Unit D: Milk Production and Quality

Lesson 2: Pasteurization of Milk

Student Learning Objectives:

Instruction in this lesson should result in students achieving the following objectives:

1. Describe the composition of milk.
2. Explain the processing of raw milk and the pasteurization process.
3. List and describe bacterial succession in milk and explain the process of milk spoilage.

Recommended Teaching Time: 3 hours

Recommended Resources: The following resources may be useful in teaching this lesson:

Milk Quality and Factors Influencing the Production of High Quality Milk. http://www.moomilk.com/archive/u-health-25.htm
Facts about raw milk: http://www.raw-milk-facts.com
Let's Process Milk: http://www2.kenyon.edu/projects/farmschool/food/milking4.htm
Dairy Microbiology: http://www.foodsci.uoguelph.ca/dairyedu/micro.html

List of Equipment, Tools, Supplies, and Facilities:

- Writing surface
- PowerPoint Projector
- PowerPoint Slides
- Transparency Masters
- Copies of student lab sheets

Terms: The following terms are presented in this lesson (shown in bold italics and on PowerPoint Slide 2):

- Caesin
- Coagulation
- Ecological succession
- Fermentation
- Metabolize
- Pasteurization
- pH
- Putrefaction
- Spoilage

Interest Approach:

People have been drinking raw milk from animals for thousands of years. The term "raw" is a misnomer because it implies that all milk should be cooked. Whether it's from cows, goats, sheep, camels, yak, water buffalo, horses, donkeys or even reindeer, unheated, unprocessed milk has been a safe, reliable food source for a long time. Even in the tropics, and centuries before refrigeration had been invented, raw milk was an important food source for many cultures. By exploiting the preservative benefits of fermentation, primitive peoples were able to take a great food and make it even better. Ask students to raise their hand if they have tasted raw (unpasteurized) milk. Ask those who raise their hand how raw unpasteurized milk tastes compared to pasteurized (whole) milk? Is raw milk safe to drink? Why is milk pasteurized? Is pasteurized milk free from bacteria and other microorganisms? Use these questions and discussion to lead into Objective 1.

SUMMARY OF CONTENT AND TEACHING STRATEGIES

Objective 1: Describe the composition of milk.
Anticipated Problem: What is the composition of milk?

(PowerPoint Slide 3)

I. Cow's milk consists of about 87% water and 13% total solids.
   A. This 13% total solids includes both fat and solids-not-fat (SNF). Principal components of SNF include protein, lactose, and minerals. Fat content varies by species and breed (in dairy cattle). ***Caesin***, the principal protein of milk, accounts for about 80% of the milk protein.

(PowerPoint Slide 4)

   B. Milk composition can vary from the following factors:
      1. Feed
      2. Stage of lactation
      3. Health of animal
      4. Age of animal
      5. Seasonal conditions
      6. Environmental conditions

(PowerPoint Slide 5)

   C. Milk fat is considered to be the most complex of all common fats. Whole milk contains about 3.3% fat, while skim milk contains .2% fat. Milk is an emulsion of fat in water. The emulsion is stabilized by phospholipids that are absorbed on the fat globules. The emulsion is broken during such treatments as homogenization and churning.

Use TM: 2-1 to review the factors affecting milk composition. Discuss with the students how the taste of milk can change based upon the time of year and/or the type of feedstuff consumed by the animal. Have students complete LS: D2-1 to see that milk is made up of particles suspended in water.

Objective 2: Explain the processing of raw milk and the pasteurization process.
Anticipated Problem: How is raw milk processed and what is the pasteurization process?

(PowerPoint Slide 6)

II. Raw milk must be processed for various reasons after a cow is milked.
   A. Processing operations for fluid milk include:
      1. Cream separation
      2. Centrifugal sediment removal
      3. Pasteurization
      4. Sterilization
      5. Homogenization
      6. Membrane separation (separation of milk components)
      7. Packaging
      8. Handling
      9. Storing

(PowerPoint Slide 7)

   B. ***Pasteurization*** is the process of heating milk to a certain temperature to kill the bacteria present in the milk. Pasteurized milk is milk which has been heat-treated to kill pathogens which cause disease.
      1. Not all pathogens are removed during the pasteurization process, so pasteurized milk is not 100% sterile, but many people consider it to be safer to drink than raw milk which has not been pasteurized at all.
      2. The bulk of the milk sold in commercial grocery stores is pasteurized, and much of it is also homogenized to prevent the cream from separating.
      3. A high number of microorganisms in raw milk suggest that it was produced under unsanitary conditions or that it was not adequately cooled after removal from the cow. If pasteurized products contain excessive numbers of bacteria, then pasteurization contamination occurred or the product was not properly refrigerated.

(PowerPoint Slide 8)

   C. There are several different pasteurization techniques which can be used to make pasteurized milk. The goal of pasteurization is to render the milk safe to drink without curdling or coagulating it, and without altering the flavor substantially, although people who are accustomed to drinking unpasteurized milk may find that pasteurized milk has an “off” flavor.
      1. Raw milk and pasteurized products are examined for microbial growth using the agar plate method or the direct microscopic method. Raw milk may sometimes have lower microbial populations than pasteurized milk, depending on the stage of microbial growth.

(PowerPoint Slide 9)

   D. In high temperature/short time (HTST) pasteurization, the milk is brought to a temperature of 71.7 degrees Celsius and held there for 15 to 30 seconds before being rapidly cooled and packaged.

1. Double pasteurization splits the process up into two segments, and is not recognized as a legal pasteurization method by some governments.
2. Extended shelf life (ESL) milk is pasteurized at a slightly lower temperature and passed through a special filter to remove microbes.
3. Ultra high temperature (UHT) pasteurization involves bringing the milk to 138 degrees Celsius for less than a second, while batch pasteurization is performed at a very low temperature, with the milk being held to temperature for 30 minutes before being cooled.

Use TM: 2-2 as a visual aid when discussing the pasteurization process of milk. Have students use the Internet to research various methods of pasteurization and present their findings to the class.

Objective 3: List and describe bacterial succession in milk and explain the process of milk spoilage.
Anticipated Problem: What is bacterial succession in milk and how can the process of milk spoilage be explained?

(PowerPoint Slides 10 and 11)

III. Bacterial succession is the main cause of spoilage in pasteurized milk.
   A. Although most bacteria are killed during the pasteurization process, some bacteria survive. ***Ecological succession*** is a gradual process whereby the species population in a community changes through establishment of a new species population that may gradually replace the original inhabitants. The succession of microbes in pasteurized milk follows the same sequence observed in unpasteurized milk:
      1. Streptococci
      2. Lactobacilli
      3. Yeasts and molds
      4. Bacillus species

(PowerPoint Slide 12)

      5. The sequence of changes in microbial populations is due to the changing chemical environment brought about by the metabolic processes of the microorganisms. To ***metabolize*** is to subject to the chemical and physical changes constantly taking place in living matter.

(PowerPoint Slide 13)

   B. Streptococci break down the milk sugar (lactose) to lactic acid in a process called ***fermentation***, the slow decomposition of sugars by microorganisms to form lactic acid. ***pH*** is the term used to describe the hydrogen ion activity of a system; a measure of the acidity or alkalinity of a solution. As lactic acid is produced, the acidity of the milk increases to a point where further streptococci growth is inhibited and lactobacilli begin to grow.

(PowerPoint Slide 14)

   C. Lactobacilli multiply and metabolize remaining lactose into more lactic acid until lactobacilli growth is also inhibited by the acidity of the milk. Lactic acid sours the milk and causes the curdling, or coagulation, of proteins.

Coagulation is the formation of noncrystalline solids, especially proteins, from solutions; the act or state of becoming viscous, jelly-like, or solid not by evaporation, but by chemical reaction. Yeasts and molds grow well in this acidic environment, metabolizing acid into non-acidic products.

(PowerPoint Slide 15)

D. Finally, Bacillus species multiply in the environment where proteins are the only nutrient source available. Bacillus species metabolize protein into ammonia products, and the pH rises. These bacteria also digest the remaining protein through enzymatic action. Milk ***spoilage***, any change in a food product that makes it unacceptable for consumption, is evident at this point by the odor of the milk.

(PowerPoint Slide 16)

E. pH changes in milk are brought about by microbial activity. Fluctuations in pH are due to fermentation and the ***putrefaction***, the chemical decomposition of plants and animals after death, processes. Spoiled pasteurized milk usually tastes and smells bitter, sour, rancid, and sometimes putrid. After the milk proteins and sugars have been fermented, resulting amino acids and peptides give the milk bitter or putrid flavors.

Use TM: 2-3 as a visual aid when reviewing with the students how bacterial succession causes spoilage in milk. Have students complete LS: D2-2 to help them understand bacterial growth in milk.

Review/Summary: Focus the review and summary of the lesson around the student learning objectives. Use the questions on **PowerPoint Slide 17** to have students explain the content associated with the objectives.

Evaluation: Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the laboratory activities. A sample written test is included.

Answers to Sample Test:

Matching

1. C
2. E
3. H
4. A
5. F
6. B
7. G
8. D

Fill-in-the-blank

1. Hydrogen
2. Fat
3. Fermentation
4. Lactic acid

Short Answer

Cream separation, centrifugal sediment removal, pasteurization, sterilization, homogenization, membrane separation (separation of milk components), packaging, handling, storing.

Sample Test

Pasteurization

Name: _____

Matching: *Match each word with the correct definition.*

a. Caesin	e. Food spoilage
b. Coagulation	f. Metabolize
c. Ecological succession	g. Pasteurization
d. Fermentation	h. Putrefaction

_____ 1. A gradual process where one species population is replaced by another.

_____ 2. Any change that makes a food unacceptable for consumption.

_____ 3. The chemical decomposition of plants and animals after death.

_____ 4. The principal protein of milk.

_____ 5. To subject to the chemical and physical changes constantly taking place in living matter.

_____ 6. The formation of noncrystalline solids from solutions.

_____ 7. To kill microorganisms from the application of heat to a liquid.

_____ 8. A slow decomposition of sugars by microorganisms to form lactic acid.

Fill-in-the-blank*: Complete the following statements*.

1. pH is a term used to describe the _____ ion activity of a system.
2. Milk is an emulsion of _____ in water.
3. The pH changes in milk are due to microbial activity, these fluctuations in pH are due to _____.
4. Streptococci break down lactose into _____.

Short Answer*: Answer the following question*.

List five of the nine processing operations used for fluid milk.

TM: 2-1

MILK COMPOSITION FACTORS

- Feed
- Stage of lactation
- Health of animal
- Age of animal
- Seasonal conditions
- Environmental conditions

TM: 2-2

RAW MILK PROCESSING

- Processing operations for fluid milk include
  - Cream separation
  - Centrifugal sediment removal
  - Pasteurization
  - Sterilization
  - Homogenization
  - Membrane separation (separation of milk components)
  - Packaging
  - Handling
  - Storing
- Pasteurization – the process of heating milk to a certain temperature to kill the bacteria present in the milk.

TM: 2-3

BACTERIAL SUCCESSION IN MILK

- STREPTOCOCCI
- LACTOBACILLI
- YEASTS AND MOLDS
- BACILLUS SPECIES
- pH CHANGES IN MILK

LS: D2-1

Separation of Milk Particles

Goal: To demonstrate that milk is made of particles suspended in water

Items Needed:

- Whole Milk and/or Skim Milk
- Vinegar or citric acid
- Coffee Filter
- Funnel
- Hot plate (optional)

What to do:

1. Pour out about 50 ml. of whole milk into a cup.
2. Add about 2 grams of citric acid or 10 ml. of vinegar to the milk and stir.
3. Filter the mixture through the coffee filter.

Or with the hot plate –

1. Pour out about 50 ml. of whole milk into a cup.
2. Add about 2 grams of citric acid or 10 ml. of vinegar to the milk and stir.
3. Heat milk on the hot plate until it is warm for 3 minutes – do not let it boil!
4. Filter the mixture through the coffee filter.

What should be observed:

With the addition of the citric acid or vinegar, you should observe small white particles in the milk. These are large enough to filter out. With heat, the particles should be larger and easier to filter.

What is happening:

The added citric acid (or almost any acid, like acetic acid found in vinegar) acts the same ways as when bacteria convert the lactose to lactic acid in the cultured dairy products. Lactic acid, or in this case citric acid, promotes coagulation of the casein particles. These are the visible white clumps that can be filtered out. The addition of heat actually helps promote polymerization of the protein. The difference between the heated and the unheated particles should be larger particles for the heated milk mixture.

Other things to try: This experiment can also be performed with skim milk. The clumps in this case will be slightly smaller with skim milk. More noticeably, though, the whole milk particles will feel smoother and creamier, resembling something like softened cream cheese. This is due to the high fat content in the whole milk.

LS: D2-2

PASTEURIZED MILK AS AN ECOLOGICAL SYSTEM FOR BACTERIA

Agricultural Applications and Practices

Food microbiology is the study of all aspects of microbial actions on food and food products. Today food microbiology has a great impact on food safety, engineering of new food products, food technology, and preservation techniques.

Milk is one of the most important and nutritional foods known to man. Using bacteria, molds, or yeasts, milk may be transformed into a variety of cultured products, such as yogurt, buttermilk, and sour cream. Dairy products are very perishable because they contain virtually all the nutrients and moisture required for microbial growth. Microorganisms appear in milk as milk passes through the teat canal and is collected in milking equipment. Commercial dairy farm operations usually consist of a milking machine, a pipeline to convey the milk directly to the tank, and a refrigerated bulk milk tank in which the milk is cooled and stored. Immediate and continuous refrigeration is necessary in order to prohibit rapid increase in microbial populations. Milk at approximately 34° C from the cow is cooled rapidly to 4.4° C or below to maintain quality. After transportation to processing plants by way of refrigerated trucks, milk undergoes a variety of processing treatments, including pasteurization. The dairy industry has developed into large production units and large processing plants, often far from the production areas. The evolutionary success of the dairy industry has depended upon sanitation, health standards, transportation systems, processing methods, pasteurization, packaging, and refrigeration.

Science Connections—Questions to Answer

1. Why is milk pasteurized?
2. What are the effects of pasteurization on microbial populations?
3. Why does bacterial growth occur in pasteurized milk?
4. What succession of bacterial growth occurs? Why?
5. Why is milk held under constant refrigeration?

Purpose of Lab and Student Performance Objectives

The purpose of this experiment is to illustrate the succession of bacterial growth by using milk as the growth medium. By participating in this lab, students will be able to:

1. Measure the pH of milk.
2. Observe and describe visible changes in milk and explain the basis for these changes.

3. Explain the effects of pasteurization on milk.
4. Grow bacteria on nutrient agar plates.
5. Identify bacteria (by shape) growing in milk after 10 days (if appropriate microscopes are available).

Materials and/or Equipment

- whole pasteurized milk (500 ml)
- skim milk (125 ml)
- buttermilk (125 ml)
- nutrient agar
- pH paper, or pH probe
- compound microscope
- crystal violet or methylene blue
- cotton swabs, or inoculating needles
- graph paper
- petri dishes
- 250 ml beakers
- 25 ml Erlenmeyer flasks
- microslides
- Gram Stain Kit

Helpful Hints:

- This lab should take between 10 to 14 days to see bacterial growth and succession of the bacteria on the agar plates.

Procedure:

Give each student or group of students a copy of the worksheet to perform the activity.

Anticipated Findings:

- Milk samples kept at room temperature will spoil in two to three days, while samples stored in the refrigerator will spoil in 7 to 10 days.
- The buttermilk sample will spoil the quickest, and the refrigerated whole milk will be slowest to spoil.
- The pH of the milk samples will decrease over time (general trend).

LS: D2-2 Student Worksheet

PASTEURIZED MILK AS AN ECOLOGICAL SYSTEM FOR BACTERIA

Procedure:

1. Assign students (individually or in groups of up to four) the type of milk and temperature for bacterial growth as follows:

   - Group 1—whole milk, room temperature (25° C)
   - Group 2—whole milk, refrigerator temperature (4° C)
   - Group 3—whole milk, incubator temperature (37° C)
   - Group 4—whole milk, boiled (100° C), then cooled to room temperature (25° C)
   - Group 5—skim milk, room temperature
   - Group 6—buttermilk, room temperature

2. Place 125 ml of each type of milk in an Erlenmeyer flask.

3. Prepare nutrient agar plates, following the directions that accompany the agar.

4. Use cotton swabs or inoculating needles to transfer milk (some with bacteria) to petri dishes containing agar. Prepare one petri dish (streak plate) for each milk sample. Flame inoculating loop. Place loop into milk sample and remove. Open petri dish slightly and touch loop to one spot in the petri dish. Spread inoculum across one quadrant. Carry inoculum to next quadrant but at right angles to the first quadrant. Repeat for quadrants 3 and 4. Flame inoculating needle between quadrants to reduce contamination from external bacteria. Repeat entire procedure for each milk sample. Place petri dishes for each sample at the same temperature as the milk sample.

5. Use a gram stain to help identify bacteria shapes. Identify the bacteria as coccus, bacillus, or spirillum using a compound microscope with an oil immersion lens, if available. To perform a simple stain, use the loop to place a small amount of bacteria in a droplet of water on a glass slide and dry the slide in air. (Do not blow on it.) Next heat fix the slide (film side up) by passing it three to four times over the flame of a Bunsen burner. Allow the slide to cool. Flood the slide with crystal violet for about two minutes, wash with water, and blot dry. Flood the slide with Gram's iodine for one minute. Pour off the iodine and wash. Add 95% ethyl alcohol one drop at a time until the material running off the slide is colorless. Wash in cold water. Flood with safranin for 1 1/2 minutes. Pour off safranin, wash slide, and blot dry. Use the Gram stain procedure to distinguish between gram-positive and gram-negative bacteria.

Source: The American Biology Teacher, May 1988.

Data Summary and Analysis:

Record daily observations using the sample chart provided as a guide **(LS: D2-3)**. Observations should include temperature, pH, odor, color, and bacterial growth on agar plates. If using a pH probe, rinse the probe in distilled water between readings. As observations are made, students should pay particular attention to physical changes in the milk's composition and record any odors, particles, growths, or other changes.

At the end of the experiment graph the pH data included in the lesson plan (see sample graph that depicts general succession). Make daily observations for 10-14 days.

Count the number of colonies growing on the petri dishes. This number provides only a relative estimate of the amount of bacterial growth.

Ideas for Additional Experiments:

1. Include samples of 2% milk, goat milk, and other milk samples in the experiment and compare the results with other milk products.
2. Conduct a similar experiment but control the moisture or oxygen environment of the samples.

LS: D2-3

DATA SUMMARY TABLE

Day	Observations Noted	Temp. (^{o}C)	pH	Odor	Color	Bacteria Colonies, Shapes and Gram Stains
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						