Moisture Variations in Brine-Salted Pasta Filata Cheese

Paul S. Kindstedt
University of Vermont, Department of Nutrition and Food Science, Burlington, VT 05405-0148

A study was made of the moisture distribution in brine-salted pasta filata cheese. Brine-salted cheeses usually develop reasonably smooth and predictable gradients of decreasing moisture from center to surface, resulting from outward diffusion of moisture in response to inward diffusion of salt. However, patterns of moisture variation within brine-salted pasta filata cheeses, notably pizza cheese, are more variable and less predictable because of the peculiar conditions that occur when warm cheese is immersed in cold brine. In this study, cold brining resulted in less moisture loss from the cheese surface to the brine. Also it created substantial temperature gradients within the cheese, which persisted after brining and influenced the movement of moisture within the cheese independently of that caused by the inward diffusion of salt. Depending on brining conditions and age, pizza cheese may contain decreasing, increasing, or irregular gradients of moisture from center to surface, which may vary considerably at different locations within a single block. This complicates efforts to obtain representative samples for moisture and composition testing. Dicing the entire block into small (e.g., 1.5 cm) cubes and collecting a composite sample after thorough mixing may serve as a practical sampling approach for manufacturers and users of pizza cheese that have ready access to dicing equipment.

Salt (NaCl) is an essential component of virtually all cheeses. Brining, i.e., the immersion of a newly made cheese in concentrated salt brine for a specified period of time, is one of several methods that may be used in cheese making to incorporate salt, depending on the cheese variety (1). Pasta filata cheeses such as Mozzarella (pizza cheese) are usually brine-salted because brining not only serves to salt the cheese but also provides for rapid cooling (2). The latter is essential because pasta filata cheese curd is heated to about 55°C in hot water and mechanically worked to a plastic consistency before it is molded into block form. The resulting block, typically ranging in weight from 2.25 to 9.1 kg for pizza cheese, is precooled during molding so that the block will retain its shape when removed from the mold. However, the center of the block may remain quite warm (e.g., 49°C), and substantial additional cooling occurs after the cheese leaves the molder. Cooling is usually accomplished by brining at low temperature (1–4°C); therefore, a large temperature difference exists between cheese and brine at the start of brining. In contrast, most other cheeses are brined at higher temperatures (10–20°C), and the temperature difference between cheese and brine is much smaller.

During brining, salt migrates from the brine into the cheese, and moisture in the cheese migrates in the opposite direction through an impeded diffusion process (1). When brining is performed at temperatures close to that of the cheese, the outward migration of moisture is caused exclusively by penetration of salt; therefore, moisture remains unchanged in regions of the cheese where salt has not penetrated (3). As salt penetrates the cheese, moisture migrates outward at a faster rate than the inward movement of salt. Consequently, moisture is lost from the cheese more rapidly than salt is taken up, resulting in a net loss in cheese weight and a substantial depletion of moisture at the cheese surface.

The opposing diffusion of salt and moisture during brining establishes a large decreasing salt gradient from the surface to the center of the cheese and a decreasing moisture gradient in the opposite direction that is fairly smooth and reasonably predictable (1, 4, 5). After brining, during subsequent aging, salt continues to diffuse toward the center of the cheese and moisture toward the surface until the salt-in-moisture content is eventually uniform throughout the cheese. Thus, brine-salted cheeses usually become more uniform in moisture content with age (3, 6).

In brine-salted pasta filata cheese, particularly in large blocks of pizza cheese, moisture distribution may differ substantially from the smooth and relatively predictable gradients found in other cheeses because the inward movement of salt is not the only factor that influences moisture migration. Apparently, the large thermal gradients that develop within pasta filata cheese during brining act as an independent driving force for the movement of cheese moisture. This may explain why patterns of moisture variation within blocks of pizza cheese vary widely, and often do not conform to the patterns observed in other cheeses (7). Such variation complicates efforts to obtain representative samples for moisture determination. The data reported below exemplify some of the unexpected patterns of moisture distribution that have been observed in commercially produced pizza cheeses and illus-
During the past decade, our laboratory analyzed numerous blocks of commercially produced pizza cheese from several different cheese factories for salt and moisture distributions. Two different sampling plans were used. The first plan (Figure 1) was used to sample 2.25 kg rectangular blocks (95 × 98 × 245 mm) brine salted Mozzarella (pizza) cheese. Distance from corners to center of block = ca 65 mm. Core samples were taken with No. 10 cork borer. Depth of core samples from corner of block: 1 = 3–21 mm; 2 = 23–41 mm; 3 = 43–61 mm.

The 4 core samples at each depth were combined and finely ground in a blender to give a composite sample. Salt was determined in duplicate by drying in a forced draft oven at 100 ± 1°C for 24 ± 1 h. Cross sections from the same block were analyzed for salt and moisture distributions within 1 day after the cheese was removed from the brine and after 7, 14, 21, and 28 days of storage at 4°C.

A second sampling plan (Figure 2) was used to evaluate salt and moisture distributions in 9.1 kg rectangular blocks of pizza cheese, as reported previously (7). Each block was refrigerated for 10–14 days after manufacture, and then cut in half. Half of the block was sent on ice by overnight delivery to the author’s laboratory for analysis. Three 10 mm cross sections were removed from the end of the block (0–30 mm from the end) and three 10 mm cross sections were obtained midway between the end and center of the block (120–150 mm from the end). Each cross section was subdivided into 3 concentric samples at different depths below the surface: 0–15, 15–30, and >30 mm (Figure 2). Each concentric sample was finely ground in a blender and analyzed in duplicate for salt (8) and moisture (forced air at 100 ± 1°C for 24 ± 1 h).

Results and Discussion

Brine salting normally results in a substantial depletion of moisture at the cheese surface and a large decreasing salt-in-moisture gradient from the surface to the center of the cheese. This creates an osmotic driving force for the continued outward migration of water after brining is completed. Thus, during aging, moisture continues to move from the cheese center toward the surface (salt moves in the opposite direction); consequently, moisture content decreases at the cheese center and increases at the surface so that overall moisture distribution of the block becomes more uniform with age (3, 6).

However, in pasta filata cheese, such as pizza cheese, changes in moisture distribution during and after brining are more complex and less predictable. The large and variable temperature difference between the warm pasta filata cheese and the cold brine results in 2 conditions that evidently contribute to variable patterns of moisture distribution. First, the outward diffusion of moisture that occurs as salt penetrates the cheese is temperature dependent (3). Therefore, water migrates more slowly through the cool region at the cheese surface during low temperature brining, and less moisture is lost from the cheese to the brine than occurs during brining at higher temperature (3, 9). Consequently, the surface of pizza cheese becomes far less depleted of moisture during brining than might be expected. Second, the cooling that occurs during brining creates a temperature gradient within the block, which may persist for some time after brining depending on the efficiency of cooling. In Cheddar cheese (10, 11) and Gouda cheese (12), persistent temperature gradients within the cheese result in movement of moisture from the warm center to the cool surface. It is probable that temperature gradients that persist in pizza cheese may likewise cause outward migration of moisture (7).

Thus, less loss of moisture from the cheese surface during cold brining, combined with the outward movement of water along salt-in-moisture gradients and temperature gradients, create conditions that may result in highly variable and atypical patterns of moisture distribution in pizza cheese. Figures 3 and 4 compare changes in the moisture distributions of 2 different commercial 2.25 kg blocks of pizza cheese during aging. These cheeses were sampled according to the plan illustrated in Figure 1. Both blocks displayed large nonlinear gradients of salt-in moisture at 1 day after brining (Figures 3A and 4A). These gradients osmotically drew moisture toward
the cheese surface during aging. Over 28 days of refrigerated storage, the salt-in-moisture gradients in both cheeses decreased and became approximately linear as they moved toward equilibrium.

Initially (Day 1), both cheeses displayed a nonlinear moisture distribution, with highest moisture occurring midway between the cheese surface and center (Figures 3B and 4B). Similar nonlinear moisture distributions have been observed in many newly brined commercial pizza cheese blocks originating from different cheese factories (data not shown). Evidently, higher moisture in the region between center and surface is caused by outward movement of moisture from the warm center along thermal gradients during brining. In both cheeses (Figures 3B and 4B), moisture content increased at the surface and decreased at the center during aging, demonstrating an outward movement of moisture along the salt-in-moisture gradient. However, a nearly uniform moisture distribution was attained quickly in the first cheese (Figure 3B), whereas a linear gradient of increasing moisture from center to surface developed and increased during aging in the second cheese (Figure 4B). Consequently, by Day 28, moisture content was about 4.5% higher at the cheese surface than at the center. An important difference between these 2 cheeses was that the second cheese had a much larger initial salt-in-moisture gradient than the first, which provided a greater and longer-lasting osmotic driving force for the outward migration of moisture during aging.

The above comparison is one example of how differences in brining conditions (brining time, temperature, block size) can impact the distribution of cheese moisture and complicate efforts to obtain representative samples for moisture determination. Moisture variation can be especially variable and problematic in large blocks of pizza cheese (9.1 kg) because salt-in-moisture and temperature gradients are likely to be larger and persist longer than in small blocks. Figures 5–8 provide 4 examples of different moisture distributions that have been observed in 9.1 kg blocks. The blocks were sampled according to the plan illustrated in Figure 2, and the cheeses ranged from 11 to 15 days old at the time of sampling.

Figures 5 and 6 are typical of many commercial cheeses analyzed in our laboratory that displayed decreasing gradients of moisture from center to surface. Gradients in Figure 5 were

![Diagram of sampling plan](image)

**Figure 2.** Sampling plan used to evaluate salt and moisture contents at 3 different depths (0–15, 15–30 mm, and >30 mm) in 10 mm cross sections taken from end (1–3) and midway between end and center (4–6) of 9.1 kg rectangular blocks (95 × 180 × 480 mm) brine salted Mozzarella (pizza) cheese. Adapted from ref. 7.
Figure 3. Salt-in-moisture (A) and moisture (B) contents at 3 different depths within 30 mm cross sections taken from 2.25 kg block of Mozzarella (pizza) cheese after 1, 7, 14, 21, and 28 days of storage at 4°C (example 1). See Figure 1 for sampling plan.
Figure 4. Salt-in-moisture (A) and moisture (B) contents at 3 different depths within 30 mm cross sections taken from 2.25 kg block of Mozzarella (pizza) cheese after 1, 7, 14, 21, and 28 days of storage at 4°C (example 2). See Figure 1 for sampling plan.
Figure 5. Moisture contents at 3 different depths within 10 mm cross sections taken from end (closed symbols) and midway between end and center (open symbols) of 9.1 kg block of Mozzarella (pizza) cheese (example 1). See Figure 2 for sampling plan.

Figure 6. Moisture contents at 3 different depths within 10 mm cross sections taken from end (closed symbols) and midway between end and center (open symbols) of 9.1 kg block of Mozzarella (pizza) cheese (example 2). See Figure 2 for sampling plan.
Figure 7. Moisture contents at 3 different depths within 10 mm cross sections taken from end (closed symbols) and midway between end and center (open symbols) of 9.1 kg block of Mozzarella (pizza) cheese (example 3). See Figure 2 for sampling plan.

Figure 8. Moisture contents at 3 different depths within 10 mm cross sections taken from end (closed symbols) and midway between end and center (open symbols) of 9.1 kg block of Mozzarella (pizza) cheese (example 4). See Figure 2 for sampling plan.
nearly linear, and the overall moisture content of cross sections taken from end of the block (cross sections 1–3) was lower than that of the cross sections taken from the interior of the block (cross sections 4–6). Lower moisture at the end of the block presumably resulted from greater surface area exposed to the brine through which additional salt was taken up and moisture was lost during brining (7). Moisture distribution in Figure 6 was somewhat more variable than that shown in Figure 5, particularly in the interior cross sections (4–6) where the highest moisture content occurred between the surface and center.

Moisture distributions in Figures 7 and 8 are strikingly different from those in Figures 5 and 6, and are typical of many other cheeses that we have analyzed. In contrast to the previous examples, substantial increasing gradients of moisture from center to surface were observed in both cheeses. However, the two cheeses differed from one another in that the interior cross sections (4–6) showed much smaller gradients than the end cross sections (1–3) in one cheese (Figure 7); however, the reverse was observed in the other (Figure 8). Furthermore, the cheeses described in Figures 7 and 8 had higher overall moisture in the end cross sections (1–3) than in the interior cross sections (4–6). Factors responsible for high moisture levels at the ends of the blocks have not been identified definitively and require further study. However, the data suggest that these blocks may have lost comparatively little moisture from the surface during brining. Moisture may have migrated longitudinally toward the end of the block and cross sectionally toward the surface during aging along salt-in-moisture gradients and, perhaps, along persistent thermal gradients.

**Conclusions**

In summary, moisture distribution in brine-salted pasta filata cheese is more variable and less predictable than that of other brine-salted cheeses. The potential for irregularities in moisture distribution, both longitudinally and cross sectionally, within blocks of brined pizza cheese greatly complicates the sampling plan needed to obtain representative samples for moisture and composition analyses, particularly if only core samples are taken with a cheese trier or borer (13). One approach to representative sampling that we have used successfully is to dice the entire block into 1.5 cm cubes, from which a composite sample is prepared after the entire cheese mass is thoroughly mixed. The unused diced cheese may be vacuum packaged and stored for subsequent use or shredded for immediate use. Most commercial block pizza cheese is diced and/or shredded before end use; therefore, this approach is compatible with industry practice and may be feasible for many industrial manufacturers and users of cheese.

**References**


(9) Nilson, K.M. (1968) in *Proc. 5th Annual Marschall Italian Cheese Seminar*, Marschall Products, Madison, WI


