If you ever left milk in the refrigerator past its expiration date, you probably noticed that the milk got lumpy. You may be surprised to learn that the lumps, or curds, are similar to fresh cheese!

During cheesemaking, the curds are formed by adding bacterial cultures and a substance called rennin to fresh milk. Sometimes, the curds themselves become fresh cheese such as mozzarella. Other times, the curds are collected and stored for several weeks or up to many years to form aged cheeses such as cheddar and Parmesan. Similarly, yogurt is another common food made with cultured milk.

Cheddar is considered the most popular cheese in the United States. It is an aged cheese made from cow's milk. Cheddar originated hundreds of years ago in the village of Cheddar in southwestern England. Today, it is made in many places around the world, including a small farmstead in rural Vermont, called Shelburne Farms, known to produce rich and flavorful cheddar.

Nat Bacon, the head cheesemaker at Shelburne Farms, shares some of the secrets that make their cheddar so popular.

By Kathy De Antonis

Bacon explains that the main ingredients in cheese are actually the same as those in milk: fats and proteins. Milk also contains a type of sugar called lactose and a lot of water—87% of milk is water.

The fat and protein molecules in milk are not dissolved in the watery part. Instead, they are spread throughout. Milk is an example of a colloid—a heterogeneous mixture composed of tiny particles dispersed in another material. The particles are larger than molecules but less than 1 micrometer in diameter.

The particles can be solid, tiny droplets of liquid, or tiny bubbles of gas; the suspending medium can be a solid, liquid, or gas—although gas-gas colloids are not possible.

Colloids often appear to be homogeneous in bulk, but when they are examined under a microscope, they are heterogeneous. In milk, the protein and fat molecules form tiny particles that are so small—0.04–0.3 micrometers in diameter for the protein particles and 1–10 micrometers in diameter for the fat particles—that you would never notice them unless they are seen under a microscope (Fig. 1).

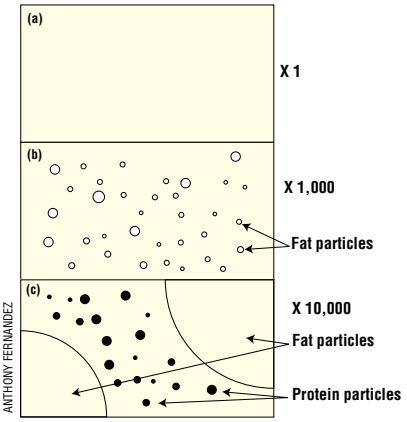

Figure 1. The main components of milk at different magnification levels: (a) as seen with the naked eye; (b) magnified 1,000 times; and (c) magnified 10,000 times. Fat particles are seen when milk is magnified 1,000 times, but protein particles are seen only when milk is magnified at least 10,000 times.

Colloids, such as milk, have the distinctive property of scattering light that goes through them, making it visible—a process called the Tyndall effect (Fig. 2). This is caused by reflection of light by very small particles dispersed in a transparent medium.

SHELBURNE FARMS, A. BLAKE GARDNER

Adding bacterial culture

Cutting the coagulated milk

Draining the whey and packing curds

Stacking cheese slabs

It all starts with milk

Shelburne Farms is a picturesque 1,400–acre farm that sits peacefully on the shores of Lake Champlain in northwestern Vermont. From a bird's eye view, the farm appears natural, almost untouched, mostly small clusters of trees with vast open pastures in between.

Cheesemaking at Shelburne Farms begins with the milk collected from a herd of 107 Brown Swiss cows. This breed accounts for less than 2% of all milking cows in the United States.

PHOTOS COURTESY OF SHELBURNE FARMS

Shelburne Farms in Shelburne, Vt.

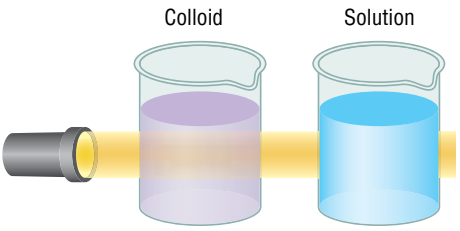

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Figure 2. The Tyndall effect

Making cheddar

At Shelburne Farms, the cows are milked twice daily, once at 4:30 a.m. and once at 3:30 p.m. Each morning, the milk collected the previous afternoon is combined with the morning milk and transported to the cheese-making facility.

Shelburne is a small-scale cheesemaking facility. The whole operation takes place in a single room which contains a large rectangular-shaped stainless-steel vat and all of the other necessary equipment.

Bacon and his team arrive at 7 a.m. Their first tasks are to prepare the previous day's cheese for aging and to sanitize the equipment. At 8:30 a.m., the milk is delivered. Bacon and his team begin the cheesemaking process by warming the milk from 55 °F to 75 °F and then by adding a bacterial culture. These bacteria, which start multiplying at this temperature, acidify the milk by changing lactose sugar into lactic acid ($C_3H_6O_3$).

After the addition of the culture, the milk is warmed at a temperature of 90 °F. During this time, the bacteria grow and multiply further, and the rate of conversion of lactose to lactic acid increases. As a result, the lactic acid causes the protein particles to unfold.

Then, Bacon adds an enzyme called rennin, which allows the curds to form. An enzyme is a biological catalyst that facilitates a chemical reaction without being consumed by it. In this case, rennin helps to break down covalent bonds between atoms inside the protein particles.

For the next 20–30 minutes, Bacon, or one of the cheesemakers at the farm, monitors the milk closely, looking for the formation of small curds which slowly increase in size and form a gel. At this point, much of the liquid whey—mostly water and milk sugar—is trapped inside the curd. The next step is to remove the whey.

Bacon and his team cut the gel into small pieces with special knives and allow the whey to drain. The curd pieces immediately begin to shrink and expel the whey. Then, the curds are cooked and stirred in the whey to 102 °F, which allows the curds to release even more whey.

After about 90 minutes, the curds start fusing with one another, forming a solid mass. The mass is cut into large, rectangular-shaped slabs, which are stacked on top of each other and then turned and restacked—a process called cheddaring. This process allows the curds to release more whey—simply because of the pressure they exert on each other.

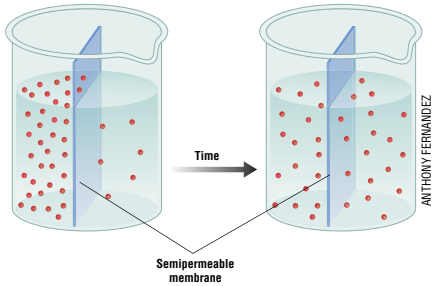

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Figure 3. Schematic representation of the diffusion process

Then, the slabs of cheddar are milled into small pieces and salted. Salt also helps to remove whey from the curds. The presence of salt at the surface of the cheese pieces causes the moisture within the cheese to be drawn out by osmosis. Osmosis is the process that occurs when two solutions of different concentrations are on either side of a semipermeable membrane—a membrane that allows only water molecules to pass freely back and forth. Water molecules move to the side with the greater concentration until both sides have the same concentration (Fig. 1 on p.18).

In this case, water flows from areas of low-salt concentration inside the cheese to areas of high-salt concentration on the surface of the cheese. At the same time, some of the salt is drawn into the cheese through the process of diffusion (Fig. 3), in which molecules tend to move toward areas where they are less concentrated until their concentration becomes uniform throughout.

After salting, the cheese is ready for the last step: the aging process. It is pressed into large rectangular-shaped stainless-steel containers, each holding 40 pounds of the salted pieces. The containers are placed in an environment similar to that of a cave, with a temperature of 50 °F and humidity at 80% to keep the surface from drying out. At Shelburne Farms, the cheddar is aged for at least 6 months and for up to 3 years.

Everyone has a favorite cheese, and the varieties are endless. "The cheese actually changes as the pastures change and the cow's milk changes," Bacon says. "It also depends what time it is. I personally like our 3-year cheddar. It's a nice mature cheddar that has a lot of flavors."

The next time you buy cheddar, you may appreciate better its different flavors, knowing how they were created and where they came from. CM

Milling the slabs into "fingers"

Pressing the "fingers" into hoops

Cutting aged cheddar into blocks

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