The producer of milk is always confronted with the problem of preventing sour milk. With the increased consumption of milk and milk products has come the demand that milk not only be sweet but that it have a pleasing flavor. Milk containing an abnormal flavor is rejected by dealers and consumers. Dairymen are giving considerable attention to the prevention of losses due to sour milk. They too rarely recognize, however, that the production of milk containing objectionable flavors not due to souring is causing an annual loss probably greater than that from sour milk.

The fact that the feed consumed by the cow may be a contributing cause of abnormal flavors in milk has long been recognized. As early as 1829 William Harley (1) described a method for "preventing milk from tasting of turnips." He also observed, "It is chiefly common turnips and cabbages that give the strong taste to milk and butter." Many other early references are available dealing with the effect of feeds on the quality of milk. Almost without exception, in these early studies, quality was based on the chemical constituents of the milk. The effect of feeds on the flavor of milk was overlooked, or, if noted, dismissed with a sentence or two.

Although some work was reported prior to that reported by Gamble and Kelly (2), apparently it was the systematic study by the latter investigators on the effect of silage on the flavor and odor of milk that initiated recent interest in the subject. They reported a wide variation among individual normal cows in the flavor and odor of the milk produced. Cows receiving the same feed and care produced milk that ranged in flavor from pleasing to objectionable. Roadhouse, Regan, and Mead (3) confirmed the fact that there is a marked difference in the flavor of milk of individual animals and later Roadhouse and Koestler (4) reported on the causes of these variations in the flavor of milk from individual cows.

Gamble and Kelly (2) showed that in feeding corn silage before milking, when as little as 10 pounds was given at a feeding, the milk took on, through the body of the cow, a faint feed flavor and odor. As the quantity was increased to 30 pounds at a feeding, the degree of silage flavor and odor was likewise increased. This confirmed the work of Knisely (5), who reports that milk from cows fed corn silage has a more pronounced odor than milk from cows fed hay. King (6) also stated "It was demonstrated beyond

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Editor's Note: This is the first of a series of reviews by recognized authorities on subjects of interest to the Dairy Industry.
question that when silage is fed a short time before milking, a sweetish odor
is imparted to milk.'"

Gamble and Kelly (2) showed further that when as little as 30 pounds of
corn silage was fed daily, in two feedings immediately after milking, the milk
showed a slight feed flavor and odor; and that when more than 40 pounds was
fed, the milk carried a slight silage flavor and odor continuously. Henry
and Morrison (7) report that as the silage-feeding period progressed the
effect of the silage became less and less apparent in the milk. Gamble and
Kelly (2) showed that this applied, however, only when less than 35 pounds
was fed per cow per day; it was shown that when over 40 pounds was con-
sumed, the sweetish feed flavor could always be detected. From their
work with corn silage they concluded that: (1) When silage is fed 1
hour before milking its taint is discernible in the milk. (2) Not over 15 to
25 pounds of corn silage can be fed twice daily after milking without
impairing a discernible flavor and odor to the milk. (3) Silage should be
fed immediately after milking.

In experiments with alfalfa, sweetclover, and soybean silages Gamble and
Kelly (2) showed that legume silages should also be fed only after milking
and then in quantities of not more than 15 pounds to a feed twice daily if
milk reasonably free from feed taints is to be obtained. In regard to soy-
bean silage, Woll and Humphrey (8) stated that satisfactory dairy products
could not be made when cows were fed this silage, and Woodward and Mc-
Nulty (9) reported that silage made from clover, while palatable, has an
objectionable odor necessitating care in feeding to avoid tainting the milk.

Russell (10) states: 'As milk is exposed during the milking process, and
very often after its withdrawal to an atmosphere that is liable to contain odors
of an undesirable character, it is not surprising to note that it may thus con-
tract flavors by direct absorption.' Ritland (11) expressed the opinion
that the flavor noted in milk of cows fed turnips is due entirely to the absorp-
tion by the milk of volatile ingredients of the turnips. Farrington (12)
says, 'It has repeatedly been proved that silage can be fed to dairy cows
without tainting the milk, butter or cream, in the slightest, but unless
certain precautions are taken to prevent this, the cream or butter may be
so tainted with silage smell that many customers will refuse to use it. The
success of feeding silage depends almost entirely upon the disposition of the
man feeding it, to constantly keep the air in the stable free from silage
smell.'

As a result of trials in which silage was spread on the floor underneath
two cows in a stable with the doors and windows tightly closed, thereby
exaggerating barn-air saturation, Gamble and Kelly (2) showed that silage-
tainted barn air may have some effect on the flavor and odor of milk under
such extreme conditions, but concluded that the effect would be relatively
small under average conditions.
They further showed that careful and prompt aeration of the warm milk will remove silage flavors and odors permanently, if the milk was only slightly tainted, and will reduce the degree of the silage flavors and odors if the taint was more pronounced. This is in agreement with Marshall (13), who stated, "Odors and taints resulting from aromatic foods, physiological processes, and disease processes may be greatly reduced permanently," by aeration.

Other facts brought out by Gamble and Kelly (2) were: (1) Feeding moderate quantities of corn silage after milking and prompt aeration of the milk may in some cases actually improve the flavor of milk that would otherwise have a flat or insipid taste. (2) While silage odors in the barn air have only a slight effect on the flavor and odor of milk, it is best to provide adequate ventilation and to practice other sanitary measures to insure the finest possible flavors. (3) The feeding of badly decomposed or moldy silage imparts undesirable flavors to milk. (4) Cream from silage-tainted milk possesses and retains silage flavors and odors to a greater extent than the milk from which it is taken. (5) Condensed milk made from silage-tainted milk has a less perceptible silage flavor and odor than the milk from which it is made.

Babcock (14–18) confirmed the work of Gamble and Kelly (2) in that he found: Feed flavors are more pronounced in the cream than in the milk from which the cream is taken. Proper aeration reduces strong off flavors and odors in milk caused by feeding highly flavored feeds, and some of the slight off flavors and odors may be eliminated. Even highly flavored feeds may be fed immediately after milking without seriously affecting the flavor of the milk produced at the next milking.

He showed that when fed to dairy cows 1 hour before milking, green alfalfa, cabbage, turnips, rape, and kale seriously affect the flavor and odor of milk. Green rye, green cowpeas, potatoes, dried beet pulp, and carrots affect milk only to a slight degree. Green corn, green oats and peas, green soybeans, pumpkins, and sugar beets have practically no effect on the flavor and odor of milk. When dairy cows were fed 1 hour before milking time and consumed 15 pounds twice daily of those feeds that were found to affect seriously the flavor of milk, objectionable flavors and odors were produced in the milk. Increasing the consumption of these feeds to 30 pounds twice daily greatly increased the intensity of the abnormal flavors and odors. When these feeds were fed in quantities up to 30 pounds twice daily immediately after milking, they had practically no effect on the flavor and odor of the milk produced at the next milking. In fact, in the case of green alfalfa, it was shown that changing the time of feeding from 1 hour before milking to 3 hours before milking, decreased the intensity of the abnormal flavor, and feeding 5 hours before milking practically eliminated it. On the other hand, large quantities of feeds like cabbage and turnips, even though fed immedi-
ately after milking, may at times slightly taint the flavor of the milk produced at the next milking. These taints, however, are slight and would seldom be noticed by the average consumer. Feeds that had only a slight effect when fed before milking had no detrimental effect when fed after milking.

In order to show more conclusively that feed flavors enter milk mainly through the body of the cow and to determine the time required for flavors to enter the milk, Babcock (19) conducted feeding experiments with garlic. This work showed that garlic flavor and odor can be detected in the milk when the milk samples are taken 1 minute after garlic is fed. The intensity of the garlic flavor increases as the time interval between feeding the garlic and taking the milk samples increases, until at 10 minutes a high degree of intensity is reached. Garlic flavor is present to a very objectionable degree in milk from cows that have consumed one-half pound of garlic 4 hours before milking. Milk drawn 7 hours after the cows consume one-half pound of garlic is practically free from garlic flavor. Strong garlic flavor is found in milk drawn 2 minutes after the cows inhale garlic odor for 10 minutes and practically disappears in 90 minutes after such inhalation. Garlic odor is readily perceived in samples of blood drawn 30 minutes after the cows are fed 2 pounds of garlic tops and strong garlic odor is present in the blood drawn 45 minutes after such feeding, indicating that the flavor is transmitted by the blood to the udder.

His work with bitterweed (20) further confirmed the fact that flavors enter milk mainly through the body of the cow. This weed is frequently found in southern pastures and, although it is practically odorless, it imparts its flavor to the milk when the cows eat it. Work with this weed also showed it to be an exception to the usual rule "that feed flavors are more pronounced in cream than in the milk from which the cream is taken," the flavor produced by bitterweed being more pronounced in skim milk than in whole milk and much less pronounced in the cream than in the skim milk. It further showed that there also may be exceptions to the rule that "feed flavors are not imparted to milk except for a few hours after feeding." When cows consume 10 pounds of bitterweed the flavor is present in the milk produced 24 hours later, but milk produced 27 hours later is practically free from a bitter flavor.

Babcock (21) summarizes his work by stating: “Proper methods of feeding are essential to the production of palatable milk. In most cases feed flavors are not imparted to milk except for a few hours after feeding. For this reason dairy cows should be given highly flavored feeds immediately after milking, never just before. When consumed in large quantities, feeds such as cabbage, which has an unusually strong flavor and odor, occasionally affect the quality of milk for 12 hours after feeding; but the intensity of the flavor has usually decreased to such an extent that it would not be noticed by the average consumer.” He further states: “Proper aeration and cooling reduce strong feed flavors and odors and sometimes eliminate slight flavors
and odors. Therefore, when the practice of feeding immediately after milking is followed by proper aeration of the milk, most highly flavored feeds will not make the milk unpalatable."

Some of the feeds studied by Babcock (14–18) are mentioned in earlier literature. Vandenhooydonck (22) reports a case in which the cause of a bitter flavor in milk was located in the feeding of Swedish turnips which had been washed in foul ditch water. Dammann (23) says “Bitterness in milk is often due to feedstuffs such as oat straw, turnip roots, cabbage, rapeseed cake, wormwood.” Dean (24) reports feeding cows 3 pecks (41 pounds) of turnips per day with the result that a slight taint was noted in the milk. When 4 pecks (55 pounds) were fed, the milk had a decided taste of turnips. Pasteurization and added starter prevented this taste from being carried to the butter. He also reported that the flavor of butter was slightly better from mixed feed than from silage feed. Lindsey, Holland, and Smith (25) report that the feeding of dried distillers’ grains or brewers’ dried grain in quantities of from 3 to 4 pounds per cow per day did not affect the flavor of the milk, and regarding the feeding of beet pulp Reece (26) reports that the milk showed no uncommon flavor of any kind when 10 pounds per head per day of the best pulp slices were being fed to cows at 4 important English agricultural colleges.

The results obtained by Gamble and Kelly (2) and by Babcock (14–21) have been confirmed and extended by other investigators. Davies (27) reported that the feeding of dried beet pulp sometimes causes a fishy or off-flavor in milk. Hening and Dahlberg (28) found no abnormal flavors due to feeding mangels or dried beet pulp and at the same time concluded that these feeds in no way prevented or increased the susceptibility of milk to the development of oxidized flavor.

Roadhouse and Henderson (29) state that “full rations of alfalfa hay, green alfalfa, clover hay, or corn silage fed 1 to 2 hours before milking produced strong, undesirable feed flavors and odors. As the interval between feeding and milking increased, the intensity of the feed flavors decreased. When these feeds were withheld during the 5-hour interval before milking, objectionable feed flavors and odors were eliminated.” These authors also found that when green barley, wild oats, foxtail, and filaree were fed to cows 2 hours before milking, in quantities required for satisfactory nutrition and as a sole source of roughage, undesirable feed flavors varying from slight to strong were imparted to the milk in every instance. Tame oat hay gave only slight after-flavor in milk when 8 to 9 pounds was fed to cows 2 hours before milking. When fed in a mixture with 7 pounds of alfalfa hay, it did not modify the intensity of the alfalfa flavor. Improperly cured hay having a musty odor transmitted a musty flavor to milk.

Studying the concentrates, these same investigators state “The usual concentrate feeds—rolled barley, coconut meal, soybean meal, cottonseed
meal, wheat bran, and dried beet pulp—when fed 1 or 2 hours before milking, in quantities used by the average commercial dairyman, did not give milk sufficient flavor to make it undesirable to the average consumer. Rolled barley and beet pulp, however, fed alone in 5-pound quantities or more, 1 and 2 hours before milking, gave either a detectable flavor or after-flavor; but the judges believed that these would not be noticed in cold milk by the average consumer. Wheat bran seemed to improve the flavor of the milk when fed in 5½ to 7 pound quantities 1 hour before milking. It gave more flavor to the milk than was present in the control samples, and the flavor was reported as pleasing."

In a study to determine the rate at which the juice of the alfalfa plant made its appearance as a feed flavor in the milk, Roadhouse and Henderson (30) concluded: "Feed flavor appears in milk 20 minutes after the ingestion of flavor-producing materials in liquid form. The most pronounced feed flavor was present in the milk drawn 45 to 60 minutes after drenching."

These same investigators (Roadhouse and Henderson) (31) found that when cows were fed alfalfa hay as roughage immediately after milking or were given access to alfalfa pasture both day and night for the entire interval between milkings, they did not consume sufficient feed during the last 5 hours before milking to seriously affect the flavor of the milk. When they were given access to the pasture only, during the interval between morning and evening milkings, they consumed sufficient feed during the 5-hour interval before milking to cause an objectionable feed flavor in the milk. Under these conditions they recommend that the cows be removed from the pasture 4 or 5 hours before milking if feed flavor in milk is to be entirely avoided. They also recommend that if large amounts of corn silage are used in the ration it be fed after milking.

Lucas (32) stated "Alfalfa hay gives to milk a rather pronounced flavor but it is objected to only by a very few people." Weaver, Kuhlman, and Fouts (33) concluded from their work with alfalfa hay that: "Alfalfa hay fed less than four hours before milking has a pronounced effect on milk flavor. This effect is observed even when the interval between feeding and milking is only one-half hour. The two-hour interval causes the most serious flavor in the milk. If the hay is fed as long as four hours before milking the flavor is entirely eliminated with some cows. With other cows it is so reduced as to be scarcely discernible. Aeration of the milk removes some of the flavor but does not entirely eliminate it. Cooling seems to be ineffective and the effect of alfalfa hay is far more serious than that of darso silage."

The important part which feeds play in the flavor of milk has been further exemplified by Weaver, Fouts, and McGilliard (34). These investigators have shown that feed flavors are the most prevalent of the numerous flavor defects encountered in milk.
SUMMARY

The investigators on the effect of feeds on the flavor and odor of milk have shown that:

Many feeds impart their flavor to milk, the intensity of the imparted flavor depending upon the character of the feed, quantity consumed, and the time the feed is consumed in relation to the time of milking.

Feed flavors enter milk mainly through the body of the cow and in most cases these flavors are not imparted to milk except for a few hours after feeding.

Strong feed flavors are reduced in intensity and slight flavors may be eliminated by proper aeration.

Highly flavored feeds should be fed immediately after, never just before, milking.

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