

Effects of Internal Nitrogen Cooling on Moisture Distribution in Cheddar Cheese

by Chris Jackson 2005

Abstract

The refrigeration of 640-lb stirred-curd Cheddar cheese blocks, commonly produced by U.S. cheese-makers, causes uneven moisture distribution that lowers cheese quality. Uneven moisture distribution in cheese blocks is caused by the standard method of refrigerating cheese since moisture migrates toward the colder outer regions of the cheese block during refrigeration. According to R.S. Reinbold and C.A. Ernstrom, “The most desirable situation [for cooling cheese] would be a uniform and rapid cooling of all positions within the cheese block.” Based on this conjecture, the purpose of my study was to determine if injecting nitrogen into stirred-curd Cheddar cheese blocks prior to refrigeration would cause more even moisture distribution than the standard method of refrigeration. I made 2-lb stirred-curd Cheddar cheese blocks using the University of Minnesota’s cheese-making protocol. I injected nitrogen using a nitrogen-injection system into half of the cheese blocks, then cut each block into five layers to be tested for moisture distribution, and compared the moisture distribution of the nitrogen-injected to control cheese blocks. I found that moisture migration toward the nitrogen-injection point was significantly profound (average $p = 0.01$). Refrigerating the cheese block after injection did not cause significant moisture migration toward the surface area of the cheese block (average $p = 0.98$). Therefore, nitrogen-injection prior to refrigeration did not result in more even moisture distribution throughout the cheese block.

Introduction

My project focused on uneven moisture distribution in Stirred-Curd Cheddar cheese blocks (for definition of stirred-curd Cheddar cheese, see Appendix A). The purpose was to determine if moisture could be distributed more evenly throughout 2-lb cheese blocks by injecting the blocks with liquid nitrogen prior to refrigeration as compared to the standard method of refrigerating cheese. While commercially-made Cheddar cheese is produced in 640-lb blocks, data from my project obtained from 2-lb blocks may prove useful to Cheddar cheese manufacturers.

Uneven moisture distribution in cheese blocks is caused by moisture migration from warmer to colder regions within the blocks (1). There are several hypotheses for how moisture migrates within cheese blocks. Refrigerating the blocks causes moisture to migrate to the outer regions of the block because the cheese is being cooled only from the surface. This standard method of cooling cheese causes the outer region of the block to have higher percent moisture than the inner region, creating uneven moisture distribution. A study done by Reinbold *et al.* found that rapid cooling by refrigeration of 640-lb blocks of stirred-curd Cheddar cheese produced uneven moisture distribution (2).

Cheese-block production systems that produce 640-lb cheese blocks became common in the U.S. cheese-making industry after their introduction in the late 1970s and early 1980s (3). These systems were developed to control cost in a highly cost-competitive market. However, a study by D. M. Barbano found that the 640-lb cheese blocks produced by these new systems posed greater cooling problems than their

predecessors (3). Reinbold *et al.* observed that the refrigeration of 640-lb stirred-curd Cheddar cheese blocks caused uneven moisture distribution. The Reinbold study also found after 24 hours of refrigeration, the exterior of the cheese block had 38% moisture, whereas the interior had 35% moisture (3).

Percent moisture in cheese directly affects the texture and, inherently, the quality of cheese; higher percent moisture causes cheese to be softer, while lower percent moisture causes cheese to be harder (4). A study by D.M. Barbano reported, “The range of moisture from center to outside surfaces of the blocks was about 5%” (3). Cheese blocks that weigh 640 pounds have such a large range of moisture, demonstrated by the Reinbold *et al.* and D. M. Barbano studies, that some portions of the cheese may be inappropriate to sell as Cheddar cheese because moisture levels fail to meet commercial specifications (4).

The first hypothesis of my project was that injecting nitrogen into the center of a cheese block prior to refrigeration would cause moisture to be distributed more evenly than the standard method of refrigerating cheese. According to R.S. Reinbold and C.A. Ernstrom, “The most desirable situation would be a uniform and rapid cooling of all positions within the cheese block” (2). My first hypothesis was based on this conjecture.

The second hypothesis of my project was that internal cooling of cheese blocks during nitrogen-injection would cause moisture migration toward the central injection point. Then, refrigeration would cause moisture migration toward the surface of the cheese block, and would thus cause moisture to disperse evenly during both migrations, creating more even moisture distribution.

Procedure

Stirred-curd Cheddar cheese blocks were made in 40-lb and 400-lb vats, yielding two 2-lb and two 20-lb cheese blocks, respectively. The University of Minnesota’s Cheddar cheese making protocol was used (5). The 20-lb cheese blocks were cut into smaller cheese blocks with dimensions of 14 cm by 14 cm by 6 cm to be close in mass to the 2-lb cylindrical cheese blocks so that all of the samples were dimensionally similar. Each cheese block was vacuum packaged individually and placed in a warm water bath for one hour to establish a sample temperature of 35 °C. Immediately after the cheese blocks had been removed from the water bath, half the blocks were punctured by a nitrogen-injection system and nitrogen was injected into the center of each cheese block. Nitrogen was injected without removing the vacuum packaging and injected while rotating the block until excess gaseous nitrogen was observed at the injection point. A second vacuum packaging was added over the original vacuum packaging that had been punctured by the nitrogen-injection system. The cheese blocks were labeled accordingly and placed in a water bath at 1 °C for one day. The remaining cheese blocks were labeled as controls and placed in a water bath at 1 °C for one day. All cheese blocks were removed from the water bath and placed in a refrigerator at 7 °C for six days. Afterwards, the cheese blocks were removed from the refrigerator and placed on a cutting board to be prepared as Cheddar cheese samples.

To prepare Cheddar cheese samples for percent moisture analysis, the vacuum packaging of a cheese block was removed. Then, 1.4 cm by 1.4 cm by 0.6 cm was cut off of each respective side of the cheese block and stored in a bag labeled L1 (layer 1). This process of cutting 1.4 cm by 1.4 cm by 0.6 cm from each respective side was continued

on the remaining cheese block until five separate layers of the cheese block were placed in labeled bags. Layer 1 was identified as the outermost layer of cheese, while layer 5 was the innermost layer of cheese. The cheese from each bag was ground to a particle size of 2-5 mm in a blender. This process was repeated for each sample. The AOAC Method for Forced Draft Oven 990.20 (Appendix B) was used to calculate the percent moisture in each of the five layers of cheese (6).

Analysis

P-values were calculated using a 2-sample t-test to determine if the differences in percent moisture of nitrogen-injected vs. control samples were significant. The p-values were considered significant when $p < 0.05$.

Linear equations were used to calculate trends in average percent moisture from layers 1-5. The linear equations of nitrogen-injected blocks from Trials 1-4 were $y = 0.40x + 48.64$, $y = 0.15x + 50.14$, $y = 0.27x + 38.54$, $y = 0.30x + 40.26$, respectively. The linear equations used to calculate trends in average percent moisture for control blocks from Trials 1-4 were $y = -0.10x + 48.10$, $y = -0.04x + 49.97$, $y = -0.04x + 39.29$, and $y = -0.10x + 41.45$, respectively.

Results

Four replicate trials comparing percent moisture in five layers of a nitrogen-injected Cheddar cheese and control cheese block were conducted. Figures 1- 4 show the relationship of percent moisture between nitrogen-injected Cheddar cheese and control cheese samples for Trials 1- 4. Data from layers 1 and 2 in Figures 1 and 2 were disregarded since the data were not relevant to moisture distribution in 640-lb Cheddar cheese blocks. This was because high pressure exerted on the surface of the 2-lb blocks during pressing caused a dense layer with low moisture, which had a profound effect on moisture distribution. Layers 1 and 2 in Figures 3 and 4 represent the layers of cheese after the outer two layers were discarded.

Figure 1

Trial 1. Average % Moisture in 5 Layers of Control and Nitrogen Injected Cheddar Cheese Blocks

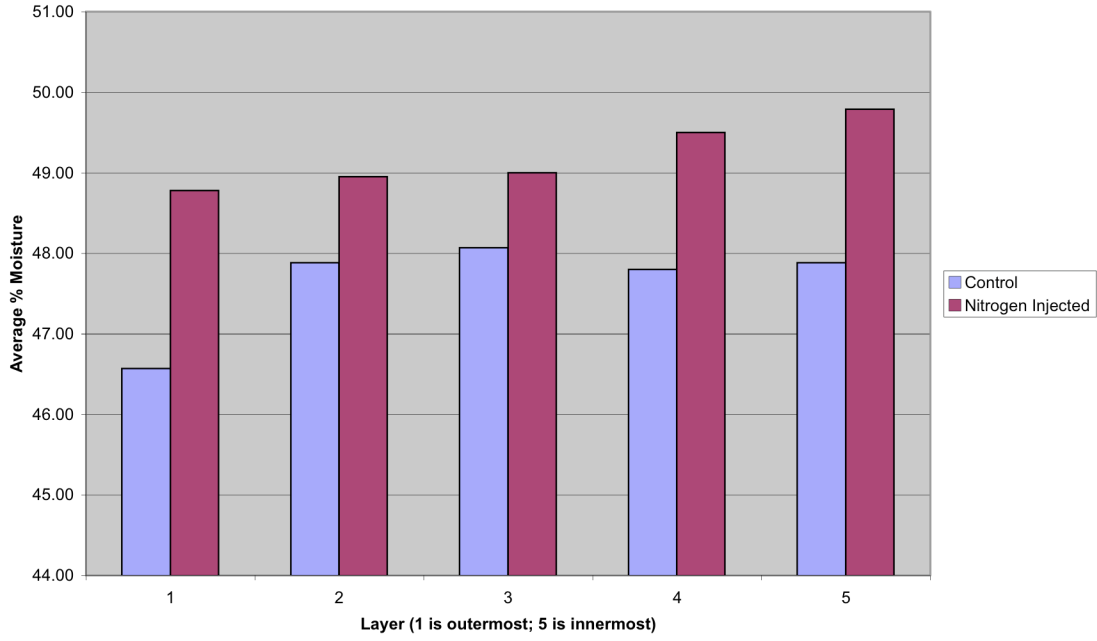


Figure 2

Trial 2. Average % Moisture in 5 Layers of Control and Nitrogen Injected Cheddar Cheese Blocks

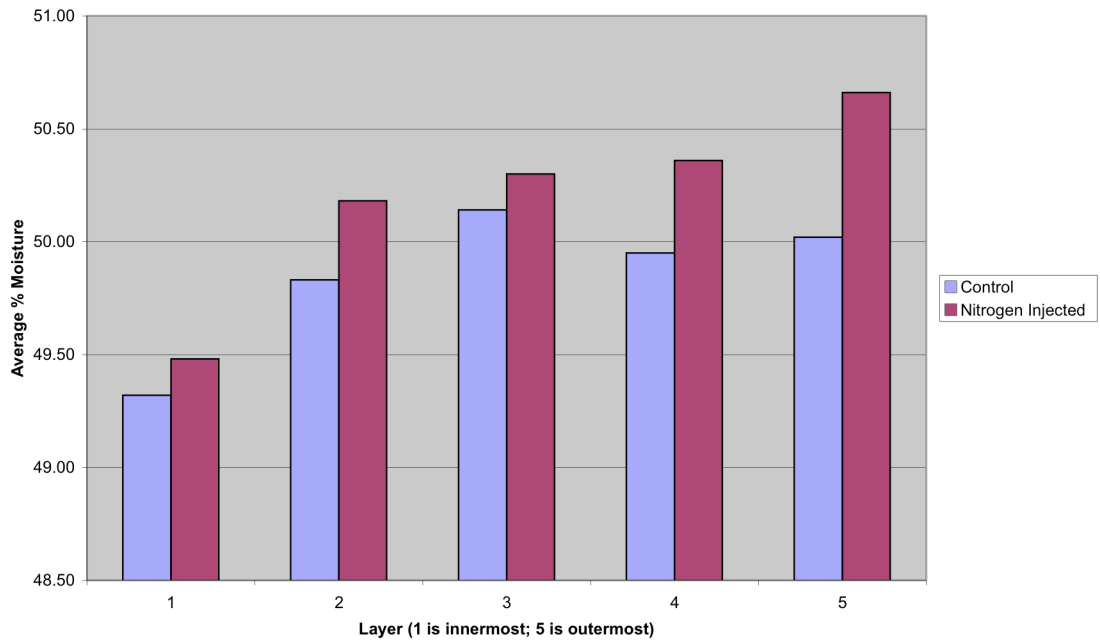


Figure 3

Trial 3. Average % Moisture in 5 Layers of Control and Nitrogen Injected Cheddar Cheese Blocks

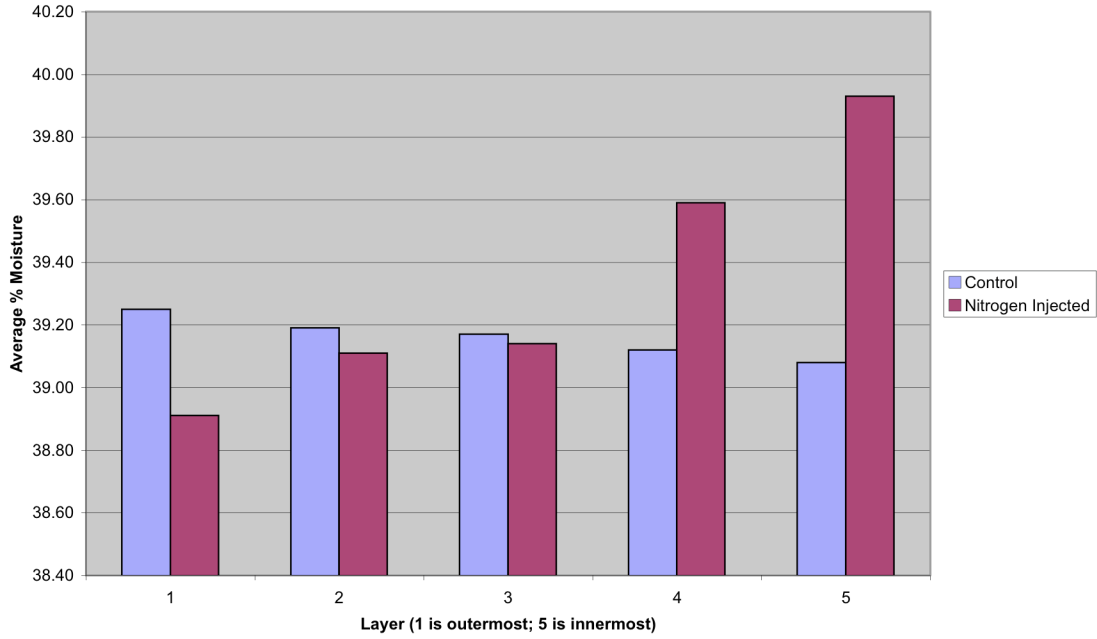


Figure 4

Trial 4. Average % Moisture in 5 Layers of Control and Nitrogen Injected Cheddar Cheese Blocks

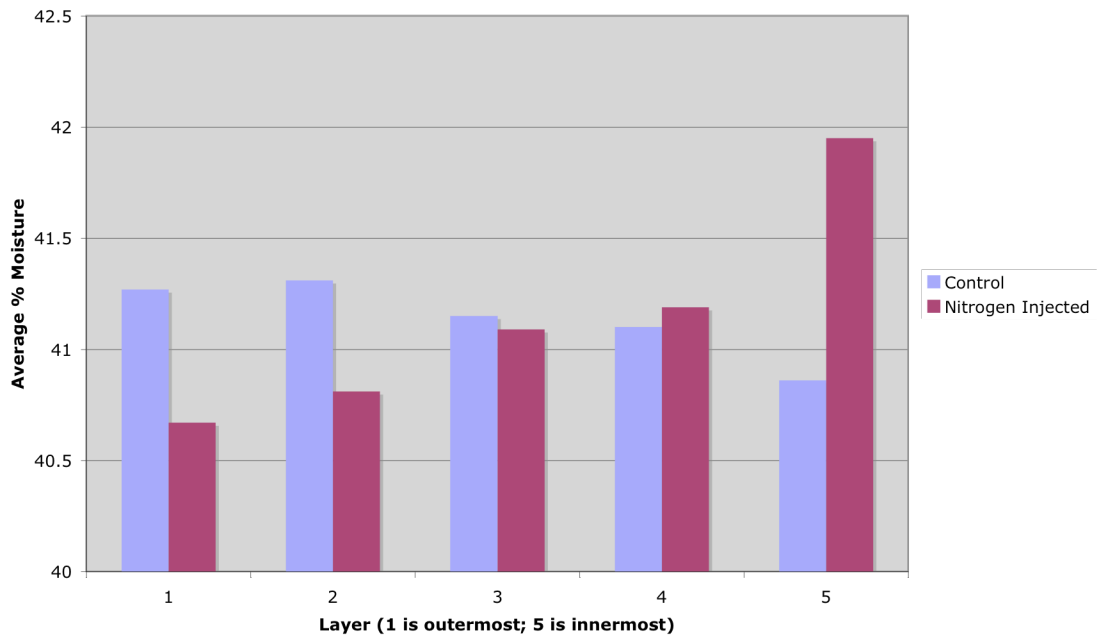


Table 1 shows that the nitrogen-injected samples from Trial 1 for layers 3-5 had significantly higher percent moisture than the control samples from the same layers ($p = 0.04, 0.00, \text{ and } 0.00$ respectively).

Table 1: p-values of each layer in the nitrogen injected Cheddar cheese block and the control Cheddar cheese block from Trial 1

Layer	p-values of nitrogen injected > control	p-values of nitrogen injected < control
1	Disregarded	Disregarded
2	Disregarded	Disregarded
3	p = 0.04	p = 0.96
4	p = 0.00	p = 1.00
5	p = 0.00	p = 1.00

Table 2 shows that the nitrogen-injected samples from Trial 2 for layers 3-5 had significantly higher percent moisture than the control samples from the same layers (p = 0.00 and 0.00 respectively).

Table 2: p-values of each layer in the nitrogen injected Cheddar cheese block and the control Cheddar cheese block from Trial 2

Layer	p-values of nitrogen injected > control	p-values of nitrogen injected < control
1	Disregarded	Disregarded
2	Disregarded	Disregarded
3	p = 0.34	p = 0.66
4	p = 0.00	p = 1.00
5	p = 0.00	p = 1.00

Table 3 shows that the nitrogen-injected samples from Trial 3 for layers 1 and 2 had significantly lower percent moisture than the control samples from the same layers (p = 0.03 and 0.05 respectively). Table 3 also shows that the nitrogen-injected samples for layers 4 and 5 had significantly higher moisture than the control samples from the same layers (p = 0.05 and 0.03 respectively).

Table 3: p-values of each layer in the nitrogen injected Cheddar cheese block and the control Cheddar cheese block from Trial 3

Layer	p-values of nitrogen injected > control	p-values of nitrogen injected < control
1	p = 0.97	p = 0.03
2	p = 0.95	p = 0.05
3	p = 0.29	p = 0.71
4	p = 0.05	p = 0.95
5	p = 0.03	p = 0.97

Table 4 shows that the nitrogen-injected samples from Trial 4 for layers 1 and 2 had significantly lower percent moisture than the control samples from the same layers (p = 0.03 and 0.02 respectively). Table 4 also shows that the nitrogen-injected samples from Trial 4 for layer 5 (p = 0.00) had significantly higher moisture than the control samples from the same layer.

Table 4: p-values of each layer in the nitrogen injected Cheddar cheese block and the control Cheddar cheese block from Trial 4

Layer	p-values of nitrogen injected > control	p-values of nitrogen injected < control
1	p = 0.99	p = 0.01

2	p = 0.98	p = 0.02
3	p = 0.73	p = 0.27
4	p = 0.14	p = 0.86
5	p = 0.00	p = 1.00

Table 5 shows linear equations of best fit ($y = ax + b$) calculated to determine the trends of average percent moisture in the nitrogen-injected and control blocks for Trials 1- 4.

Table 5: linear equations for % moisture trend of the five Cheddar cheese layers in Trials 1, 2, 3, and 4

Trial	Linear equation for average % moisture in 5 layers of nitrogen injected Cheddar cheese	Linear equation for average % moisture in 5 layers of control Cheddar cheese
1	$Y = 0.40x + 48.64$	$Y = -0.10x + 48.10$
2	$Y = 0.15x + 50.14$	$Y = -0.04x + 49.97$
3	$Y = 0.27x + 38.54$	$Y = -0.04x + 39.29$
4	$Y = 0.30x + 40.26$	$Y = -0.10x + 41.45$

Conclusion

The results do not support my first hypothesis, which was that injecting nitrogen into the center of the cheese block prior to refrigeration would cause moisture in cheese to be distributed more evenly than the standard method of refrigerating cheese. Table 5 shows that the trends of average percent moisture in nitrogen-injected samples for Trials 1- 4 are steeper than the trends of average percent moisture in control samples. Steeper trends indicate greater uneven moisture distribution. Therefore, nitrogen-injection prior to refrigeration caused greater uneven moisture distribution than the standard method of refrigerating cheese.

The results support the first part of my second hypothesis, which was that internal cooling of cheese blocks during nitrogen-injection would cause moisture migration toward the central injection point. The p-values from layer 5 of Trials 1-4 show that the nitrogen-injected samples from this layer had significantly higher percent moisture than control samples ($p = 0.00$, $p = 0.00$, $p = 0.03$, and $p = 0.00$, respectively). Therefore, nitrogen-injection caused significant moisture migration toward the nitrogen-injection point in the center of the cheese block.

However, the results do not support the second part of my second hypothesis, which was that refrigeration would cause moisture migration toward the surface of the cheese block and would thus cause moisture to disperse evenly during both migrations, creating more even moisture distribution. The p-values for layers 1 and 2 from Trials 3 and 4 show that the nitrogen-injected samples from these layers had significantly lower percent moisture than control samples (Trial 3: $p = 0.03$ and $p = 0.05$; Trial 4: $p = 0.01$ and 0.02 , respectively). Once again, the p-values for layer 5 from Trials 3 and 4 show that the nitrogen-injected Cheddar samples had significantly higher percent moisture than control samples ($p = 0.03$ and $p = 0.00$, respectively). In conjunction, the linear equations from Trials 3 and 4 of the nitrogen-injected Cheddar cheese samples are positive equations. Thus, the trend in moisture distribution of the nitrogen-injected samples from

Trials 3 and 4 began significantly lower than the control samples at layers 1 and 2, then increased to layer 5, where the trend showed significantly higher percent moisture than the control samples. Inherently, the control samples from the same Trials showed a moisture distribution trend opposite of the trend for the nitrogen-injected samples. These factors indicate that moisture migration toward the nitrogen-injection point in the center of the cheese block was profound, since the percent moisture for layer 5 of the nitrogen-injected samples was always significantly higher than the control samples. The moisture migration was so profound that refrigerating the cheese block after injection could not cause a significant amount of moisture to migrate toward the surface of the cheese block, since the percent moisture for layers 1 and 2 of Trials 3 and 4 of the nitrogen-injected samples was always significantly lower than the control samples. Therefore, nitrogen-injection prior to refrigeration did not create more even moisture distribution throughout the cheese block.

Although the hypotheses for my project were not supported by the results, more research is needed to determine if cooling cheese blocks by nitrogen-injection can create more even moisture distribution than the standard method of refrigerating cheese. This project was the first to test the effect of nitrogen cooling on moisture distribution in cheese blocks, so there were variables that were not tested. The amount of nitrogen injected into each cheese block during this project depended on how long it took for excess nitrogen to be expelled from the cheese block. The time for excess nitrogen to be expelled was different for each trial, and thus, different amounts of nitrogen were added each trial. Injecting smaller amounts of nitrogen may lessen the profound moisture migration caused by the nitrogen-injection and lead to more even moisture distribution. Also, decreasing the refrigerator temperature may cause more moisture migration after nitrogen-injection.

Further research on cooling cheese with nitrogen, including studying the untested variables above, should be conducted since nitrogen-injection proved to affect moisture distribution in cheese. This new method of cooling cheese should be pursued because if it can be proven to cause even moisture distribution, it may benefit commercial cheese production.

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Sources Cited

1. Emmons, D.B., *et al.* (2001) *J. AOAC INTERNATIONAL* 84, 620.
2. Reinbold, R. S., and C. A. Ernstrom. 1988. Effect of nonuniform cooling on moisture, salt, and pH distribution in 290-kilogram blocks of stirred-curd cheddar cheese. *J Dairy Sci.* 71: 1499.
3. Barbano, D.M. (2001) *J. AOAC INTERNATIONAL* 84, 613.

4. L. Metzger, personal communication, (2004, May 13).
5. R. Miller, personal communication, (2004, June 8).
6. NA, *Food Analysis*, S.S. Nielsen, Ed. (Aspen Publishers, Inc., New York, ed. 2, 1998), NA.
7. F. Kosikowski, *Cheese and Fermented Milk Foods* (Edwards Brothers, Inc., Michigan, ed. 2, 1977), 228-260.

Bibliography

- Barbano, D.M. (2001) *J. AOAC INTERNATIONAL* **84**, 613.
- Barbano, D. M., and J. W. Sherbon. 1983. Cheddar cheese yields in New York. *J. Dairy Sci.* 67: 1873.
- Blattner, T. M., *et al.* (1985) *J. AOAC* **68**, 718.
- Emmons, D.B., *et al.* (2001) *J. AOAC INTERNATIONAL* **84**, 620.
- F. Kosikowski, *Cheese and Fermented Milk Foods*. (Edwards Brothers, Inc., Michigan, ed. 2, 1977), 228-260.
- L. Metzger, personal communication, (2004, May 13).
- L. Metzger, personal communication, (2004, May 15).
- Reinbold, R. S., C. A. Ernstrom, and C. L. Hansen. 1992. Effect of container materials on temperature profiles of large blocks of Swiss and Cheddar cheese. *J. Dairy Sci.* 75: 2637.
- Reinbold, R. S., and C. A. Ernstrom. 1988. Effect of Nonuniform Cooling on Moisture, Salt, and pH Distribution in 290-Kilogram Blocks of Stirred-Curd Cheddar Cheese. *J Dairy Sci.* 71: 1499.
- Reinbold, R. S., C. A. Ernstrom, C. M. Gale, C. L. Hansen. 1993. Pressure and temperature during vacuum treatment of 290-kilogram stirred-curd Cheddar cheese blocks. *J. Dairy Sci.* 76: 909.
- Reinbold, R. S., C. A. Ernstrom, and C. L. Hansen. 1992. Temperature, pH, and moisture profiles during cooling of 290-kilogram stirred-curd Cheddar cheese blocks. *J. Dairy Sci.* 75: 2071.
- R. Miller, personal communication, (2004, June 8).
- T. M Cogan, D. G. Dalgleish, B. Foltmann, P. F. Fox, M. L. Green, T. P. Guinee, C. Hill, K. R. Langley, J. Law, A. Marcos, R. J. Marshall, J. –L. Maubois, P. L. H. McSweeney, V. V. Mistry, J. H. Prentice, E. Renner, L. B. Smith, J. Wallace, P. Walstra, M. G. Wilkinson, E. A. Zottola, in *Cheese: Chemistry, Physics, and Microbiology*. P. F. Fox, Ed. (Chapman and Hall, New York, 1993), pp 1-36.
- NA, *Food Analysis*, S.S. Nielsen, Ed. (Aspen Publishers, Inc., New York, ed. 2, 1998), NA.

Appendix A

“Cheddaring” cheese consists of piling and re-piling blocks of warm cheese in a vat to increase lactic acid production and kill bacteria (7). Stirred-curd Cheddar cheese implies that the Cheddar cheese was made by stirring curd with whey present, which differentiates this method from other Cheddar cheese-making methods.

Appendix B

AOAC Method For Forced Draft Ovens 990.20 (6):

A forced draft oven was heated to 38 °C. Then, 20 small aluminum dishes were labeled from 1-20 and two aluminum dishes labeled B1 (Blank 1) and B2 (Blank 2) for each cheese block. Each aluminum dish was weighed using an electronic balance that measured to the fourth decimal place. The mass was recorded and the balance was re-zeroed. Then, exactly 2.0000 g of ground cheese was removed from bag L1, put into the respectively labeled dish, and the exact mass was recorded. Three more 2.0000 g ground cheese samples from bag L1 were weighed into separate aluminum dishes, resulting in four separate cheese samples for layer 1. This process was repeated for all other layers, which resulted in 20 aluminum dishes of weighed cheese samples with two aluminum dishes left blank (B1 and B2) for each cheese block. All dishes were placed into the preheated forced draft oven for one day. The dishes were removed from the oven, weighed, and the mass of the remaining solids and aluminum dish was recorded. A “Moisture Analysis- Forced Draft Oven” spreadsheet was used to calculate the average percent moisture of each sample and the average percent moisture of each layer was determined.