4b). Along with SC diminishing, the decrease in the TA diminished the value of adhesiveness of the sample (Figure 5b). The adhesiveness of cheese increases with the increase of salt concentration in cheese was reported by Pastorino et al.(2003). Results obtained in the present study are in line with this report.

Effect of independent variables on cohesiveness

The model for cohesiveness could explain the more than 91 % of the variance in the experimental data (Table 3). The first order terms (excluding TA) were found to be significantly effective on the cohesiveness value of Kashar sample (at least p≤0.05). On the other hand, at quadratic terms, cohesiveness was affected only by ST term (p≤0.01).The influence of all interaction parameters on cohesiveness was not significant. Figures 3 - 5 clearly shows an influence on the adhesiveness by the interaction terms. While the ST increased the cohesiveness value up to a temperature of approx. 75 °C, above this temperature, cohesiveness decreased. A diminish in the TA also intensified this effect (Figure 3c). As the SC decreased, increasing the ST decreased the cohesiveness value of cheese sample. This effect was intense when the ST was 86 °C and the SC was 6% (Figure 4c). Increasing the TA with the increase of SC increased the cohesiveness of cheese(Figure 5c). Cohesiveness value increased when the temperature of soaking whey increased in cheese production. It has been reported that when the TA rises, the cohesiveness of the cheese also rises and *vice versa*. In the current study, the re-

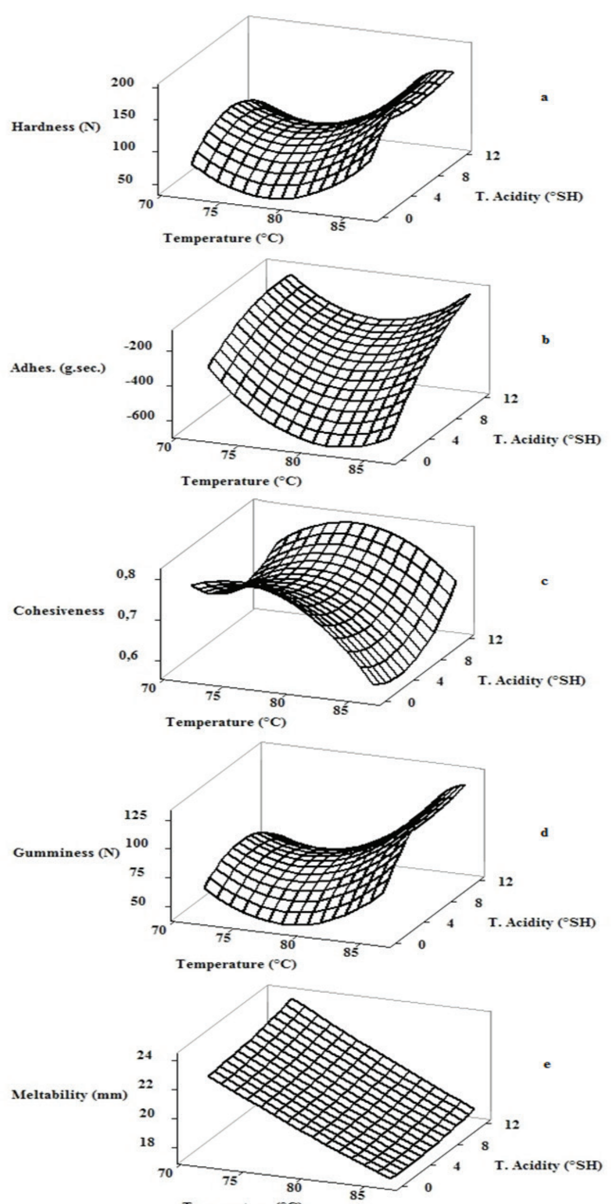

Figure 3. Surface plots of responses of kashar cheese influenced by ST and TA factors of stretching process effect of independent variables on adhesiveness

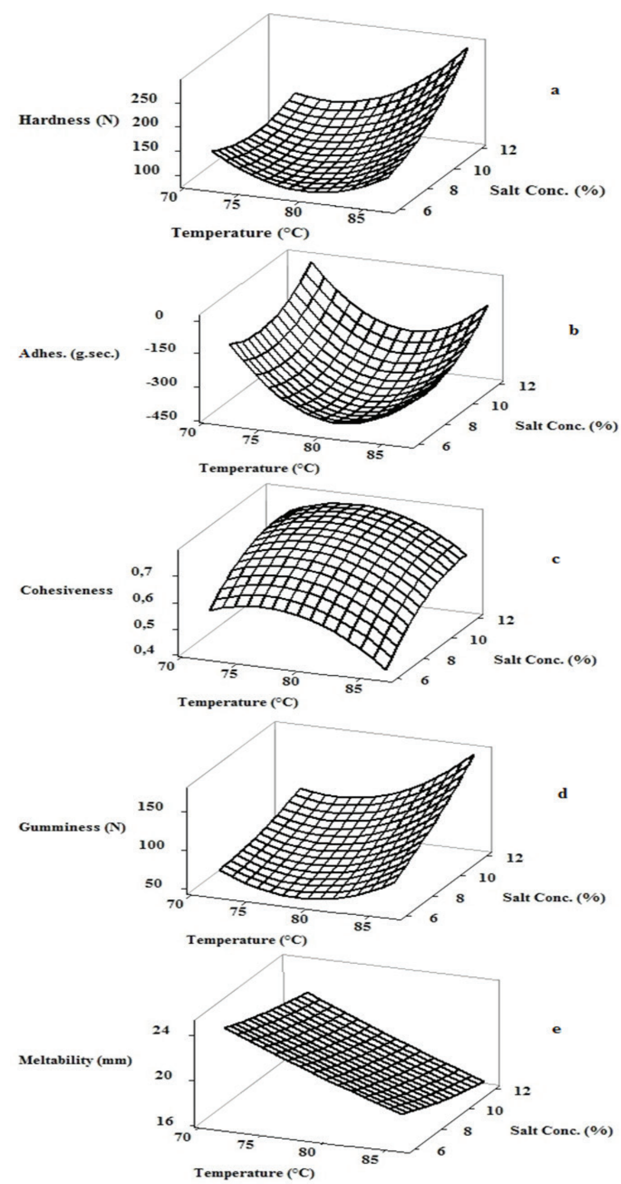

Figure 4. Surface plots of responses of kashar cheese influenced by ST and SC factors of stretching process effect of independent variables on gumminess

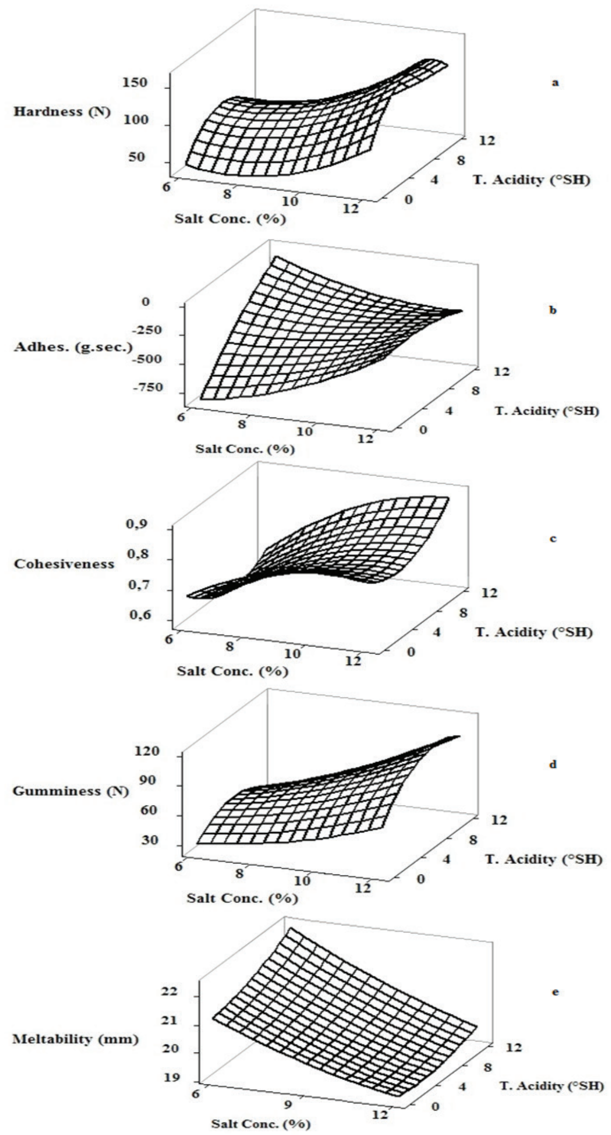

Figure 5. Surface plots of responses of kashar cheese influenced by TA and SC factors of stretching process effect of independent variables on meltability

lationship between the cohesiveness and the TA is in line with the previous reports (Kahyaoglu et al., 2005; Maldonado et al., 2013).

Effect of independent variables on gumminess

More than 97 % of the variation in the gumminess as affected by the stretching process was explained by gumminess model.Model analysis showed that effects of interactions (excluding the interaction of TA and SC) on gumminess was significant ($p \leq 0.05$). The first order terms (excluding TA) were found to be significantly influence on the gumminess value of Kashar sample ($p \leq 0.001$). On the other hand, at quadratic terms (excluding SC), gumminess was affected at least at the $p \leq 0.01$ level. Figures 3 - 5 are presented for clearly shows the interactions terms influence on the gumminess. The TA increased with the increase of ST (Figure 3d). An increase in the SC and ST increased the gumminess of the sample. This influence is intensified at excessive SC (Figure 4d). With the increase in the TA up to 8 - 10 °SH, an increase in the SC increased the gumminess value of cheese sample. Above 10 °SH, the gumminess value again started to decrease (Figure 5d). Earlier reports show that increasing the ST increases the gumminess. It is reported that as the ST increases, a lesser non-fat dry matter content cheese is obtained. There are reports showing that the gumminess of the sample increases when the moisture content is decreased (Erbay et al., 2010; Kahyaoglu et al., 2005). Ayyash et al. (2013) has stated that salt concentration affects the degradation of proteins and rises gumminess of the cheese. In the current study, the effect of ST and SC on gumminess is similar to the relationship stated by previous studies.

Effect of independent variables on meltability

More than 99 % of the variations in the meltability as affected by the stretching process, was explained by meltability model. The proposed model indicated that the interaction of independent factors influence on meltability was insignificant. However, all first order levels were found to be significantly effective on the meltability of Kashar sample($p \leq 0.001$). Similarly, at quadratic terms (excluding ST) were found to be significantly affected on the meltability ($p \leq 0.05$). Figures 3 - 5 are presented for clearly shows the interactions terms influence on the meltability. The meltability of the sample decreased when the ST increased (Figure 3e). The increase in SC with the increase in ST decreased the meltability sample (Figure 4e). When the SC decreased, the increase in the TA increased the meltability value of the sample (Figure 5e). Meltability of Kashar cheese increased as the SC increased with the ST. With the increase in the SC, the decrease in the TA decreased the meltability value of the Kashar cheese. The decrease in the dry matter and salt content of the cheese sample, as well as the weakening of the cheese structure, has been proposed as explanations for this phenomenon.Therefore, meltability of the sample is rise (Say and Guzeler, 2008).

Optimal values and validation results

As optimal values of process variables, 80.20 °C for ST, 0.61 °SH for TA, and 12.00 % SC were found and the related models produced the following responses at these conditions: 79.53 N for hardness, -292.24 g. sec for adhesiveness, 0.74 for cohesiveness, 51.20 N for gumminess, and 19.05 mm for meltability values.

For model validation, cheese sample was produced at optimal conditions stated above. Experimental results showed that the measurements fall within the confidence intervals (at 95 % level) of each response obtained at optimal conditions(Table 4). Thus,the existing model works well to predict the responses of sample in the studied limits of each independent factor presented in Table 1.

Table 4. The results of validation production of kashar cheese

Analysis	Validation production mean ± standard deviation	95 % PI*
Hardness (N)	79.53±8.20	66.80 - 160.60
Adhesiveness (g.sec)	-292.24±9.07	-516.00 - -47.00
Cohesiveness	0.74±0.02	0.58 - 0.95
Gumminess (N)	51.20±9.04	48.21 - 107.42
Meltability (mm)	19.05±0.85	18.29 - 19.22

95 % PI* - prediction interval.

CONCLUSION

ST, SC, and TA used in the stretching process were optimized with respect to the textural and meltability characteristics of the Kashar cheeses collected from the marketplace and ripened utilizing the RSM. The results determined at the end of the optimization process were confirmed with a 95 % prediction interval (PI).Optimum conditions to produce Kashar cheese were found as follows: 80.20 °C for ST, 0.61 °SH for TA (adjusted with whey), and 12.00 % for SC. For model validation, cheese sample was produced at optimal conditions stated above. Kashar cheese, which is produced at optimal conditions, were found 79.53 N for hardness, -292.24 g. sec for adhesiveness, 0.74 for cohesiveness, 51.20 N for gumminess, and 19.05 mm for meltability values.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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