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Dairy Foods:

Producing the Best



Dairy Foods: Producing the Best

A facts booklet for agricultural instructors
and those preparing for the FFA Dairy Foods
Career Development Event (CDE)

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INTRODUCTION

This publication was written to assist teachers of agriculture in their educational and training sessions and is particularly designed to inform students of principles related to the FFA Dairy Foods Career Development Event (CDE). The author has served as superintendent of the state dairy foods contests in Missouri for over 40 years and as a member of the team that conducts the National FFA CDE for nearly as long.



The *Career Development Events Handbook*, published by the National FFA Organization, presents the rules of the event. The most recent edition of the handbook is available on the FFA Web site at <http://www.ffa.org>.

The information in this publication applies to the following careers: milk producer; bulk milk hauler; field representative of dairy companies or cooperatives; milk sanitarian; technician of the milk processor or health authority; and technical sales representatives for suppliers, including equipment, cleaning and sanitizing compounds, pesticides, and antibiotics.

MILK PRODUCTION OVERVIEW

The production of milk in the United States takes place on farms that vary greatly in location, size, type of housing, source and types of feeds, equipment used, and management. Most of the milk is produced under Grade A regulations, but some meets manufacturing milk standards. The trend since World War II (60 years) has been toward fewer dairy farms and larger herds. Data from the U.S. Department of Agriculture (USDA), which was collected from Federal Milk Marketing Orders and represents 74% of the milk produced in the United States, show that in 1965 nearly 15 million cows on 1.1 million farms produced 44.8 billion pounds of milk. Average pounds of milk produced per cow and per farm approximated 3,000 and 41,000, respectively. In 2002 only 9.1 million cows on only 92,000 farms produced 125.5 billion pounds of milk. Average pounds of milk produced per cow and per farm approximated 13,800 and 1,364,000, respectively. Farms with more than 2,000 cows now produce about 15% of the total milk supply.

The International Dairy Foods Association (1250 H Street, NW, Suite 900, Washington, DC, 20005, <http://www.idfa.org>) annually publishes a booklet called *Dairy Facts*. Students participating in the FFA Dairy Foods CDE should use this booklet as the source of the most recent data on milk production and

utilization in preparation for tests they will take during the CDE. The subjects in the booklet that are recommended for review are as follows:

- History of Dairy
- Milestones of Milk History in the United States
- Nutrition Information
- Definitions of Fluid Milks
- Farm Level Production Information
- Milk Production per Cow and Number of Milk Cows
- Milk Production in the Five Largest Dairy States
- Milk Supply Utilization by Product
- Percent Total Distribution by Farm Size
- Average Cost of Producing Milk, by Hundredweight
- Supermarket Sales of Cheese by Type

MILK QUALITY AND SAFETY

Regulations and Responsible Organizations

Control of milk's quality and safety in the United States is the responsibility of the states and municipalities, and the final seat of that responsibility varies from state to state. In general, however, most of our milk is regulated under rules written in the *Grade "A" Pasteurized Milk Ordinance* (abbreviated PMO), published by the Public Health Service of the U.S. Food and Drug Administration (USPHS/FDA). More than 90% of the milk in the United States is produced under these rules. The first FDA-written milk ordinance was published in 1924 in *Public Health Reports*. The latest edition is available via the Internet at <http://www.cfsan.fda.gov/~ear/pmo03toc.html>.

In 1946 the Conference of State and Territorial Health Officers requested the U.S. Public Health Service to develop a plan to certify interstate milk shippers. This request was made because shippers from states were encountering widely different regulations in various receiving states. Additionally, inspectors were traveling among states to inspect and enforce these varying regulations. The goal was to find agreement among the states on the requirements for production and processing of Grade A milk products. As a result the U.S. surgeon general invited all states to send a representative to St. Louis, Missouri in 1950 to participate in the first Interstate Milk Shippers Conference. Out of this meeting came the National Conference on Interstate Milk Shipments (NCIMS) and the adoption by the states of the PMO for control of the safety of the nation's milk supply. Agencies in states receiving milk shipments now accept the inspection and testing by officials in the shipping states, because the rules of production, processing, inspection, testing and enforcement are the same among the states. And no state may impose a requirement that is in excess of those required by the PMO. Furthermore, the NCIMS meets biennially to update the PMO with the concurrence of the USPHS/FDA.

In Missouri the agency responsible for milk safety is the State Milk Board. The office and employees operate under a budget approved by the state government, but technical and managerial decisions are under the board of directors, the members of which represent producers, processors, health departments, and consumers.

Typically, qualified sanitarians inspect producing farms at least twice annually and processing plants quarterly. They use an inspection form to guide them in checking for adherence to the regulations and mark any deficiency on the form, providing time in which a deficiency must be corrected. Periodically each state or local health unit must be checked by an FDA rating officer to determine whether the sanitarians and laboratories within the unit are correctly enforcing the PMO requirements and that the producers and processors are complying with the regulations.

Inspectors collect samples for testing and deliver them to approved laboratories that follow procedures published in *Standard Methods for the Examination of Dairy Products* (SMEDP), published by the American Public Health Association, and in *Official Methods of Analysis*, published by AOAC International. An excellent reference for compositional and labeling standards for milk and milk products is found in chapter 16 of SMEDP, 17th edition, published in 2004.

The FDA is responsible for monitoring the proficiencies of laboratories involved in testing under the PMO. For example, the FDA periodically sends “split samples” to official laboratories, and these are tested for such properties as bacteria count, somatic cells, antibiotics, pesticides, and freezing point. Within a specified period, results must be returned from each participating laboratory to the FDA for statistical analysis. Those laboratories that fail to produce results within an acceptable tolerance must correct their procedures or face losing their certified status.

In the *Code of Federal Regulations*, the USDA has published *General Specifications for Approved Plants* that pertains to their grading and inspection service. These are plants that produce butter, cheeses, and dry milk products that bear a grade label, for example, Grade AA butter. Milk produced for use in these products must either be from Grade A supplies or from farms that are subject to the requirements of the USDA’s *Milk for Manufacturing Purposes and Its Production and Processing: Recommended Requirements*. This document sets forth requirements similar to, but less stringent than, those for producing Grade A milk.

Regulatory Standards for Grade A Milk

Temperature

On the farm, milk shall be cooled to 7°C (45°F) or less within 2 hours after milking, and the temperature of milk blended after the first and subsequent milkings shall not exceed 10°C (50°F). The milk processor shall maintain the temperature at 7°C (45°F) or less except when processing.

Bacterial limits

The Standard Plate Count (SPC), which estimates the number of aerobic bacteria, shall not exceed 100,000/ml (milliliter) for an individual producer's milk. The count may be as high as 300,000/ml in commingled milk (milk from multiple herds). The rationale for this is that pumping the milk during transport operations breaks clumps and chains of bacterial cells resulting in increased numbers of bacterial colonies when counts are made. The SPC limit for pasteurized milk is 20,000/ml. In addition to the SPC, tests for coliform bacteria are applied to pasteurized milk. A selective medium is available on which visible colonies of coliforms develop within 24 hours. Nearly all other bacteria are inhibited by the medium, and coliforms, being producers of acid from lactose (milk sugar), form deep red colonies as they lower the pH and change the color of the violet red dye. Since coliform bacteria are easily killed by pasteurization, their presence in pasteurized milk indicates contamination after pasteurization. They are commonly present in the environment of dairy plants and in equipment that has not been properly cleaned and sanitized. The count limit for coliforms is 10/ml.

Participants in the FFA Dairy Foods CDE may be required to compute the SPC from information provided. The following is the general procedure for performing the SPC test on raw milk.

1. Take a sample aseptically (avoiding contamination) and place it into a sterile container. Keep the sample refrigerated and store it no more than 24 hours before testing.
2. Mix the sample and transfer 1 ml to 99 ml of sterile diluent, making a 1:100 dilution.
3. Transfer 1 ml of this diluted sample to 9 ml of diluent, making a 1:1,000 dilution.
4. Place 1 ml of each diluted sample onto a Petrifilm® plate that contains the nutrients needed to support growth of bacteria plus a water-soluble gelling agent.
5. Lower the transparent cover of the plate onto the sample and apply a spreading device so the spread sample is kept within an area of 20 cm².
6. Incubate the plates aerobically at 32°C for 48 +/- 3 hours.

7. Select plates containing 25–250 colonies for counting because a number less than 25 is too low to give good precision, and a number over 250 introduces too much error in counting.
8. Multiply the number of colonies counted by the reciprocal of the dilution. For example, if the plate containing 1/100 ml of milk yields 260 colonies and the one containing 1/1,000 ml yields 30 colonies, use the count of 30 and multiply by 1,000 to provide an estimate of 30,000/ml.

Note: Petri dishes and plate count agar may be used instead of the Petrifilm® plate for doing the test. The procedure is otherwise quite similar.

Somatic cell count (SCC) limit

Somatic cell counts of milk from uninfected mammary glands consistently fall below 100,000/ml. Counts of somatic cells in individual producer milk shall not exceed 750,000/ml. A lower limit of 400,000/ml is being applied in Canada and Europe; therefore, it is being considered by NCIMS for application in the United States. The limit for somatic cells in goat milk is 1,000,000/ml.

Because there can be significant variations in numbers of bacteria and somatic cells in milk due to sampling and laboratory errors, the standards are applied on counts made from the last four samples. When two of the last four samples produce counts above the limit, a producer or processor is notified that the permit to sell Grade A milk will be suspended if the counts of three samples of the last five are over the limit. Following suspension of the permit, tests must show that an effective remedy has been applied before the permit to sell can be reinstated.

Drug residues

No positive test shall result when approved methods of detection are applied. (See the section on antibiotics.)

Phosphatase

The limit of this enzyme in pasteurized milk is less than 1 microgram (µg) per milliliter by the Scharer Rapid Method or 500 milliunits/liter by the fluorometric procedure. Phosphatase, which is abundant in raw milk, is inactivated almost completely by the minimal temperature and time of heating during pasteurization (161°F for 15 seconds). Therefore, this test is applied as an added insurance that milk and milk products have received sufficient heat treatment to inactivate pathogenic bacteria that may have been in the raw milk.

Milk with drug residues or phosphatase is excluded from the supply. There is no allowance for application of the 3-out-of-5 rule to these important substances.

Results of applying the regulations

Whereas foodborne disease outbreaks traceable to milk amounted to 38% of the total outbreaks in 1938, such outbreaks amount to less than 1% of total outbreaks today. We conclude, therefore, that application of the requirements of the PMO has resulted in a great reduction in human illness due to milkborne microorganisms.

Cattle can be carriers of microorganisms that infect humans. During the early to mid-1900s, tuberculosis (*Mycobacterium tuberculosis*) and brucellosis (*Brucella abortus*) were endemic in cattle in the United States. Government programs of testing and elimination of infected animals plus calfhood vaccination for brucellosis were successful in virtually eliminating these serious diseases. The organisms of concern today are *Listeria monocytogenes*, pathogenic *Escherichia coli*, and some species of *Campylobacter*.

Adulterants and Adulteration

The adulterants most commonly found in raw milk are antibiotics, extraneous matter, pesticides, and chemicals used in cleaning and sanitizing equipment or the udders and teats of cows. These get into the milk during operations that are not carefully controlled by the milk producer. Usually they are present in traces only and are not harmful to consumers. However, there are good reasons to avoid contamination of milk with any one of them.

Antibiotics

Although antibiotics are sometimes used to treat milk cows with other diseases, they are most often used to treat cases of bovine mastitis. (See the section on bovine mastitis.) Antibiotics are usually infused (squirted through the teat canal) into the quarter from a syringe, but sometimes they are given by injection into muscle tissues or, in severe cases, into the bloodstream. Tests by drug suppliers have determined the time that milk must be withheld from the market after a cow receives treatment. This withholding time, usually 72 hours after the last treatment, is given on the label. This means that milk from six or more milkings will be lost from sale. For this reason, dairy producers are reluctant to use antibiotics on producing cows unless the infection is serious. Instead, they place much of their efforts on preventing infections and on treating infected cows during the dry period.

Nevertheless, many cows receive antibiotic therapy during lactation. Therefore, the PMO requires that all tank loads of milk be tested for beta-lactam type antibiotics before they are offloaded at the milk processing plant. In the event of a positive test, samples must be taken from individual farms that make up that load and tested for antibiotics in order to identify the offending producer. Heavy penalties or fines are commonly levied on such producers. **This practice of careful testing has caused the incidence of positive antibiotic tests to decrease markedly to less than one in 1,000 samples.** The Center for Veterinary Medicine (CVM) of the FDA monitors testing for antibiotics nationally by testing 750 samples that state regulatory agencies have submitted from the national sample of 5,000 farms. States are responsible for enforcement. In addition, the CVM evaluates the rapid test kits that are used in this screening program. The test kits must include a negative and positive control sample for quality control purposes.

Table 1. Antibiotic-Positive Milk Samples 1994 and 2004 – U.S. National Sample

Source of Sample	Year	Total Samples	Number Positive	Percent Positive
Bulk milk tanker	1994	3,213,220	2,024	0.063
	2004	3,589,082	1,571	0.044
Producers	1994	824,132	1,634	0.198
	2004	677,507	895	0.132
Pasteurized products	1994	61,775	3	0.005
	2004	57,875	4	0.007
Source: FDA's <i>National Milk Drug Residue Data Base Report</i> See http://www.cfsan.fda.gov/~ear/milkrp03.html .				

It is of much concern to dairy producers to limit the incidence of mastitis because the disease causes decreased milk production and protein content of the milk while it increases milk's somatic cell content. Several Federal Milk Marketing Orders contain the provision that higher prices will be paid for milk low in somatic cell count. This is especially true in regions that have a high amount of the milk made into cheese. Yield of cheese is determined by the amount of protein in the milk. Furthermore, farmers do not want to see their animal suffer disease, and this disease can cause a cow to lose all of the production capacity of an infected quarter or, in extreme cases, to die.

Antibiotics can be detected in milk with tests that can be completed within 15 minutes or less. These are usually used as "screening tests." However, such tests are not sensitive to all antibiotics at comparable concentrations.

Confirmatory tests, usually high-performance liquid chromatography, are often done to identify the specific drug contained in the milk. Readers should consult the latest edition of *Standard Methods for the Examination of Dairy Products* (the 17th edition was published by the American Public Health Association in 2004) to learn which test is recommended for which purpose.

Antibiotics commonly used to treat mastitis include penicillin and cloxacillin (beta-lactam antibiotics), streptomycin (an aminoglycoside), and the tetracyclines, such as aureomycin. Sulfa drugs (not antibiotics) have been used sparingly. Most of the commonly used tests for antibiotics in milk are designed to detect beta-lactam type antibiotics. The sensitivity of many of the tests is 5 ng/ml (5 parts per billion) or 0.008 International Units (IU) of penicillin G or 10 ng/ml of cloxacillin. The amount of penicillin G normally infused into a single quarter is 100,000 IU.

The PMO sets strict limits on the concentration of the positive control included with each test kit. The concentration of penicillin G must be 5.0 ng/ml with an allowable error of 10%, i.e., 5 ± 0.5 ng/ml.

Here is a hypothetical example:

- If a treated cow releases 80,000 IU of the penicillin at the next milking after treatment, that milk will need to be diluted to a concentration of 0.008 IU/ml, which is equivalent to 8 IU/liter or about 30 IU/gallon. Therefore, $80,000 \text{ IU} \div 30 \text{ IU/gal} = 2,666$ gallons of penicillin-free milk needed to reach just below the detection limit.
- So, 520 cows giving more than 44 lb of milk each would need to contribute to the milk supply to dilute the penicillin to below the detectable limit. If the cow releases only 50% of the antibiotic into the next milking, milk from 325 typical cows would be needed to dilute the antibiotic to near the detectable limit.
- Since some of the antibiotic is absorbed into the bloodstream and tissues, the amount excreted decreases as the number of milkings increases, and, typically, only traces remain 72 hours after the last treatment.

The data show that only a small number of positive tests occur and that the number is very small in pasteurized milk and milk products. However, it is evident that dilution accounted for this small number since producer samples were positive in about one of every 750 tests, whereas tanker loads, representing mixed milk from multiple herds, were positive in about one of 2,300 tests. Removal of milk from tankers that were found positive at the plants accounts for the very low incidence of positive tests of pasteurized products, which amounted to only one for each 14,500 tests. Furthermore, the data show that the program has reduced the incidence of drug residue positive samples in raw milk.

Extraneous matter

The major sources of extraneous matter in milk are the udders and teats of cows that have not been cleaned adequately before milking. Occasionally a milking machine may fall off a cow. When this occurs, vacuum within the machine may draw extraneous matter from the environment into the milk line. An estimated 80% of the extraneous matter is dissolved in milk. It is a major source of bacteria.

Many milk producers insert filters in the milk line to remove sediment from milk before it enters the bulk milk tank for cooling. This process does not remove all insoluble matter, but the materials that accumulate on filter pads include insoluble extraneous matter, clots of milk from mastitic mammary glands, somatic cells, and bacteria. Insoluble extraneous matter is called sediment because it tends to fall to the bottom of the storage vessel.

The insoluble matter can be detected by the sediment test. This test is normally applied to milk samples taken from the farm bulk milk tank after agitation to suspend the insoluble materials. The procedure calls for straining 470 ml (1 pint) of milk at a temperature of 35–38°C through a cotton lintine filter disc with a filtering diameter of 1.02 cm. The amount of extraneous matter collected is estimated by comparison with photographs of standard discs prepared by the USDA, Standardization Branch, Dairy Division, Agricultural Marketing Service, Washington, DC, 20250. Presently the test is seldom run at the receiving plant. Instead, processors rely upon tests for microorganisms in the milk to control milk's quality.

Pesticides

Pesticides are toxic to humans as well as pests. They can get into milk from direct application to animals or from contaminated feeds. In the past there was great concern over this class of adulterants of milk when there were few restrictions on uses of chlorinated hydrocarbon insecticides, such as methoxychlor and DDT, and of the organophosphate chemicals such as malathion and diazinon. The chlorinated hydrocarbons accumulate in the fat of animals and are excreted in milk. However, the organic phosphorus types are metabolized by cattle when ingested and are not found in animal fat or milk unless ingested in large amounts.

Today these pesticides are not permitted for direct use on animals. Furthermore, applications to crops are limited, and times for withholding treated crops from the feed supply apply to pesticides, all of which must be approved by USDA for each intended use. Pyrethrins, which can be extracted from the pyrethrum flower or made synthetically, paralyze insects, have a very low toxicity to humans, and break down quickly in the environment.

They are permitted for use on dairy cattle except at the time of milking and are widely used as space sprays.

Whereas some use of pesticides is necessary in milk production, emphasis is placed on prevention of fly breeding by removal of manure and applications of larvacides. Control of pesticide use in dairy farms and plants is monitored by public health officials who check that all pesticides stored on the premises are approved for use. They are detected in dairy products by chromatographic methods that are described in the FDA's *Pesticide Analytical Manual*.

Water

(Ask your friend for some dihydrogen oxide.)

The most common adulterant of milk is water. When milk is priced according to weight with only the fat content and class of use determining the price, it is usually profitable for the milk producer to add water. Here is an example of why this can be profitable.

- Assume the uniform price for class I milk (that used for fluid purposes) is \$15.00 per cwt of milk containing 3.5% milk fat and the milk fat differential is \$0.20. (The milk fat differential is the amount added or subtracted for each 0.01% the fat content of the milk is above or below 3.5%, respectively.) Further, assume that Producer A delivers milk testing 4.0% milk fat. In this case, Producer A should be paid \$15.00 + (5 x \$0.20) or \$16.00.
- Now, assume that Producer A can get by with diluting that milk down with water to 3.5% milk fat. This is a dilution factor of 4/3.5 or 1.14. So, the addition of approximately 14 pounds of water, at essentially no cost to the producer, will produce 114 pounds of diluted milk worth \$15.00/cwt or a total of \$17.10, which provides a net "profit" from illegal addition of water of \$1.10 (minus hauling costs for 14 pounds).

Such an undeserved gain in value cannot be obtained by producers when milk is purchased on a "component price" basis. In such pricing, milk is tested for protein and fat with values being set for each component based on commercial prices of butter and cheese. A factor is used for "other solids" based on the value of whey solids in the marketplace. Thus, the amount of water in the milk is of no consequence in pricing. Of course, added water is of consequence to the manufacturer of dairy foods, especially cheeses and dry milk products, for which yield depends on concentration of solids in milk.

The unlawful adulteration of milk with water can be detected by testing for the freezing point of milk. Milk has a rather constant freezing point of about -0.517°C. Variability in this number is affected by certain environmental factors and bovine mastitis. Freezing point is one of the colligative properties

of fluids. The others are boiling point, vapor pressure, and osmotic pressure. These properties are directly affected by the amount of dissolved substances in a solution. As osmotic pressure goes up, freezing point goes down. Since the animal must control the osmotic pressure of the bloodstream closely, and since blood must circulate through the mammary gland in the synthesis of milk, milk's freezing point is closely and biologically regulated by the concentration of blood's dissolved substances.

The freezing point test is done using a thermistor-type cryoscope, which can deliver the test results in 5 minutes or less. In enforcement of the freezing point standard, it is accepted that once a test shows a high value, an inspector will visit the farm, make sure that there is no water in the milking system, and then take a milk sample from the bulk tank after all of the cows are milked. The result from testing this "authentic" sample will then be compared to the result of the suspicious test. The freezing point of the original sample is usually permitted to be 0.004°C above the freezing point of the authentic sample to allow for the normal variance in repeatability of the test. The freezing point increases about 0.006 °C with each 1% added water.

Mycotoxins

Certain toxins produced by microorganisms of the environment have been found in milk. The molds *Aspergillus flavus* and *Aspergillus parasiticus* produce a group of highly toxic secondary metabolites called **aflatoxins**. These toxins belong to a broader group called mycotoxins (i.e., toxins of molds). Aflatoxins can be produced on seeds, such as corn, that are used in livestock feed. Of the common forms, B₁, B₂, G₁, and G₂, B₁ is most toxic. Cows that consume contaminated feeds convert B₁ toxin to M₁ by hydroxylation reaction. Milk is then contaminated with toxin M₁. However, the toxin disappears from the milk within 3 to 4 days following removal of a contaminated feed source.

In years when there has been a drought and harvest of corn or other grains is delayed by wet weather, feed manufacturers are alert to the possibility for aflatoxins in the grain supply and may monitor incoming grains for fluorescence under an ultraviolet light (black light). Fluorescence within the grain indicates possible contamination. The fluorescence is caused by kojic acid that *Aspergillus flavus* produces along with the aflatoxin. Best results are obtained on cracked or ground kernels. Black light positive samples usually contain some aflatoxin, but this method cannot quantify the aflatoxin levels and can give false positive responses. Further testing is then required to determine whether significant concentrations of aflatoxins are present. All corn exported from the United States must be tested for aflatoxin.

Tests for aflatoxins can be done by quantitative affinity chromatography with fluorometric detection, by enzyme-linked receptor binding assay, or by

competitive binding assay with antibodies to aflatoxins B₁ and M₁. These tests are described in *Standard Methods for the Examination of Dairy Products*, 17th edition. The USDA Grain Inspection, Packers and Stockyards Administration provides testing service for aflatoxins. The FDA will consider action if aflatoxin levels exceed 20 ppb for corn and other grains intended for immature animals or for dairy cattle.

Clean and Sanitary Cows and Equipment

The major sources of spoilage bacteria of milk are dirty cows and dirty equipment. The bacteria that come from these sources include the **psychrotrophs**, those that can grow well at temperatures used in milk storage, 1 to 5°C (34 to 41°F). When these two sources of microorganisms are well controlled, the bacteria that get into the milk will come primarily from the interiors of the mammary glands and will be of the types that grow poorly at refrigeration temperatures.

Therefore, it is highly important that cows be kept clean and prepared well before milking. Cows that are on pasture tend to be clean as they enter the milking barn, whereas those that are confined in lots or barns tend to have soil and manure attached to their skin and hair. Therefore, it is important to keep the hair well clipped and the cow's environment clean. Those cows that enter the milking facility with dirty udders must be cleaned and sanitized before milking. Various methods are used, but certain principles apply to all of them. Firstly, all soil must be removed that will have a chance of entering the milk. Secondly, the udder must be practically dry because water carries bacteria into the milk. Finally, the teats should be disinfected with an effective sanitizer such as hypochlorite or iodophor. If the udder appears clean, it is most effective to simply disinfect and then to dry the teats and the area immediately above them to remove excess sanitizer. Bacteria clinging to dry skin and hair above the area covered by the inflations are immobile unless released by water.

The process of cleaning and sanitizing the teats has the additional benefit of inducing the cow to secrete oxytocin, the milk let-down hormone. Thus, the glands are filled when the milking machine is attached, limiting potential injury to the mammary tissues during milking.

Milking equipment can be a major source of psychrotrophic bacteria. The major species of these bacteria in milk is *Pseudomonas fluorescens*. Therefore, it is important that milking equipment is designed and constructed to be easily cleaned.

Equipment must be cleaned after each use. Most equipment is cleaned in place, and minimal take-down of the milking machines and milk lines is needed. As soon as milk has been drained from the lines into the bulk cooling

tank, the pipe leading into the bulk tank is relocated to become the return line for the cleaning solutions and rinsing with water is begun. Following the rinse, a solution of hot chlorinated alkaline cleaner is circulated through the milking machines, receiver jars, and milk lines. This treatment lasts several minutes and is terminated with a water rinse. The rate of flow through the equipment is highly important because turbulence provides scrubbing action. The minimal rate of flow is 5 feet per second. Periodically, if not daily, an acidified rinse is used to remove residual minerals that may precipitate from the alkaline cleaning solution. The equipment is then allowed to drain dry. This is important because some bacteria still remain in the equipment and they will grow given small amounts of nutrients and water.

The fat and proteins of milk are removed from equipment with alkaline-type cleaners, whereas the minerals are best dissolved and removed with acid-type cleaners. Milk fat, which is at about 99°F (37°C) when removed from an udder, starts to solidify on cooling at about 93°F (34°C), and solid fat is more difficult to remove from surfaces than is liquid fat. Furthermore, detergents are more effective in hot than cold water. Therefore, cleaning is normally done with hot water. Rinse waters do not need to be warm. Alkaline detergents suspend and saponify fats so they are easily removed from surfaces. Mineral deposits on dairy equipment are composed of insoluble salts of calcium, magnesium, and other minerals plus proteins. This residue, when visible, is called **milkstone** (also water spots). Hot acid cleaner should be used to remove it. Milkstone tends to be deposited on equipment when hard water is used for cleaning and rinsing, only alkaline cleaners are used, and insufficient detergent is used.

All milking equipment must be sanitized just prior to milking. The sanitizing solution is most often composed of sodium hypochlorite at 150 mg/liter (parts per million) in tap water. The minimal concentration of chlorine in the solution at the end of use is 50 mg/liter. Sanitizer must be drained well from equipment before use, but rinsing after sanitizing is not permitted because of the likelihood of recontamination of the surfaces. Hot water at 180°F or higher is often used to sanitize milk lines and filling equipment in milk processing plants in order to destroy spoilage bacteria that may be hidden in junctions between two components inaccessible to chemical sanitizers. This is not practical on dairy farms. Hypochlorite sanitizers tend to be inactivated by residues of soil on equipment. Furthermore, bacteria, being so minute, are protected from a sanitizer by soil. This means that equipment must be clean for chemical sanitizers to be effective.

COMPOSITION OF MILK

Milk is defined as the lacteal secretion from the complete milking of one or more healthy cows and is practically free of colostrum, the secretion of cows just after parturition (birth of a calf). By official definition, it contains no less

than 3.25% fat and 8.25% nonfat milk solids. These percentages are lower than those normally found in milk at the farm, even among individual cows. Cows of the Holstein breed, the dominant breed in this country, produce an average of about 3.65% milk fat and 8.7% nonfat milk solids, making the total solids content about 12.35%. Cows of the Jersey breed produce nearly 5% fat and 9% nonfat milk solids. The solids content of milk from other breeds usually falls between these extremes.

The consumption of milk and other dairy foods, which contribute minerals, bioactive lipids, and unique protein components, has been shown to help reduce the risks of certain chronic diseases, especially osteoporosis, hypertension (high blood pressure), excess body weight and body fat, dental caries, and some cancers.

Milk Fat

Fat content can be determined using the Babcock test in which fat is released from its emulsified state and the protein and lactose are digested by concentrated sulfuric acid. The lightweight fat (density of 0.93 g/ml) floats to the top of the neck of a calibrated test bottle and is measured in percent. The Babcock test is called volumetric because milk and fat are each measured based on the assumption that the average density of milk at 60°F (15°C) is 1.032 g/ml. Addition of water and centrifugation assist in the separation process. Fat testing can be done also by extracting it from weighed milk with a mixture of solvents, mainly ethers. The extracted fat is separated from the aqueous phase that contains the water and nonfat solids, and the solvent is evaporated before the extracted fat is weighed. Since both the sample and the fat are weighed, this is called a gravimetric type of test. Either of these tests may be used in testing a series of samples containing representative percentages of fat to construct a standard curve for calibration of electronic testing machines. The error among individual technicians using the Babcock test with milk should not exceed 0.133%, which is about twice that expected for tests by the ether extraction method.

Electronic testers are the primary tool used for testing fat in modern dairy laboratories. They permit rapid testing with repeatability comparable to the chemical tests. Much of the testing is done with infrared analyzers that are capable of determining the concentrations of protein and lactose as well as fat because chemical groups in each component absorb infrared energy at different wavelengths. Total solids of the product can be estimated by summing the quantities of fat, protein, and lactose, and adding a value for other solids (mostly minerals) based on other analyses.

Table 2. Composition of Fluid Milk Products Containing Various Concentrations of Milk Fat

Name of Product	Fat ^a	% NMS ^b	% TS ^b
Skim or nonfat milk	<0.5g	8.25	8.25
Lowfat milk	NMT ^c 3g	8.25	9.50 ^d
Milk	3.25%	8.25	11.50
Half and half	10.5%	7.5	18.0
Cream (coffee)	18.0%	6.8	24.8
Cream (whipping)	30.0%	5.8	35.8
Cream (heavy whipping)	40.0%	5.0	45.0
^a Labeling regulations set the maximum weight of fat per serving, 8 oz of milk, for products labeled nonfat and lowfat. Otherwise, percentages of fat are used to define products. ^b The minimal NMS and TS of products having more fat than milk are based on the percentage of skim milk in those products. ^c NMT—not more than ^d 3 grams in 8 oz equals 1.25% milk fat Source: Adapted from the U. S. <i>Code of Federal Regulations</i> , Title 21, Part 131 Milk and Cream			

The label of market milk products includes the words pasteurized, homogenized, vitamin D added, and, in the case of products with 2% or less fat, vitamin A added.

Proteins

The proteins of milk consist of 75–80% casein, plus a mixture of whey proteins. Casein is composed mainly of alpha, beta, and kappa types and occurs suspended as a colloid containing a high percentage of milk's calcium, some of the magnesium, and considerable phosphate. Each colloidal particle (micelle) carries a net negative electrical charge plus a thin layer of tightly adsorbed water. The kappa portion of casein occurs primarily on the surface of the micelles where it is easily attacked by rennin, the natural enzyme of the young calf, thus starting the digestion of casein. Humans discovered early that they could extract rennin (impure extract is called rennet) and use it to coagulate the proteins of milk in making cheese. Molecular biologists discovered how to clone this enzyme, called chymosin, in bacteria or yeasts and to purify it for cheese making. Casein can be precipitated (caused to coagulate) by lowering the pH to the point that the negative charges on the micelles are neutralized by protons (H₃O⁺). When there are no net negative charges on the micelles, they aggregate to form a clot and whey is released. In cheese making, whey is removed leaving curd, the raw material for development of more than 400 varieties of cheese.

Whey proteins are soluble in milk and whey. They consist of alpha-lactalbumin, beta-lactoglobulin, bovine serum albumin, several

immunoglobulins, and fragments of proteins called proteose peptones. A valuable and unique component of whey proteins is lactoferrin, an iron-binding protein that may have a role in establishing a healthy intestinal flora of bacteria in infants. Recently, isolated lactoferrin has been used on fresh meat to inhibit attachment and growth of certain undesirable bacteria. Whey proteins can be precipitated by high heat. This is the basis of producing ricotta and similar whey cheeses.

Lactose

Nearly all of the carbohydrate of milk is in the form of the 12-carbon sugar lactose. Two simple sugars, glucose and galactose, are combined by the cow as she produces milk containing nearly 5% lactose. Lactose is only one-half to one-fifth as sweet as table sugar, sucrose. Therefore, milk tastes only slightly sweet. The relatively low solubility of lactose causes it to form crystals in certain products, especially sweetened condensed milk and ice cream, both of which have a lactose content that exceeds the limit of solubility. In the case of sweetened condensed milk, the process of manufacture involves a step that minimizes the sizes of the crystals that form and permits the product's texture to be quite smooth. Since ice cream is quickly frozen, there is insufficient time for lactose crystals to form initially. Furthermore, the high viscosity of the unfrozen syrup inside ice cream prevents lactose crystallization as long as temperature abuse and long-term storage do not occur.

Lactose constitutes about 7% of human milk compared with 5% of cow's milk. Therefore, when infant formulas are made using cow's milk, it is important to add supplemental lactose. There is a strong positive correlation between the size of the brain in mammals and the concentration of lactose in mother's milk.

Numerous milk products are characterized by their content of acids produced by the fermentation of lactose. The product is mostly lactic acid, a 3-carbon carboxylic acid with a hydroxyl group (OH) on the central or beta carbon. Thus, it can be called beta-hydroxy propionic acid. This clean-tasting acid has no aroma. However, the desirable bacteria used to make cultured buttermilk, yogurt, cottage cheese, and many cheeses provide the delicious characterizing aromas. These lactose-fermenting bacteria include *Lactococcus cremoris*, *Lactobacillus bulgaricus*, *Lactobacillus acidophilus*, and *Streptococcus thermophilus*. Before the days of mechanical cooling of milk on farms, it was necessary to transport milk to processing dairies within a few hours of milking to prevent the souring of milk by lactic acid-producing bacteria that got into the milk on the farm. This group of souring bacteria, mainly lactococci, is of little importance today. Instead, it is primarily the bacteria of the psychrotrophic group that attack the fat and proteins of milk causing most of the spoilage.

Some persons digest lactose incompletely because they produce an insufficient amount of lactase (β -D-galactosidase), the enzyme that breaks the bond between the glucose and galactose permitting absorption into the bloodstream. If a significant amount of lactose reaches the human colon, it is fermented by gas-producing bacteria, including the coliform group, producing flatulence. If a very large amount of lactose reaches the colon, the osmotic pressure will rise resulting in an influx of water and, consequently, producing diarrhea.

Processors may use microbially produced lactase to reduce the lactose content of certain milk products such as lactose-reduced milk. They also may remove much of the lactose by a process called ultrafiltration. However, this treatment reduces the volume of the product while concentrating the protein and fat of the milk. Fermentation of lactose by bacteria reduces the amount of lactose in fermented products. In fact, ripened cheeses contain virtually no lactose. On the other hand some dairy products, notably frozen desserts, contain more lactose per serving than does an equal quantity of milk.

Most lactose-sensitive individuals can consume a normal serving of milk or ice cream with no symptoms of lactase insufficiency, especially if the milk product is consumed with other foods.

Minerals

Milk is widely recognized as the major source of dietary calcium for people in North America, supplying about 70% of the total. Much of it is associated with phosphate and citrate in milk. Humans need adequate calcium along with vitamin D to build and maintain healthy bones and teeth. Since milk and most other foods contain limited amounts of vitamin D, and since many people are not exposed to adequate sunlight to synthesize vitamin D in their skin, milk has been chosen as a food to be fortified with vitamin D at the rate of 400 International Units per quart.

USDA surveys indicate that the diets of 9 of 10 teenage girls and adult women, and 7 of 10 teenage boys and adult men fail to meet calcium recommendations. Only 5% of women of ages 50 and older consume 100% of the calcium recommended. The low dietary intake of calcium by adolescents is of particular concern because it coincides with the period of rapid skeletal growth, the period when bone mass can be maximized. About 90% of human bone mass is achieved by age 17. This presents a major public health problem that will result in osteoporosis among many persons as they pass midlife. Low calcium consumption is correlated with a large increase in consumption of soft drinks and decrease in consumption of milk and milk products. In 1945 Americans consumed more than four times as much milk as soft drinks. In contrast, in 1998, 2.3 times more soda was consumed than milk. By age 18, daily consumption by adolescents is approximately 19 oz of soda but less

than 8 oz of milk. The 2005 report of the Dietary Guidelines Advisory Committee on the relationships between milk product intake and health concluded that “consuming three servings of milk and milk products each day can reduce the risk of low bone mass and contribute important amounts of many nutrients.”

Vitamins

Vitamins are found in low concentrations in the tissues of plants and animals where they are necessary for normal metabolic reactions, each having specific functions. Animals and humans must ingest most vitamins, although some are produced in part by bacteria in the alimentary canal. When fat is separated from milk, the fat-soluble vitamins, A, D, E, and K, are also removed. Cream contains only the proportion of water-soluble vitamins supplied by the aqueous (skim milk) portion. For example, cream containing 40% fat contains only about 62.5% as much riboflavin (vitamin B2) compared with milk containing 4% fat. (Solution to this example: nonfat milk portion of milk = 96% and of cream = 60%; therefore, $60/96 \times 100 = 62.5\%$).

The vitamin A content of milk varies with feeds and feeding practices. The carotenoids that compose provitamin A occur abundantly in green leafy plants. However, their potency decreases during preparation of hay and silage. So, in general, milk produced by cows on pasture contains more vitamin A than that produced by cows on dry feeds. Golden-colored β -carotene, provitamin A, is converted to colorless vitamin A by the cow and the human that consumes the milk. Since Guernsey cows convert only about 60% while Holstein and Ayrshire cows convert about 80% of the β -carotene secreted in milk, Guernsey milk has a creamy color compared to the more white color of the other two breeds. The rate of conversion by other breeds falls between these percentages. Two molecules of β -carotene are needed to make one molecule of vitamin A. One quart of milk contains about 1,500 IU of vitamin A equivalents, enough to supply 25–30% of the needs of a person who consumes 1 quart of milk per day. Since milk is traditionally a major source of vitamin A in the diet, fluid milk products that are reduced in fat content must have vitamin A added to make up for that lost in removal of fat to make those products.

As mentioned in conjunction with calcium, vitamin D is vital for the absorption and transport of calcium through the intestinal wall for its assimilation into bone and other tissues. The content of vitamin D is low in milk and other nonfortified foods. It appears that nature intended us to obtain vitamin D by activation of provitamin D through exposure of our skin to sunlight. Therefore, the addition of 400 IU of vitamin D per quart of milk for drinking purposes is uniformly practiced. Milk contains relatively small amounts of vitamins E and K.

Vitamins of the B-complex are synthesized by microorganisms of the rumen, so that quantities in milk do not depend on content in the feed. One quart of milk supplies about 30% of the thiamine and 90% of the riboflavin that humans need daily. Milk also contains significant amounts of niacin activity, pyridoxine equivalents, choline, biotin, folic acid, and vitamin B12. Although vitamin C content of fresh milk is relatively high, much of it is oxidized to an inactive form during the pumping and heating of commercial processing. Therefore, milk is not recognized as a good source of vitamin C.

Enzymes

The enzymes of milk are wholly or partially proteins that catalyze reactions without being used up themselves. The most important one is lipase because it can cause the breakdown of milk fat. This hydrolytic (addition of water) reaction releases fatty acids from the glycerol (a 3-carbon tri-alcohol). The short-chain fatty acids, especially butyric acid, are highly volatile, so they escape the surface of the milk and are easily detected by smell. The long-chain fatty acids, especially palmitic and stearic, form soaps with calcium and magnesium, and these are easily detected in the mouth as a soapy sensation. This condition is called hydrolytic rancidity. Fortunately, the membrane of the milk fat globule effectively limits contact between milk fat and lipase. Disturbance of this protective layer by agitation exposes fat to the enzyme. The rate of breakdown is directly related to the amount of fat exposed and temperature up to about 140°F (60°C), because the enzyme is more active at higher temperatures.

The natural proteases of milk are responsible for some breakdown of proteins in cheeses, especially those made from raw milk or milk given low heat treatments.

Phosphatase is important in the test for adequate heat treatment of milk to kill pathogenic microorganisms by pasteurization. This enzyme has enough resistance to heat to allow it to remain partially active until near the end of the pasteurization process. By application of a simple test, the amount of residual phosphatase can be quantified, and limits have been set by public health authorities to help ensure safety of pasteurized milk. A similar test for peroxidase is used in testing for adequate heating by the ultrahigh temperature method.

Bacteria that grow in milk produce enzymes that are released from their cells to break down large molecules for transport into the bacterial cells. These are called exoenzymes. Of special concern are the exoenzymes of the psychrotrophic bacteria, especially those of the genus *Pseudomonas*. This bacterium produces abundant amounts of proteases, lipases, and phospholipases. Furthermore, these enzymes are sometimes so stable to heat that they remain active after pasteurization of the milk and continue to

degrade proteins, lipids, and phospholipids even though the bacteria that produced them have been killed by the heat treatment. This makes it highly important that these bacteria in raw milk be prevented from growing to high numbers. In milk the activity of proteases commonly causes bitterness, whereas activities of lipases and phospholipases cause rancidity. The unclean and fermented flavors result from the combined activities of these and other enzymes.

Because white blood cells contain catalase, milk with a high somatic cell count is expected to contain large amounts of this enzyme. Hydrogen peroxide is a substrate for the enzyme. Most people have observed the bubbles of oxygen that evolve when hydrogen peroxide is put onto an infected cut to destroy bacteria, such as the catalase-producing infective bacterium, *Staphylococcus aureus*. Here is that reaction:



In the mid-1900 period, milk was frequently tested for catalase content as an indicator of the presence of mastitic secretions. The test involved adding hydrogen peroxide and the subject milk to a test tube with a screw cap. The tube was immediately inverted. A small hole drilled in the cap permitted milk to flow out of the tube as oxygen was released by the action of catalase. Since the tube was inverted, the oxygen that rose in it forced milk out through the hole. After a standard amount of time, the amount of milk displaced by oxygen was measured. After referencing a chart showing the regression of millimeters of milk displaced over numbers of somatic cells, a decision was made as to whether the milk was acceptable for use.

In some countries where inadequate cooling is available for raw milk, catalase may be added to milk in small amounts to delay bacterial growth until that milk can be delivered to the processing facility.

EQUIPMENT USED IN MILK PRODUCTION

The materials and construction of milking equipment and farm storage tanks are approved by an organization known as 3-A Sanitary Standards, Inc. This organization had its beginning when representatives of manufacturers and users of equipment in dairies and public health officials came together in the 1920s to standardize equipment design.

These groups were represented by members of the Milk Industry Foundation (now a part of the International Dairy Foods Association, IDFA), the Dairy and Food Industry Supply Association (now the International Association of Food Industry Suppliers, IAFIS), and the International Association of Milk, Food and Environmental Sanitarians (now the International Association for Food Protection, IAFP). This group wrote the first uniform standards for

fittings used on milk pipelines. Other industry groups later joined the cooperative efforts, but the name first given to the program, 3-A Sanitary Standards, still is applied. The U.S. Public Health Service, a component of the FDA, officially recognized the program in 1944.

There are three 3-A Sanitary Standards subcommittees that represent (1) dairy processors, (2) equipment manufacturers, and (3) public health officials or sanitarians. When an item of equipment has received the endorsement of each of these three groups, the manufacturer is entitled to place on it the 3-A emblem of approval. A new component added to the program in the early 2000s involves third-party verification. Inspections of equipment that is certified by 3-A is done by independent inspectors, called certified conformance evaluators, who have been awarded credentials based on their proven qualifications.

Stainless steel is the preferred material for use in equipment used by milk producers and processors because surfaces can be polished to a smooth finish, surfaces do not corrode easily, and there is little chance for copper to get into milk. Glass, being inert and easily cleaned, is excellent for weigh jars, receiver jars, and certain milk lines. However, use of stainless steel for milk lines provides the advantage of not having gaskets in the lines since smooth welds can be made in these lines. Joints with gaskets can trap milk solids and bacteria. Loose joints permit air to be pulled into the line by the lowered pressure produced by the vacuum pump of the milking machine. This moving air carries bacteria with it and causes excess agitation of the milk in the line. Such agitation may activate lipase that can release fatty acids from damaged fat globule membranes causing milk to become rancid.

The *Grade A Pasteurized Milk Ordinance* limits the types of materials that may be used in production and processing of milk. In general, these materials are stainless steel or other equally corrosion-resistant metals, rubber, and both flexible and inflexible plastics. Plastic or rubber and rubberlike materials must be relatively inert, resistant to scratching, scoring, decomposition, crazing, chipping, and distortion. They are nontoxic, fat resistant, relatively nonabsorbent, and do not release component chemicals or impart flavor or odor to the product. Flexible plastic and rubber must be elastic and resilient. Materials containing copper are excluded because it is a catalyst of oxidation in milk.

When made into components of milking equipment, surfaces must be smooth and free of openings that can retain milk solids and microorganisms. Product contact surfaces shall be easily accessible for cleaning either as assembled (circulation or spray cleaning) or disassembled (hand cleaning). They shall be self-draining also. Pipelines should be free of “dead ends” because they interfere with turbulent flow of cleaning solutions.

The 3-A specification for cooling capacity of farm bulk milk cooling tanks calls for cooling the milk from 90°F to 50°F within the first hour after milking and from 50°F to 40°F within the next hour. When milk is picked up every other day, cooling capacity is rated at one-fourth the volume, whereas with every day pick up, the capacity is rated at one-half the tank's volume. Finally, the blend temperature of the milk during subsequent milkings shall not exceed 50°F.

Evaluation of Defects

Participants in the FFA Dairy Foods CDE evaluate milker unit parts for eight defects, four each with rubber and metal parts. The following are tips on interpretation during evaluation.

- Defects, including **dirty**, are marked if they appear on any surface. This includes “water spots” on equipment. Furthermore, if a part is badly dented or damaged, checked or blistered, or has an open seam, it is likely to be dirty even though the smooth surfaces appear clean.
- A split or hole in a hose will cause it to be marked **leaky** if it is positioned so that air may pass through it. Leaks cause the loss of vacuum and result in poor milker performance.
- The defect is **poorly fitted** when a split occurs in the end of a hose or a rubber part does not fit the metal part onto or into which it belongs, for example, when it is obvious that an inflation does not fit into the shell of the teat cup.
- To be criticized as **badly dented or damaged**, the defect must be great enough to affect cleaning or function. For example, small **pits** or scratches, frequently seen on the bottoms of the claw part of the teat cup assembly, are not criticized. However, it is not uncommon to find bent ends of the tubes of the claw onto which the inflations are attached. If this damage makes the part difficult to clean or restricts the flow of milk, it should be criticized.
- Stainless steel seldom becomes **corroded** unless a very strong acid or hypochlorite solution is applied to it. Also, when attached to dissimilar metals or exposed to stray electrical current, stainless steel may corrode. Participants should observe carefully whether a dull or discolored appearance is caused by corrosion or merely reflects incomplete polishing of the metal part.
- The presence of tiny cracks in any rubber part in any amount justifies marking the **checked or blistered defect** because this makes it



impossible to remove soil and to disinfect the part. Blistering is almost never seen on today's milking machine parts. Checks on rubber inflations occur only after extended use and are sure indications of low elasticity of the rubber, and therefore, poor milking function.

- Openings between components of metal parts constitute **open seams**. This occurs most often when tubes have been pressed into holes in the metal part of the claw and the opening has not been filled and polished. To be criticized, the seam must be large enough to trap soil or milk solids. Openings on the outside of the claw that are no wider than a human hair are not to be criticized.

FLAVOR AND ODOR OF MILK

The first line of protection of milk's flavor is the milk producer who must manage the feeding, disease prevention, housing, cleaning, and milking for the dairy herd and must ensure that the milk is cooled quickly to prevent bacterial growth. The first representative of the milk buyer and of the public health agency is the bulk milk hauler. This person must check each tank of milk for normal appearance, freedom from off odors, and acceptable cold temperature. The next check on quality and safety comes at the receiving plant where a person checks the odor of the milk and samples it to be tested for antibiotics before off-loading from the tanker.

Although milk is among the most nutritious of all foods, it cannot be acceptable to consumers unless it has the rather bland and slightly sweet, clean flavor. Of course, pasteurization imparts a cooked flavor, but this flavor dissipates quickly leaving a pleasing fullness to the flavor. The four taste sensations found in milk that cannot be detected by smell are bitter, flat, salty, and sour. Some odors, however, can be associated with these taste sensations. This is nearly always true of sourness. Off flavors and odors of raw milk can be caused by feeds consumed by the cow, illnesses of the cow, or chemical changes that occur due to activities of enzymes that are either naturally in milk or produced therein by bacteria.

Participants in the Dairy Foods CDE are asked to score milk samples based on flavor and odor. The following discusses the types of off flavors and their causes.

Evaluation of Defects

Caused by the cow's diet

Fresh raw milk should have very little aroma, and most of the aroma results from volatile substances derived from the feeds the cows have eaten. Therefore, the **feed** flavor is the most common off flavor of milk. Generally, the more succulent the feed (e.g., fresh green pastures in the early spring), the

more offensive the feed flavor of the milk. **Onion and garlic** are particularly offensive. Silage produces more off flavor than does hay. Since these off flavors have several possible causes, the flavors and odors that result vary with the type of feed. Feed flavors tend to disappear from the mouth and nose more quickly than do many of the more offensive flavors, including rancid and oxidized.

Caused by bacteria

The **acid** (sour) flavor of milk results from fermentation of milk's sugar, lactose, by bacteria generally of the *Lactococcus* genus. Interestingly, this word means the milk (lacto) seed or sphere (coccus). Lactococci are so named because they were found in milk when first described. The main product of this fermentation is odorless lactic acid, which causes the sour flavor. The aroma that accompanies the sour taste is caused by other small molecules produced by these bacteria. Development of sourness requires the presence of fermenting bacteria along with poor cooling because these bacteria grow poorly at temperatures below 10°C (50°F). Sourness is quickly perceived by most persons, appears near the front of the tongue, and leaves the mouth feeling clean if not accompanied by other off flavors. Millions of bacteria are in milk that has a sour taste. A chemical test for the amount of acid in milk is described later in this booklet.

A flavor closely related to acid is **malty**. The bacteria responsible for this defect produce both sourness and a maltlike aroma. They are known as *Lactococcus lactis* subspecies *multigenes*. Some reports relate the malty defect in milk to consumption of certain pasture grasses. The offending compound has been reported to be 3-methyl-butanal (isovaleraldehyde). In general, similar small aldehyde molecules are responsible for a wide range of off flavors.

As discussed in the section on enzymes, a group of off flavors is caused by bacteria, the psychrotrophs that grow at relatively low temperatures. These flavors can be **bitter, unclean, rancid, fermented, and fruity**. They result primarily from the degradation of proteins and fat. These bacteria grow slowly at the cold temperatures of milk stored on the farm, and the time between pick ups is no more than 48 hours. Therefore, it is uncommon for the fermented and fruity flavors to develop in milk at the farm, and they have not been included in the FFA score card. However, the enzyme content may be sufficient to produce detectable off flavor at the processing plant, especially if milk is not pasteurized before the end of the 72-hour period permitted for holding raw milk at the plant.

Bitterness in milk may have multiple causes. The most frequent one is breakdown of proteins into very small peptides. As discussed above in relation to psychrotrophic bacteria, this is uncommon in raw milk at the farm. However, bitterness may also accompany feed, weed, foreign, and rancid

flavors in milk at the farm level. The reaction time for bitter flavor is long, and the sensation lingers more than that of most flavors. It is particularly noted on the back of the tongue.

The major cause of the **rancid** defect is hydrolysis of milk fat by the natural lipase enzyme of milk. (See the section on enzymes of milk.) The odor of this highly offensive defect resembles that of butyric acid or blue cheese. Short-chain fatty acids released from fat molecules cause the odor. The soapy mouth feel that is present results from the soaps formed by reactions of long-chain fatty acids (16 and 18 carbons) with calcium and magnesium. The aftertaste of this flavor is especially unpleasant to many people.

Caused by chemical reactions

The most frequently found, highly objectionable off flavor in pasteurized milk is **oxidized**. Descriptions of the flavor vary depending on the specific causes. They include burnt, oily, wet cardboard, tallowy, stale, and metallic. The latter is characterized by flatness and the feeling of a “nail in the mouth.”

In the FFA Dairy Foods CDE, oxidized and metallic have been combined because of their similarities in flavor and cause. These defects are seldom seen in raw milk because catalysts are needed to produce them. These catalysts are metal ions, especially copper, and ultraviolet (UV) light. Only infrequently is milk exposed to sunlight. As discussed under equipment, contamination of milk with copper has been reduced on the farm by limiting the types of metal used in equipment. This means that copper content of feed is the main variable affecting copper content of milk. Milk is seldom exposed on the farm to the two main sources of UV light, sunlight and fluorescent light. The usual place of oxidation of milk is the milk display cases of grocery stores. It takes only minutes to a few hours for the off flavor to be detectable when plastic or glass containers of milk are permitted to sit within a few inches of fluorescent light bulbs, and this is frequently practiced in stores. The UV-catalyzed flavor is distinctly of wet cardboard. Many of us have experienced a similar odor when we have removed a brown paper sack from a freezer after leaving it there for a few weeks.

Milk produced by cows on pasture is more resistant to oxidation catalyzed by copper than is milk produced by cows on dry feeds, probably because of the higher amount of natural antioxidants in the green feeds. Alpha-tocopherol, vitamin E, appears to be the major antioxidant involved. Copper from an external source is more likely to produce oxidized flavor than is natural copper.

During the first several hours after pasteurization, milk is less susceptible to light-induced oxidation than is raw milk because the heat treatment causes formation of sulfhydryl compounds (responsible for the cooked flavor). Once these reducing agents have been oxidized, pasteurized milk loses its resistance to oxidation. Very high heat treatments prevent or retard oxidative

reactions in milk products. Homogenization, by dislocating fat globule membranes, increases milk's susceptibility to oxidation.

The light-induced oxidized flavor can be prevented by using an orange filter on the fluorescent bulbs of milk storage cabinets or by packaging milk in orange plastic containers. Paper containers tend to block the offensive wavelength of UV light, but some penetration can occur with white paperboard containers. The higher the fat content, the less the penetration of UV light, and the slower the rate of oxidation.

The author highly recommends returning defective milk to the retailer with a specific explanation that the defect is primarily under control of the seller. Furthermore, complaints should be lodged with the milk distributors who can influence retailers to merchandise their milk in a more careful way.

In addition to the offensive taste of oxidized milk, it also is lower in nutritional value. Riboflavin and ascorbic acid (vitamin C) concentrations decrease in proportion to the amount of exposure to UV light. Researchers showed that UV light destroys some amino acids: tryptophan, methionine, tyrosine, cysteine, and lysine. Methional, the product of oxidation of methionine, has been reported to be a major contributor to the light-induced oxidized flavor.

Related to milk's composition

The **flat** and **salty** defects are not frequently found in milk. Flat generally results from the addition of water to milk or the removal of fat. Addition of water is illegal, and most consumers realize that they must compromise on the richness flavor note when they choose to consume lowfat or nonfat milk products. Salty is associated with the inclusion of mastitic (abnormal) milk in the supply. As discussed in the section on bovine mastitis and somatic cells, this is largely prevented by the application of somatic cell count standards to raw milk.

As can be concluded from the previous discussion about off flavors of milk, only feed, flat, garlic/onion, and salty are likely to occur in freshly drawn milk. Of course, the flat flavor is sometimes produced when water gets into milk after it leaves the cow.

Samples for Training in Flavor Evaluation

Although the emphasis in the FFA Dairy Foods CDE is on the policies and practices of producing high quality and safe raw milk, the evaluation portion of the CDE includes only pasteurized products. There are two reasons for not evaluating raw milk for flavor and odor. Safety is the main concern, but, secondly, tasting of raw milk is not practiced on the farm or in the plant. Instead, milk is examined by the sense of smell before the hauler pumps it into his truck's tank, and the quality assurance technician at the plant uses the same method.

When suspicions about quality arise, selected tests may be applied as well, including titratable acidity for sourness (acid), acid degree value for rancidity, freezing point for flat/watery, and chlorides for salty. Then there is the regular (usually monthly) testing for counts of bacteria and somatic cells. Temperature of the milk is recorded every time the hauler picks it up. The sanitarian periodically inspects for cleanliness, adulteration, condition of equipment, and more.

Taste testing is routinely done on pasteurized products at the processing plant by qualified personnel. They check freshly processed products, store them at marginally cold temperatures for the time they are expected to remain flavor-acceptable, and then examine them again by taste and smell. Failure to meet the firm's goal will prompt much detective work to ascertain the cause(s).

Table 3. Methods of Preparation of Milk Samples (1 pint or 500 ml) for Training to Detect Important Off Flavors of Milk

Defect	Method of Preparation
Acid	Add about 2% cultured buttermilk.
Bitter	Add 1 ml of a 2% suspension of quinine sulfate or caffeine.
Feed	Suspend 1/2 cup silage or alfalfa hay in 2 cups water in a side arm flask. Stopper the top of the flask. Place tubing on the side arm and extend it into the milk. (See Figure 1.) Heat slowly to drive volatiles into the milk where they will condense. Remove the tubing from the milk before removing the flask from the heat source or the milk will be drawn back into the suspension.
Flat/watery	Add 10 to 15% water.
Foreign	Add 1 ml laundry bleach, but be aware that flavor changes with time.
Garlic/onion	Add 2 drops of garlic or onion juice for "definite" intensity.
Malty	Add 10 ml malt extract or soak 2 teaspoons Grape Nuts® cereal in 100 ml milk for about an hour; filter and use to flavor the sample. Addition of 5–10 ml of cultured buttermilk is also recommended.
Metallic/oxidized	Add 2 drops of 1% cupric sulfate to the milk and expose to direct sunlight for 15 minutes or place very close to a fluorescent lightbulb and expose for about an hour.
Rancid	Add 10% raw milk to warm (100°F) pasteurized homogenized milk and refrigerate overnight. Heat momentarily to 160°F to produce a safe product, and cool before tasting. Alternatively, add 1 ml of 10% butyric acid. This will not produce the typical rancid flavor but will be useful for practice. Butyric acid may be used to supplement the naturally rancid flavor as well.
Salty	Add 0.5g table salt.
Unclean	Select from pasteurized milk samples that have exceeded the pull date by a few days. Typical samples will have a somewhat putrid odor and bitter flavor. Dilute "bad" samples with good milk so the defect is slightly detectable.



Figure 1. Setup for preparing milk sample with off flavor of feed

Testing Milk's Acidity

Participants in the FFA Dairy Foods CDE may be required to perform a test for titratable acidity of raw milk. The following is the principle and procedure for the test. Normal fresh milk contains certain buffering substances that act as acids, neutralizing alkaline substances. This is called the "apparent acidity" of milk and averages about 0.16% expressed as titratable acidity. As acid-producing bacteria grow in milk, they ferment lactose to lactic acid and the amount produced is called "developed acidity." The sum of apparent and developed acidity is called "total acidity" and is the value obtained in the titration of milk to the pH that the pH indicator, phenolphthalein, changes from colorless to pink/purple.

The procedure is as follows:

1. Measure 17.6 ml of well-mixed milk into a beaker with a pipet that delivers approximately 18 g of milk.
2. To this milk, add 36 ml of water and 0.5 ml phenolphthalein indicator.
3. Titrate the sample with 0.1 normal NaOH (sodium hydroxide) until a slightly pink color persists in the sample.
4. Determine the amount of NaOH used from the calibrated buret. Calculate the titratable acidity by dividing the milliliters of NaOH used by 20. For example, when 4.0 ml of NaOH is used, the percent titratable acidity is $4/20 = 0.20\%$. The following formula explains this approach to the problem:

$$\% \text{ acidity} = \frac{(\text{ml NaOH}) \times (\text{Normality of NaOH}) \times (.09) \times 100}{\text{Sample weight in grams}}$$

Further explanation: One molecule of NaOH neutralizes one molecule of lactic acid. Lactic acid weighs 90 grams per mole. NaOH is 0.1 N, so the milliequivalent weight of lactic acid neutralized per milliliter of this base is 0.09g. The product of the equation is multiplied by 100 to convert to percent. Here is the solution:

$$\% \text{ acidity} = \frac{4.0 \text{ ml} \times 0.1 \text{ N} \times .09 \times 100}{18} = 0.20$$

CHEESE IDENTIFICATION

More milk is used to make cheese in the United States than for any other single purpose. U.S. production in 2004 totaled 8.849 billion pounds. At 3.65 billion pounds, production of Italian-type cheeses almost caught up with American-type cheeses at 3.74 billion pounds. In fact, more Mozzarella cheese (2.9 billion pounds) was produced than Cheddar (2.76 billion pounds). American- and Italian-type cheeses make up about 70% of the cheeses produced in this country. Other cheeses produced in large quantities in the United States in descending order of amount are Cream/Neufchatel, Swiss, Hispanic, Muenster, Blue, and Brick. About 2.16 billion pounds of processed cheese, cheese food, and cheese spread are produced annually.

Participants in the FFA Dairy Foods CDE identify 10 samples of cheeses chosen from a group of 14. Training the senses of taste, smell, sight, and feel is important for this task. Many of these cheeses look alike when cut into slices or cubes. Furthermore, differences in texture and flavor are often not distinct. Therefore, identification depends on abilities to mentally integrate information about each of the characteristics. Practice is especially important in differentiating among mild and sharp Cheddar, Colby, Brick, Monterey, and Muenster. The table on the next page has descriptions and tips that may assist in this training.

Table 4. Characteristics of Types of Cheeses

Cheese	Appearance	Texture	Flavor
Blue	White to cream with blue to green spots from the spores of the mold <i>Penicillium roqueforti</i> , mostly within small holes (open texture)	Crumbly	Sharp and pungent
Brick	Light yellow to orange	Semisoft, waxy, often with small holes	Mildly pungent, sweet, and nutty
Brie/Camembert	Feltlike layer on the surface and white to cream color inside	Firm rind but soft to creamy inside	Mild to pungent, sometimes has a slight aroma of ammonia
Cheddar	White to yellow to orange, depending on source of milk and amount of color added	Firm with few or no openings	Slightly sour and mild to sharp, depending on moisture content and age
Colby	Light yellow to orange often with small irregular openings	Softer and more open than Cheddar	Slightly sour and mild cheesiness
Cream/Neufchatel	White, moist surface	Soft and smooth	Very mild acid with a hint of nutty
Edam/gouda	Creamy yellow	Softer than Cheddar, open, somewhat mealy	Mild nutlike
Monterey (Jack)	Cream to yellow color	Softer than Cheddar	Slightly acid and mild
Mozzarella	Creamy white	Very elastic or pliable	Mild acid
Muenster	White to yellow	Soft	Mild to mellow
Processed American	Yellow, sometimes contains very small round holes formed as bubbles after the melting and emulsifying process	Semisoft and elastic	Cooked, slightly sour, and similar to Cheddar in cheesiness
Provolone	Golden to yellow	Hard	Distinct to sharp
Swiss	Cream to light yellow	Firm, pliable, with large uniform holes that have shiny interiors	Nutlike and sweet

REAL VERSUS IMITATION DAIRY PRODUCTS

The problem-solving part of the FFA Dairy Foods CDE includes identification of real dairy foods and imitations of them. The following is a list of such products.

Dairy	Nondairy
Butter ¹	Margarine ¹
Coffee cream	Coffee whitener
Cream cheese	Imitation cream cheese
Milk	Soy milk
Process cheese	Imitation process cheese (fanciful name)
Sour (cultured) cream	Imitation sour cream
Whipped cream	Imitation whipped cream

¹May be in the regular or whipped form

BOVINE MASTITIS AND SOMATIC CELLS

The Disease

This disease is caused by infection of the individual quarter of the cow's udder with bacteria, the most common of which are *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus uberis*, and coliform bacteria including *Escherichia coli*. More than 20 different species of microorganisms have been isolated from cases of mastitis. The ones listed above, however, are the major offenders. These bacteria invade the mammary gland via the teat canal and cause inflammation of the milk-secreting tissues. This results in the release of millions of white blood cells (leukocytes) and other somatic (body) cells into the milk.

A cow may become infected in a single quarter with one species of bacteria and in another quarter with another species, and, since the quarters do not have common openings between or among them, an infection is usually isolated within a single quarter until and unless pathogenic bacteria invade and infect another quarter of the udder.

Bacteria get into a cow's mammary gland almost exclusively via the teat canal. They may establish a colony at the teat opening, living on nutrients in residual milk left after milking. If the teat sphincter muscle is weak and the canal open, the organisms may actually grow into the gland. (Figure 2)

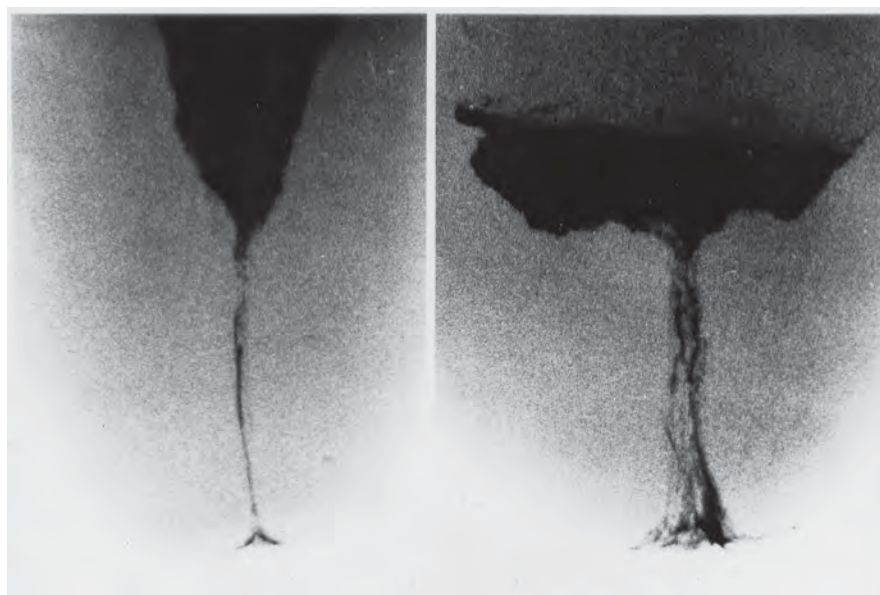


Figure 2. Widening of the teat canal of a lactating cow is illustrated by these two X-ray photographs of the lower portion of a single teat. The photos were taken early in the first lactation (left) and again in a subsequent lactation (right). This widening is believed to make easier the passage of mastitis-causing bacteria into the mammary gland as the cow ages. (Courtesy of Dr. J. S. McDonald, National Animal Disease Laboratory, USDA, Ames, IA)

Poor milking machine design and/or function can result in milk being “jetted” onto the end of the teat, or the teat end may be flooded during milking thus forcing infective bacteria into the teat canal or even the teat cistern. When cows are milked past the time when milk ceases to flow, the vacuum of the milking machine tends to lower the pressure in the mammary gland permitting “back-flow” of any milk left on the teat. This situation can cause the transport of infective bacteria into the teat once the machine is removed.

Researchers at the University of Missouri discovered that bacteria of the *Corynebacterium* group were able to take up residence in the central portion of the teat canal where they provided protection from infection by mastitis pathogens. It appeared that the presence of these bacteria caused elevation of leukocyte numbers sufficient to phagocytize the invading pathogens before they had a chance to establish an infection. Unfortunately, dipping of the teats with strong disinfectant after milking eliminated the corynebacteria from the teat canals. After-milking teat disinfection with a strong sanitizer,

such as 5,000 mg/liter of iodophor (organic iodine), is widely practiced in prevention of mastitis. Treatment of dry cows with antibiotics to eliminate infections already existing and to prevent new infections during the dry period is also widely practiced.

Recently, researchers with the USDA, Agricultural Research Service announced the development of *poly-x*, a mild irritant that increases somatic cell counts to protective levels against establishment of infection when administered to dry cows early in the dry period. Also, through genetic engineering, these researchers have inserted a modified gene into cows to produce an enzyme, lysostaphin, that lyses cells of *Staphylococcus aureus* when they invade the mammary gland, thus preventing infections by this major mastitis pathogen. Since the genetically modified cow makes the protein, it is not recognized as foreign, so the cow's immune system makes no antibody against it.

Mastitis can be of the acute or chronic type, depending on the virulence of the bacterium and the immunity of the cow. Staphylococci and streptococci tend to cause chronic mastitis, in which there are periodic "flare-ups" of inflammation followed by periods of relatively little evidence of disease. However, as the disease progresses, more and more of the milk-secreting cells die off and scar tissues replace them reducing the quarter's ability to produce milk. The coliform group of bacteria, including *Escherichia coli*, can cause acute mastitis, the type that infects both the mammary gland and the circulatory system of the cow and can result in death of an animal. Such cases must be treated immediately and usually with both infused and injected antibiotic. Often it is the young animal in early lactation that is affected because of her relatively low immunity to the invading pathogen.

Somatic Cells in Milk

As previously discussed, the number of somatic cells permitted in raw milk is regulated by the states through agreements with the FDA and USDA. In 2005 the maximal number was limited to 750,000/ml. However, other major milk-producing countries use 400,000/ml as the enforcement level. This has caused the NCIMS to consider lowering the acceptable count. Enforcement is based on the results of the last four samples tested. When counts on two of the last four samples exceed this number, a warning notice is given to the producer. When three of the last five counts exceed the limit, the producer loses the permit to sell milk. For the producer to again be permitted to sell in the market, the cause of the problem must be determined, correction made, and tests performed that show acceptable counts.

Federal Milk Marketing Orders may contain a provision for adjusting the payment for milk based on the average of somatic cell counts (SCC). The rationale for this is that the concentration of protein and lactose in the milk

decreases with increases in somatic cell count above a value estimated as 350,000/ml. The somatic cell adjustment rate is calculated as the price of cheese x 0.0005, and the rate is per 1,000 somatic cell count difference from 350,000. This means that milk prices are lowered when the average count is above 350,000/ml. In the following example, the cheese price = \$2.00/lb and the average SCC = 450,000/ml.

$$\text{Adjustment \$} = (\$2.00 \times 0.0005) ((550,000 - 350,000)/1,000) = \$0.20$$

In this case, the producer would lose \$0.20 per hundred pounds of milk sold.

Somatic cell counts are made in the laboratory using direct microscopic or electronic methods. Electronic instruments are calibrated using results of direct microscopic counts (DMC). The DMC procedure requires that 0.1 ml of milk be placed within an area of 1 cm² on a glass slide. After drying, the film of milk is stained with methylene blue dye. Cells in the film are then counted under 1,000x magnification with a calibrated microscope to obtain a statistically valid number. DMC counts are made on milks containing low to high numbers of somatic cells before these same milk samples are used to calibrate the electronic counters. Whereas the DMC method requires several minutes per sample and an experienced technician, electronic cell counters can test high numbers of samples per hour. A fluorescent dye, ethidium bromide, is used to stain the cells for electronic counting, and the stained cells are detected as they pass a lamp or laser that causes them to fluoresce. The electrical pulses emitted by the cells are counted, and the total cell count is printed out or sent to a computer.

California Mastitis Test (CMT)

At the farm, numbers of somatic cells in milk are estimated using the California Mastitis Test (CMT) or the electrical conductivity of milk. The CMT is based on the principle that somatic cells in milk can be lysed with detergent (3% alkyl aryl sulfonate), releasing their nuclear material, DNA, which forms a gel. A pH indicator, brom cresol purple, is included in the reagent. The cowside test involves collecting about 2 ml of foremilk from each quarter into flat-bottom plastic cups on a white plastic paddle. The amount of milk is adjusted in each cup by tipping the paddle. An equal amount of CMT reagent is added and the paddle is rotated to mix the milk and reagent and to permit the reading of the results. The higher the number of cells lysed in the milk, the greater the viscosity of the milk-reagent mixture.

The test is sensitive (i.e., the mixture thickens perceptibly) to somatic cell numbers of about 150,000/ml. Slight thickening and precipitate become visible as counts increase to about 500,000/ml. Counts of 1,000,000/ml +/- 500,000/ml cause formation of distinct precipitate without gel formation. Gel becomes visible with counts above about 1,000,000/ml. This gel adheres to the paddle and forms a central peak as the mixture is swirled when counts are about 5,000,000/ml.

The data cited above show that the precision of this test is low. However, the test has the great advantage of quick and economical identification of mammary glands that are inflamed. Not all inflammation results from infection. Research at the University of Missouri showed that more than 90% of the quarters were infected with typical mastitis pathogens when distinct gel formed during the test. When tests were weakly positive, the percentage of infected mammary glands dropped to 50–75%. Quarters showing a negative test result were not always free of typical mastitis pathogens as evidenced by recovery of mastitis bacteria from about 25% of the aseptically taken samples from such quarters.

The CMT should not be used to test the milk from cows until more than 3 days after parturition (birth of the calf), because colostrum milk usually contains high numbers of somatic cells.

Participants in the FFA CDE perform the California Mastitis Test to evaluate milk samples for abnormality. Participants do the test in the following steps on eight samples of milk:

1. Squirt about 2 ml of milk from four of the samples separately into the four cups of a CMT paddle (Figure 3).
2. Adjust the quantity of milk in the cups by tipping the paddle over a pan (Figure 4).



Figure 3



Figure 4

3. Add about 2 ml of CMT reagent from a squirt bottle (Figure 5).
4. Mix the milk and reagent by swirling the paddle for about 10 seconds and read the reaction (Figure 6).



Figure 5

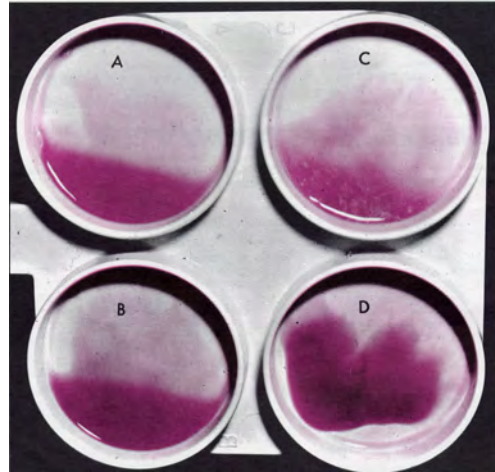


Figure 6

Scoring of the CMT is based on the amount of gel formed as somatic cells are lysed by the reagent. Scores in the FFA CDE range from 0 (negative with no thickening of the mixture) to 8 (strong gel forms and tends to cling to the paddle forming a distinct central peak when the paddle is swirled). In this case (Figure 6), reactions should be read as follows: Cup A - CMT 0, Cup B - CMT 4, Cup C - CMT 6, Cup D - CMT 8

Additional information regarding the California Mastitis Test can be found on the Internet at <http://muextension.missouri.edu/explore/agguides/dairy/g03653.htm>.

Electrical Conductivity Test

As mammary glands become inflamed, the lactose (milk sugar) content of the milk decreases and salts from the bloodstream filter into the milk to make up for the lowered osmotic pressure of the milk. Basically, the osmotic pressure of the milk must stay very close to that of the blood that continuously flows into the mammary gland to supply nutrients for milk synthesis and cell preservation. This replacement of non-ionized, therefore nonconductive, lactose with ionized and conductive salts, primarily sodium, causes the electrical conductivity of the milk to increase. Microelectronics is applied in making instruments to measure changes in electrical conductivity. A handheld version of the instrument is used with individual quarters. There are also small units that can be inserted into the milk tubes of the inflations to measure the conductivity during milking. Computers and software are used to compare conductivities among quarters of the same cow thus identifying one or more showing abnormally high results.

Electrical conductivity instruments are checked with a standardized solution of sodium chloride. On a scale of 0 to 9, a reading of 5 indicates abnormal conductivity. Not all herds have the same basic level of conductivity, so care is advised in interpretation of the results.

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