

DAIRY FOODS

Pressure and Temperature During Vacuum Treatment of 290-Kilogram Stirred-Curd Cheddar Cheese Blocks¹

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ABSTRACT

Pressure and temperature during vacuum treatment at 8.0 kPa of absolute pressure were determined at the center and sides of 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops that had or had not been pressed at 7.9 kPa of surface pressure prior to vacuum treatment. Pressure and temperature in the vacuum chamber also were determined. Pressure at the center of blocks that had not been pressed decreased to an average of 11.9 kPa of absolute pressure, and the pressure at the center of blocks that had been pressed decreased to an average of 17.0 kPa of absolute pressure during vacuum treatment. Temperature at the center of blocks that had not been pressed decreased by an average of 3.9°C, and the temperature at the center of blocks that had been pressed decreased by an average of 3.6°C during vacuum treatment. We concluded that pressing blocks prior to vacuum treatment compressed curd, which created a barrier to rapid air and whey evacuation from blocks during vacuum treatment. Entrapped air and whey may increase mechanical openness and may contribute to uneven moisture distribution in blocks of cheese.

(Key words: vacuum treatment, pressure, cheese)

INTRODUCTION

Vacuum treatment of cheese reduces the size of mechanical openings in cheese blocks and thereby produces a smooth, closely textured cheese. Czulak et al. (1) proposed that removal of air by vacuum treatment helped to reduce the size of mechanical openings in Cheddar cheese. Irvine and Burnett (3) thought that whey brine pockets trapped between curd surfaces caused mechanical openness. Price et al. (4) and Irvine and Burnett (3) found that moisture was removed from cheese blocks more effectively by pressing plus vacuum treating curd than by pressing alone. Robertson (8), Czulak et al. (1), and Irvine and Burnett (3) recommended vacuum treatment of curd before application of pressure to help to reduce mechanical openness in Cheddar cheese. Scott (10) proposed that too rapid application of pressure on curd could compress the surface layer on blocks and lock moisture into pockets in the body of the cheese. Reinhold and Ernstrom (5) found that 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops released 25% more whey when pressing before vacuum treatment was eliminated.

Geurts (2) concluded that unevenness of moisture distribution in Gouda cheese increased with increasing moisture content of cheese. Reinhold and Ernstrom (6) found that removal of excess moisture before cooling of 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops produced cheese with more even moisture distribution.

The purpose of this study was to evaluate effects during vacuum treatment by observing

Received March 20, 1992.

Accepted November 20, 1992.

¹This research was supported in part by the Utah Agricultural Experiment Station, Utah State University, Logan. Approved as Journal Paper Number 4296.

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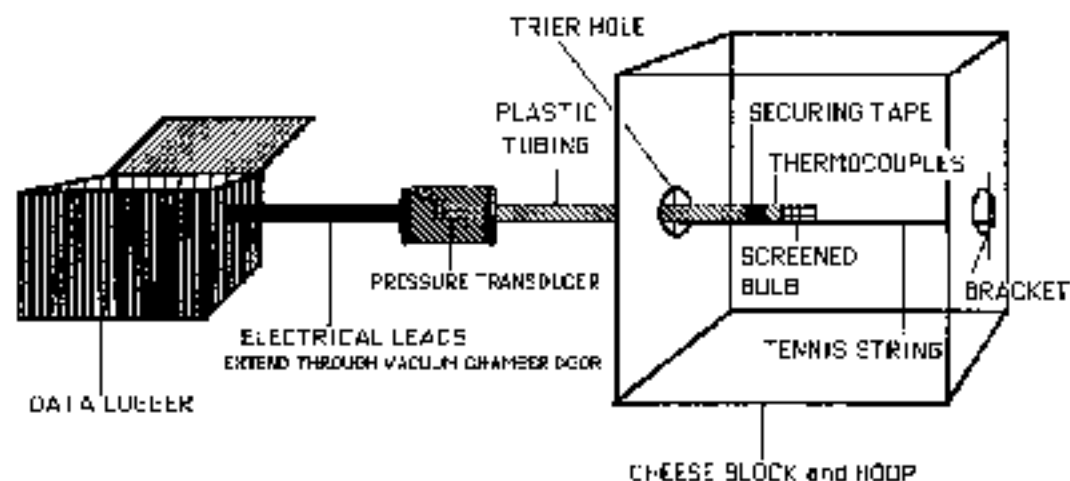


Figure 1. Experimental apparatus for determining pressure and temperature in the center of 290-kg stirred-curd Cheddar cheese blocks during vacuum treatment.

pressure and temperature changes in 290-kg blocks of stirred-curd Cheddar cheese that had or had not been pressed before vacuum treatment. Better understanding of vacuum treatment would aid the cheese maker in producing cheese with desired texture and moisture distribution.

MATERIALS AND METHODS

Cheese was manufactured at Cache Valley Dairy Association, Smithfield, UT. Curd was produced in double O vats (Darrow Co., Fond du Lac, WI) from 22,727 kg of milk, drained, salted on enclosed finishing tables, and then air-conveyed to stainless steel hoops (74.9 cm high \times 71.1 cm long \times 55.9 cm wide). Before stainless steel hoops were filled, tennis string was drawn across the hoop interior and fastened to steel brackets extending across trier holes at the hoop sides. Screened plastic bulbs connected to rigid plastic tubing and copper-constantan thermocouples were secured to the tennis string in the center and at the side of the hoop. The screen protected the pressure-sensing bulb from the surrounding cheese. Each hoop was filled with 327 kg of curd at 32°C. Ambient room temperature was approximately 22°C. After filling, the screened bulb was 2.5 cm from the side of the hoop. For each

vat (eight hoops per vat, one test hoop per vat), curd either was pressed at 7.9 kPa of surface pressure for 2 h or remained unpressed for 2 h. The hoops were then transferred to a vacuum chamber.

Before vacuum treatment, rigid plastic tubing was attached to a Super TJE absolute pressure transducer (0.05% accuracy, range 0 to 100 kPa of absolute pressure; Sensotec, Columbus, OH) located inside the vacuum chamber. Electrical leads from the copper-constantan thermocouple in the cheese block, a thermocouple attached to the inside wall of the vacuum chamber, and the pressure transducer were connected to a Campbell Scientific 21X Datalogger (Campbell Scientific, Logan, UT) outside the vacuum chamber. Curd in hoops was vacuum treated at 9.11 kPa of absolute pressure for 1 h without mechanical pressure. While the curd was still under vacuum, mechanical pressure was applied, curd was pressed at 12.4 kPa of surface pressure for 1 h, and then vacuum was released. When the pressure in the vacuum chamber reached atmospheric pressure, mechanical pressure was released. Pressure and temperature in blocks and pressure and temperature in the vacuum chamber was monitored continuously throughout vacuum treatment. Vacuum chamber pressure was monitored by observation of the

vacuum chamber pressure gauge. Figure 1 depicts the experimental apparatus.

Pressure and temperature at the center of the block, at the side of the block, and in the vacuum chamber during vacuum treatment were determined three times each for a test block from vats that had been given the 2-h pressing prior to vacuum treatment and from vats that had not been pressed prior to vacuum treatment. Data from the three trials were averaged and depicted graphically (Figures 2 and 3).

Statistical analysis. Randomized block design analyses of variance (9) for pressure and temperature were determined from all data (during vacuum treatment and for 2 h after vacuum was turned off), from the data acquired during vacuum treatment (between 0 and 2.0 h), and from the data between .3 and 2.0 h of vacuum treatment. The statistical block was a single replication in each of six blocks of cheese with repeated measurements over time. Table 1 shows the mean squares and the *F* ratios for the analyses of variance from data between .3 and 2.0 h of vacuum treatment.

RESULTS AND DISCUSSION

Figure 1 shows pressures, during vacuum treatment at 8.0 kPa of absolute pressure, in the center and side of 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops. Curd was pressed at 7.9 kPa of surface pressure prior to the vacuum treatment (pressed blocks). Figure 2 also shows pressures when curd was not pressed prior to the vacuum treatment (unpressed blocks).

The center pressure of pressed blocks decreased from an average of 89.5 to 17.0 kPa of absolute pressure (range of 15.3 to 20.9 kPa of absolute pressure for the three trials) before mechanical pressure was applied during vacuum treatment.

The center pressure of unpressed blocks dropped from an average of 88.6 to 11.9 kPa of absolute pressure (range of 11.0 to 13.1 kPa of absolute pressure for the three trials) before mechanical pressure was applied during vacuum treatment. Atmospheric pressure ranged from 87.1 to 87.5 kPa of absolute pressure during the studies. Pressure in the vacuum chamber was approximately 8 kPa.

TABLE 1. Mean squares and *F* ratios for the analysis of variance for pressure and temperature from data between .3 and 2.0 h of vacuum treatment

Factor	df	<i>F</i> Ratio	Pressure	Temperature
R	2		74.78	19.18
P	1	MSP/MSP × P	35.65	107.15**
L	2	MSL/MSE(a)	328.93**	888.51**
P × L	2	MSP × L/MSE(a)	9.54	96.04*
R × P	2		172.51	2.22
Error (a) ¹	8		4.34	17.38
T	9	VSTMSP × T	1.95**	4.02
P × T	9	VSP × T/MSP × P × T	1.09	.47 ⁴
L × T	18	MSL × T/MSE(b)	.85	1.24
P × L × T	18	MSP × L × T/MSE(a)	.39	1.17
R × T	18		.75	3.09
R × P × T	18		1.23	3.08
Error (b) ²	72		.49	2.37

¹R = Replication of trials; P = pressure or no pressure application prior to vacuum treatment; L = location of pressure transducer in center or side of cheese block or in vacuum chamber; T = time that pressure or temperature was monitored.

²Analysis of variance of data between 0 and .3 h of vacuum treatment showed that temperature dropped significantly more ($0.01 < P < .05$) in unpressed than in pressed blocks.

³Error (a) was a pooling of the R × L and R × P × L interactions.

⁴A paired *t* test between 1.0 and 1.01 h of vacuum treatment showed that temperature increased significantly in the center of unpressed blocks during mechanical pressure application.

⁵Error (b) was a pooling of the R × L × T and R × P × L × T interactions.

**P* < .05.

***P* < .01.

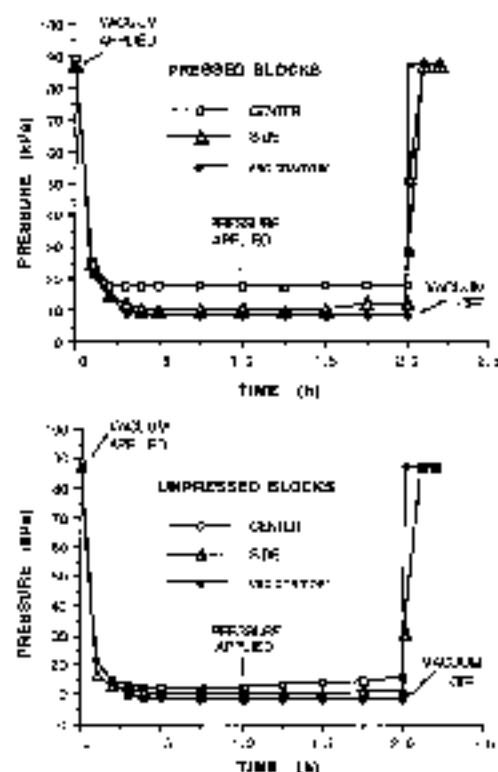


Figure 2. Pressure during vacuum treatment at 8.3 kPa of absolute pressure, in the center and side of pressed (7.9 kPa of surface pressure) and unpressed 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops. Vacuum chamber (vac chamber) pressure also is shown.

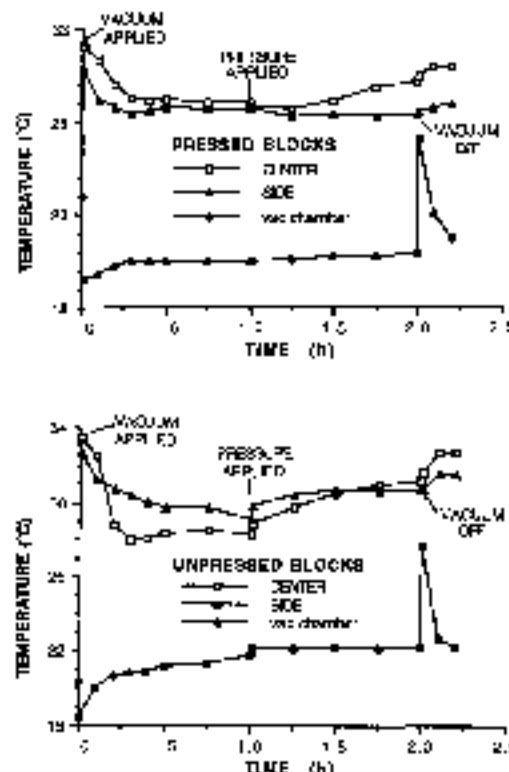


Figure 3. Temperature during vacuum treatment at 8.3 kPa of absolute pressure, in the center and side of pressed (7.9 kPa of surface pressure) and unpressed 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops. Vacuum chamber (vac chamber) temperature also is shown.

Because pressure in the center of unpressed blocks was lower than in the center of pressed blocks (depicted graphically and indicated by the significant ($P < .05$) pressure and location interaction in Table 1), pressing of blocks prior to the vacuum treatment may have compressed and sealed curd, which then created a barrier to rapid air and whey evacuation from the blocks. No difference was observed in vacuum chamber pressure between the two treatments.

Figure 3 shows the temperatures in the centers and sides of pressed and unpressed 290-kg blocks of stirred-curd Cheddar cheese in stainless steel hoops during vacuum treatment. Vacuum chamber temperatures also are shown. For both pressed and unpressed blocks, the decrease in temperature in the center and side of blocks and the decrease in temperature in the vacuum chamber at the start of vacuum

treatment were probably caused by evaporative cooling. Increases in temperature were probably caused by heat of condensation as the vacuum chamber pressure returned rapidly to atmospheric pressure.

Center temperature decreased by an average of 5.9°C (range of 5.8 to 5.9°C for the three trials) in unpressed blocks and by an average of only 3.6°C (range of 3.1 to 4.7°C for the three trials) in pressed blocks. For the three trials, center temperature decreased by 5.9, 5.9, and 4.7°C, respectively, in unpressed blocks and by 2.8, 2.4, and 3.2°C, respectively, in pressed blocks between 0 to .3 h of vacuum treatment.

Statistical analysis of the data between 0 and .3 h of vacuum treatment (Table 1) showed that the center temperature dropped to significantly lower values ($P < .05$) in un-

pressed than in pressed blocks, indicating that pressures were lower in unpressed blocks and that curd was more compressed in pressed blocks. Rapid heat transfer from compressed curd to thermocouple junctions could have opposed evaporative cooling in pressed blocks, which, in turn, provided evidence that compressed curd in pressed blocks could have provided a barrier to rapid air and whey evacuation from the cheese.

Table 1 indicated that temperature increased significantly ($P < .05$) in the center of unpressed blocks during mechanical pressure application. The temperature increased by an average of 4°C . Temperature change in the center of pressed blocks, in the side of either pressed or unpressed blocks, and in the vacuum chamber was not significant ($P > .05$). However, temperature in some locations in blocks increased or decreased by 2.0 or 9°C , respectively, during pressure application. Similar findings have been reported previously (7). Presumably, these temperature changes were the result of heating produced by condensation of vapor or cooling produced by evaporation of moisture.

The analyses of variance for all data and for the data acquired during vacuum treatment showed results similar to the analysis of variance depicted in Table 1 (data between .3 and 2.0 h). However, the time factor was more significant for both of these undepicted analyses because temperature and pressure changed rapidly between 0 and .3 h of vacuum treatment and for the .2 h after vacuum was shut off. Also, the pressure and location interaction factor was not significant in the analysis that included the .2 h after the vacuum was shut off because pressure increases in pressed blocks were not uniform. However, significance of the pressure factor in this analysis increased because pressure increases in pressed blocks were not uniform.

Figure 2 substantiates the statistical findings that pressure increase was more uniform in unpressed than pressed blocks after vacuum was shut off and further suggests that all locations in unpressed blocks released air and whey more uniformly during the vacuum treatment.

CONCLUSIONS

Pressure was higher, and temperature dropped less rapidly, during vacuum treatment

in blocks that were pressed before vacuum treatment than in blocks that were not pressed before vacuum treatment. Temperature increased or decreased in some block locations when mechanical pressure was applied during the vacuum treatment. Through this work and previous studies (1, 3, 4, 5, 8, 10), we conclude that too much pressing before vacuum treatment may compress curd to produce a barrier to air and whey evacuation. Entrapped air and whey may produce mechanical openness in cheese (1, 3, 4, 8, 10). Excessive free moisture trapped in cheese blocks at the start of cooling may increase uneven moisture distribution in cheese (2, 6). Novel pressing and vacuum treatment regimens must be devised by the cheese maker to minimize mechanical openness and uneven moisture distribution in cheese.

ACKNOWLEDGMENTS

We thank R. Gleason, M. Harris, and D. Larson, Cache Valley Dairy, for their assistance. We also thank Paul Campbell, Campbell Scientific, for use of the Datalogger and pressure transducer.

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