TOPIC

20

Silage Quality

OBJECTIVES

- To understand the factors affecting silage quality.
- To describe the silage gases, molds, and storage losses.
- To describe how to put up silage.

Harvesting silage crops at the proper stage of maturity ensures the maximum yield and nutrient content. Corn should be harvested after the early dent stage and prior to the black layer forming. Corn harvested for silage in early dent stage is highly digestible, but total yield per acre and nutrient content of the silage will be lower than if the corn is harvested after this stage. On the other hand, when the grain reaches full physiological maturity, several layers of cells near the tip of the kernel turn black, forming the black layer (Figure 20.1). This layer can be detected by removing several kernels from the middle of the ear and splitting them lengthwise or cutting off the tip. If the black layer is present, usually the grains are dented and glazed, the lower four to six leaves of the corn plant are brown, and the plant contains 60 to 67 percent moisture. If the corn is harvested for silage at this stage, yield per acre is highest, but silage digestibility is lower than if the corn is harvested prior to this stage. Optimal harvest stage occurs at somewhere around one-half milkline stage, and cow productivity is highest when they are fed silage harvested at this stage.

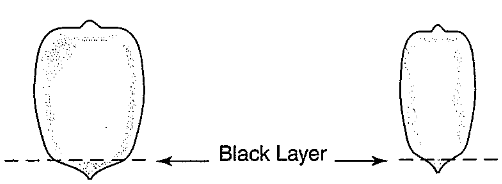

Figure 20.1 The black layer test is useful for determining readiness for harvest of corn silage. *(Courtesy of M. E. Ensminger)*

Sorghum should be cut for silage when the seeds are hard. Grass silage forages (grasses, legumes, and cereal crops) should be cut at the same stage at which they would make the best hay. The length of the cut sections affects the packing and hence the quality of the silage (Table 20.1). Also, the proper length of cut varies with the crop and the moisture content. Thus, for corn and sorghum crops, forage harvesters should be set to make a theoretical cut of ⅜ inch. If the knives are sharp and set up to the cutter bar, the result is about 15 percent of the particles being 1.5 inches and over, 25 percent of the particles being ¾ to 1½ inch, and 60 percent being ⅛ to ¾ inch in length. Grass silages should be more finely chopped than corn or sorghum silage to improve packing. Also, wilted and dry forage and forage with hollow stems should be chopped more finely than forage of high-moisture content, thus permitting more thorough packing and eliminating most air pockets.

Moisture content is one of the most important factors in determining the quality of silage. Moisture content between 60 and 67 percent is best

TABLE 20.1 Effect of Chop Length on Whole Kernels in Silage and Passage into Manure

Chop (Inches)	*Silage Dry Matter (%)*	*Whole Kernels in Silage (% of Dry Matter)*	*Whole Kernels in Manure (% of Whole Kernels Fed)*
⅛	28	0.02	0
¼	26	0.1	93
⅛	34	0.31	68
¼	32	0.53	66
⅛	48	1.4	63
¼	50	2.1	66

Source: Modified from J. G. Linn, D. E. Otterby, and N. P. Martin, Feeding Corn Silage to Dairy Cattle and Agricultural Extension Service, University of Minnesota.

(Figure 20.2). However, low-moisture silage of 40 to 60 percent moisture can be preserved successfully in oxygen-limiting silos or tall, conventional silos that are properly topped off with heavy, wet forage or sealed with a plastic cover. Forage containing more than 60 to 67 percent moisture is heavier and more costly to handle; is apt to produce slimy, putrid silage due to the presence of butyric and other undesirable acids; produces excessive seepage (Figure 20.3) and loss of nutrients; results in excessive deterioration in the silo walls due to the high acidity; and exerts greater pressure on the silo walls (the greater the moisture content, the greater the pressure.) Cows also have reduced intakes when consuming these excessively high-moisture silages in part because of the different end products of fermentation produced during the ensiling process. If corn and sorghum are harvested at the stage recommended, their moisture content is right. However, freshly cut grass and/or legume forage contains 75 to 80 percent moisture, which means that for proper ensiling its moisture content must be lowered by 10 to 15 percent. The moisture content of silage material may be lowered by conditioning and/or wilting; adding dry hay or straw; combining with corn or sorghum silage; or adding a dry preservative of grain, dried molasses, or dried by-products of citrus or beets.

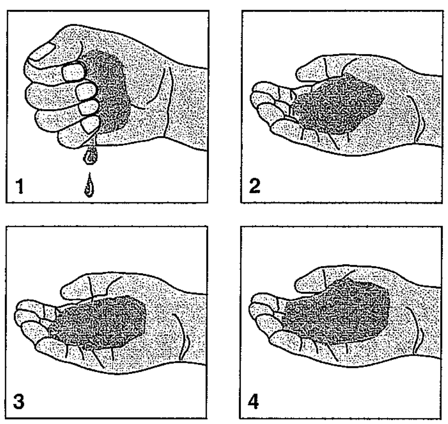

Figure 20.2 Quick determination of moisture content of silage: 1, 75 to 85 percent; 2, 70 to 75 percent; 3, 60 to 65 percent; 4, less than 60 percent. *(Courtesy of M. E. Ensminger)*

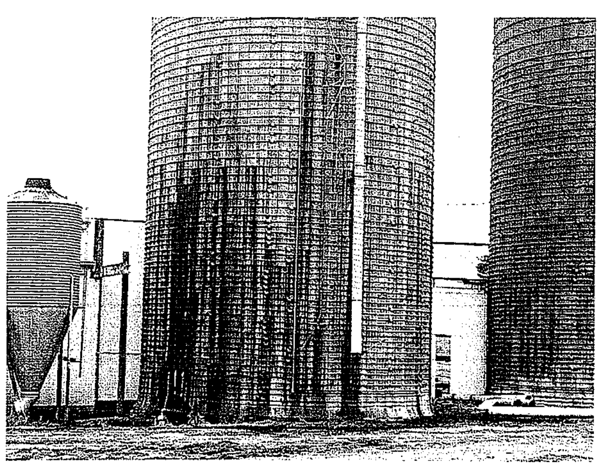

Figure 20.3 Seepage stains are apparent on the side of this upright silo. *(Courtesy of Mark Kirkpatrick)*

Conditioning and/or wilting of grass silage increases the percentage of sugar in the forage, decreases seepage losses from the silo, lessens the pressure on the silo walls, and decreases the destructive action of the acids on the silo walls. The needed 10 to 15 percent reduction in the moisture content of grass silage material can be accomplished by wilting for about 2 hours on a good drying day and up to 1 day or longer in slow drying weather. The combination of conditioning and wilting is the method most commonly followed. Excellent equipment is available for conditioning. Excess drying should be avoided because it results in the forage becoming too dry for proper ensiling.

The moisture content of any wet silage material can be lowered effectively by mixing dry hay or straw with it at the time of filling. Thus, during poor wilting weather, the moisture content of grass forage can be brought within the desired range by adding 5 to 20 percent hay or straw. This is the standard method of lowering the moisture content of high-moisture products such as potatoes. Conditioning and wilting is the preferred method of lowering the moisture content of grass silage, rather than adding dry hay or straw which reduces digestibility and energy content. Dry preservatives such as ground grain; corn-and-cob meal; dried molasses; and dried citrus meal, citrus pulp, or beet pulp reduce the moisture content of freshly cut and unwilted forage and, in turn, decrease seepage from the silo.

If the crop is overripe and too dry when cut or if it becomes overwilted, water should be added to the silo. A preferred alternative is to harvest the crop as hay rather than ensiling it. Drier material may be used for silage by cutting shorter and packing more thoroughly. If necessary, water should be added or the dry material should be mixed with very green, freshly cut material by alternating loads.

SILAGE ADDITIVES AND PRESERVATIVES

Silage additives provide supplemental nutrients that enhance the feeding value of silage. Silage preservatives enhance the keeping qualities of silage. High-quality silage can be made without the use of additives or preservatives if you start with good material and all proven good practices are followed. But there are times when the ensiled material is either too wet or too dry, does not contain sufficient fermentable carbohydrates, is deficient in certain nutrients, and lacks palatability, and/or the proven good practices cannot be followed. Under such circumstances, silage additives or preservatives may reduce silage losses and/or improve the feeding value of the silage. Normally, additives or preservatives are not needed for corn or sorghum silages. But additives or preservatives may be very helpful if ensilling a grass/legume forage with over 70 percent moisture. The decision about using any silage additive or preservative is based on how much it improves animal performance and net profit, not whether it merely makes silage look and smell better.

Silage made from legumes or grasses may be improved under certain conditions by the addition of ground grain (corn, wheat, or barley), ground ear corn, beet pulp, citrus meal, citrus pulp, or other appropriate feed ingredient. The ground material provides a readily available source of carbohydrates (sugar and starch) for bacterial fermentation and the production of acids, increases the feeding value of the silage because 75 to 85 percent of the feeding value of the grain is retained if the silo excludes air properly, and likely improves palatability. If the primary concern is to reduce the moisture content of the silage, cheaper materials, such as ground corn cobs, cottonseed hulls, oat hulls, or chopped straw or hay, may be more appropriate than ground grain. Dry, finely ground corn cobs absorb nearly 200 pounds of water per 100 pounds of the cob material; dried beet pulp absorbs even more. These materials may be added by feeding them into the blower from a properly adjusted hopper attachment. When green forage is ensiled at a proper moisture content, there is usually no advantage to adding grain for the purpose of preservation or palatability.

Some green forages, such as legumes and certain grasses, are rather low in sugar content. Hence, adding molasses, which is high in sugar, may increase lactic and acetic acid production and improve silage quality and preservation. Also, molasses improves the palatability of silage and increases its nutritive value. For legumes, about 80 pounds of molasses is added per ton of silage; for grasses, about 40 pounds is added per ton (molasses weighs 12 pounds/gallon). Addition of much less than these amounts, as an ingredient in mixed preservatives, is of little value. Much of the feeding value of the molasses is retained in the silage under good storage conditions and when there is no seepage loss. Molasses may be added in either liquid or dehydrated form as the forage enters the blower. When a grass and/or legume is wilted to 50 to 60 percent moisture content and adequately protected from air, an excellent feed with a good aroma and keeping quality can be obtained without the addition of molasses.

Adding dried whey to alfalfa silage or haylage slightly improves the quality and digestibility. There is also indication that adding dried whey to urea-treated corn silage may help reduce nitrogen losses and improve the feeding value of the silage.

Urea, ammonia, and other nonprotein nitrogen products can be added to corn or sorghum silage at the time of ensiling as a source of nonprotein nitrogen. Urea increases the crude protein content of the silage and the amount of lactic and acetic acids produced. The addition of 10 pounds of urea per ton of ensiled corn material makes the following approximate increases on a dry-matter basis: crude protein, from 8.3 to 12.3 percent; lactic acid, from 4.2 to 5.4 percent; and acetic acid, from 0.9 to 1.2 percent. Since the amount of nonprotein nitrogen that can be converted to microbial protein by the organisms in the rumen is limited, no more than 10 pounds of urea should be added to a ton of ensiled corn material. The urea can be added by spreading it over the top of each load of chopped corn, or it can be added to the chopped corn through the blower by commercially manufactured metering equipment. Ammonia-containing materials, including ammonia-water solutions, ammonia-mineral solutions, ammonia-mineral-molasses solutions, anhydrous ammonia gas, and cold-flow ammonia, can also be added to corn silage as a source of nonprotein nitrogen. For dairy cattle, 5 pounds of actual nitrogen (about 6 pounds of ammonia) may be added per ton of wet silage. Ammonia-treated corn silage has been found to contain increased concentrations of true protein, lactic acid, and acetic acid. Also, it may have a higher pH and be more stable than untreated silage when exposed to air. Special equipment is required to add ammonia or ammonia-containing materials.

When corn silage spiked with urea or ammonia is the major source of protein fed to ruminants, there may be inadequate sulfur for the rumen organisms to manufacture their own protein. In such cases, the addition of sulfur to achieve a nitrogen-sulfur ratio of less than 15:1 improves both growth and the milk production of cattle. The most practical way to provide additional sulfur is to add gypsum (calcium sulfate) at the rate of 1.8 pounds per ton of silage. Even under ideal conditions, about 10 percent of the urea may be lost; under average conditions, up to 30 percent of the urea may seep away or be lost as ammonia gas. Ammonia gas is dangerous, causes irritation and can accumulate in the silo.

Limestone (calcium carbonate) may be added at a level of 0.5 to 1 percent to corn silage to increase acid production. It neutralizes some of the initial acids as they are formed, allowing the lactic acid bacteria to perform longer and to produce more desirable acids. The addition of limestone at ensiling time raises the naturally low calcium content of corn silage, a fact that should be considered when balancing rations.

Both inorganic (mineral) and organic acids may be used as additives. Mineral acids lower the pH immediately, while organic acids have a limited effect on lowering pH. Both mineral and organic acids limit microbial growth and help to stabilize silage. Inorganic acids (hydrochloric acid, sulfuric acid, phosphoric acid) have been used as silage preservatives, almost entirely in Europe, in connection with the ensiling of high-moisture material. These acids substitute for the acids produced by bacterial action; however, they are very corrosive, creating application difficulties including corrosion of silo walls and silage-handling equipment. Of the three acids, phosphoric acid is preferred because it is less corrosive than sulfuric acid or hydrochloric acid, it may enhance the phosphorus content of the silage, and it increases the residual manure value from the silage. But phosphoric acid may introduce a problem of proper calcium-phosphorus ratio. When mineral acid preservatives are used, it is recommended that ground limestone or some other form of calcium or sodium carbonate be fed to animals at the rate of approximately 1 ounce for each 10 pounds of silage to neutralize the acid.

In general, the use of mineral acid preservatives is not considered as desirable as the use of molasses or grain because they produce a more sour and less palatable silage; they may damage clothing, machinery, and/or masonry silo walls due to their corrosiveness; and they do not add to the nutrient value of the silage except by enhancing the preservation of carotene. In general, the use of mineral acids has more disadvantages than advantages.

Propionic, acetic, lactic, citric, and formic acids are used in a manner similar to inorganic acids, but they are much less corrosive and not so difficult to handle, although precautions must be taken. Organic acids enhance the preservation of forage without the loss of palatability. Also, they serve as mold inhibitors. Even so, like all additives, they cost money; hence, the economics of using them when making silage must be considered. Organic acids are of the greatest benefit in the preservation of high-moisture grain.

Fermentation aids include bacterial cultures, yeast cultures, and enzyme supplements. Controlled experiments support the claims made for some of these products, but not all of them; they should be purchased only from reputable sources that have valid research data to support the claims made for them. Silage additives containing cultures of acid-forming bacteria (Lactobacillus) provide an inoculum to increase the numbers of these bacteria and ensure rapid fermentation. Advocates of these products claim that they increase the dry matter, energy, and protein of the silage. The number of bacteria provided through such additives is insignificant compared to the numbers already present on the ensiled material, and inclusion of these products must be justified on some other basis.

Yeast cultures have also been included in certain silage additives. However, yeasts sometimes grow in silage without an inoculum being added. When this happens, the silage has a yeasty odor and taste, which is considered undesirable. Yeast does have nutritional value, but because of the small quantity involved in additives, the contribution is minimal.

Cultures of molds or of molds with other microorganisms are sometimes added to silage to provide a source of enzymes. Some claim that these enzymes improve the nutritive value of the silage by increasing its digestibility or digestible nutrient content. Although the enzyme activity of these preparations has not been measured experimentally, the quantity of enzymes added is insignificant compared to those already present in the silage.

Preservatives include antibiotics, salt, and sterilants. These products preserve silage by inhibiting microbial action or undesirable fermentations. All of them are of questionable value if air is properly excluded from the silage. If air is not excluded, they must be added at very high levels to be effective. Theoretically, antibiotics can preserve silage by selective action: by inhibiting undesirable microbial activity while allowing the desirable organisms to develop. So far, the results have been inconsistent. Also, at an appropriate level, salt inhibits certain microorganisms without preventing the action of bacteria that produce the desirable acids.

Sterilants include sulfur dioxide, sodium diacetate, sodium metabisulfite (sodium sulfite), sodium benzoate, and sodium nitrate. Sodium propionate and other organic acids have also been used as preservatives because of their mold-inhibiting properties. Each of these products appears to reduce carotene losses, improve the odor of silage, and/or lessen the production of toxic gases. But their effect on palatability is variable. The cost and inconvenience of application of these products may not justify their advantages.

Additives or preservatives are not essential to good silage formation when conditions of moisture and storage are right. Under special circumstances, however, they can be recommended for use. For example, molasses, grain, or grain by-products might be a wise addition to silage when conditions do not allow for proper wilting prior to ensiling or when an all-in-one silage is being made. Urea may be an appropriate addition when increasing the protein content of the silage simplifies its feeding. It is doubtful that there is any justification for adding limestone unless this is a convenient method of calcium supplementation. The economy of most nutritive additives of this type depends largely on how well their nutrients are retained in the silage and the use made of them in balancing the rations.

When forages are stored at the proper moisture content and when air is properly excluded, nutrient losses are low, and a good-quality silage forms. Additives such as lactic acid bacteria, mold inhibitors, antibiotics, salt, enzymes, yeast cultures, and mineral acids can therefore do little, if anything, to improve the preservation of the silage or its feeding value. When high-moisture material is ensiled, grain is superior to any of these additives. When air is not properly excluded, none of these additives correct the large fermentation and spoilage losses. There is no substitute for good management of forage crops for silage, with proper control of factors such as stage of maturity at harvest, harvesting methods, moisture content, fineness of chopping, distribution and packing, and exclusion of air.

PUTTING UP SILAGE

Once silo filling is started, it should be rapid to avoid spoilage before the silo is filled and sealed (Figure 20.4). Typically, a silo should be filled in two days or less. To avoid the presence of air pockets and spoilage, it is essential that any kind of chopped forage be distributed uniformly in the silo and that it be packed well. Proper silage distribution is obtained by keeping the material nearly level or slightly higher at the center. Silage-distributing equipment is available for keeping the material in an upright silo level. These devices are very helpful, especially in silos of 14 feet or larger in diameter.

When corn, sorghum, and sunflower forage is harvested at a green, immature stage and cut into short lengths, tramping in an upright silo is not necessary, but uniform distribution is very important. The only filling precaution under these conditions is to ensure that the top is carefully leveled, well-packed, and covered whenever filling is completed. Grass silage (especially when wilted), hollow-stemmed forages, and forages that have matured or dried beyond the best silage stage should always be tramped well, especially near the wall. Packing in a trench silo should be ensured by use of a large tractor.

Figure 20.4 Molds form in areas where silage is exposed to air. *(Courtesy of Mark Kirkpatrick)*

Sealing or topping off is necessary to avoid excess spoilage, especially with grass silage, which tends to dry out on the surface and to shrink away from the silo walls. This may be accomplished by leveling off the top and thoroughly tramping the last few feet, especially near the walls; topping off the silo with two to three loads of wetter material; or covering the top with plastic cut to fit the silo diameter and turned up against the silo wall a distance of 5 to 8 inches.

Seepage losses vary with the moisture content, depth of silage, distribution of the silage, and the amount of nutrients in the seepage. Seepage losses may be as high as 14 percent of the dry matter stored. The nutrient losses vary, but generally they are in proportion to the runoff. The nutrients lost in seepage from a 100-ton silo may equal the nutrients in ¾ ton or more of hay.

SILAGE GASES AND MOLDS

Two types of toxic gases may be formed when making silage: carbon dioxide (CO_2) and/or nitrogen dioxide (NO_2). Carbon dioxide forms soon after filling begins and continues until fermentation stops. It is a colorless, suffocating gas that is heavier than air and tends to collect in low places. Under drought conditions, corn, sorghum, and other grass species may accumulate higher than normal levels of nitrates. When ensiled, nitrates are converted to nitrites, and then nitrites are converted to nitrogen oxide by bacteria and plant cells. As the nitrogen oxide comes in contact with air, it is oxidized to form nitrogen dioxide, a reddish brown gas that is heavier than air. This gas is highly toxic to both humans and farm animals. Precautions against hazards caused by silage gases include operating the blower for a 15-minute period if it is still connected or using proper life-support equipment when entering an oxygen-limiting or sealed silo. Also, adequate provision for ventilation of the silo through the roof is essential. A victim of silo gas should be moved into fresh air immediately, and artificial respiration should be applied. A physician should be called immediately.

Mycotoxicosis (silo filler's disease or farmer's lung disease) is a reaction to molds on silage. It occurs most often when opening a silo that has been previously sealed. It is a flu-like illness; the best cure is to avoid the problem. Wearing a protective mask when opening a silo is a useful precaution.

SILAGE STORAGE LOSSES

Tight structures, good distribution and packing, and the proper use of plastic covers minimize silage storage losses (Figure 20.5). Losses from different types of silo storage vary widely based primarily on length of time and season of feedout; this is especially critical for silages continuously exposed to air. Losses in trench and open stack silos are also influenced by depth; less surface is exposed in deeper silos.

Losses in the silo include surface or top spoilage, seepage, gas production, and heating losses (browning reaction and spontaneous combustion). Surface or top spoilage losses of 20 percent or more may occur in stack silos and in any uncovered bunk, trench, or pit silo (Figure 20.6). These losses can be reduced with the use of suitable protection, such as a plastic cover.

Seepage losses can be high in high-moisture silage stored in upright silos. The higher the silo, the greater the pressure and the higher the losses through seepage. The seepage carries soluble feed nutrients with it. Horizontal silos have less seepage loss than do upright (tower) silos because of lower vertical pressure. Seepage losses are reduced by wilting forages to less than 65 percent moisture before ensiling.

Gas production is unavoidable as long as the plant material respires and there is subsequent fermentation. These losses can be minimized, however, by keeping air out of the silo, having the pH decline rapidly, and encouraging favorable fermentations. Lowering the moisture without excluding the air may lead to heat damage, known as the browning reaction or Maillard reaction. Spontaneous ignitions sometimes occur in low-moisture silage (haylage). For such losses to occur, there must be a buildup of temperature to the combustion point in the silo mass, combined with a low transfer of heat. These fires are difficult, often impossible, to extinguish. The addition of water may build up pressure and lead to an explosion. Most silo fires should be allowed to burn.

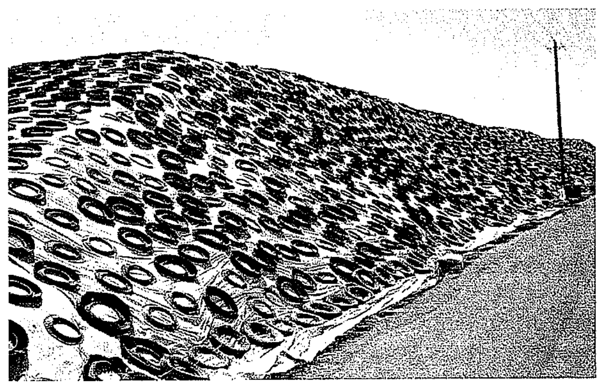

Figure 20.5 This extended pile of silage is covered with plastic that is held in place with half-tires until it is ready to be fed to the cattle. *(Courtesy of Howard Tyler)*

Figure 20.6 Under adverse conditions, plastic coverings protecting silage can be damaged or lost, which can result in spoiled or moldy silage. *(Courtesy of Howard Tyler)*

SUMMARY

- Harvesting feed at the proper stage of maturity ensures the maximum yield and nutrient content.
- The length of the cut sections affects the packing and quality of silage.
- Moisture content is one of the most important factors in determining the quality of silage.
- Silage additives provide supplemental nutrients while enhancing the feeding value of silage.
- Urea, ammonia, and other NPN products can be added to corn or sorghum silage at the time of ensiling as a source of nonprotein nitrogen.
- Inorganic acids have been used as silage preservatives.
- The higher the silo, the greater the pressure and the higher the losses through seepage.
- Two types of toxic gases may form when making silage: carbon dioxide and/or nitrogen dioxide.
- Tight structures, good distribution and packing, and the proper use of plastic covers all help minimize silage storage losses.

QUESTIONS

1. What test can be applied quickly and easily to determine when to harvest corn for maximum yield and nutrient quality?
2. What are some disadvantages to silage with a moisture content greater than 60 to 67 percent?
3. What is mycotoxicosis (silo filler's disease or farmer's lung disease)?
4. What are the advantages of conditioning and/or wilting grass silage?
5. Why would a dairy farmer add limestone to the corn silage?
6. What are the three inorganic acids used as silage preservatives?
7. What is the greatest benefit in the preservation of high-moisture grain?
8. What is the typical time to fill a silo?

ADDITIONAL RESOURCES

Book

McDonald, P. *The Biochemistry of Silage.* Chichester, UK: Wiley, 1981.

Articles

Dewar, W. A., P. McDonald, and R. Whittenbury. "The Hydrolysis of Grass Hemicelluloses During Ensilage." *Journal of the Science of Food Agriculture* 14 (1963): 411–417.

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Nagel, S. A., and G. A. Broderick. "Effect of Formic Acid or Formaldehyde Treatment of Alfalfa Silage on Nutrient Utilization by Dairy Cows." *Journal of Dairy Science* 75 (January 1992): 140–154.

Pitt, R. E., and R. E. Muck. (Trans.). "Enumeration of Lactic Acid Bacteria on Harvested Alfalfa at Long and Short Wilting Times." Transactions of the American Society for Agricultural Engineers ASAE 38 (June 1995): 1633–1639.

Weinberg, Z. G., A. Ashbell, and A. Azrieli. "The Effect of Applying Lactic Acid Bacteria at Ensilage on the Chemical and Microbiological Composition of Vetch, Wheat and Alfalfa Silages." *Journal of Applied Bacteriology* 64 (January 1988): 1–7.