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The effect of homogenization on texture of reduced dry matter processed cheese

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Abstract

Since the cost of processed cheese is high in Iran, in this research we studied the effect of homogenization at the pressures of 100, 150 and 200 bar on the quality and texture of processed cheese followed by reducing dry matter. Results showed no significant difference between the pH and dry matter of processed cheese samples at different pressures ($p > 0.05$). Also, different pressures of homogenization had no significant effect on overall acceptability ($p > 0.05$). With increasing homogenization pressure, texture improved significantly ($p < 0.05$). Homogenization treatment at the pressure of 200 bar had the highest influence on the improvement of the processed cheese texture.

Keywords: processed cheese; dry matter; homogenization; texture.

Practical Application: The improvement of the texture of reduced dry matter processed cheese through homogenization.

1 Introduction

Production of processed cheese is based on the use of cheddar and other cheeses and also citrate and phosphate salts as the emulsifiers. Despite the fact that casein has emulsifying properties in cheese production, making processed cheese without the use of emulsifying salts, such as citrate and phosphate is impossible. Spreadable processed cheese contains more than 20% milk fat that will be provided through raw material, butter, cream powder or cream; so, it will bring soft texture to the cheese (Gunasekaran & Mehmet, 2003). In general, fat acts as a lubricant and proteins reinforce the strength of three-dimensional matrix leading to processed cheeses with more solid-like behavior (Dimitreli & Thomareis, 2008). An essential step in the production of processed cheese is melting of raw materials and stirring of the mix with the emulsifying salts. Heating is carried out indirectly or directly through injection of steam into the cooker that inactivates starter bacteria and other bacteria and enzymes present in raw cheese which increases the storage time (Tamime, 2011). The effect of particular types of phosphates on processed cheese firmness increases in following order: orthophosphate < polyphosphate < diphosphate < triphosphate (Sadlikova et al., 2010).

Homogenization is not a necessary unit operation in cheese production because of added manufacturing cost and time, unless in production of particular cheeses. However, it may be used for making some cheeses, such as blue cheese and low-fat cheese. Also, homogenizers are not necessary for the production of processed cheeses, because the new cooking equipment used has mixing systems which creates the uniform emulsion. Strong flows created by agitator inside the cooker decrease the size of fat globules and other components, and create emulsion oil in the water. Stirrer speed control in the cooker has a direct effect on controlling the texture of produced processed cheese. On the other hand, the new cooking equipment has high-pressure steam injection systems which affect agitators of cooker and enhance mixing of the particles and reduce the size of particles. However, if homogenizers are required, they can be installed after the cooker. Intermediate dairy products such as processed cheeses with high dry matter and fat contents are homogenized in two steps. After homogenization, the ratio of volume to surface area in fat globules reduces protein coverage on their surface increases and leads to the formation of more bonds which results in interconnected protein network (Tamime, 2011).

Oommen et al. (2000) observed a significant increase in the body and texture scores of Cheddar cheese treatments with homogenization of cream. Desrumax et al. (2000) found that applying high pressure homogenization on emulsion containing 40% fat in dry matter at a pressure of 20 to 300 MPa reduced viscosity. Ruger et al. (2002) reported that dual-stage homogenization lowered ice cream mix flow time in the presence of stabilizer, but no difference in flow time was observed without stabilizer addition. Madadlou et al. (2007) confirmed that cream homogenization at 6.0/2.5 MPa effectively improved the textural property of low-fat Iranian White cheese. Pereda et al. (2007) investigated the effect of high pressure homogenization (200 MPa) and pasteurization at a temperature of 90 °C for 15 seconds on microbial population of milk, and found that during the period of 14 to 18 days of storage at 4 °C, these two methods had equal performance. Juan et al. (2009) reported that high pressure homogenized cheese had better texture and more retained moisture compared with non-homogenized cheese. Paskov et al. (2010) observed that homogenized milk samples fermented with the same strains as the non-homogenized ones were much more consistent. Zamora et al. (2011) confirmed that starter-free fresh cheeses made of high pressure homogenized milk were firmer and

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had higher water-holding capacity. Abd El-Gawad et al. (2012) revealed that Mozzarella cheese made from homogenized buffalo milk was firmer and more elastic than non-homogenized samples. Coutouly et al. (2014) reported that increasing the homogenization pressure led to a decrease in fat globule size and consequently an increase in the cream cheese firmness. Sohrabvandi et al. (2013) observed that homogenization at 50 bar after heating led to the highest hardness, whilst non-homogenized and homogenized treatments at 150 bar before heating resulted in the lowest hardness. Massoud et al. (2015) showed that during storage period along with increase in pressure, temperature and stages of homogenization, viability of probiotic bacteria increased. As it is pointed out, a lot of researches have been studied the effect of homogenization on the quality of dairy products, but no research has been reported on the subject of replacement of homogenization with a part of dry matter in processed cheese so far. It should be noted that decrease in dry matter results in creation of undesirable texture and appearance in the final product. It seems that if homogenization is used after the cooking unit operation, then it will result in reduction of the size of fat globules, in addition to reduction in the protein particle size and increase in the contact area between them. Increase in surface area in turn increases the bonds between fat and protein units which it is expected to improve the texture of the processed cheese. Therefore, the effect of dual-stage homogenization followed by reduction of dry matter on processed cheese quality is investigated in the current study.

2 Materials and methods

2.1 Materials

The experimental materials were provided by following companies: butter and Cheddar cheese from Fonterra (News land), skim milk powder (SMP) from Ariarama (Iran), milk protein concentrate (MPC 70) from Eximo (Germany), emulsifiers include di- and triphosphates from Joha (Germany), salt from Kave (Iran), sulfuric acid, alcohol amilic, silver nitrate, nitric acid, buffers 4 &7 and oxalic acid from Merck (Germany)

2.2 Processed cheese preparation

Materials were prepared in mixing room in 2 parts. The first part, dried materials, were skim milk powder (9%), milk protein concentrate (5.5%), emulsifiers (2.8%) and salt (0.4%). wet materials, the second part, included butter (19%) and cheddar cheese (15%). The two parts were then moved to cooker (Stephan, Germany) and after closing the door of cooker, vacuum pump lowered the pressure and also the temperature was increased to 85 °C by the steam. Then, vacuum was detached and pressure returned to normal condition. After that, temperature was increased to 115 °C by steam belt through indirect heating within 5 minutes, the pressure rose to 2 bar and central agitator (named cutter) started to rotate. During the cooking process, a central scrubber prevented the cheese from sticking to the internal surface of cooker and burning. At the end of cooking, the pressure was cut by opening of steam valve and cooker contents were pumped to homogenizer balance tank. During the waiting period and keeping in balance tank, temperature was decreased to 95 °C. After dual-stage homogenization of the mix at the specific pressures presented in Table 1, samples were moved to Creamage tank with the aim of improvement in their texture with a low speed mixing at 85 °C for 15 minutes. The samples were then moved to hopper of packaging machine and packed at 15 g aluminum foil portions. Triangular-shaped portions were arranged in round packages, placed in carton boxes and transferred to fridge after palletizing. Production volume and conditions were same in all tests. Difference between the processed cheese samples was in their formulations. While one of them had 44% dry matter without homogenization, the other one had 42% dry matter with 3 different pressures of homogenization.

2.3 Analysis of processed cheese samples

The fat content of processed cheese was determined by Van Gulik method (ISO 3433, 2008). The moisture and the protein contents were determined by oven drying (ISO, 2004) and Kjeldahl methods, respectively (ISO, 2014). The pH was measured by direct insertion of a calibrated Unicam glass/Ag/AgCl combination pH electrode attached to a pH meter (WTW Model 720, Germany) into the cheese sample. The samples were evaluated after production and after 30, 60 and 90 days of storage at 6 °C.

Textural property (firmness) was measured using a texture analyzer (LLOYD, UK) having a 7mm diameter probe and 5 mm/s speed (Bourne, 2002). The samples were analyzed immediately after production and also after 7, 15, 30, 45, 60, 75 and 90 days of storage at 6 °C

A panel composed of 5 trained panelists from Bel Rouzaneh (Dairy Company, Iran) was used to evaluate the processed cheese score with 5 points hedonic scale by standard questionnaire (scores: 1 = dislike very much, 2= dislike a little, 3= neither like nor dislike, 4= like a little, 5 = like very much). Krouskall Valis nonparametric test was used to analyze data obtained from sensory tests. Analysis of variance (ANOVA) was carried out using SAS 9.1 software. Since the final index assessment is overall acceptability, results of overall acceptability are reported in this research. Overall acceptability was determined immediately after production and also after 15, 30, 45, 60, 75 and 90 days of storage at 6 °C.

Table 1. Specification and homogenization condition of the samples.

Treatment	pH	Fat in DM(%)	Protein (%)	Fat (%)	DM (%)	Dual-stage Homogenization (pressure)
T0 (Control)	5.55	47.2	9.77	21	44	-
T1	5.55	47.6	9.60	20	42	100 bar (70, 30 bar)
T2	5.55	47.6	9.60	20	42	150 bar (110, 40 bar)
T3	5.55	47.6	9.60	20	42	200 bar (150, 50 bar)

2.4 Experimental design and statistical analysis

A factorial experiment was used in a randomized complete block design (for sensory test) and complete randomized design (for pH, moisture, dry matter and firmness). For each treatment, 3 replicates were considered. The statistical significance of the data was determined using Duncan test. p-value < 0.05 was considered sufficient to reject the null hypothesis. Statistical analysis was performed by SAS 9.1 software.

3 Results and discussion

The pH of samples had a significant statistical difference ($p < 0.05$) in different treatments (Table 2). Since citric acid was used to adjust the pH of processed cheese samples, the initial pH difference was not related to difference between treatments, but it was related to the impossibility of setting it on a fixed number because the recorded pH results of samples in the cooker (before entering the homogenizer) were also different. Results are consistent with those of Juan et al. (2009) who found that the pH of cheeses made of goat's milk with different homogenization pressures were identical. Findings are also in accordance with Kietczewska et al. (2006) who observed that the pH of milk samples with different fat contents was not affected by homogenization pressure. Consistent with our study, Lu et al. (2013) reported that homogenization pressure had no influence on the pH of UHT milk during storage at 25 °C.

During storage period, the highest and lowest pHs were observed on the first and 90th days, respectively. Results indicate that the pH amount shows a downward trend by increasing storage time. During 90 days of storage with 30-day intervals, no significant difference in pH between days 30 and 60 was seen ($p > 0.05$), but there was significant differences between days 0 and 90 ($p < 0.05$). During the storage period, activity of heat-resistant microorganisms along with bacteria from post process contamination (PPC) leads to the fermentation of lactose and produces lactic acid and reduces the pH of processed cheese samples. Additionally, the growth of these bacteria in pasteurized products is intensified because competing microorganisms and some milk antimicrobial agents are inactivated during this thermal process (Salwa & Galal, 2002).

While the control sample had the lowest moisture content, the samples treated with different pressures of homogenization showed higher moisture contents; therefore, increased pressure of homogenization had no effect on the moisture content (Table 3). The amount of dry matter in T1, T2 and T3 had no significant difference ($p> 0.05$), but there was a significant difference between these three treatments and control treatment ($p < 0.05$). Similarly, this difference is studied well. Therefore, the pressure of homogenization has no effect on dry matter content. The highest amount of dry matter was related to the control sample (Table 4). Our results are consistent with the results obtained by Kietczewska et al. (2006) who claimed that homogenization pressure did not affected the dry matter of milk with different fat contents. Also, Lu et al. (2013) reported that homogenization pressure had no influence on dry matter of UHT milk during storage at 25 °C.

There was a statistically significant difference between the samples in dry matter during cold storage ($p < 0.05$). In all samples, the moisture content was reduced and dry matter content was increased during storage that is due to the evaporation of water from cheese samples (depending on the permeability of the package) (Fox et al., 2004; Muir et al., 1999). Our results are also consistent with the findings of Salwa & Galal (2002) who reported moisture reduction in Domiati cheese during storage.

Homogenization has two important effects on processed cheese; First, better mixing of all ingredients which results in increased interconnection between the components. Second, reduction in the size of all of the components, especially fat globules, and creating a uniform texture in the cheese. It is noteworthy that these two factors improve the texture of the cheese (Tamime, 2011).

The structure of processed cheese consists of the fat globules dispersed in an aqueous phase (with the size of 0.3 to 5 µ), and protein components that originate from raw materials used in the cheese and cover around the fat globules and create a network. Increasing the cheese shearing force increases the number of bonds and strengthens this network. These proteins are hydrated caseins with structure of sodium para-caseinate and calcium phosphate para- caseinate. Along with the change

Table 2. pH variation in processed cheese samples homogenization-treated at different pressures followed by reducing dry matter during cold storage.

Days Treatments	0	30	60	90
T0	5.6^{cd}	5.6^{de}	5.6^{de}	5.6^{def}
T1	5.6^{de}	5.6^{def}	5.6^{ef}	5.5^{f}
T2	5.6^{a}	5.6^{ab}	5.6^{ab}	5.6^{ab}
T3	5.6^{ab}	5.6^{ab}	5.6^{b}	5.6^{bc}
Standard error	0.004			

$^{a-f}$Means with different subscripts differ significantly (p<0.05).

Table 3. Dry matter (%w/w) variation in processed cheese samples homogenization-treated at different pressures followed by reducing dry matter during cold storage.

Days Treatments	0	30	60	90
T0	44^{c}	45^{bc}	45^{b}	45^{a}
T1	42^{g}	42^{efg}	43^{def}	43^{d}
T2	42^{fg}	42^{efg}	43de	43^{d}
T3	42^{fg}	42^{efg}	43^{def}	43^{d}
Standard error	0.062			

$^{a-g}$Means with different subscripts differ significantly (p<0.05).

Table 4. Moisture (%w/w) variation in processed cheese samples homogenization-treated at different pressures followed by reducing dry matter during cold storage.

Days Treatments	0	30	60	90
T0	56^{c}	55^{c}	55^{c}	54^{d}
T1	58^{a}	58^{ab}	57^{ab}	57^{b}
T2	58^{ab}	58^{ab}	57^{ab}	57^{b}
T3	58^{ab}	58^{ab}	57^{ab}	57^{b}
Standard error	0.120			

$^{a-d}$Means with different subscripts differ significantly (p<0.05).

in the amount and type of emulsifying salts and pH, protein and fat network conditions change. It should be noted that in processed cheeses with high dry matter and fat, reducing fat globules increases contacts between proteins and melted fats, and covers them effectively which in turn leads to the formation of more bonds and thereby stronger texture (Tamime, 2011).

An important factor in the strength of processed cheese texture is its cooling process from temperatures higher than 75 °C to 4-8 °C. It is noteworthy that in mass production of cheese, the cheese is put inside the packs, packs are placed inside the cartons, and cartons are stacked on pallets. Decreasing trend of temperature takes about 20 hours in order to cool the innermost point of cheese to desired temperature. This interval also improves the texture of the final product. Factors such as shape and structure of proteins on the surface of fat globules, crystallization of fat globules, and formation of an amorphous structure based on the accumulation of components lead to further strengthen of texture. Also, the presence of materials such as calcium phosphate may facilitate strengthening of the structure. It is undeniable that cooking and mixing temperature that creates conditions necessary for the formation of emulsion is highly effective on the formation and strengthening of processed cheese structure (Tamime, 2011).

Based on the results of this research, there is no significant statistical difference between the firmness of T1 and T2 samples ($p > 0.05$), but difference between the control sample and samples T1 and T2 is significant. Likewise, there is a significant difference between T3 and samples T1 and T2 ($p < 0.05$). The lowest firmness was seen in the control sample (Table 5). Samples treated at 100 and 150 bar had almost identical firmnesses, while the sample treated at 200 bar showed higher firmness. In general, firmness of T1, T2 and T3 is higher than the control sample on the first day. It may be due to decrease in the size of constituents; particularly the fat globules, and improvement of structural network between fat and hydrated proteins, and the presence of emulsifiers and phosphate salts. High pressures induce higher value of textural characteristics and viscosity, lower syneresis and increased water holding capacity (Sfakianakis & Tzia, 2014). These results are in accordance with the findings of Juan et al. (2009) who showed that texture of the cheese made of goat milk improves with increase in the pressure of homogenization; also, with the results of Zamora et al. (2011) who concluded that the texture of starter-free fresh cheese improves with increase in homogenization pressure of milk. In contrast to these findings, Nguyen et al. (2015) found that homogenization pressures higher than 160 bar results in a lower gel firmness in yoghurts made of buffalo milk, possibly due to the presence of bigger fat-protein clusters within the homogenized milk. This is in contrast to the findings of Foury et al. (2000) who confirmed that high-pressure homogenization (up to 350 MPa) in different oil water emulsions induces a great decrease in the viscosity.

There were significant differences between the firmness of the samples during cold storage. Differences were observed from the first day until the day 45. However, there was no significant difference between days 45 and 60, and also between days 75 and 90 ($p > 0/05$). Firmness increased with increase in the storage time. From days zero to 45, increased firmness was obviously evident, while no change was visible on days 45 to 60. Again, a significant change was observed from days 60 to 90. It is worth mentioning that most of the texture changes in all samples were found between days zero to seven, so that on day zero, firmness value of samples control, T1, T2 and T3 was 21.06, 26.90, 25.83 and 31.48 gf, respectively, whereas on day 7this value was 44.38, 55.39, 55.86 and 65.35 gf, respectively. According to the current study, the highest increase in firmness of all samples was observed at the first seven day and followed by improvement of their texture at 6 °C.

There were no significant difference between overall acceptability scores of samples ($p > 0.05$). However, there was significant difference between overall acceptability of different treatments during cold storage ($p < 0/05$). Zero-day overall acceptability had the lowest score (Table 6), but it improved until day 15and no significant differences were observed between overall acceptability of the samples from day 15 to day 90. This is in contrast with the findings of Juan et al. (2009) who found that cheese made of goat milk without homogenization step had more appropriate appearance and taste. Our results were also different from findings of Zamora et al. (2011) who stated that the fresh free-starter cheese obtained from high-pressure homogenized milk had firmer texture and higher water-holding capacity, but at consumption stage, it induced a feeling of dryness in consumers' mouth. This may be due to the water holding capacity and amount of protein content which improves cheese structure. This discrepancy is probably related to the type of their cheese in which the processing steps are different from processed cheese discussed in this study.

Table 5. Firmness (gf) variation in processed cheese samples homogenization-treated at different pressures followed by reducing dry matter during cold storage (Mean±Standard deviation).

Days Treatments	0	7	15	30	45	60	75	90
T0	21±1^{r}	44 ±0^{o}	48±1 ^{no}	50±1^{mn}	52±1^{lmn}	53±1^{klm}	54±1^{klm}	54±1^{jkl}
T1	27±1^{q}	55±2^{ijkl}	58±2^{hij}	60±3^{fgh}	62±3^{efgh}	64±3^{def}	64 ±3^{def}	66±3de
T2	26±1^{q}	56±2^{ijk}	59±2^{ghi}	61±2^{fgh}	63±2^{defg}	65±2^{def}	66±2de	66±2^{d}
T3	31±2^{p}	65±4de	67±2^{cd}	71±4^{bc}	73±4^{ab}	73±4^{ab}	75±4^{a}	75±4^{a}
Standard error				0.78				

$^{a-o}$Means with different supscripts differ significantly ($p<0.05$).

Table 6. Overall acceptability variation in processed cheese samples homogenization-treated at different pressures followed by reducing dry matter during cold storage.

Days Treatments	0	15	30	45	60	75	90
T0	3^{e}	4^{ab}	4^{ab}	4^{bc}	4^{bc}	4^{c}	4^{c}
T1	3^{e}	4^{de}	4^{c}	4^{ab}	4^{bc}	4^{bc}	4^{bc}
T2	3^{f}	4^{bc}	4^{ab}	4^{bc}	4^{bc}	4^{c}	4^{c}
T3	3^{e}	4^{ab}	5^{ab}	4^{bc}	4^{ab}	4^{c}	4^{c}
Standard error				1.98			

$^{a-f}$Means with different supscripts differ significantly (p<0.05).

4 Conclusion

Evaluation of results obtained from processed cheese samples with different homogenizations followed by decreasing dry matter indicated that homogenization pressure variations were not significantly affected by changes in pH and dry matter content. The lowest firmness was related to the control sample, samples homogenized at pressures 100 and 150 bar had almost the same firmness and the highest firmness was seen in the sample prepared at 200 bar. The difference in homogenization pressures had no significant effect on sensory properties. In this study, the sample homogenization-treated at pressure of 200 bar had the most desirable texture and was selected as the best treatment.

It should be noted that in case of using homogenization in processed cheese production, maintenance costs in shorter service time for homogenizer will be added to production costs due to the high dry matter content of this cheese. Therefore, economic efficiency of the present study should be considered.

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