INTRODUCTION

Correct identification is one of the major problems facing those working with milk flavors. This committee sought first to develop a practical classification for off-flavors. Next, methods for producing some of the more common off-flavors were studied. Finally, a bibliography covering the literature from 1950 to 1976 on off-flavors was prepared. This report is intended to aid in training both research and quality control personnel in the hope that more uniform terminology will result.

NOMENCLATURE

The present terminology for describing off-flavors in milk includes different types of terms. Descriptive terms such as papery, associative terms such as oily, or causative terms such as oxidized are used. A classification based on causes is simpler and more useful than the present system. On this basis off-flavors were divided into seven categories which are listed in Table 1 along with corresponding descriptive and associative terms.

This classification is not perfect, but it should aid in training personnel to identify off-flavors and their causes at the same time. This scheme should eliminate pointless quibbling over such things as whether an oxidized sample tastes metallic or papery. Regardless of which term is used, the remedy lies in preventing oxidation. The committee recognized that causes of some flavors are not known. Such flavors would be placed in the miscellaneous category until the causes have been identified.

Heated Flavor

The effect of heat treatment on milk flavor is generally recognized. The kind and intensity of the flavor depends on the time and temperature of the treatment.

There appear four kinds of heat-induced flavor alternations: cooked or sulfurous, heated or rich, caramelized, and scorched. Pasteuriza-
TABLE 1. Categories of off-flavors in milk.

<table>
<thead>
<tr>
<th>Causes</th>
<th>Descriptive or associative terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heated</td>
<td>cooked, caramelized, scorched</td>
</tr>
<tr>
<td>Light-induced</td>
<td>light, sunlight, activated</td>
</tr>
<tr>
<td>Lipolyzed</td>
<td>rancid, butyric, bitter*, goaty</td>
</tr>
<tr>
<td>Microbial</td>
<td>acid, bitter*, fruity, malty, putrid, unclean</td>
</tr>
<tr>
<td>Oxidized</td>
<td>papery, cardboard, metallic, oily, fishy</td>
</tr>
<tr>
<td>Transmitted</td>
<td>feed, weed, cowy, barny</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>absorbed, astringent, bitter*, chalky, chemical, flat, foreign, lacks freshness, salty.</td>
</tr>
</tbody>
</table>

*Bitter flavor may arise from a number of different causes. If the specific cause is not known, it should be classified under miscellaneous.

Light-Induced Flavors

Milk exposed to various forms of radiant energy develops off-flavors (19 to 35). These are of practical importance when milk is exposed to sufficient direct sunlight, fluorescent light, or even diffused daylight. The problem was brought into focus in the period when dairy products were distributed in glass containers and left on customers’ doorsteps. Factors which contribute to the intensity of “sunlight flavor” are wavelength and intensity of light, exposure time, translucence of the container, levels of ascorbic acid, and riboflavin (16, 19, 20, 22, 27, 28).

The light-induced flavor has (13) two distinct components — one a burnt, activated, or sunlight flavor which develops rapidly and has been attributed to degradation of serum protein components; the second component is similar to oxidized flavor. The latter flavor, attributed to lipid oxidation, seems to develop more slowly (14). The lipid-oxidation component of the light-induced flavor undoubtedly contains some of the same volatile carbonyl compounds that are in typical oxidized flavors. Presumably, because of the difference in rate of development of the two flavor components, the flavor of milk exposed to radiation changes with time. Initially, the “burnt” note predominates, and after 2 or 3 days the “oxidized” note becomes more pronounced; therefore, the off-flavor that develops several days after light exposure may be difficult to differentiate from oxidized flavor.

In milk exposed to light, homogenization enhances the light-activated component of the
off-flavor and inhibits the oxidized component. A recent study compared pasteurized milk exposed to sunlight with and without homogenization. The level of n-pentanal was three times as great as n-hexanal in the homogenized milk and only 2/3 as great in the unhomogenized milk. All other carbonyl compounds were less in the homogenized milk (16). Methional, formed by the degradation of free methionine, contributes to the activated flavor component (12, 25). A study with S35-labeled milk confirmed that upon irradiation, mercaptans, sulfides, and disulfides increased significantly in the milk. It is likely that these compounds contribute to the activated flavor component (26).

Recently the widespread use of plastic milk containers has increased the occurrence of the light-induced flavor. Exposure of milk in blow mold, plastic containers to fluorescent lights in display cases has resulted in the development of oxidized (light-induced) flavor in about 80% of the samples (15).

The 2-thiobarbituric acid test (TBA), which has been used to measure oxidized flavor, is ineffective in monitoring the light-activated component of the light-induced flavor (20). Probably the TBA test is effective only in measuring the slower developing lipid oxidation phase of the reaction.

Lipolyzed Flavors

The milk lipase-catalyzed hydrolysis of milk fat triglycerides causes a common flavor defect in fluid milk. Historically, several terms have been used to describe this flavor defect. "Rancid", the most commonly used, is ambiguous since it is used also to describe the flavor defect resulting from lipid oxidation. The descriptive terms "goaty", "soapy", and "butyric" also have been used. "Bitter", another descriptive term, is also ambiguous since bitter flavors may result from protein degradation. Also, lipases secreted by microbial contaminants in milk can produce flavor defects which usually are accompanied by bitterness resulting from concurrent protein degradation.

Since lipase-catalyzed hydrolysis of triglycerides commonly is termed "lipolysis", it is recommended that "lipolyzed flavor" be used henceforth to denote the lipase-induced flavor defects in fluid milk. However, we recognize that controlled lipolysis, which is used to produce flavors in certain dairy products, is a valuable and useful technology (36). Animal-derived pregastric esterases are used to produce the characteristic "picante" flavor of Romano and Provolone cheese. Such preparations are used for flavor production in other cheese types. Lipolyzed whole milk powder, butterfats, and cheeses are used widely to flavor processed foods.

Literature on milk lipase is voluminous but includes little information on the chemical or organoleptic characteristics of the lipolyzed flavor defect. A review by Herrington (39) provides a comprehensive overview of milk lipase biochemistry. There may be several milk lipases and their activity is influenced by triacylglyceride and gross milk composition. Also, lipolyzed flavor can be affected by the mechanism of enzyme activation, such as "spontaneous" rancidity, excessive agitation, homogenization, separation or clarification, and heat shock.

Willey and Duthie (47) reported two types of lipolyzed flavor: (a) "sickening", which resulted from the mixing of raw and homogenized milks, churning, intense agitation via Waring blender or temperature fluctuation; and (b) "unclean", resulting from foaming or spontaneous lipolysis. This report suggests the need for more basic research on the nature of lipolyzed flavor.

Kuzdzal-Savoie (43) has reviewed the limited literature on the characteristics and chemistry of the lipolyzed flavor defect. Certain fatty acids are principally responsible for lipolyzed flavors. Scanlan et al. (45) evaluated the effect of individual milk samples. Even-numbered fatty acids, butyric, caproic, caprylic, capric, and lauric, were the major flavor contributors. None of these compounds exerted a predominant effect. The addition of fatty acid blends to milk did not impart a typical lipolyzed flavor profile. Scanlan et al. also demonstrated that long-chain fatty acids C-14 and C-18, contributed little, if any, flavor. Kolar and Mickle (42) demonstrated that very short-chain fatty acids, formic, acetic, and propionic, do not play a significant role in lipolyzed flavor defect.

Paulet et al. (44) demonstrated that sodium salts of capric or lauric acids imparted a soapy-like taste to water at 25 ppm or greater. The threshold in sucrose solution was 50 ppm and in saline solution, 100 ppm. Tuckey and Stad-
houders (46) reported that lipolyzed flavors can be detected more readily as the test medium pH is decreased.

Kolar and Mickle (42) reported a positive correlation between the lipolyzed flavor, fat acidity, and short-chain fatty acid content. Dunkley (38) determined that fat acidity determinations were helpful in classifying cream as "not rancid" but of little value as a measure of lipolyzed flavor intensity. Rancidity was estimated more conveniently by changes in surface tension, but both sampling procedure and milk fat content influenced the method. A series of reports concerning causes, detection, and control of lipolysis were presented at International Dairy Federation Symposia in 1974 and 1975 (40, 41).

**Microbial Flavor**

Serious flavor defects in both raw and pasteurized milk may result from an accumulation of the products of bacterial metabolism (51, 52). These are produced by the action of the complex enzyme systems of contaminating organisms on the constituents of milk.

Most of the common organisms of milk spoilage are believed to have come originally from the soil and associated plant life and have become indigenous to milk because of the excellence of milk for their growth and persistence. Rigorous sanitary procedures are required to limit the initial contamination of milk during its production. Rapid cooling to and holding at 4.4°C or below to inhibit the multiplication of possible contaminants is imperative if the flavor quality of milk is to be maintained until pasteurization. Proper pasteurization will destroy all pathogenic and a very high percentage of nonpathogenic bacteria in milk, however, any off-flavors of bacterial origin which have developed prior to pasteurization are not affected greatly by this process, nor can they be removed completely by any of the currently employed commercial vacuum treatment processes.

Properly pasteurized milk may be contaminated by subsequent contact with unsanitary equipment. Such contamination often includes psychrotrophic bacteria (48, 50, 54, 55, 56) which are commonly responsible for flavor defects in pasteurized milk. These organisms multiply slowly at 4.4°C or lower and, unless the contamination is appreciable, flavor defects may not be evident before 10 to 14 days storage. However, in milk which has not been cooled to below 4.4°C immediately after pasteurization or which is stored at 7.2 to 15.6°C, the psychrotrophic organisms may multiply rapidly and cause flavor defects in a few days (56).

Although bacteria may be responsible for a number of different flavor defects in both raw and pasteurized milk, only those defects described as acid, malty (51), and fruity (52) can be recognized as being of microbial origin by sensory perception alone. The microbial genesis of these defects and the specific flavor compounds responsible have been demonstrated unequivocally (53). The flavors described as stale, barny, unclean, bitter, foreign, rancid, and feed can be caused by bacteria, but determination of the actual cause is often difficult without bacteriological analyses because of the similarity of these flavors to flavors due to other causes.

**Acid flavor.** Because of the universal distribution of *Streptococcus lactis* in the environment of milk production, most milk is unintentionally inoculated with this organism immediately after milking. If the milk is not cooled immediately to 4.4°C or below, it eventually will develop an acid taste due to proliferation of the organism and its conversion of lactose to lactic acid. The speed with which this defect develops is related to the degree of contamination and the temperature history of the milk.

Pure lactic acid has a clean acid taste and, because of its low vapor pressure, has no odor. However, the development of lactic acid in milk is accompanied by an odor usually described as sour. This is due to the production of very small amounts of acetic and propionic acids. Titratable acidity development in milk of 0.07% to 0.10%, calculated as lactic acids, is commonly detectable by most individuals. However, the odor of the volatile acids may be detected by experienced individuals when the titratable acidity has increased by as little as 0.01%.

Since *S. lactis* is destroyed by proper pasteurization of milk, acid development in milk subsequent to pasteurization is not likely. However, pasteurization will not improve the flavor of raw milk if acid already has developed.

**Malty flavor.** A flavor and aroma which in the past has been described as cooked, burnt,
caramel, "grapenuts", and malty, may develop in raw milk as a result of the metabolism of *Streptococcus lactis* subsp. *maltigenes* (49). The term malty seems to have attained priority through common usage and to most nearly describe this defect.

The responsible organism seems common in dairy environment in certain geographical areas (e.g. Northeastern U.S.), whereas in milk produced in other areas (e.g. Pacific Coast states) the organism is rare.

The organism enters milk through contact with improperly sanitized equipment during production. Multiplication of the organism is favored by delayed cooling and holding of the milk at 10°C or above.

Except for its ability to produce a detectable malty aroma in milk before any appreciable acid is produced, the organism is identical to *S. lactis* (49). When grown in sterile milk as a pure culture, a malty aroma can be detected over the culture when the standard plate count reaches $10^7$ to $10^8$ per ml. The aroma becomes more intense as the acidity increases and the milk coagulates.

Although the volatile compounds produced by *S. lactis* subsp. *maltigenes* include a number of aldehydes and alcohols which are derived from amino acids, the characteristic aroma and flavor are due principally to the production of 3-methylbutanal from leucine.

*S. lactis* subsp. *maltigenes* cells are inactivated by pasteurization, but the volatile products of their metabolism are not affected by this process nor can they be removed effectively by any of the vacuum treatment processes currently used for improvement of milk flavor.

**Fruity flavor.** The aroma which may develop in pasteurized milk and other processed dairy products as a result of the metabolism of *Pseudomonas fragi* has been described as strawberry-like, resembling a May apple, ester-like, and fruity (52). Fruity seems to have priority by virtue of common usage and probably is related most readily to the defect.

*P. fragi*, a psychrotrophic water and soil form, is distributed widely in dairy environments. The organism is very heat sensitive, and its presence in pasteurized products is due to post-pasteurization contamination. The organism is capable of multiplication at 5°C to 7°C and will outgrow many other species in dairy products during refrigerated storage. Because they are aerobic, multiplication of and flavor development by psychrotrophic organisms is enhanced by aeration of milk after pasteurization and by storage in partially filled containers in home refrigerators. In agitated milk inoculated with *P. fragi*, unclean flavors have been noted when the plate counts reached $5.5 \times 10^6$ and fruity aromas at $5 \times 10^6$ per ml.

The fruity aroma produced in milk by *P. fragi* is due to ethylbutyrate and ethylhexanoate. The organism elaborates a lipase which liberates butyric and caproic acids from milk lipids and an esterase which then esterifies these acids with ethanol. *P. fragi* produces only small amounts of ethanol, and it is likely that the production of the fruity esters is enhanced in milk containing increased amounts of ethanol due to silage feeding or growth of organisms which produce either acetaldehyde or ethanol.

Strains of *Bacillus* have been isolated from milk which have characteristics similar to those of some species of *Pseudomonas* and are able to produce similar defects, e.g. fruity flavor. These sporeforming organisms may be the cause of flavor defects in aseptically-packaged "sterilized" milk and fluid milk products.

**Unclean, bitter, and putrid flavors.** Although unclean and bitter flavors may be due to other causes, these and putrid flavors often are caused by growth of psychrotrophic organisms in pasteurized milk. Contamination of milk with these organisms subsequent to pasteurization occurs through contact with or moisture drip from improperly sanitized surfaces. Bacteria responsible for these defects grow rather slowly at 4.4°C or lower, and the resulting flavor defects usually become evident upon extended storage of milk. Such milk may lack freshness or develop stale flavors prior to development of the more serious flavor defects.

Although not yet well-defined, the mechanism involved in the development of these defects most likely involves limited breakdown of the milk proteins. This results in the formation of bitter peptides and decomposition of the amino acids to produce putrid flavors.

**Oxidized Flavor**

This undesirable flavor is often in fluid milk and results from a reaction between molecular oxygen and lipids. The polyunsaturated fatty acids in the phosphatides at the interface of the
milk fat globule are considered the precursors of the flavor (96).

Milk varies considerably in its susceptibility to this defect (59, 61, 89, 96, 102). Milk from some cows develops this defect so quickly and without any abuse that it is said to oxidize "spontaneously". There is considerable evidence that this "spontaneous" oxidation is caused by the combined catalytic action of copper ions and ascorbic acid (99, 101). Some scientists (57, 58) have claimed that the enzyme xanthine oxidase is involved, but this has been disputed (94, 98). Numerous workers (62, 86 to 88, 99) have studied the role and importance of copper as a pro-oxidant. In the past, milk-handling equipment which contained copper or copper alloys was a significant source of copper contamination. Contamination (96) or fortification (95, 104) of milk with iron also can accelerate formation. Milk from cows on dry lot feeding often shows more susceptibility to this defect than that of cows on pasture (96). Pasteurization under mild conditions may encourage the formation of this flavor, but more rigorous pasteurization tends to inhibit its development (60, 100). The inhibitory effect of pasteurization is believed to result from the development of sulfhydryl compounds during heating. Such compounds inhibit oxidations that proceed by a free radical mechanism; however, the possible masking effect of heated flavor on oxidized flavor or the interaction of metal ions with other milk constituents during heating cannot be excluded as modes of action.

Tryptic action inhibits oxidation (74, 75, 96) presumably by either exposing anti-oxidants such as sulfhydryl groups or by reducing the activity of pro-oxidants (76, 96). Homogenization inhibits the development of oxidized flavor (77, 99), but there is no agreement regarding the mechanism. Oxidized flavor development can be inhibited by the addition of certain phenolic antioxidants (65, 66, 69, 80, 85) which inhibit free radical oxidations; however, the addition of such compounds to milk is not legal in the United States. In some states milk may be fortified with ascorbic acid (vitamin C). Although this compound acts at certain concentrations in the presence of copper to stimulate oxidized flavor development, at higher concentrations it inhibits flavor formation (84, 96). Light promotes the oxidation of milk lipids, but under these conditions some protein breakdown is believed to occur and other flavors develop. Light-induced flavor formation was discussed in a previous section of this report.

The oxidation of dairy products leads to flavors termed oxidized, cardboard, cappy, metallic, tallowy, oily, and fishy. The term oxidized has been used by some investigators to designate a specific flavor, but the committee recommends its use as a generic term that includes all flavors resulting from lipid oxidation. The most common of the oxidized flavors is described as cardboard, or cappy; metallic, tallowy, oily, and fishy flavors occur less frequently.

The oxidation of milk lipids leads to the formation of hydroperoxides, but these compounds have no flavor. The flavor results from the scission products formed from the hydroperoxides or from the free radicals involved in the reaction. The presence of hydrocarbons, alcohols, acids, aldehydes, and ketones has been reported in the scission products (63, 64, 67, 68, 70, 71, 72, 73, 78, 90, 92, 93). Of these, the carbonyl constituents have generally been considered the chief culprits (63, 64, 79, 81, 82, 83, 91). There have been unanimous agreement that vinylamyl ketone (1-octene-3-one) alone imparts a metallic flavor to dairy products (79, 103, 105), and vinylamyl ketone in combination with an aldehyde imparts a cardboard flavor (79). Aside from these two examples, there has been no general agreement about which compounds cause particular flavors. Progress in this area has been hampered by the instability of many of the compounds that have been identified and their unavailability commercially, especially in the degree of purity required.

**Transmitted Flavors**

Milk flavors may arise by passage of substances from the cow's feed or surroundings in milk while it is in the udder. This transfer may be via the respiratory and/or digestive system and blood stream. Such flavors are considered transmitted flavors. Examples of a variety of these transmitted flavors have been reported (106, 108, 113, 115, 118 to 127); some of the volatile components associated with these flavors have been identified (109, 111, 112, 114, 116, 117, 120 to 127). The more volatile materials from feeds in the atmosphere sur-
rounding the cow or in the gas eructated from the cows rumen are inhaled and pass rapidly from lungs to udder (107, 126). Volatile and nonvolatile flavor materials pass from the digestive system to the udder slower. When the source of the flavor material is no longer available to the cow, and the air she inhales is relatively odor free, the volatile flavor materials accumulated in the milk in the udder gradually are returned to the blood stream and exhausted via the lungs.

Feed flavor. When cows are allowed to consume and/or inhale the strong odor of many common dairy feeds (e.g. silage, green forages, etc.) within 2 to 4 h before milking, the milk will have a sweet and aromatic taste, and odor which may be characteristic of the feed. Many such feeds can be fed immediately after milking and withheld 4 to 5 h before milking without producing a feed flavor in the milk. Feed flavor problems often are associated with an abrupt change from dry winter rations to one including lush green pasture forage.

Weed flavor. Numerous species of weeds when consumed by the cow impart serious off-flavors to milk. One of the most common and readily recognized weed flavors is that caused by the consumption of wild garlic. The flavor components from some weeds are relatively nonvolatile and are not exhausted rapidly from the cows body via the lungs. Therefore, they may affect the flavor of the milk until they are excreted or otherwise metabolized, a process which may take as long as 12 h.

Cowy flavor. It has been suggested (110) that cows suffering from ketosis or acetonemia produce milk having a cow-like odor. The odor of the breath of affected cows is similar to that of the milk and may be so strong that it is transmitted to the milk of neighboring cows if the ventilation of the area is inadequate. The cowy odor was at one time reputed to be due to the acetone bodies released into the blood stream from incomplete metabolism of fat. However, Potts and Kessler (125) found that acetone in milk also could be affected by acetone in feeds such as silage. These workers were unable to find a relationship between the amount of acetone in the milk and intensity of off-flavor. Suprathreshold amounts of methyl sulfide also impart a cowy flavor to milk (124). More work is needed to establish the exact nature of this cowy flavor.

Barny flavor. Milk from cows housed in unventilated areas in which they are forced continuously to inhale strong odors may have a flavor and odor described as barny. The nature of the barny flavor has not been characterized or distinguished clearly from cowy flavor.

Miscellaneous Flavors

The miscellaneous category of flavors includes those flavors that either cannot be attributed to a specific cause or specifically defined in sensory terms. In some cases, such as foreign, there are a variety of types and causes.

Absorbed flavors. The term absorbed is applied to those flavors — usually odors — that are absorbed from the environment (129, 133, 134). In earlier days it was assumed that most feed and environmental odors were absorbed by milk directly from the air. Now it is known that such odors are transmitted frequently through the cow. However, some volatile substances may be absorbed directly from the air. The evidence indicates that fat-soluble substances, such as turpentine and other volatile solvents are absorbed readily, particularly if the cream has risen. (Homogenized milk and skim milk do not readily absorb these odors.) The milking and milk storage areas should be kept free of these odors.

Astringent flavors. Astringent has been used to describe a dry puckery, oral sensation which involves the sense of touch or feel rather than taste. The terms rough, chalky, or powdery also have been used to describe this sensation. Astringency has been associated most frequently with milk products that have been processed at high temperatures (132, 136, 138). In these cases, the astringency has been attributed to large protein-salt and salt particles. Astringency in acidified milk products is attributed to protein particles with low mineral content. Fortification of milk with iron salts, especially ferrous salts, can produce astringent flavors (130). Astringency has been reported in fresh raw milk, but the cause has not been identified.

Bitter flavor. This flavor is caused frequently by proteolysis since some peptides and amino acid elicit bitter flavors (131, 140, 142). In fluid milk, the proteolysis usually is caused by microbial proteases since the activity of the natural milk proteases is slight. Bitter flavor may be caused by lipolysis or certain weeds,
e.g. bitterweed. An alkaloid may be the cause of the bitterweed flavor since a number of alkaloids are bitter. One cannot identify the source of bitterness if bitter flavor is the only clue to the problem.

Chalky flavor. The term chalky has been used to describe a tactual defect which is similar to the astringent sensation. In fact, some people have used these terms interchangeably. Chalky has been described as a sensation suggesting finely-divided insoluble powder particles. Shortly, after the commercial introduction of homogenized milk, several reports indicated that homogenized milk had a chalky flavor. Perhaps this chalkiness may have been caused by improper pasteurization-homogenization procedures since there is no evidence that proper homogenization produces chalkiness.

Chemical flavors. Flavors that are caused by contamination of milk with chemicals associated with cleaners, sanitizers, and disinfectants (128, 135, 139, 141, 144 to 146) are included in this group. Chlorine and iodine compounds are probably the most frequent contaminants (135, 145, 146). Phenolic compounds from disinfectants (139) and some weed killers (141) are also capable of causing this defect. A chlorophenol flavor has been found in milk (144). This flavor has been attributed to products of a reaction of chlorine sterilizing reagents with phenols which were in the water supply. Chemical flavors may be transferred to milk from returnable plastic milk bottles which have been misused as containers for gasoline, disinfectants, pesticides, herbicides, etc.

Flat. This defect is characterized by a lack of flavor and a tactual sensation of thinness. This sensation can be simulated by diluting milk. Addition of as little as 3 to 5% water can produce this defect. Some people feel that vacuum treatment of milk produces a flat tasting product. The flat taste of milk can be reduced by the addition of solids-not-fat (143).

Foreign flavors. Those flavors that cannot be identified either by cause or chemical nature are classified in this group. This group is sometimes referred to as abnormal flavors.

Lack freshness. This term is used to describe milk that does not have the complete pleasing taste of high quality fresh milk. The term should be used only when a more specific defect cannot be identified. Even fresh milk may lack the full flavor of high quality milk. Thus, one cannot say with certainty that this defect is necessarily due to age unless the sample had been judged when it was fresh.

Salty flavor. This defect is identified easily by tasting. It is most commonly in milk from cows in late lactation and occasionally from milk of cows with mastitis.

PREPARATION
OF REFERENCE STANDARDS

Considerable research has been undertaken to develop methods for preparing specific standards of off-flavors. Such standards should aid in the identification of off-flavors and the training of personnel.

In most cases, off-flavors are due to a mixture of flavor components which are difficult to duplicate artificially. Although synthetic mixtures may simulate natural flavors, they rarely duplicate them. It is not necessary to duplicate a flavor exactly, but there is a danger of improper identification if a "nontypical standard" is used. The methods of preparation cited below are believed to give reasonably typical flavors.

Heated Milk Flavors

These four notes of heated milk can be demonstrated as follows:

1. Cooked or sulfurous: Heat milk to 75 C for 1 min. The flavor will be more pronounced if the holding time is increased.

2. Heated or rich: Heat milk to 146 C for 4 s. Refrigerate sample for 2 to 3 days to allow sulfurous note to dissipate. Alternatively, the heated or rich note can be induced by heating milk to 95 C for 10 to 15 min.

3. Caramelized: Autoclave whole milk for 15 min in a metal can (300 × 406) at 121 C. (In addition to the above treatment it took approximately 10 min for the pressure in our autoclave to return to atmospheric. When the pressure returned to atmospheric, the cans of milk were removed from the autoclave and cooled in ice water.)

4. Scorched: Put enough milk into a beaker to just cover the bottom and place on a hot plate until the water evaporates and the milk residue turns a light golden color. Fill the beaker 1/3 full with milk, bring to a boil, and cool in ice water. The resulting milk will have a strong scorched to burnt flavor. This milk can
be diluted with unheated milk to obtain the desired intensity.

**Light Induced Flavor**

*Method A. Sunlight.* A light induced flavor of reasonably high intensity will be produced by exposing a quart of freshly-processed pasteurized-homogenized milk in a clear glass container (e.g., a 1 liter Erlenmeyer flask) for 20 min to midday sunshine. A reasonable radiant energy would be 1 g cal/cm² (1 ly)/min at 7 to 10 C. (ly = Langley) Store at 4 to 5 C and note changes in flavor after 24 and 48 h.

*Method B. Fluorescent light.* Expose pasteurized-homogenized milk at 7 C in either a glass Erlenmeyer flask or an all plastic jug to 40-Watt cool white fluorescent lamps (F 40 CW) for 12 to 16 h. The illumination should average 1080 lux perpendicular to the light source at the midpoint of the exposed vertical surface. If 2150 lux intensity light is employed, the exposure time may be reduced to 4.5 to 6 h. Note in both methods, the addition of ascorbic acid (50 mg/liter), minimizes the development of the oxidized flavor component and enhances the development of the activated flavor component.

**Lipolyzed Milk Flavor**

*Method A.* Warm 200 ml of raw whole milk to 37 C and agitate vigorously in a Waring blender for 1 min; hold sample at 37 C for 15 min or until a characteristic lipolytic flavor develops. Following the holding period, pasteurize samples, cool, and hold overnight at 5 C prior to tasting. (Samples may be pasteurized by heating to 72.2 C for 2 min.) If the desired intensity of off-flavor has developed, the sample may be freeze-dried and canned under 4920 k/m² pressure (95% nitrogen, 5% hydrogen) or under vacuum.

*Method B.* Add 20 ml raw milk to 180 ml homogenized milk, mix, and hold overnight at 5 C, pasteurize prior to tasting. The sample may be freeze-dried as under Method A.

**Directions for reconstituting freeze-dried products.** Add contents of can to 125 ml of room temperature distilled H₂O that is free of off-flavors, and agitate to reconstitute samples. Make samples up to 200 ml with distilled H₂O, mix thoroughly, and hold overnight at 5 C prior to tasting. If evidence of clumping persists in the reconstitution step, warm milk to 37 C, and stir vigorously in a Waring blender for 1 min.

**Directions for tasting samples.** Warm samples to room temperature and mix thoroughly prior to tasting. Samples may be diluted with clean, fresh whole milk that is free of off-flavors to meet taste requirements. One can prepare dilutions that will give specified acid degree values. However, different milks with the same acid degree value may have different flavor impacts. (Attempts to prepare typical lipolyzed flavor with fatty acids mixtures were not successful. Seemingly the added fatty acids were not distributed between the aqueous and lipid phases in the same manner as the enzymatically released fatty acids.)

**Microbial Milk Flavors**

**Acid flavor.** Samples of milk having varying degrees of acid flavor and sour odor may be prepared by allowing acidity to develop in raw milk and making appropriate dilutions with fresh raw or pasteurized milk. Alternatively good quality pasteurized raw milk may be inoculated with a suitable culture of *S. lactis*, and the acidity allowed to develop to the desired level.

**Malty flavor.** Milk samples for use in training individuals in recognition of the malty defect may be prepared by inoculation with *S. lactis* subsp. *maltigenes* (ATCC 29146) culture or by addition of a synthetic flavor preparation. In the former procedure about 50 ml are removed from .95 liter of good quality pasteurized-homogenized milk to provide suitable head space for aroma build-up. The bottle and remaining contents are warmed to room temperature (21.1 C). The milk is inoculated with 1 ml of an active milk culture and then swirled to disperse the culture thoroughly. As prepared, the sample is allowed to stand at room temperature until a malty aroma can be just detected over the milk but before any appreciable acid development (4 to 6 h). Then the milk should be cooled rapidly to and held at 2 C to limit further metabolic activity. Immediately prior to use in training sessions, the sample, or diluted portions thereof, should be warmed to about 15.6 C.

The dominant malty note of the defect can be simulated in milk by addition of high purity 3-methylbutanal from slightly above the aver-
age organoleptic threshold (.10 ppm) to .5 ppm. A concentration of .34 ppm in milk is recommended for training judges in recognition of the defect. This may be obtained by diluting 30 μl of 3-methylbutanal to 100 ml with pure 1,2-propanediol (Matheson Coleman and Bell, item no. CQ 2493) and adding 1 ml of this to a .95-liter container of high quality pasteurized homogenized milk from which 46 ml have been removed. Such samples may be diluted further (e.g. 1:1) for more experienced judges. Morgan (51) described an alternate simple procedure for preparation of the malty flavor reference standard for use when high purity 3-methylbutanal is not available.

Fruity flavor. A typical fruity aroma can be produced in a good quality pasteurized-homogenized milk that has been fortified with .1 to .2% ethanol, inoculated with an active culture of P. fragi, and incubated at 7 C for 4 to 6 days. Alternatively, milk known to contain excessive numbers of psychrotrophic organisms may be heated in flowing steam for 1 h and cooled to 7 C before addition of ethanol and inoculum. Although milk prepared in this manner will have a strong heated odor, this will not interfere with detection of the fruity aroma when it develops. Samples prepared in this manner can be incubated at 21 C for more rapid development of the typical aroma (48 to 72 h).

The characteristic fruity aroma can be simulated in milk by addition of 1 ml of a solution prepared by diluting .0315 g (36 μl) of ethyl butyrate and .0450 g (52 μl) of ethyl hexanoate to 100 ml with 1,2-propanediol (Matheson Coleman and Bell item no. CQ 2493) to 900 ml of good flavored homogenized milk. The purity of the esters employed in this preparation should be at least 99.9%. As prepared, the milk will contain .35 ppm of ethyl butyrate and .50 ppm of ethyl hexanoate, the concentrations detected in a fully developed milk culture of P. fragi. Although these concentrations exceed the average threshold concentrations for the individual esters or mixtures thereof, samples prepared in this manner have been suitable for training individuals in recognition of the defect. Samples can be diluted further for use with experienced judges.

Oxidized Flavor

Milk with a cardboard flavor may be produced by adding a copper salt to milk. A convenient method is to prepare a stock solution of cupric chloride, sulfate, or lactate so that 1 ml of this solution will give a concentration of 1 ppm of copper when added to 1 liter of milk. The milk is held at 4 to 5 C. Usually milk containing 1 ppm of copper will develop a cardboard flavor within 24 h, but some samples may require a longer time and a higher concentration of copper. The oxidation also can be speeded by the addition of about 20 ppm of ascorbic acid along with the copper. Different intensities of the flavor can be obtained by adding slightly different amounts of copper and ascorbic acid and holding for different lengths of time.

Metallic flavor in milk can be simulated by the addition of 1 to 10 ppb if vinylamyl ketone (1-octene-3-one). The addition of an equal amount of octanal or other saturated aldehyde along with vinylamyl ketone gives a cardboard flavor to milk. These compounds are unstable but may be preserved as urea complexes (79).

Transmitted Milk Flavors

Feed flavor. A very common feed flavor may be simulated by adding appropriate quantities of a filtrate from a blended mixture of equal volumes of silage and water to a liter of milk. To produce truly authentic feed flavor, one can feed the appropriate feed 2 to 3 h before milking. If the feed (such as fresh corn silage) has strong volatile odors, the odor can be imparted to the milk through the cow's lungs. One merely has to place the odoriferous feed in front of the cow for 15 to 20 min prior to milking.

Weed flavor. One very typical weed flavor may be simulated by addition of 1 g of garlic salt or an appropriate quantity of fresh garlic juice to a liter of milk. As with feed flavors, authentic weed flavors can only be imparted to the milk by the cow.

BIBLIOGRAPHY

This bibliography contains important references pertaining to the nomenclature and causes of off-flavors in milk published since 1950. (For articles published prior to 1950 see Flavors of Milk. A Review of Literature, D. R. Strobel, W. G. Bryan, and C. J. Babcock, USDA Bulletin. 1953.) A more inclusive list of references pertaining to off-flavors in milk can be ob-
HEATED FLAVOR


LIGHT-INDUCED FLAVOR


34 Weinstein, B. R., and G. M. Trout. 1951. The

LIPOLYZED FLAVOR

MICROBIAL FLAVOR

OXIDIZED FLAVOR
NOMENCLATURE OF MILK OFF-FLAVORS


82 Keeney, M., and F. J. Doan. 1951. Studies on oxidized milkfat. II. Preparation of 2,4-dinitrophenyl-hydrazone from the volatile material from oxidized milk fat. J. Dairy Sci. 34:719.

83 Keeney, M., and F. J. Doan. 1951. Studies on oxidized milkfat. III. Chemical and organoleptic properties of volatile material obtained by fractionation with various solvents and Girard's reagent. J. Dairy Sci. 34:728.


TRANSMITTED FLAVOR


MISCELLANEOUS


sources of variations in milk flavor. J. Dairy Sci. 50:1384.