THE DAIRY PRACTICES COUNCIL®

IDENTIFYING AND PREVENTING OFF-FLAVORS IN MILK AND MILK PRODUCTS

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Guideline Preparation and Review Process

Guideline development within Dairy Practices Council (DPC) is unique and requires several levels of peer review. The first step in the process of guideline development starts with a Task Force subcommittee comprised of individuals from industry, regulatory and education interested in and knowledgeable about the subject to be addressed. Drafts, referred to as "white copies," are circulated until all members are satisfied with the text. The final white copy may then be distributed to the entire Task Force, DPC Executive Vice President and whoever the Task Force Director feels would add strength of the review. Following final white copy review and correction, the next step in the process requires a yellow cover draft that is circulated to the member Regulatory Agency representatives that are referred to as "Key Sanitarians." The Key Sanitarians may suggest changes and insert footnotes if their state standards and regulations differ from the text. After final review and editing the guideline is distributed in the distinctive DPC green cover to people worldwide. These guidelines represent the state of the knowledge at the time they are written.

Disclaimer

The DPC is not responsible for the use or application of the information provided in this Guideline. It is the responsibility of the user to ensure that the information addresses their needs and that any action taken complies with appropriate regulations and standards.

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INTRODUCTION

Primary traits of high-quality dairy products are clean flavors that are characteristic of the specific product, and that the product is free from off-flavors during its expected shelf life. Dairy producers and processors are responsible for ensuring that their products meet and maintain these standards of excellence that are critical for consumer satisfaction and lead to a profitable and sustainable dairy business. Consumer complaints of off-flavors and/or shorter-than-ideal shelf-lives are not new. The dairy industry cannot afford to ignore the reality that if dairy products do not taste good, consumers will buy alternate products.

The ability to consistently meet consumer demands for good tasting, long lasting dairy products is based on establishing a robust quality assurance (QA) program, from farm to consumer. A key aspect of a strong QA program is sensory evaluation by trained individuals of raw materials and finished products that starts at the farm and continues throughout processing and through the expected shelf life of the product.

Off-flavors and off-odors in milk products may originate in the raw milk supply directly from the farm and/or be influenced by raw milk handling and storage during transport and receiving at the processing plant. If poor quality milk can be identified early in the processing chain, it can be removed before it can contaminate larger quantities of good quality milk, thereby improving the quality of the commingled milk. Off-flavors may further occur during processing, packaging, storage, distribution, and at point-of-sale, influenced by a variety of factors including handling conditions and packaging materials. Being able to identify and describe typical off-flavors will assist dairy operations in preventing off-flavors and in determining causes and correcting problems when they occur.

This guideline will describe common off-flavors (e.g., light-induced oxidized, bitter, rancid, cooked, fruity/fermented, and unclean) and other typical defects that may occur in milk and milk products. Off-flavor attributes presented in standardized terms are categorized by their general cause and described by their defining sensory characteristics. The causes or mechanisms that generate the off-flavor and suggestions for control and/or prevention at the farm and the processing plant are provided as possible. While the focus of this Guideline is on pre-pasteurized ("raw") and pasteurized fluid milk, the information is applicable to all dairy products because any off-flavors that occur in raw milk may carry through to the finished product, whether it is bottled fluid milk, cheese, ice cream, or others.

DEFINITIONS

Flavor – A blend of taste and smell sensations evoked by a substance in the mouth (Merriam-Webster).

Off-Flavor – Detected flavor that is not typically associated with the product, typically considered a defect and objectionable.

Off-Odor – Detected odor that is not typically associated with the product, typically considered a defect and objectionable. Often included under Off-Flavor in this Guideline.

PMO – Grade A Pasteurized Milk Ordinance.

Identifying Off-Flavors & Off-Odors in Milk

Basic information on the sensory evaluation of raw and pasteurized milk, including how to sample milk, sensory tools (e.g., taste, smell, appearance), sensory evaluation procedures and personnel, defined attributes, and ballot information will be covered later in this Guideline.[1] This information is useful for in-house panelists as part of an ongoing quality monitoring program, as well as student judges for the Future Farmers of America[2] and Collegiate Dairy Product Evaluation[3] contests.

To identify and detect off-flavors successfully and consistently, it is necessary to be familiar with the characteristics of normal, good tasting milk. Milk from dairy cattle, goats, sheep, water buffalo, and other dairy animals will each have a unique taste and mouth-feel based on the normal composition and characteristics of the milk. For example:

- Cattle milk - pleasant, slightly sweet taste, no odor, and a pleasant or no after-taste.
- Goat milk - may have a mild "caprine essence" both in flavor and odor that is not considered a defect unless it is strong or pronounced. When pronounced, the caprine flavor has a lingering, unpleasant aftertaste, that is often described as "goaty."

This Guideline is focused on defects associated with dairy cattle milk but is applicable for any type of milk if the evaluators first learn what is normal for that type of milk and then proceed with troubleshooting the defects.

Off-flavors commonly found in milk have been well described and are broadly categorized by the primary cause of the defect. Traditionally, these were referred to as the "ABCs" of off-flavor, representing Absorbed, Bacterial, and Chemical. Some defects do not fit neatly into this scheme. In this Guideline update, we use "P" for Processing and "Q" for Questionable to further organize the causes of off-flavors and off-odors commonly associated with milk. An easy way to mentally categorize the off-flavors is to "remember your ABCs" and "be aware of your Ps and Qs"!

A brief description of the major categories of off-flavors in milk follow, with details in subsequent sections. Some off-flavors have multiple causes and may be listed in more than one category, which should be taken into account when troubleshooting based on flavor profile.

Absorbed Off-Flavors

Absorbed off-flavors typically result from compounds in the environment that are directly absorbed into the milk or "absorbed" through the cow. They can develop in raw milk before, during or after milking. In pasteurized milk products, absorbed off-flavors can develop during storage in bulk or after packaging. In raw milk, off-flavors may be absorbed into the milk from feed sources, the environment, or as a result of animal related issues. Some feed and environmental related off-flavors and odors are considered "transmitted," rather than "absorbed," from the rumen or the lungs through the animal's blood to the udder and into the milk. An example of a transmitted off-flavor is an unclean barny note from breathing the air in a poorly maintained barn just prior to milking. In pasteurized milk, an example of an absorbed

[1] More detailed information on these subjects can be found in reference books such as *The Sensory Evaluation of Dairy Products* (2009), and *Standard Methods for the Evaluation of Dairy Products* (2004).
[2] (www.ffa.org)
[3] (dairyproductscontest.org)

off-flavor is an unclean refrigerator flavor that results from storing packaged milk in areas that have strong odors or are poorly cleaned.
Common absorbed off-flavors include – feed, barny, cowy, unclean, musty, weedy, garlic, onion, foreign, and refrigerator or dirty cooler odors.

Bacterial Off-Flavors

Bacterial off-flavors result from the extensive growth of unwanted bacteria in raw or pasteurized milk. Milk can become contaminated from a variety of sources, including the milking animals; improperly washed or sanitized equipment at the farm, during hauling, or at the processing plant; and from the environment. Excessive bacterial growth may be caused by poor cooling after milking or during processing, and through prolonged storage. Some bacteria found in dairy products grow at refrigeration temperatures, called *psychrotrophic* or *psychrotolerant* bacteria, and cause off-flavors.

Common Bacterial off-flavors include – acid, bitter, rancid, malty, unclean, fruity, and lacks freshness.

Chemical Off-Flavors

Chemical off-flavors in raw and pasteurized milk may result from direct contamination by chemicals (e.g., cleaning compounds) or generated from chemical and biochemical reactions that may occur. Chemical off-flavors in raw milk may be caused by animal health (e.g., ketosis), feed sources and additives, or by rough raw milk handling practices. In pasteurized milk products, chemical off-flavors may be the result of chemically catalyzed or enzymatic reactions that generate off-flavors. A particularly prevalent chemical off-flavor in pasteurized, bottled milk is light-induced oxidized that occurs when milk is exposed to excessive light, such as sunlight or retail fluorescent light. The light catalyzes oxidation reactions in the milk proteins and fats (lipids) and creates off-flavor compounds that have a plastic-like, cardboard, and burnt hair flavor.

Common Chemical off-flavors include – light-induced oxidized (cardboard, burnt hair, burnt feathers), rancid (baby vomit, blue cheese-like), foreign, salty, and unclean/medicinal.

Processing Off-Flavors

Processing off-flavors generally result from processing conditions and handling procedures during the manufacture and storage of pasteurized milk and dairy products. High heat treatments for pasteurization can cause a “cooked” flavor, that may be considered desirable or undesirable depending on the intensity and the product. Improper draining of water in processing lines between cleaning or product changeover can lead to watery, “flat” tasting products. Some off-flavors associated with processing operations are more accurately categorized as absorbed flavors, such as those from dirty coolers or plastic flavors that migrate from packaging and heat-sealing compounds.

Common Processing off-flavors include - cooked, flat, watery, plastic/package, foreign, and storage flavors.

Questionable Off-Flavors

In the routine monitoring of milk and dairy products for quality, sensory evaluators may encounter off-flavors typically associated with dairy products but that are difficult to describe,

or that have a cause that is not clearly associated with the absorbed, bacterial, chemical, or processing categories. Some of these unknown, or "Questionable" off-flavors, such as unclean and foreign, may also be absorbed, biological, or chemical in origin. The terms "unclean" or "foreign" may be the best way to describe subtle off-flavors before they develop to the extent that a cause may be easy to identify, as in the case of microbial spoilage. The term "lacks freshness" falls into the category of questionable off-flavors because the flavor profile and causes may be difficult to clearly define and is generally described as a product losing its fresh dairy flavor over the course its shelf-life.

Common questionable off-flavors include – foreign, unclean, lacks freshness, and bitter.

Absorbed Off-Flavors in Milk

Absorbed off-flavors can occur in both raw and pasteurized milk. Being able to identify the off-flavor characteristics can help determine where the problem originates and how to control it.

Absorbed Off-Flavors in Raw Milk

Description of Absorbed Off-Flavors in Raw Milk

Absorbed off-flavors in raw milk are most often associated with the farm environment and feed. Strong environmental odors can be absorbed directly into the milk during handling or storage or may be absorbed from the environment or feed by the cow prior to milking. Some flavors classified as "absorbed" may be better described as "transmitted" because they are transmitted to the milk through the animal from the feed they eat or the odors they inhale. The route of transmission is from the rumen and/or the lungs via the blood stream to the udder and into the milk during synthesis.

Descriptors associated with absorbed off-flavors in raw milk include:

- **Barny**. An unpleasant odor and flavor of a poorly maintained barn or unpleasant feed. May be perceived as unclean, manure or urine-like depending on the farm and barn environment. Flavor will often persist and leave an after taste. Barny flavors may be transmitted through the animal from the environment or absorbed directly in stored milk.

- **Cowy.** An unpleasant odor and flavor of cow's breath. May have medicinal, acetone, or chemical-like odors and flavors, with an unpleasant lingering aftertaste. Cowy flavors can originate in animals that exhibit signs of ketosis, a metabolic disease that causes the production of acetone and ketones that are transmitted into the milk.

- **Feed.** Feed flavors vary from sweet and grassy to bitter and unclean, depending on the source of the feed. Feed off-flavors are often slight and not objectionable; they may be considered desirable in milk from grass or pasture-fed animals. Some types of feed may result in stronger odors and flavors that become objectionable with bitter or unclean notes. While Feed is a standardized term, evaluators should attempt to further characterize the flavor (e.g., "tastes grassy") to help identify the cause.

- **Foreign**. Foreign is a descriptor that refers to odors and flavors that are not commonly associated with milk. Foreign flavors are often described as having a

chemical or medicinal character and can be transmitted through the animal or absorbed directly into the milk. Examples of absorbed foreign off-flavors are the presence of kerosene-like flavors from heaters used in milk rooms or medicinal flavors from topical medicines absorbed through the skin of the milking animal and transmitted to the milk. Foreign off-flavors may also have chemical, bacterial, and unknown or questionable origins. While Foreign is a standardized term, evaluators should attempt to further characterize the flavor (e.g., "tastes like chlorine") to help identify the cause.

- **Garlic/Onion**. Garlic, onion, and related flavors and odors are transmitted into the milk through eating and are considered objectional. Wild onions, chives, and garlic are naturally occurring in some pastures.

- **Musty**. Musty can be described as damp, moldy basement, or attic like. Musty aromas and flavors may be absorbed in the milk from poorly maintained barn and storage environments. Musty flavors may also be transmitted into the milk through moldy or poorly stored feed.

- **Unclean.** Unclean is a catch-all phrase used to describe unpleasant flavors in milk that are not otherwise categorized. The flavor profile can range from a dirty dish-rag or dirty gym socks aroma to an undefined character. These flavors do not clean up quickly in the mouth after swallowing or expectorating. Unclean off-flavors may also have chemical, bacterial, and unknown or questionable origins.

- **Weedy.** Objectional odors and flavors that come from various weeds in pasture or other feeds that are transmitted into the milk by eating. The flavor profile is dependent upon the types of weeds that the animal eats.

Mechanisms of Off-Flavors in Raw Milk

Mechanisms of Absorbed Off-Flavors in Raw Milk

Milk, by nature, has the ability to absorb volatile flavor and odor compounds directly from the surrounding environment such as the air, and through gas-permeable storage containers, such as some plastics. Milk fat is a particularly good flavor sink for fat soluble off-flavors.

Mechanisms of Transmitted Off-Flavors in Raw Milk

The two primary methods that flavor is transmitted within the animal are from the rumen through the digestive system (feed) or from the lungs through the respiratory system (feed, environment). This can be diagrammed as follows:

FEED / DIGESTION ROUTE mouth → digestive tract → blood → milk *or* mouth → digestive tract → regurgitation/belching → lungs → blood → milk
BREATH / INHALATION ROUTE mouth or nose → lungs → blood → milk
SKIN ROUTE ointment on skin (→ lungs) → blood → milk

Usually for flavors to be absorbed into the milk through eating or breathing they must be strong. Unclean barns and milking parlors, and/or those with poor ventilation, can cause typical barn aromas to become highly concentrated and breathed in by the animals. The transmission of these types of flavors can happen quickly. For some feeds, it is critical to stop feeding 0.5 to 3 hours (h) prior to milking to prevent off-flavors in the milk. Strong odors inhaled from the environment can be transmitted to the milk in as little as 30 minutes.

Sources of Absorbed Off-Flavors in Raw Milk

Feed Sources of Absorbed Off-Flavors in Raw Milk

The extent to which feed off-flavors are detected in milk depends on feed source (e.g., mixed-rations, feed additives, and pasture), feed quality (e.g., musty, poorly fermented), and when animals are fed in relation to milking times. Some feed flavors in raw milk are pleasant, slightly sweet, and have a grassy taste that is considered acceptable. In recent years, "pasture-fed" has become a desirable marketing strategy and consumers anticipate a slightly grassy flavor in these products.

Sources of feed with minimal effect on milk flavor include:

- Corn, grain
- Molasses
- Oats, rye, green peas
- Soybeans, carrots, pumpkins, potatoes
- Soybean hay
- Sugar beets and dried pulp
- Timothy hay
- Urea

Sources of feed that are commonly detected as off-flavors in milk include:

- Alfalfa (green or hay)
- Barley and Rye (green)
- Cabbage, turnips, turnip, and beet tops
- Clover hay
- Distiller's or brewer's grain in wet form

Fermented Feeds

- Haylage
- Silage

Note: most feeds, if well-balanced and of good quality, should not result in significant off-flavors. Poor control over feed storage (e.g., musty) and/or fermentation (e.g., butyric) may result in additional off-flavor concerns.

Naturally occurring weeds in pasture known to cause unpleasant flavor in milk and include:

- Ailanthus shoots
- Bitter weed
- Boneset
- Buckhorn Plantain
- French weed
- Mustard
- Pepper grass
- Ragweed
- Skunk cabbage
- Tac weed
- Wild dog fennel
- Wild garlic
- Wild onions and chives

In addition to feed sources, some feeding practices may contribute to off-flavors in milk:

- Feeding components known to be transmitted to milk just before milking (0.5-3 h).
- Abrupt changes in feed source, including using a different feed or moving animals to pasture or green chop after the winter months.

- Using poor quality or moldy feeds.
- Using strong flavored by-products of other agricultural practices such as apple pumice from a cider mill.

Environmental Sources of Absorbed Off-Flavors in Raw Milk

Off-flavors in raw milk caused by environmental sources can be from strong odors that are breathed in by the animals and transmitted into the milk. This is primarily due to an unclean environment combined with inadequate ventilation in the free stall or stanchion housing areas and/or holding areas of milking parlors. These off-flavors are more prevalent when animals are kept inside with marginal ventilation systems, such as in the winter. Milk houses that are unclean (e.g., old milk pools) or have strong chemical odors (e.g., disinfectant cleaners, kerosene fumes) can be sources of off-flavors absorbed directly into the bulk milk.

Animal Related Sources of Absorbed Off-Flavors in Raw Milk

Absorbed off-flavors may come from animals with ketosis or other metabolic disorders. Ketosis, or acetonemia, is a metabolic disease that occurs when the cow is in severe state of negative energy balance. Cows with ketosis produce acetone and ketone bodies that may result in a cowy or medicinal odor in the milk. The acetone and ketone produced are excreted in the animal's breath. Ketosis may be brought on by the stresses of calving, deficiencies in nutrition, or other factors. Other metabolic disorders caused by improper feeding, such as unbalanced rations, may cause unclean off-flavors in the milk.

Prevention and Control of Absorbed Off-Flavors in Raw Milk

Absorbed off-flavors in milk can be prevented or controlled with well-managed feeding programs, maintaining a clean farm environment with proper ventilation, and by maintaining good animal health and handling practices.

Recommendations for Feed and Feeding Practices

- Avoid feeds that are strongly associated with off-flavors (see list above) or restrict feeding until after milking.
- Avoid feeding silage and other strong feeds 0.5-3 hours prior to milking.
- Inspect feeds for quality and eliminate moldy, poorly fermented, or objectional feeds.
- Change feeds gradually. Manage pasture feeding by restricting initial time in the pasture to allow for adjustments.
- Eliminate objectionable weeds in pastures or cow yards as appropriate or fence off areas where weeds are prevalent.
- Develop balanced feed rations that promote animal health and optimum milk production to minimize feed off-flavors and metabolic disorders such as ketosis. Work with animal nutritionists as appropriate.

Recommendations for Environmental Control and Monitoring

- Maintain the barn and milking parlor environment as clean as possible.
- Remove manure and other odorous materials to prevent excessive build-up.

- Keep floors, walls and ceilings of dairy housing and milking areas clean.
- Avoid slotted flooring that collects manure and urine.
- Avoid closing off housing and holding areas with limited ventilation.
- Eliminate overcrowding in feeding and housing areas.
- Design or modify dairy housing and holding areas to allow for proper mechanical ventilation.[4]

Recommendations for Animal Health and Handling

- Keep cows clean and comfortable, provide adequately bedded stalls.
- Clip hair from udder, teats, and flanks of milking animals.
- Properly prepare animals before milking: clean and dry udders using a sanitizer and single service towel on each animal.
- Provide adequate nutrition; consult dairy nutritionist.
- Monitor animal health and learn to recognized signs of ketosis and other disorders.
- Withhold milk from animals with ketosis or other disorders influencing flavor.
- Do not use medicines with strong odors that can be inhaled or absorbed through skin.

Recommendations for Milk House and Milk Storage Areas

- Keep milk house clean and well-ventilated as possible.
- Do not use petroleum products, combustion engines or any device creating fumes or other odors.
- Do not use cleaning agents with strong odors such as household disinfectants or deodorizers; use dairy cleaners.

Absorbed Off-Flavors in Pasteurized Milk

Description of Absorbed Off-Flavors in Pasteurized Milk

In pasteurized milk, absorbed flavors are caused by volatile flavor compounds absorbed into the milk during storage when the milk is exposed to an environment where strong odors are present, or from odors absorbed from or through packaging materials.

Descriptors associated with Absorbed off-flavors in pasteurized milk include:

- **Foreign**. Foreign is a descriptor that refers to odors and flavors not commonly associated with milk and are often described as having a chemical or medicinal character. Foreign flavors in pasteurized milk may originate in the raw milk or may occur during storage in areas with strong odors. Examples include “chemical” or “fruity” notes in milk stored in coolers in close proximity to fresh oranges or in white milk stored next to strawberry milk, where the fruit flavors penetrate the milk packaging. Other sources may include scented cleaners or disinfectants, and exhaust fumes from transport vehicles in improperly vented cooler loading areas. Foreign off-flavors may also have chemical, bacterial, and unknown or questionable origins.

[4] Refer to the following DPC Guidelines: DPC001, *Planning Dairy Freestall Barns*, DPC037, *Planning Dairy Stall Barns*, DPC044, *Mechanical Ventilation of Dairy Tie-Stall Barns*.

- **Refrigerator/Storage.** Refrigerator or storage flavors in pasteurized milk are absorbed from the environment when milk is stored in areas that have strong flavors such as onions, garlic, fruits, cheeses, and smoked meats. The flavor characteristics range depending on the item emitting the strong flavor, or may generally be classified as a stale, dirty refrigerator aroma.

- **Unclean.** Unclean is a catch-all phrase used to describe unpleasant flavors in milk that are not otherwise categorized. The flavor profile can range from a dirty dishrag or dirty gym socks aroma to an undefined character. These flavors do not clean up quickly in the mouth after swallowing or expectorating. Unclean flavors in pasteurized milk may be due to absorption of refrigerator odors. Unclean off-flavors may also have chemical, bacterial, and unknown or questionable origins.

Causes of Absorbed Off-Flavors in Pasteurized Milk

Absorbed off-flavors in pasteurized milk are usually caused by storing milk in tanks in the processing plant or packaged milk in areas with strong odors, or poorly ventilated storage rooms. Low quality packaging may leach plastic components into the milk causing undesirable flavors in finished products.

Prevention and Control of Absorbed Off-Flavors in Pasteurized Milk

The best means of preventing Absorbed flavors in pasteurized milk is to store bulk and packaged products in environments with no odors and good ventilation, and to use high quality packaging materials. Recommendations include:

- Ensure that bulk milk storage areas are clean, well ventilated, and free unwanted odors.
- Keep all bulk storage tanks closed and protected.
- Use only scent free dairy chemicals for cleaning all areas throughout the plant.
- Keep coolers clean and free of materials or food items that may produce volatile odors such as onions, citrus fruits, scented cleaners /disinfectants. Store fruit flavored milks separately.
- Provide retail establishments and schools with guidelines on how to properly store packaged milk products to maintain quality.

Bacterial Off-Flavors in Milk

Bacterial off-flavors result from the extensive growth of unwanted bacteria in raw and pasteurized milk. Bacterial off-flavor characteristics are similar in both raw and pasteurized milk. Bacterial off-flavors that develop in raw milk cannot be eliminated and may worsen during and after processing.

Description of Bacterial Off-Flavors in Milk

Bacterial off-flavors are generated during bacterial growth and metabolism, which produce acids and other flavor compounds, and through the action of bacterial enzymes that degrade fats, proteins and other milk components to byproducts that cause undesirable flavors. The type of off-flavor is dependent on the type(s) of bacteria present and the extent of growth. Bacteria counts generally need to be high (>1,000,000) before microbial off-flavors become apparent.

Descriptors associated with Bacterial off-flavors include:

- **Acid.** A sour flavor that sometimes is associated with a tingling feeling. Sour is one of the basic tastes perceived on the tongue. Acid or sour flavors are caused by the conversion of lactose to lactic acid during bacterial metabolism, primarily by Lactic Acid Bacteria (LAB) (e.g., *Lactococcus lactis*). Most LAB do no grow well under refrigeration and this off-flavor tends to be associated with poorly cooled raw milk.

  Lactic acid provides the typical tart flavor of fermented dairy products such as yogurt, but acid and sour flavors are undesirable in milk. Sour flavors may also be characterized as a vinegar-type flavor (acetic acid) or a lemony, citrusy flavor (citric acid).

- **Bitter.** A sharp, unpleasant flavor. Bitter is one of the basic tastes perceived on the tongue. Bitter flavors result from the action of bacterial enzymes that break down proteins into peptide fragments that are perceived as bitter. Bitter is a common off-flavor in spoiled pasteurized milk.

- **Coagulated.** Curdled, thickened or "chunky" milk, generally caused by coagulation of the milk proteins. Separated clear liquid or whey may be evident. Coagulation may be caused by high acid production (see "Acid" above) or by the enzymatic break-down and destabilization of milk proteins that results in what is called "**sweet curdling**" because of the lack of acid production.

- **Fermented/Fruity**. Fermented flavors are characterized as a sauerkraut or vinegar flavor, which may sometimes be called acidic or sour from the acetic acid produced during bacterial metabolism. The fruity flavors are described as pineapple, apple, or other types of fruit. In some cheeses, fruity flavors may be desirable, such as in parmesan cheese, but they are considered to be a defect in milk. Fermented/fruity is a common off-flavor in spoiled pasteurized milk.

- **Lacks freshness.** A stale or old product flavor, lacking in bright, fresh dairy notes, and may be perceived as "less sweet." The stale lacks freshness flavor may be noticeable before bacterial growth becomes excessive and results in more identifiable off-flavors.

- **Malty.** A flavor characteristic of malted milk shakes or the breakfast cereal Grapenuts™. Malty flavor is caused by the growth of *Lactococcus lactis var. maltigenes* in poorly cooled milk (see "Acid" above).

- **Rancid.** An undesirable, potent flavor that can be described as bitter, soapy, blue-cheese or baby vomit-like. Rancid flavors in milk are due to fat breakdown by bacterial enzymes that release short chain fatty acids with unpleasant flavors. Rancid off-flavors may also have origins that fall under "chemical," such as those caused by enzymes from sources other than bacteria.

- **Unclean.** Unclean is a catch-all phrase used to describe unpleasant flavors, typically with a persistent aftertaste, that are not otherwise categorized. The flavor profile can range from a dirty dishrag or dirty gym socks aroma to an undefined character. Unclean off-flavors may also have chemical and unknown or questionable origins.

Causes of Bacterial Off-Flavors in Milk

Bacterial off-flavors result from the extensive growth of unwanted bacteria in raw or pasteurized milk. Bacterial limits for milk are set by the Pasteurized Milk Ordinance (PMO; US FDA, 2019). The limits for raw milk are 100,000 cfu/mL for a single producer and 300,000 cfu/mL for commingled milk, and 20,000 cfu/mL for pasteurized products.

Different bacteria have different optimal growth conditions, and most bacteria grow better at warmer temperatures. However, there are some types of bacteria found in dairy products, called *psychrotrophic* or *psychrotolerant* bacteria, that grow at refrigeration temperatures (< 45°F/7°C) and cause off-flavors and product spoilage. Excessive bacteria growth in milk is caused by poor cooling after milking, during storage, and during processing, and/or by extended storage times.

Causes of Bacterial Off-Flavors in Raw Milk

Bacterial contamination in raw milk can be from the animals, improperly washed or sanitized equipment, and the environment. Generally, initial contamination levels are low and subsequent growth is needed to cause off-flavors. Growth can occur due to poor cooling after milking and/or prolonged storage time. Raw milk may be legally stored up to 48 h at the farm and up to 72 h at the processing plant (PMO; US FDA, 2019). Poor cooling (>45°F/7°C) is one of the most common causes of bacterial defects in raw milk.[5]

Causes of Bacterial Off-Flavors in Pasteurized Milk

Pasteurization destroys most spoilage organisms, but if growth was high enough in the raw milk to cause off-flavors prior to pasteurization then the off-flavors will remain. While some bacteria survive pasteurization, most do not grow under refrigeration. The most common cause of bacterial spoilage in packaged pasteurized milk is post-pasteurization contamination (PPC) with psychrotrophic bacteria. PPC of milk comes primarily from improperly washed, sanitized, and/or maintained equipment, and the environment within processing plants. Initial levels are generally low, and defects usually become apparent later in shelf-life when time for growth has occurred. Gram-negative psychrotrophic bacteria (e.g., *Pseudomonas* spp. and others) are the most common agents of spoilage in pasteurized milk. Marginal cooling (e.g., 40 - 45°F (4.4-7°C)) will allow more rapid growth of psychrotrophs, while poor cooling, temperatures above 45°F (7°C), will allow growth of other potential spoilage organisms.

Heat Stable Enzymes. Another source of off-flavors in pasteurized milk products are heat stable bacterial enzymes that survive pasteurization even though the bacteria are destroyed. These active enzymes may degrade fats, proteins and other components in milk resulting in rancid, bitter, and other off-flavors in finished products. Generally bacterial counts need to be well above the 300,000 cfu/ml raw milk limit for heat stable enzymes to influence flavor, with extended shelf -life (ESL) and shelf-stable milk products most susceptible.

Psychrotrophic / Psychrotolerant Spore Formers. While pasteurization inactivates most common spoilage organisms in raw milk (e.g., gram negative psychrotrophs), certain spore-forming bacteria (e.g., *Bacillus, Paenibacillus*) are able to survive pasteurization and grow under refrigeration. These organisms generally grow slower under refrigeration and will spoil milk later in shelf-life. Off-flavors and other defects may be similar to those

[5] More information on bacterial contamination and growth in raw milk can be found in: DPC024, *Troubleshooting High Bacteria Counts of Raw Milk*.

associated with other bacterial contaminants, while the "sweet curdling" defect is characteristic of some spore-formers.[6]

Prevention and Control of Bacterial Off-Flavors in Milk

Bacterial contamination of milk, and therefore prevention and control, can occur on the farm, during raw milk transport, and at the processing plant.

Prevention and Control of Bacterial Off-Flavors on the Farm

Bacterial off-flavors in milk can be prevented and controlled by good animal health, hygienic milking practices, sanitation, and milk handling and storages practices on the farm.[7]

Recommendations for Animal Health and Handling

Important aspects include:

- Keep animal housing areas and cow yards reasonably clean.
- Restrict access to areas where mud and stagnant water may contaminate udders and teats.
- Keep udders and teats clean and hair trimmed.
- Keep animals free of disease. Mastitis and subclinical mastitis can contribute to high bacterial counts in milk.

Recommendations for Hygienic Milking Practices

Important aspects include:

- Ensure teats are clean, use pre-dips/sprays, individual clean drying cloths, and post-dips.
- Use strip cups or other means to detect abnormal milk and separate it from the bulk tank supply.
- Clean all milk handling equipment surfaces after each use and sanitize just prior to reuse.
- Ensure milk filters are clean and properly installed. Replace filters as needed during long milking times.[8]

Recommendations for Cleaning and Sanitizing the Milk Parlor and Equipment

Good sanitation practices are one of the more important ways to reduce bacterial contamination in milk.[9]

Important aspects include:

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[6] More specific information on bacterial contamination and growth can be found in: DPC010, *Maintaining and Testing Fluid Milk Shelf Life*, DPC060, *Trouble Shooting Microbial Defects in Dairy Processing Plants.*

[7] For more information see DPC Guideline: DPC024, *Troubleshooting High Bacteria Counts of Raw Milk.*

[8] For detailed information on hygienic milking practices, see DPC Guideline: DPC098, *Milking Procedures for Dairy Cattle.*

[9] For detailed information see DPC Guidelines: DPC002, *Effective Installation, Cleaning, and Sanitizing of Milking Systems*, DPC004, *Installation, Cleaning, and Sanitizing of Large Parlor Milking Systems*, DPC009, *Fundamentals of Cleaning & Sanitizing Farm Milk Handling Equipment*, DPC028, *Troubleshooting Residual Films on Dairy Farm Milk Handling Equipment*, DPC070, *Small Ruminant Milking Systems*, DPC102, *Installation, Cleaning, and Sanitizing of Tie Barn Milking Systems*.

- Make sure all milking equipment is in good repair and free from cracks. Replace gaskets and hoses as needed.
- Clean all milk handling equipment surfaces after each use and sanitize just prior to reuse.
- Clean and sanitize farm bulk milk tanks and agitators each time they are emptied.
- Follow standard cleaning or sanitation operating procedures (SSOPs) for all equipment and use appropriate procedures for clean-in-place, clean-out-of-place, and manual cleaning. Implement verification procedures to ensure program is working.
    - Use approved, potable water sources, for all plant operations.
    - Ensure adequate hot water is available for all cleaning operations.
    - Use approved cleaners and sanitizers at the correct concentrations. Overuse generally does not improve cleaning and may result in chemical off-flavors.
    - Work with chemical company to ensure CIP systems are set up properly.

Recommendations for Temperature Control at the Farm

While animal handling and sanitation procedures are used to minimize microbial contamination of raw milk, bacteria will be present, thus keeping milk cold is paramount in keeping them from growing to high numbers.[10]

Important aspects include:

- Make sure the bulk tank refrigeration is turned on during milking and the tanks are agitated regularly.
- Cool milk to ≤ 40°F (4.4°C) within 1 hour of the completion of milking. Temperatures should remain below 45°F (7.2°C) during second and subsequent milkings and cooled back down to ≤ 40°F (4.4°C) within 1 hour of completion.
    - Heat exchangers can be used to pre-cool milk prior to entry into bulk tanks. Install drip shields to protect condensate from dripping down the cooling line into the bulk tank.
    - Direct loading raw milk into bulk tank trucks without refrigeration requires milk to be precooled prior to loading, ideally to ≤ 40°F (4.4°C), although cooling to maintain milk temperatures at ≤ 45°F (7.2°C) is acceptable under the PMO.
    - Refrigeration systems should be equipped with automatic controls and accurate recording thermometers (±1°F).
- Hold raw milk at 40°F (4.4°C) or below until processed.

Prevention and Control of Bacterial Off-Flavors During Raw Milk Transport

The same basics control principles of sanitation and keeping milk cold apply to milk during transport.[11]

Important aspects include:

- Make sure tankers and hoses are properly cleaned and in good repair.
- Keep milk cold (40°F/4.4°C) during shipping.

[10] For more information see: DPC024, *Troubleshooting High Bacteria Counts of Raw Milk*, Pasteurized Milk Ordinance (PMO), Item 18r. Raw Milk Cooling (US FDA, 2019).

[11] For more information see DPC Guidelines: DPC025, *Cleaning & Sanitation Responsibilities for Bulk Pickup & Transport Tankers.*

- Evaluate the aroma of the milk in the bulk tank prior to loading. If sour, malty, or fermented odors or visible abnormalities (e.g., churned fat, off-color, debris) are detected, the milk should not be loaded. If in doubt, do not load milk; consult quality assurance personnel.

Prevention and Control of Bacterial Off-Flavors at the Processing Plant

Preventing and controlling bacterial off-flavors at the processing plant starts with accepting only good quality raw or heat-treated milk and ensuring that it is properly stored and processed as soon as possible. During processing, bacterial off-flavors in milk can be prevented and controlled by maintaining temperature control of the milk and practicing good sanitation and milk handling practices.

Recommendations for Milk Acceptance at the Processing Plant

Milk should not be accepted and unloaded at the processing plant unless it is of good bacterial quality.[12]

Important aspects include:

- Evaluate the aroma of the milk in the incoming tanker. If sour, malty, or fermented odors or visible abnormalities (e.g., churned fat, off-color, debris) are detected, the milk should be rejected or tested before being accepted. If in doubt, consult quality assurance personnel.
- Screen milk with the Direct Microscopic Clump Count (DMCC) to estimate bacteria numbers. May be used for estimating Somatic Cell Counts as well. Flow cytometry systems can also be used; bench top units are available.
- Monitor the bacterial counts of producers and incoming loads using Standard Plate Count (SPC) or equivalent. This will indicate when milk exceeds the legal bacteria limits and provide a history of raw milk quality for trouble-shooting purposes as appropriate.
- Perform a titratable acidity test (TA) to indicate an increase in acidity from bacterial growth. Normal acidity results range from 0.13% to 0.17%, and acid flavors are not detected until TA is above 0.20%. *Note*: this test is rarely performed especially where DMCC is used.

Recommendations for Temperature Control at the Processing Plant

While milk handling and sanitation procedures can minimize contamination, bacteria will be present in the milk at the plant, thus keeping milk cold is paramount in keeping bacteria from growing to high numbers in pre-pasteurized and processed milk. During manufacturing, pasteurization reduces bacterial numbers, but some will survive, thus pasteurized milk, and packaged finished dairy products must be kept cold.

Important aspects include:

- Keep raw milk below 40°F (4.4°C) and process within 48 hours after collection.
- Follow required procedures for pasteurization.
- After processing, the milk should be held at 40°F (4.4°C) until consumed. Pasteurized fluid milk products must be < 45°F (7.0°C) at packaging.

[12] For more information see DPC Guidelines: DPC021, *Raw Milk Quality Tests, DPC024, Troubleshooting High Bacteria Counts of Raw Milk.*

- Refrigeration systems and holding tanks should be equipped with automatic controls and accurate recording thermometers (±1°F).

Recommendations for Cleaning and Sanitizing at the Processing Plant

While pasteurization generally eliminates most psychrotrophic spoilage organisms, post-pasteurization contamination often results in reduced shelf-life of milk. Good sanitation practices are one of the more important ways to reduce bacterial contamination in milk.[13]

Important aspects include:

- Make sure all processing equipment is in good repair and free from cracks.
  - Develop a preventive maintenance (PM) program to inspect, repair and replace equipment and worn parts (e.g., gaskets; valve plugs, seats, and O-rings; pump and agitator seals) as needed.
- Clean all processing equipment and associated lines, valves, and pumps, after each use and sanitize just prior to reuse following established SSOPs.
  - In fluid milk plants fillers are a critical area of concern and require extra attention for cleaning and routine maintenance such as replacing gaskets, O-rings, rubbers, and other parts that wear out.
  - Bulk raw milk and pasteurized milk storage tanks and agitators must be cleaned and sanitized each time they are emptied.
- Follow standard cleaning or sanitation operating procedures (SSOPs) for all equipment and use appropriate procedures for clean-in-place, clean-out-of-place, and manual cleaning. Implement verification procedures to ensure program is working.
  - Use approved, potable water sources, for all plant operations.
  - Ensure adequate hot water is available for all cleaning operations.
  - Use approved cleaners and sanitizers at the correct concentrations. Work with chemical company to ensure CIP systems are set up properly.
  - Use separate cleaning systems for raw and pasteurized side equipment, including CIP and manual cleaning vats and utensils (e.g., color coded brushes).
  - Include routine cleaning procedures for equipment exteriors, and the general plant environmental (e.g., floors, walls, ceilings, drains, panels).

Recommendations for Sanitary Design & Good Manufacturing Practices (GMPs) at the Plant

Using properly designed and operated equipment along with Good Manufacturing Practices will help reduce bacterial contamination.[14]

Important aspects include:

- Train all employees in proper Good Manufacturing Practices (GMPs) including wearing proper attire in the processing plant and using practices such as handwashing to reduce contamination.

[13] For detailed information see DPC Guidelines: DPC010, *Maintaining and Testing Fluid Milk Shelf Life*, DPC029, *Cleaning & Sanitizing in Fluid Milk Processing Plants*, DPC060, *Trouble Shooting Microbial Defects in Dairy Processing Plants.*

[14] For more information see the Code of Regulations 21 CFR 117 Subpart B Good Manufacturing Practice (US FDA, 2022) and DPC Guidelines: DPC016, *Handling Dairy Products from Processing to Consumption*.

- Use properly designed, operated, and maintained equipment. Make sure it is in good repair, and preventive maintenance programs are in place.
- Design and maintain the processing area so condensation from pipes or the ceiling cannot drop into vats, filler bowls, or containers used for pasteurized milk.
- Keep all vats and fillers covered.
- Use separate pipelines and equipment for raw and pasteurized milk to prevent cross contamination. Ideally separate CIP and COP systems should be used for raw and pasteurized equipment.

Chemical Off-Flavors in Milk

Chemical off-flavors can occur before and after milking in raw milk and in pasteurized milk. Chemical off-flavors may result from direct contamination, by absorption of chemical compounds, or from chemical and enzymatic reactions involving milk components that generate undesirable flavor compounds.

Chemical off-flavors in milk have different flavor profiles depending on the cause. Strategies used to prevent chemical off-flavors are also based on the cause. The terms "oxidized" and "rancid" are sometimes used interchangeably, but to correct the problem, it is essential to determine the nuances in the flavor profiles so that the issue can be traced to the correct source. Therefore, for ease of troubleshooting, this subsection is organized by off-flavor.

Descriptors associated with Chemical off-flavors include:

- **Flat**. Described as watery based on mouthfeel, and/or less sweet. It lacks the pleasing sweetness, characteristic flavor notes of fresh milk and has a thin mouthfeel. No odor or aftertaste.

- **Foreign.** Refers to odors and flavors that are not commonly associated with milk. May be described as having a general chemical-like or medicinal character, or more specific descriptor (e.g., menthol). Foreign is a standardized term, evaluators should attempt to further characterize the flavor (e.g., "tastes like chlorine") to help identify the cause. Foreign off-flavors may also have absorbed, bacterial, and unknown or questionable origins.

- **Oxidized, Light-induced**. Light-induced oxidized flavors are described as burnt hair or feathers, cabbage-like, potato-like, and plastic. Light-induced oxidized flavor is common in bottled pasteurized milk, and a unique flavor that once learned, is easily detected.

- **Oxidized, Metal-induced**. Metal-induced oxidized flavors are described as cardboardy, tallowy, metallic and old oil-like. Metal-induced oxidized off-flavors are no longer common in dairy products.

- **Rancid**. Sharp, unclean, soapy, blue-cheese, or baby vomit-like flavors with an unpleasant after-taste.

- **Salty**. Salt is one of the basic tastes perceived on the tongue.

Flat Off-Flavors from Chemical Sources in Milk

Description of Flat Off-Flavors from Chemical Sources in Milk

Flat milk may be described as watery based on mouthfeel, and/or a less sweet taste. It lacks the pleasing sweetness, characteristic flavor notes of fresh milk and has a thin mouthfeel. There is no odor or aftertaste associated with a "flat" defect. A flat taste is caused by milk low in solids (chemical origin) or by the unintentional or intentional addition of water to the milk (processing origin). Milk that is "flat" generally does not elicit consumer complaints unless milk solids are excessively low.

Flat flavor may be confused with mildly light-induced oxidized milk. This can be checked by holding the sample for two or three days to see if the characteristic oxidized flavors develop.

Causes of Flat Off-Flavors from Chemical Sources in Milk

The flat off-flavor from chemical sources may be the result of milk with low solids as produced by the milking animal. Low milk solids is most often related to feeding practices that are lacking in proper nutritional balance. Genetics may also play a roll.

Prevention and Control Flat Off-Flavors from Chemical Sources in Milk

Farm management practices that ensure animal health and proper milk handling are key to preventing flat defects in the raw milk supply. Recommendations include:

- Work with animal nutritionist to ensure proper balanced rations.
- Monitor milk components, especially protein and lactose.

Foreign Off-Flavors from Chemical Sources in Milk

Description of Foreign Off-Flavors from Chemical Sources in Milk

Foreign is a broad descriptor that refers to off-flavors not commonly associated with milk. Foreign flavors of chemical origin may be described as having a general chemical-like note, or medicinal or "bandage" character.

Causes of Foreign Off-Flavors from Chemical Sources in Milk

Foreign off-flavors in milk from chemical sources are often the result of contamination with cleaning chemicals or other materials used in milk handling from milking through processing. Foreign off-flavors from chemical sources may also be absorbed into the milk as discussed previously, using the examples of kerosene odors from milkhouses, fruity flavors in milk transmitted through packaging during storage, and the use of medicinal ointments on milking animals.

Prevention and Control of Foreign Off-Flavors from Chemical Sources in Milk

Prevention and control strategies depend on cause, and it may be difficult to find the cause of foreign off-flavors from chemical sources. Recommendations include:

- Ensure that employees are well-trained using written standard sanitation operating procedures (SSOPs) that cover proper chemical usage and cleaning procedures. Applies at the farm and plant. Ensuring proper drainage is critical.
- Avoid using topical or other treatments on dairy animals that may transmit to the milk.
- Maintain an active chemical inventory management system to help reduce the incidence of chemical contamination into products. Applies at the farm and plant.
- Make certain that all milk storage areas (raw, bulk, packaged) are free from odoriferous substances that can be absorbed directly into exposed milk or through packaging such as:
    - Exhaust fumes in milk houses, plant storage and loading areas. Processing and storage areas free from chemical odors is critical.
    - Cleaners that have strong odors (e.g., spray disinfectants). Use only dairy chemicals.
    - Food items that have strong odors such as onions, citrus fruits in storage coolers.

Oxidized Off-Flavors in Milk

Description of Oxidized Off-Flavors in Milk

In dairy products, there are several mechanisms responsible for the oxidation of protein and fat (lipid) components in milk and generation of off-flavors. Oxidation reactions are complex. The cascading reactions are initiated by reactive oxygen at double bonds in the carbon chains of fats and proteins and can produce many different flavor compounds at different stages of the reactions. Each mechanism creates its own characteristic flavor profile, and in turn, determines the manner of prevention and control needed. Therefore, it is common to describe oxidized off-flavors by the way in which the oxidation reactions are initiated, but keep in mind that the substrate being oxidized (e.g., protein or lipid) or also influences the flavor compounds and profiles generated:

- Light-induced: catalyzed by exposure of milk to light.
- Metal-induced: catalyzed by exposure to some oxidizing metals.
- Spontaneous: oxidized off-flavors in milk occurring immediately after milking, with no apparent exposure to light or metal.

The most common cause of oxidized off-flavors in milk is exposure to light. Metal-induced and spontaneous oxidized off-flavors are not very common but do still occur.

As was noted above in differentiating between the terms “oxidized” and “rancid,” understanding nuances in the flavor profile helps identify the source of a problem and facilitates troubleshooting. There are also many nuances *within the category of oxidized flavors*, due to the cause of oxidation and the stage of reaction. Flavors may increase in intensity or change character as the oxidation reactions progress and the product ages.

Light-Induced Oxidized Off-Flavors in Milk

Description of Light-Induced Oxidized Off-Flavors in Milk

Light-induced oxidized off-flavors in milk can be described as having the flavor and odor of burnt hair, burnt feathers, cabbage-like, potato-like, medicinal, and plastic. Light oxidized flavor compounds include sulfide compounds (e.g., dimethyl sulfide) that result from the breakdown of proteins and aldehydes, esters, and ketones that result from the breakdown of fatty acids.

Unfortunately for the dairy industry, light-induced oxidized off-flavors are too common in retail containers of milk. Milk is very susceptible to light oxidation, with flavor changes that can be noticeable when milk is exposed to direct sunlight for as little as 5 minutes. Light oxidized flavors are also found in products like cottage cheese and sour cream when the retail plastic containers are too lightweight and do not contain sufficient light-blocking agents.

Causes of Light-Induced Oxidized Off-Flavors in Milk

The oxidation reactions are initiated by exposure to light. The amount of light that reaches retail milk is a function of the lighting used in the processing plant, warehouses, and retail locations and product packaging.

The Light-Induced Oxidation Reaction Mechanism in Milk

Oxidation reactions can be initiated by exposure to light and catalyzed by riboflavin (Vitamin B2), a photosensitive vitamin naturally occurring in milk. It is likely that other photosensitive compounds such as porphyrin and chlorophyll, are also involved. When these photosensitizers are activated, by natural or artificial light, a chain reaction is initiated which creates free-radical compounds and singlet oxygen that go on to form peroxides and participate in further oxidation reactions, which generate flavor compounds.

The amount of protein and fat that are broken down during these reactions is very small, but the flavor compounds produced are exceptionally strong. Riboflavin, as well as other vitamins (e.g., vitamin A) may be seriously depleted in oxidized milk.

Influence of Light Factors on Light-Induced Oxidized Off-Flavors in Milk

Factors relating to the light exposure that contribute to light-induced oxidized off-flavors include:

- Wavelength spectrum (color spectrum) and peaks of the light source.
- Distance of product from the light source.
- Light intensity at the product.
- Exposure time.
- Translucence of the milk packaging material (discussed in next section).

Any light which emits rays in the 350 to 650 nanometer range is potentially a source for initiation oxidation reactions. The catalyst riboflavin has a maximum absorbance of light in the 420 to 480 nm range. While riboflavin has been considered the primary photosensitive catalyst, more recent research suggests that protoporphyrin IX, chlorophyll are responsible for oxidation induced by wavelengths > 500 nm[15], making selection of lighting based on color spectrum / wavelength peaks challenging. The sources of light that affect milk flavor include sunlight, diffused daylight, fluorescent light, halogen, sodium, LED, and other vapor lamps. Sunlight emits radiation in the ultraviolet (100 to 400 nm), visible (400 to 700 nm), and infrared (700 nm to 1 mm) regions.

Controlling the wavelengths of light that reaches dairy products may be more difficult than controlling the amount and intensity of the light to which they are exposed. Direct

[15] (Wold et al, 2015).

sunlight can provide 6,000-foot candles (fc) (64,583 Lux) of light on containers of milk while intensity of light in store dairy display cases varies from less than 50 fc, (538 Lux) to more than 300 fc (3229 Lux).

The amount of light exposure in the retail case is a major source of light oxidized flavors in milk. Many grocery stores have extended hours, which means exposure time in the dairy cases, where bright lights are used for visibility and marketing. The use of LED lights has been implemented as an energy cost savings measure, but research has shown that LED lights either do not have a significant advantage to reducing light-induced oxidized off-flavors in milk or the results are mixed.[16]

Influence of Packaging on Light-Induced Oxidized Off-Flavors in Milk

The other key variable that influences the amount of light oxidized off-flavors present in milk and dairy products is the packaging. The more light that gets through the packaging, the more potential for oxidation reactions to occur and generate off-flavor. Traditional milk packaging was focused on cost and convenience for the manufacturer. The primary packaging materials for fluid milk were glass, paperboard, and translucent plastic jugs, with glass regaining some popularity in recent years.

Translucent and clear bottles, while popular for cost and marketing reasons, offer little protection against exposure to light in retail dairy cases and in consumers' homes. Neither glass nor translucent plastic is very effective at blocking light, and the market is moving away from gable-top paperboard milk cartons, hence the pervasiveness of light oxidized flavors in retail milk.

Manufacturers can add light-blocking agents (e.g., titanium dioxide) and pigments to the plastic and create opaque and colored milk jugs to reduce light transmission. While these materials may reduce light transmission, they do not provide 100% light blocking and therefor do not provide 100% protection against oxidized flavors.

Scientists continue to investigate the properties of new packaging designs, materials. and light blocking agents to deliver the best quality dairy products to the consumer.[17]

Prevention and Control of Light-Induced Oxidized Off-Flavors in Milk

The prevention of light oxidized flavors begins on the farm and continues through to processing, distribution, and in retail establishments. Most exposure occurs post-packaging, so prevention and control of light-induced oxidized off-flavors in milk requires reducing the amount of light that reaches the milk container and reducing the amount of light that passes *through* the container. Use of light-block packaging will further protect the milk flavor once in the consumer's home, contributing to a longer shelf life and increased consumer satisfaction.

Recommendations for Reducing Light Exposure in the Processing Plant and Distribution Chain

- Place containers, cases, stacks, and pallets of milk in a cold storage room immediately after filling to minimize exposure to daylight and bright lights in the processing area.

[16] (Brothersen et al., 2016; Martin et al., 2016; Potts et al., 2017).
[17] (Cadwaller et al, 2022; Chapman et al, 2002; Wang et al, 2022).

- Avoid installing fluorescent, halogen, low sodium, mercury vapor or any other similar lights in close proximity to the milk in cold storage rooms. Most energy efficient lights emit rays in the critical 350 to 500 nm range that causes light oxidation.
- Turn off cooler lights when possible.
- Design lighting and rotation systems in warehouses and distribution facilities to minimize light exposure of the containers in the top cases of stacks directly under lights. Sanitary covers (e.g., opaque plastic sheets) for the top of cases can be used.
- Keep load-out doors of the cold storage room closed except when in use to prevent sunlight and daylight exposure.
- Ensure that deliveries of milk cases are not left on the dock or other areas where direct sunlight may reach product containers.
- Provide guidance to retail stores on the risk to quality and how best to protect milk from light.

Recommendations for Reducing Light Exposure in Retail and Food Service Operations

- Reduce the intensity of existing fluorescent and LED lighting. Open, vertical dairy display cases usually provide far more light than is necessary.
- Use protective shields on lights to block the light energy.
- Limit the amount of time product is on display and exposed to light by stocking for a quick turnaround (less than 48 h) and rotating containers regularly.
- Do not use lights in the dairy case or area adjacent as night lights for the store.
- Turn off cooler lights when possible.
- Design lighting and rotation systems in cold storage areas to minimize light exposure of the containers in the top cases of stacks directly under lights. Sanitary covers (e.g., opaque plastic sheets) for the top of cases can be used.

Recommendations for Packaging for Milk and Dairy Products

- Work with your packaging supplier to incorporate light blocking agents to the plastic resins used for milk jugs. There are several FDA approved chemicals that can be added.
- Use colorants to block light and provide marketing interest to packaging.
    - Colors used for milk jugs include green, orange, yellow, white, and black; yellow has been used most often.
    - Consumers have shown a preference for clear containers so they can see the product level; providing a consumer education message on the package label explaining the use of opaque containers to preserve milk flavor from light exposure may improve acceptance.
- Use light-blocking over wraps and printed labels on clear containers and pouches. The more surface that is covered, the better the protection from light exposure, and the more space for information and marketing on the package.

Metal-Induced Oxidized Off-Flavors in Milk

Description of Metal-Induced Oxidized Off-Flavors in Milk

Metal-induced oxidized off-flavors in milk are described as metallic, stale, wet cardboard, tallowy, or old oil-like. Metal induced off-flavors primarily result from the oxidation of lipids.

Causes of Metal-Induced Oxidized Off-Flavors in Milk

Oxidation reactions can be catalyzed when milk comes in direct contact with certain metals (i.e., divalent copper (Cu), iron (Fe), manganese (Mn)). Metal-induced oxidized off-flavors used to be more common in milk because white or "dairy" metal, which contained copper, was used to manufacture dairy processing equipment. The copper would leach from the equipment into the products and initiate oxidation reactions and off-flavors. Requirements for dairy equipment as specified in the PMO no longer allow the use of this metal in dairy processing and so this should no longer be a source of metal-induced oxidized off-flavors.

A possible source of metal that can result in oxidized off-flavors that still occurs today is from copper water pipes on farms and in older processing plants. If water is acidic, it can leach copper from the water pipes and contaminate and/or form deposits on piping, equipment, and other milk contact surfaces. Additionally, the presence of metals in the water supply could serve as a source of contamination.

Prevention and Control of Metal-Induced Oxidation Off-Flavors

- Check all farm and plant equipment surfaces to assure they are stainless steel or other approved materials. White metal or copper bearing metal are not PMO approved surfaces.
- Use plastic rather than copper pipes if the water supply is acidic (pH of less than 7.0).
- Monitor water supply for iron and copper content, treat water if levels become a problem.

Spontaneous Oxidized Off-Flavors in Milk

Description of Spontaneous Oxidized Off-Flavors in Milk

Spontaneous oxidation can occur in milk from individual animals, with no apparent exposure to light, metal, or other catalysts. While this is an infrequent issue, it does occur, and the cause may not always be determined. Spontaneous oxidized off-flavors in milk can be described as stale, wet cardboard, tallowy, or old oil-like, and come from the breakdown of fats (lipids); essentially the same descriptors used for milk with metal-induced oxidized off-flavors.

Causes of Spontaneous Oxidized Off-Flavors in Milk

The cause of spontaneous oxidized off-flavors in milk may be difficult or impossible to determine. Possible causes include:

- High copper content in the milk, coming from either the animal's own genetic make-up or from copper contamination in the feed or water supply.
- Cattle receiving inadequate protein or total energy in their feed ration can produce milk that becomes oxidized more easily.
- Stored feeds may lose their antioxidant properties and have less ability to prevent oxidation in the milk in later winter and early spring.

Prevention and Control of Spontaneous Oxidation

- Work with animal nutritionists:
  - to determine the correct levels for vitamin supplementation (vitamins A and E) in the animal's diet to account for changes in the antioxidation capacity of the feed throughout the year.
  - to balance rations to reduce risk of spontaneous oxidation (e.g., fat levels, sources, copper / iron content)
- Monitor the water supply for high copper, iron or manganese levels in the animal's drinking water and treat if necessary.

Rancid Off-Flavors in Milk

Description of Rancid Off-Flavors in Milk

Rancid flavors in milk tend to be sharp and have an unpleasant character that can be described as soapy, blue-cheese, provolone cheese, or baby vomit-like with an unpleasant aftertaste. Rancid flavors are caused by volatile short chain fatty acids released during the breakdown of milk fats by enzymes. Rancid odors and flavors are primarily caused by butyric, capric, and caproic acids. Soapy flavors are caused by lauric and myristic acids, but free glycerol is the cause of any soapy sensation detected. A technique used to assist in detecting rancid odors is to place a thin film of milk on the back of the hand, give it a moment to let your hand warm the milk, and then inhale to detect the rancid odors.

It should be noted that while rancid flavors are undesirable in fluid milk, they are desirable in some cheeses like provolone, Romano, and feta. Lipase may be added to milk in the make process to provide the rancid note that is characteristic of these cheeses.

As stated in the previous section on oxidized off-flavors, the terms "oxidized" and "rancid" are sometimes used interchangeably to describe off-flavors, but to correct the problem, it is essential to determine the nuances in the flavor profiles so that the issue can be traced to the correct source. Rancid flavors have different characteristics, different causes, and different control mechanism than oxidized flavors.

Causes of Rancid Off-Flavors in Milk

The Mechanism of Rancidity Reactions in Milk

The mechanism that causes rancid off-flavors in milk is called lipolysis. In this reaction, enzymes breakdown triglycerides, the principal form of fat in milk, by hydrolyzing, or cleaving, individual free fatty acids (FFA) from the glycerol backbone. The shorter chain free fatty acids, from 4 to 10 carbons in length, are volatile and contribute to dairy flavors.

The enzymes that breakdown fat are called lipases. Lipases that cause rancid off-flavors are naturally present in milk, but can also come from somatic cells, bacterial contaminants, and bacteria that are added to milk in the production of fermented dairy products. Lipases naturally present in milk are heat sensitive and, therefore, are mostly inactivated by pasteurization. While proper pasteurization halts inherent lipase enzyme activity, it does not remove any rancid flavors that may have already developed. Some microbial lipases are thermo-stable and may be responsible for rancid flavor development in stored pasteurized milk.

Hydrolytic rancidity reactions occur when the enzyme is in direct contact with the triglyceride molecules. In milk, most of the triglycerides are located in the core of the milk fat globule that is protected by a membrane, which prevents the lipase from reacting with the fat. When the milk fat globule membrane is damaged the lipase is able to make contact with the milk fat resulting in lipolysis.

Some dairy animals produce milk that is more susceptible to developing rancidity, sometimes referred to as "spontaneous rancidity." While not common, it has been known to occur in milk. Typically, cattle in late lactation, or with low production, and/or are nutritionally deficient are more likely to produce milk that is or becomes rancid. Mastitis and increased somatic cell counts can be a contributing factor.

Influence of Milk Handling on Rancid Off-Flavors in Milk

Milk fat globule membrane damage can be caused mechanically by rough handling of the raw milk from farm to processing, prior to pasteurization. Generally, most damage is done when the milk is still warm, so prompt cooling is critical. Milk handling activities that may promote rancidity include:

- Violent or excessive agitation of warm raw milk.
- Excessive pumping.
- Pumping raw milk through underfed or "starved" centrifugal pumps or obstructed pipelines.
- Poorly sloped milk lines or risers that promote milk slugs. Milk slugs occur when lines under vacuum, where milk flows primarily by gravity, become totally flooded such that the vacuum aggressively sucks a "slug" of milk.
- Poorly sized milk lines for the amount of milk/milkers that promote milk slugs.
- Leaking fittings (e.g., gaskets, hoses, milk hose inlets) that allow air to enter the milk stream.
- Freezing of raw milk in milk tanks.
- Separating or clarifying warm raw milk that is not immediately pasteurized.
- Homogenizing raw milk below 140°F (60°C) without pasteurizing immediately.
- Mixing homogenized milk and raw milk or homogenized products with raw milk (i.e., rework products).

Prevention and Control of Rancid Off-Flavors in Milk

One of the most important ways of preventing rancid off-flavors in milk is the gentle handling of raw milk. Thus, attention at the farm, during hauling, and at the processing plant prior to pasteurization are warranted to protect milk flavor.

Prevention and Control of Rancid Off-Flavors at the Farm

Farm management practices that ensure animal health, and address equipment maintenance and proper milk handling are key to preventing rancid off-flavors.[18]

Important aspects include:

- Keep herd and individual animal somatic cell counts low.
- Cull animals that produce spontaneously rancid milk and/or those with low production.
- Work with animal nutritionist for optimum production.
- Minimize the number of milking animals that are in late lactation.
- Ensure that milking equipment is properly designed for the milk volume and the number of milking units used and operated to ensure a gentle flow of milk.
    - Ensure pipelines are properly sloped and sized to prevent slug formation.
    - Generally, low-line parlors are less likely to cause rancidity than high-line or stanchion (round the barn) systems. Bucket milkers are also gentle to the milk.
- Limit air intake at teat cup clusters to a minimum.
- Check for unintentional air leakage through teat cups, milk hoses, milk line inlets, receiver jars, milk pumps, cracked / loose gaskets, and other potential sites.
- Use properly sized bulk milk tanks.
    - If the tank is too large, proper agitation will be impossible during the first milking and freezing may occur. Freezing will disturb the milkfat globule membrane.
    - If the tank is too small, then it may need to agitate for excessive lengths of time to cool the milk.
- Inspect milk tank for signs of foam that may indicate air incorporation.

Prevention and Control of Rancid Off-Flavors During Milk Hauling

The milk hauler must exercise similar care to prevent rancid flavor development. Important aspects include:

- Check milk prior to loading for off-odors and excess foam and to ensure that milk is cold.
- Minimize pumping air and foam when the bulk milk tank is empty. The truck pump should not run more than 30 seconds at the end of the pickup.
- Be mindful of excessive agitation of mixed milk tank loads prior to sampling.
- Minimize transporting partial milk loads over long distances.

Prevention and Control of Rancid Off-Flavors at the Processing Plant

The damaging effects of mechanical handling in each step from farm to package are cumulative. The most effective means of preventing rancid flavors in milk from plant causes is the rapid processing of the milk and milk products.

Important aspects include:

[18] For more information see DPC Guidelines: DPC002, *Effective Installation, Cleaning, and Sanitizing of Milking Systems*, DPC004, *Installation, Cleaning, and Sanitizing of Large Parlor Milking Systems*, DPC018, *Field Person's Guide to Troubleshooting High Somatic Cell Counts*, DPC070, *Small Ruminant Milking Systems*, DPC071, *Somatic Cell Counts in Sheep*, DPC072, *Somatic Cell Counts in Goats*, DPC098, *Milking Procedures for Dairy Cattle*, DPC101, *Farmer's Guide to High Somatic Cell Counts in Cattle*, DPC102, *Installation, Cleaning, and Sanitizing of Tie Barn Milking Systems.*

- Check milk prior to off-loading for off-odors and to ensure that milk is cold.
- Inspect equipment operations and procedures regularly to maintain the integrity of the milk fat globule membrane.
- Store milk cold and process as rapidly as possible after receiving.
- Avoid excessive agitation in raw milk tanks.
- Check for unintentional air leakage in pumps, and pipelines.
- Pasteurize separated or clarified warm raw milk immediately.
- Avoid homogenizing raw milk below 140°F (60°C) unless it is immediately pasteurized.
- Never mix homogenized milk with raw milk.
    - If it is necessary to rework homogenized milk with raw milk for manufactured products, the raw milk should first be pasteurized, or the mixture immediately heat-treated after combining the two.
- Pasteurize milk above minimum legal pasteurization temperatures to ensure more complete destruction of natural milk lipase.

Salty Off-Flavors in Milk

Description of Salty Off-Flavors in Milk

Salt is one of the basic tastes perceived on the tongue. The salty taste is perceived relatively quickly, and the milk will likely be perceived as less sweet.

Causes of Salty Off-Flavors in Milk

Salty milk is the result of an increase in the sodium chloride (NaCl, salt) content in milk that occurs when animals have mastitis or are in the late stages of lactation. This is rare defect in milk, especially in large, well-managed herds, but may occur in smaller herds where management practices are lacking.

Prevention and Control of Salty Off-Flavors

For salty milk caused by mastitis, the obvious prevention and control is better animal health management. The increase in sodium due to lactation stage is a normal occurrence and typically is not a problem in commingled milk, unless the herd is seasonal (all freshen at once).[19]

Processing Off-Flavors in Milk

Description of Processing Off-Flavors in Milk

Processing off-flavors occur as a result of how milk was handled during the manufacture and storage of pasteurized milk and dairy products. Many off-flavors described in the previous sections on absorbed, bacterial, and chemical off-flavors may occur during processing and storage, but the focus in this section is on off-flavors that are a direct result of processing and storage operations that were not previously discussed.

[19] See DPC Guidelines: DPC018, Field Person's Guide to Troubleshooting High Somatic Cell Counts, DPC071, *Somatic Cell Counts in Sheep*, DPC072, *Somatic Cell Counts in Goats*, DPC098, *Milking Procedures for Dairy Cattle*, DPC101, *Farmer's Guide to High Somatic Cell Counts in Cattle.*

Two common descriptors associated with processing operations were previously discussed in detail are:

- **Foreign**. Foreign is a descriptor that refers to odors and flavors that are not commonly associated with milk and can come from a variety of sources.
- **Refrigerator/Storage.** Refrigerator or storage flavors in pasteurized milk are absorbed from the environment when milk is stored in areas that have strong flavors such as onions, garlic, fruits, cheeses, and smoked meats. The flavor characteristics range depending on the item emitting the strong flavor, or may generally be classified as a stale, dirty refrigerator aroma.

Descriptors associated exclusively with processing that are discussed in this category of off-flavors are:

- **Cooked.** Cooked flavors range from rich, caramelized to sulfurous and eggy or burnt, and may be desirable or undesirable depending on the product.
- **Flat.** Described as watery based on mouthfeel, and/or less sweet. It lacks the pleasing sweetness, characteristic flavor notes of fresh milk and has a thin mouthfeel. No odor or aftertaste.
- **Package/Plastic.** Flavors may be absorbed from paperboard and plastic containers and described as plastic-like, carton, wet paper, or burnt paper.

Cooked Off-Flavors in Milk

Description of Cooked Off-Flavors in Milk

Cooked flavors in milk can exhibit a range of desirable and undesirable flavors described as slightly sweet, rich, heated; to caramelized, slightly sulfurous and eggy; to overly sulfurous, burnt or scorched, and cabbage-like.

Causes of Cooked Off-Flavors in Milk

Cooked off-flavors are the result of the degree of heat treatment used for milk processing. Mild "cooked" flavor is generally the result of denaturation of whey proteins. It is often found in pasteurized fluid milk at low levels and is not considered objectionable. In some instances, a slightly cooked note is desirable such as in butter and French vanilla ice cream. A more severe form of cooked is "scorched," which is caused by the caramelization of the sugars in the milk during pasteurization at too high a temperature or for too long.

While minimum pasteurization parameters generally will not result in significant cooked flavors, many plants use conditions above minimum. Cooked flavor intensity typically increases with process type as follows:

- High Temperature Short Time (HTST) – absent or slight at minimum temperatures; can be slight to pronounced as hold temperatures increase (e.g., >168°F).
- Vat Pasteurization – slight to definite.
- Ultra-Pasteurized (UP) – definite to pronounced (strong sulfurous).
- Ultra-High Temperature (UHT) – pronounced (caramelized, cabbage-like).

Packaging also plays a role in the persistence of cooked aromas and flavors in the product, as most cooked flavors are due to volatile compounds that dissipate over time. Packaging with more barrier properties will retain the cooked flavor longer. UHT/aseptic milk will generally retain strong cooked off-flavors longer than UP milks due to the high barrier properties of packaging used, even though heat treatments may be similar.

Prevention and Control of Cooked Off-Flavors in Milk

To prevent and control cooked off-flavors in milk:

- Control and monitor pasteurization times and temperatures to avoid excessive pasteurization time and/or temperature.
- Avoid recirculation of milk in an HTST system due to downstream issues; should be kept to a minimum as each time the milk is recycled through the processor the likelihood of this defect increases.
- Consider packaging used relative to the milk processing used.
- Delay distribution as appropriate to allow cooked off-flavors to dissipate (e.g., hold UP milks for 3-5 days before distribution), packaging dependent.

Flat Off-Flavors from Processing in Milk

Description of Flat Off-Flavors from Processing in Milk

Flat milk may be described as watery based on mouthfeel, and/or a less sweet taste. It lacks the pleasing sweetness, characteristic flavor notes of fresh milk and has a thin mouthfeel. There is no odor or aftertaste associated with a "flat" defect. A flat taste is caused by milk low in solids direct from the milking animal (chemical origin, discussed previously) or by the unintentional or intentional addition of water to the milk (processing origin) that "water downs" the solids content. Milk that is "flat" generally does not elicit consumer complaints unless milk solids are excessively low.

Flat flavor may be confused with mildly oxidized milk. This can be checked by holding the sample for two or three days to see if an oxidized flavor develops.

Causes of Flat Off-Flavors from Processing in Milk

Flat milk is most often associated with added water that gets into the milk through raw milk handling or plant processing errors, such as not fully draining lines and tanks before starting filling operations.

While rare, intentional watering of milk for economic gain has occurred. Added water can be more readily detected in milk supplies by measuring its Freezing Point (FP); most milks are less than minus 0.540°H (more negative), although minus 0.530°H is often used as a cut-off.[20]

Prevention and Control of Flat Off-Flavors in Raw Milk

Farm management practices that address proper milk handling are key to preventing flat off-flavors from added water in the raw milk supply. Recommendations include:

[20] For more information see: DPC017, *Prevention of and Testing for Added Water in Milk*.

- Ensure that milking systems and storage tanks are designed and routinely inspected for proper drainage (proper slope and drainage points).
- Avoid flushing milk lines with water.
- Follow standard operating procedures to ensure minimal residual water in tanks or lines. Prior to first milking:
  - inspect bulk tank, receiver jar, and other components to ensure proper drainage.
  - ensure that wash lines are disconnected from milking system.
- Inspect milk trucks (hauler) to ensure they are properly drained prior to first pick-up.

If there is a trend for a producer to have high FP (more than a one-time occurrence), then a milking time inspection may be warranted to rule out added water as the cause:

- Prior to the first milking, thoroughly inspect the empty bulk tank and milking system to ensure proper drainage and that water/wash lines are not connected.
- Observe milking procedures to ensure that water is not added (e.g., milk claw flush).
- Observe shutdown and wash and sanitization procedures.
- Sample bulk tank at the end of the first milking and test for FP.
- Repeat for subsequent milkings (should cover AM & PM) and loads as appropriate.
  - If FP is still high (less negative) without evidence of added water, it can be assumed that cause may be nutritional or genetic in nature.
  - If FP is normal with repeated milk time inspections, added water on original testing may have been the cause (unless a dramatic shift in cows/feed occurred).

Prevention and Control of Flat Off-Flavors at the Processing Plant

Proper quality assurance procedures are key to preventing added water and flat off-flavors:

- Check FP of all incoming milk supplies prior to off-loading. Reject loads as appropriate.
  - If FP are high (less negative), determine root cause:
    - Test producer samples, trace to producer (see above).
    - Inspect hauler procedures. Retrain as needed.
- Monitor milk components, especially protein and lactose of incoming milk supply.
- Check raw milk storage tanks after washed/sanitized and prior to filling with milk to ensure proper drainage.
- Ensure that milk handling systems and storage are designed and inspected for proper drainage (proper slope and drainage points).

- Follow standard operating procedures to ensure minimal residual water in tanks or lines. Prior to processing:
  - Inspect pasteurized storage tanks, filler bowls, lines, and other components to ensure proper drainage.
  - Ensure that water/wash lines are disconnected from processing system.
- Develop HTST start-up and shut down procedures to prevent added water:
  - At start-up, use FP or flow rate to determine *time* when milk is free of water before it is diverted to pasteurized milk tanks.

- At shut down, use FP or flow rate to determine *time* when milk will become contaminated with water, to ensure that it is diverted to drain when flushing the system when pasteurization is complete.

Package/Plastic Off-Flavor in Milk

Descriptors of Packaging Off-Flavors

Off-flavors related to packaging may be described as plastic-like, carton, wet paper, or burnt paper. Off-tastes/odors may be very subtle.

Some off flavors related to packaging may be perceived as similar to "light-induced oxidized," so care in interpretation is needed.

Causes of Package/Plastic Off-Flavors in Milk

Package and plastic off-flavors in milk typically result from absorption of off-flavor compounds from the packaging directly into the milk. This can occur with less expensive grades of plastics, defective paperboard, and/or poor-quality control at the supplier.

For paperboard packaging, the degree of heat seal applied is critical for proper carton closure (no leaks, easy to open). Excess heat can result in cartons difficult to open and potential "carton" off-flavors. Unless burnt, these tend to be very subtle in nature and occur more frequently in smaller cartons (e.g., half-pints vs half-gallon) due to increased surface area to volume.

Prevention and Control of Package/Plastic Off-Flavors in Milk

Preventing off-flavors and defects related to product packaging begins with the supplier and carries through the filler and package handling. Recommendations include:

- Purchase packaging materials only from reputable approved single service providers. Work with suppliers to meet your needs and correct issues when they arise.
- Test each new lot of packaging received e.g., taste product after filling.
- Use the appropriate packaging design for the fillers used.
- Set heaters for paperboard packaging at the minimum required to ensure proper seal.
- Inspect packaging after filling and in the cooler for damage, leaks, or soils.

"Questionable" Off-Flavors in Milk

Description of "Questionable" Off-Flavors in Milk

This last category of off-flavors in milk is called unknown, or "Questionable," because while the flavor profiles may be common in milk, their causes are unknown or not captured in a previous discussion. The off-flavors in this category are:

- **Bitter.** A sharp, unpleasant flavor. Bitter is one of the basic tastes perceived on the tongue. Bitter flavors result from the action of non-bacterial enzymes that break down proteins into peptide fragments that are perceived as bitter. Bitter is a common off-flavor in spoiled pasteurized milk.

- **Lacks Freshness.** Described as a product losing its characteristic sweet, fresh dairy flavor before the end of shelf-life.

Bitter Off-Flavors in Milk

Description of Bitter Off-Flavors in Milk

Bitter is a sharp, unpleasant flavor, and one of the basic tastes perceived on the tongue. Bitter flavors in milk result from the breakdown of proteins by enzymes.

Causes of Bitter Off-Flavors in Milk

Bitter flavors result from enzymes present in milk that break down proteins (proteases) into peptide fragments that are perceived as bitter. Common sources of enzymes include bacteria (covered under Bacterial Off-Flavors), somatic cells, and enzymes found naturally in milk.

Prevention and Control of Bitter Off-Flavors in Milk

Prevention and control of bitter off-flavors in milk starts with having high quality milk that is low in somatic cell count to keep the initial load of unwanted enzymes to a minimum in the raw milk.

Lacks Freshness Off-Flavors in Milk

Description of Lacks Freshness Off-Flavors in Milk

A typical off-flavor associated with quality issues in dairy products is "lacks freshness," which is described as a product losing its characteristic sweet, fresh dairy flavor before the end of shelf-life.

Causes of Lacks Freshness Off-Flavors in Milk

The cause of this flavor is often not clearly defined and may be indicative of the beginning stage of more serious defects such as microbial spoilage.

Recommendations for prevention and control of lacks freshness flavor include:

- Pay attention to incoming raw milk quality.
- Watch milk handling and sanitation throughout storage.
- Maintain a good sensory evaluation program to monitor when the lacks freshness off-flavor is detected to assist with troubleshooting the cause.

Sensory Evaluation of Milk

The routine sensory evaluation of milk and milk products is a critical part of any processor's robust quality assurance program. The ability to follow up on consumer complaints is helpful but finding issues before the consumers do is even better. To ensure the production of high-quality dairy products with clean, characteristic flavors and a long shelf life, start by monitoring incoming raw milk for quality and rejecting poor quality loads, and continue by evaluating the product through the end of its shelf life to understand when off-flavors develop.

Milk is the highest quality possible as it comes from the cow, and anywhere along the route from cow to finished product can cause off-flavors to develop. Being able to describe and identify an off-flavor can greatly assist with finding the root cause of a problem during troubleshooting. As a reminder, this Guideline is focused on off-flavors associated with dairy cattle milk. To identify and detect off-flavors successfully and consistently, it is necessary to be familiar with the characteristics of a processors' normal milk. Milk from dairy cattle, goats, sheep, water buffalo, and other dairy animals will each have a unique taste and mouthfeel based on the normal composition of the particular milk.

Basic information on the sensory evaluation of milk is contained in this Guideline for easy reference.[21]

Sensory Tools

This guideline focuses on "off-flavors" in milk and milk products. While "flavor" and "taste" are often used interchangeably, flavor has been described as "a blend of *taste* and *smell* sensations evoked by a substance in the mouth" (Merriam-Webster). Depending on the product evaluated, all senses may, and should be utilized when possible. The use of all senses is illustrated below using an ideal milk sample as an example:

- *Vision* – visual inspection shows the milk to be uniform, free from particles, off-colors, coagulation, and separation. Raw milk may have a cream line after settling.
- *Smell* – milk should have a clean, dairy odor; slight feed odors may be noted in raw milk. Many off-flavors are easily detected by smell (if it does not pass the nose, no reason to taste). The volatile compounds that provide "flavor" are usually perceived in the nose by the sense of smell, rather than in the mouth by the sense of taste.
- *Taste* – when placed in the mouth, milk should be slightly sweet, with no off-notes or aftertaste. Taste refers to the basic tastes as detected by receptors on the tongue (sweet, sour, bitter, salty, umami). Basic tastes generally have little, or no smell associated with them. "Flavor" however is perceived in the mouth, combining taste and smell.
- *Touch* – when placed in the mouth, milk should feel slightly creamy, but not greasy or chalky on the tongue and in the mouth ("mouthfeel"). The sense of touch as evaluated with the fingers may be used to describe textual defects in other products such as cheese.
- *Sound* – the sound of mixing milk when preparing samples or swirling in a cup should sound smooth and fluid, coagulated milk will differ.

People and Points for Sensory Evaluation of Milk

A robust, comprehensive QA program includes sensory evaluation that starts at the farm and continues through the end of the expected shelf life of the product. If poor quality milk can be identified early in the processing chain, it can be removed before it contaminates larger quantities of good quality milk, thereby improving the quality of the commingled milk. Milk and milk products should be evaluated *by trained individuals*. People and points where milk and milk products should be evaluated include:

- *Milk Haulers* / *Farm Pick-Up* - haulers are required to check farm tanks for defects visually and by smell. Haulers should be trained to recognize objectionable odors, and these should be rejected or sampled for confirmation before loading the tanker.

[21] More detailed information on these subjects can be found in reference books such as *The Sensory Evaluation of Dairy Products* (2009) and the *Standard Methods for the Evaluation of Dairy Products* (2004).

- *Plant Milk Receivers / Raw Milk Receiving* - a visual and aroma check should be performed on each load received at the processing plant prior to unloading.
- *Plant QA Personnel / Raw Milk Storage* - raw milk from plant storage tanks should be evaluated just prior to processing, depending on storage time. ***NOTE***: Flavor evaluation on raw milk is not recommended due to the potential presence of pathogens. If flavor evaluation on an incoming raw milk sample is needed, it should be pasteurized in the laboratory prior to testing. Milk and dairy product samples should be tasted after pasteurization and throughout shelf life to ensure product quality.
- *Plant QA Personnel and/or Plant Filler Operators / At Filling* - packaged pasteurized milk should be evaluated by sight, smell, and taste at the initial start-up for each filler.
- *Plant QA Personnel / Product Hold* - packaged pasteurized milk representing all products and fillers should be held at temperatures likely to be found in retail for evaluations over shelf-life.
- *Consumers / Home Use* - all consumer complaints should be taken seriously and documented, including the consumer's complaint description (e.g., tasted like plastic). Corrective actions should be taken as needed.

Preparing and Handling Milk Samples for Evaluation

In any quality control program, proper sampling technique is critically important. A sample that is not representative of the supply, unclean or is contaminated will yield results that are misleading. Care must be taken in training personnel and procuring and storing milk samples in an acceptable manner.[22]

Important aspects include:

- The sample container should be clean and free from any contributing odor or flavor. If used for bacterial analysis and/or stored for further evaluations it must be sterile (e.g., single-service sample vials). The sample container must have a tight-fitting lid.
- Sample containers used for flavor and odor evaluation should be tightly covered and not be filled more than three-quarters full to provide an air space to collect and concentrate the volatile odors from the milk.
- Splitting a milk sample, raw or pasteurized, for re-examination on two different occasions is useful in determining and/or confirming rancid, oxidized, bacterial, and other off-flavors where the flavor develops over time and may not be easily identified on the initial evaluation. It is best that samples be split at the source and while the milk is stored refrigerated.
- Raw Milk Samples:
  - should be taken from a well-mixed tank, being particularly careful not to overagitate raw milk and initiate rancidity reactions.
  - must be taken with properly cleaned and sanitized stainless-steel dippers or other approved sampling devices.
  - sterile single-service sample vials should be used for all raw milk samples.
- All samples should be stored refrigerated (≤ 40ºF (4.4ºC), unless used for shelf-life testing) and protected from light, heat, potential absorbed odors, and excessive agitation until prepared for evaluation.

[22] For more information see: DPC007, *Sampling Fluid Milk*, DPC010, *Maintaining and Testing Fluid Milk Shelf Life*.

- When presented for tasting, the size of the sample necessary to make an accurate flavor evaluation is about two ounces (60 ml). Four-ounce lidded cups work well and provide sufficient sample size and head space for individual tastings.

Pasteurized milk samples collected for sensory evaluation should be representative of the products and the processing and filler lines. The extent of sampling and evaluations will depend on the dairy plant's quality assurance protocol, storage space, and resources. Considerations for collecting and evaluating finished pasteurized product samples include:

- Representative of raw milk storage tanks used.
- Representative of product types (e.g., fat levels, flavors), pasteurizing systems, and pasteurized milk tanks used.
- Representative of fillers and package sizes used; specific filler valves can be sampled if applicable or during troubleshooting, but this is often not practical for large multi-valve fillers on a routine basis.
- Initial milk to filler and after changeovers to detect defects related to raw milk or sanitizer contamination.
- Milk should be stored at selected shelf-life temperature (e.g., 43°F (6.1°C)) and tested at code date or code date plus expected days past code.

Sensory Evaluation Procedures

Sensory Evaluation of Raw Milk Samples

The evaluation of raw milk should be by smell only, as there is a risk of the milk containing pathogens that may cause human illness. Milk haulers should open bulk tanks and evaluate the milk by visual inspection (e.g., for off-color; debris) and by odor before it is loaded to the tank truck. Milk receivers must do the same before the milk is pumped off into plant storage.

If the odor is questionable but not certain, then the sample should be collected for further odor evaluation and/or to be *laboratory pasteurized* so the milk can be tasted safely. Allowing a raw milk sample to warm (e.g., run the closed container under warm water), may make off-odors easier to detect and identify.

If a raw milk sample must be tasted, it should be pasteurized in the lab first, following proper procedures. Milk may be lab pasteurized in single service containers or appropriate laboratory glassware that will stand a 100°F (37.8°C) change in temperature. The general procedure for lab pasteurization is as follows:

1. Heat a circulating water bath controlled at 145°F ± 1.0°F (62.8°C ± 0.5C). It is recommended that water temperature be slightly higher to ensure that the sample reaches a minimum of 145°F (62.8°C).
2. Seal the lid of the sample container and fully submerge it into the water bath along with a sample container of equivalent sized and volume as a temperature control with a calibrated thermometer.
    a. Sample container should be leak proof, capped, and sealed and filled to no more than 3/4 full.
    b. It is preferable to gently agitate the samples during heating and cooling. This provides better heat transfer and prevents the formation of a skin on the surface.
    c. Alternatively, the sample containers can be submerged such that water bath level is at least 1 inch above the level of the milk in the sample container.

d. Care should be taken to avoid any milk droplets on the container wall above the milk level (e.g., use a pipet to fill container).

3. As soon as the sample reaches the desired temperature, start timing, and hold for at least 30 minutes. Temperature must be maintained at >145°F (62.8°C) for the entire time.
4. Immediately cool the sample along with temperature control in an ice-water bath. Cool to 60°F (15.6°C) if it is to be tasted right away or to 40°F (4.4°C) if it is to be stored.

Caution: Do not overheat the samples. A strong, cooked flavor may mask all but the strongest off-flavors. Lab pasteurized milks may have a mild cooked flavor.

Sensory Evaluation of Pasteurized Milk and Dairy Product Samples

For best results, milk judging should be done in a well-lit, well-ventilated, quiet room as available. Milk samples must be protected from light as possible prior to judging. Ideally a reference, defect-free milk should be available.

The following steps are a useful guide to the sensory evaluation of milk when preparing for a formal sensory panel:

1. **Mix**. It is important to evaluate a representative sample. General mixing procedures include those used for bacteriological testing (e.g., invert 25 times for retail samples), or appropriate depending upon the container.
2. **Pour.** Pour equal amounts of each sample into individual cups with lids. Equal sample amounts ensures that each judge receives a sample that has been equally tempered.
3. **Temper**. Ideally milk should be 55-65°F (12.8-18.3°C) for evaluation so that any odor present may be detected readily by smelling the container headspace.
4. **Agitate.** Before removing the lid, gently swirl the milk and look for a thin film of milk on the inner surface. Milk will generally leave an even coating on the cup that falls slowly. Observe for coagulated milk, butter flakes, off-colors, or other abnormalities.
5. **Smell**. Immediately after swirling, place nose directly over the container and open the lid while inhaling a full whiff of air. Note any off-odor. If a pronounced, objectionable odor is present, tasting may not be required.
6. **Taste.** Take a generous sip, roll the sample about in the mouth, note flavor sensations, and expectorate. Swallowing milk makes it more difficult to purge a bad flavor from the mouth between samples and may satiate one's appetite, reducing the ability to discriminate flavors, and should be avoided.
7. **Breathe**. Draw a breath of fresh air slowly through the mouth and then exhale slowly through the nose to enhance detection of off-flavors and note any aftertaste.
8. **Rinse**. Rinse mouth with water after tasting an objectionable sample. A piece of unsalted "saltine" is also useful for cleansing the palate.

The following steps are a useful guide to the sensory evaluation of milk when preparing for a less formal panel, such as might be conducted in an industry setting when evaluation time needs to be quick, the evaluation group is standing close together, and/or there is a high throughput of samples:

1. **Mix**. Mix well for a representative sample. Procedures will depend upon the container.
2. **Smell**. Immediately after mixing, place nose directly over the container and open while inhaling a full whiff of air. Note any off-odor. If a pronounced, objectionable odor is present, tasting may not be required.

3. **Pour** into the tasting cup.
4. **Swirl** and observe for visual defects.
5. **Smell** the milk in the cup again.
6. **Taste** a generous sip, roll the sample in the mouth, note flavor sensations, expectorate.
7. **Breathe**. Draw a breath of fresh air slowly through the mouth and then exhale slowly through the nose to enhance detection of off-flavors and note any aftertaste.
8. **Rinse**. Rinse mouth with warm water after tasting an objectionable sample. A piece of unsalted "saltine" is also useful for cleansing the palate.

The Sensory Ballot and Scoring

The design of sensory ballots and scoring systems is unique to each processor's situation. Different attributes may be evaluated at different times throughout shelf life, therefore requiring different ballots or a way of differentiating multiple evaluation attributes and dates on the same ballot. Scoring systems can vary widely, but the important point is that by assigning numbers to attributes, processors have a way to analyze the data, track trends, identify outliers, and assist in other production monitoring and troubleshooting.[23]

The Collegiate Dairy Products Evaluation Contest (DPEC) represents one example of milk judging. This contest only evaluates the flavor of milk due to contest constraints, but processors may also want to evaluate the body and appearance characteristics of their products as well. The DPEC uses a 10-point system for milk evaluation, with 10 being perfect. Each attribute has its own score for slight, definite, and pronounced levels of off-flavors. What are often considered minor processing defects, such as cooked, is scored as a 9 for a slight level, whereas a slight level of acid in milk is scored as a 3 because it is highly objectionable and represents a serious failure of quality, and potentially safety, on the part of the processor. Suggested milk flavor attributes and scores are:

Flavor Criticism	**Intensity of Defect**		
	Slight	**Definite**	**Pronounced**
Acid (sour)	3	1	0
Bitter	5	3	1
Cooked	9	8	6
Feed	9	8	5
Fermented/Fruity	5	3	1
Flat	9	8	7
Foreign	5	3	1
Garlic/Onion	5	3	1
Lacks Freshness	8	7	6
Malty	5	3	1
Oxidized – Light	6	4	1
Oxidized – Metallic	5	3	1
Rancid (Lipolysis)	4	1	0
Salty	8	6	4
Unclean	3	1	0

[23] Information on typical attributes to use for milk ballots and suggested scoring systems can be found in references such as *The Sensory Evaluation of Dairy Products* book and the *Collegiate Dairy Products Contest* website (www.dairyproductscontest.org). These should be used as guidelines and adapted to each processor's needs.

An alternate scoring system would be to use a rating system such as below, which would benefit from having a numerical value or range for acceptability:

Good	No discernable defect
Fair	Mild to moderate defect that a consumer is not likely to notice or find objectionable in cold milk
Poor	Distinct defect that consumers will notice in cold milk and find objectionable

Using Sensory Evaluation Data

The value in having a robust quality assurance program that includes a formalized sensory evaluation program is that a processor has data and a way to collect history on their products. This data can help track trends, identify outliers, and assist in other production monitoring and troubleshooting situations.

Tracking sensory data can be as simple as recording scores in a notebook for small processors or having a sensory department and computerized ballot data collection and analysis system. Whatever the means used, the take home message is that sensory evaluation is a powerful tool that should be used routinely by processors to assure themselves that they are providing the highest quality, safest dairy products to their customers.

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