The Chemistry of Butter

Objective

Students will read about butter and conduct experiments to observe chemical reactions and changes in properties in milk.

Background

Butter is a dairy product made by churning fresh or fermented cream to separate the butterfat from the buttermilk. Most frequently made from cows' milk, butter can also be made from the milk of other mammals, including sheep, goats, buffalo, and yaks.

Heavy cream is an emulsion. An emulsion exists when tiny droplets of one type of liquid are floating around in another type of liquid that does not like to mix with the first. In the case of heavy cream, tiny globules of fat are suspended in mostly water. The globules are surrounded by membranes of phospholipids (fatty acid emulsifiers) and proteins, which prevent the globules from pooling together in a single mass. Churning the cream forces the fat globules to slam into one another. If they hit each other with enough force, they will stick together, the fat collection becoming bigger and bigger with each extra globule. After enough churning, the fat globules form a chunk of butter. What remains is a watery liquid with small butter grains floating in it. This is called "buttermilk" and is drained off and saved for other purposes. The butter is pressed and kneaded into a solid mass to remove any remaining pockets of buttermilk or water.

Milk fresh from the cow has both cream and milk mixed together. The cream is less dense than the milk, so the cream rises to the top of the container, where it can be skimmed off. Before modern factory butter-making, cream was usually collected from several milkings and was several days old and somewhat fermented by the time it was made into butter. Butter made from a fermented cream is known as cultured butter. During fermentation, the cream sours as bacteria convert milk sugars into lactic acid. Fermentation produces additional aroma compounds, which makes a fuller-flavored, more "buttery" tasting product. Today, cultured butter is usually made from pasteurized cream whose fermentation is produced by the introduction of Lactococcus and Leuconostoc bacteria. These are bacteria that do not cause illness.

The milk left behind after the cream is skimmed off is called fat-free milk. The whole milk we buy in the grocery store is homogenized to keep the milk and cream mixed together.

Most dairy products are pasteurized to kill harmful bacteria and other microbes that can cause foodborne illness. Butter made from pasteurized fresh cream is called sweet cream butter. Butter made from fresh or cultured unpasteurized cream is called raw cream butter. While butter made from pasteurized cream may keep for several months, raw cream butter has a shelf life of roughly ten days.

Oklahoma Academic Standards

GRADE 5

Speaking and Listening: R.1,2,3; W.1,2. Reading and Writing Process: R.1,3. Vocabulary: R.1,3,5. Research: R.1,2,3; W.1,2,3,4. Physical Science: 1-1,2,4

GRADE 6

Speaking and Listening: R.1,2,3; W.1,2. Reading and Writing Process: R.1,3. Vocabulary: R.1,3,5. Research: R.1,2,3; W.1,2,3,4. Physical Science:1-4,5

GRADE 7

Speaking and Listening: R.1,2,3; W.1,2. Reading and Writing Process: R.1,3. Vocabulary: R.1,3,5. Research: R.1,2,3; W.1,2,3,4. Physical Science: 1-1,2

Vocabulary

bacteria— any of a group of single-celled microorganisms that live in soil, water, the bodies of plants and animals, or matter obtained from living things and are important because of their chemical effects and disease-causing abilities

by-product— a product or result produced in addition to the main product or result

centrifugal— proceeding or acting in a direction away from a center or axis

churn— to stir or shake in a churn (as in making butter)

cultured—grown in a prepared medium

emulsion— a material consisting of a mixture of liquids that do not dissolve in each other and having droplets of one liquid scattered throughout the other

fermentation— chemical breaking down of a substance (as in the souring of milk or the formation of alcohol from sugar) produced by an enzyme and often accompanied by the formation of a gas

fresh— not stale, sour, or spoiled

globule—a tiny ball

homogenized— reduce to small particles of uniform size and distribute evenly

lactic acid— an organic acid present especially in muscle tissue as a result of the breakdown of carbohydrates (as glycogen), is made from carbohydrates usually by fermentation by bacteria, and is used especially in food and medicine

membrane— a thin soft flexible sheet or layer especially of a plant or animal part (as a cell, tissue, or organ)

microbe—microorganism, germ

pasteurization— the process of heating a liquid (as milk) to a temperature high enough and keeping it at that temperature long enough to kill many objectionable germs and then cooling it rapidly without causing a major change in its chemical composition

The buttermilk produced as a byproduct of butter-making is not the same as the buttermilk sold in stores. That is fat-free milk that has been soured by adding lactic acid. Until the age of refrigeration, milk soured quickly in the kitchen, and most butter ended up being made from milk that was slightly spoiled. As a result, some historical sources use the word buttermilk to describe the byproduct of butter-making; others use it to describe the sour milk used in butter-making.

By the late 1800s, cookbooks started calling for the sour milk version of buttermilk in recipes for bread made with baking soda. Baking soda reacts as a leavener when mixed with an acid. Sour milk contained acid. Now most recipes call for baking powder, which has both ingredients needed for the reaction.

Naturally-occurring sour milk had become rare, thanks to modern refrigeration. So commercial dairies began to culture low fat milk with lactic acid bacteria and sell it as buttermilk. Low-fat milk is cheaper than whole milk but still takes on a thick, creamy body when cultured.

Large butter manufacturers dry their butter byproducts and sell them to processed-food manufacturers to add body and texture. If you've ever eaten ice cream or a candy bar with "buttermilk solids" on the ingredients list, you've consumed the by-product of butter.

The first butter factories appeared in the US in the early 1860s. In the late 1870s, the centrifugal cream separator was introduced. This eliminated the need to let cream rise naturally to the top of milk. In the beginning, whole milk was shipped to butter factories, and the cream separation took place there. As cream-separation technology became smaller and less expensive, farmers began separating the cream on the farm, and shipping the cream alone to the factory. By 1900, more than half the butter produced in the United States was factory made.

Procedures

1. Provide copies of the reading page, included with this lesson.
   —Students will read the passage and identify unfamiliar vocabulary words.
   —Students will use context clues and prior knowledge to define the words.
   —Students will work in groups to find group definitions of the words.
   —Students will use dictionaries to find the correct meanings of the words.
   —Students will answer the comprehension questions.
   —Students will discuss their answers in groups or as a class.
2. Students will use online or library resources to research and write about one of the following or other related topic:
   - Pros and Cons: Butter vs. Margarine—Saturated vs. Trans

Fats

- History of Buttermaking
- History of Buttermilk
- Dairy Inventions
- Louis Pasteur and Pasturization
- Milkmaids and the Smallpox Vaccine

Butter is a water-in-oil emulsion resulting from an inversion of the cream, an oil-in-water emulsion; the milk proteins are the emulsifiers. Butter remains a solid when refrigerated, but softens to a spreadable consistency at room temperature, and melts to a thin liquid consistency at 32–35 °C

3. Discuss butter as an emulsion. Students will list other emulsions. Students will work in groups to make butter.
   —Provide one quart jar, one new marble and cream for each group.
   —Students will weigh the jar, record the weight, and then measure again after adding one cup of cream into the jar. Students will subtract the weight of the jar from the total to get the weight of the milk and record the weight.
   —Students will drop a new marble into the jar and close the lid tightly.
   —Each group will assign a timekeeper to keep track of the time it takes to make butter.
   —Group members will take turns shaking the jar. in a figure eight motion. The container should keep moving at all times. Play music to help students keep moving.

Explain: The butter goes through three stages. It starts as a liquid. You should be able to hear sloshing sounds. It stops sloshing when it has become a solid. In addition, the marble will stop making noise as it is surrounded by solids. Finally, after the participles of fat and milk solids stick together, the solution separates and become solid and liquid. You should be able to hear a sloshing again and the butter thumping against the side of the jar.

   —When the group decides the butter is ready, students will remove the marble and weigh the jar again. Students will subtract the weight of the jar to determine of the true weight of the mixture has remained the same.
   —Students will pour the liquid off the butter into a measuring cup and record the measurement. Students will pour the buttermilk into another container and measure the butter.
   —Students will add the two measurements together to determine if the total matches the amount with which they started (one cup).
   —Students will find the ratio of butter to buttermilk and convert the ratios to fractions.
   —Provide crackers or stick pretzels for students to enjoy with their butter.
4. Students will make “buttermilk” like the kind used in cooking, as described in the background.
   —Students will describe the appearance of one cup of milk, using their senses of smell, sight and touch (stir the milk with a spoon to determine

Materials

whole milk

food coloring

dish soap

large plastic dinner plate

pasteurized heavy whipping cream at room temperature (one pint for 18-20 students)

quart jars with lids

new marbles

container for pouring off buttermilk

vinegar

Ag Careers: Food Scientist and Technologist

JOB DESCRIPTION: Food scientists and technologists usually work in the food processing industry, universities, or the federal government and help meet consumer demand for food products that are healthful, safe, palatable, and convenient. They also develop ways to process, preserve, package, or store food according to industry and government regulations. Food technologists generally work in product development, applying the findings from food science research to the selection, preservation, processing, packaging, distribution, and use of safe, nutritious, and wholesome food. The work of agricultural food scientists plays an important part in maintaining the nation's food supply by ensuring agricultural productivity and the safety of the food supply. Agricultural food scientists may study farm crops and animals and develop ways of improving their quantity and quality. They research methods of converting raw agricultural commodities into attractive and healthy food products for consumers.

SKILLS: Strong basic science foundation and hands-on experience in applied food science subjects. Food scientists also need strong oral and written communications skills.

PREPARATION: A bachelor of science in food science focuses on agricultural science and technology. Courses may include food processing and packaging, agricultural analysis and chemistry, dairy biology, nutrition and food law. A graduate degree focuses on advanced, specialized training in technology and principles of food engineering with courses in food microbilology, chemistry, preservation, food safety and research methods.

consistency.)

—Students will hypothesize what will happen if they add an acid (vinegar or lemon juice).

—Students will add one tablespoon of vinegar to one cup of milk and wait one minute.

—Students will use their senses again and record their observations.

—Students will use online or library resources to research the process that caused the vinegar to sour the milk.

5. Conduct the following demonstration to isolate fat molecules in milk.

—Pour enough milk into the bottom of a large plastic dinner plate to cover the bottom.

—Drop various colors of food coloring in the milk.

—Dip a cotton swab in dish detergent and plunge it into the milk in the center of the food coloring drops. You should immediately see the milk react and the food colouring rapidly disperse.

—Ask students if they can explain what is happening.

Explain: Food colouring is less dense than the milk itself, so it remains suspended within the fat molecules of the milk. Dish soap, because of its bipolar characteristics (nonpolar on one end and polar on the other), weakens the chemical bonds that hold the proteins and fats in solution. The soap's polar, or hydrophilic (water-loving), end dissolves in water, and its hydrophobic (water-fearing) end attaches to a fat globule in the milk. The molecules of fat bend, roll, twist, and contort in all directions as the soap molecules race around to join up with the fat molecules. The food coloring molecules are bumped and shoved everywhere, providing an easy way to observe all the invisible activity. As the soap becomes evenly mixed with the milk, the action slows down and eventually stops.

—Students will repeat the experiment in groups and develop further experiments by changing variables, such as adding another drop of soap, using liquids other than milk, like water, using dairy products with more fat (half and half and cream), etc.

—Students will document their experiment and report what they have found to the class.

—Groups will exchange experiments and repeat what other groups have done to verify results.

Extra Reading

Basel, Roberta, *From Milk to Cheese*, Capstone, 2005.

Birmingham, Christian, *The Fight Against Microbes: Pasteur's Story (Science Stories),* Matthew Price, 2006.

Fandel, Jennifer, *Louis Pasteur and Pasteurization*, Capstone, 2007.

Reading Page

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butter churn

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COMPREHENSION QUESTIONS

1. Identify two main ideas in the passage and explain how they are supported by key details.
2. What is the writer's purpose?
3. What is an emulsion? What makes cream an emulsion?
4. What prevents butterfat globules from clumping together in milk?
5. What is the difference between sweet cream butter and raw cream butter?
6. In your own words, explain the chemical process that turns cream into butter and buttermilk.

Oklahoma Ag in the Classroom is a program of the Oklahoma Cooperative Extension Service, the Oklahoma Department of Agriculture, Food and Forestry and the Oklahoma State Department of Education.