SDSU Extension

iGrow Corn

BEST MANAGEMENT PRACTICES

Chapter: 18

Corn Silage Production and Utilization

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Silage is a high moisture fermented fodder used as a feed for livestock. It is produced by allowing chopped green vegetation to ferment under air-tight conditions. During the ensiling process water-soluble carbohydrates are converted to acids, which lowers the pH and protects the silage from further deterioration. To optimize silage production, management practices specifically designed for this purpose should be followed. This chapter focuses on the production of the corn crop used to produce silage and provides examples on how to assess its quality. When growing corn for silage, it is important to consider animal performance in addition to yield.

Selecting a Corn Hybrid

Selecting the same corn hybrids and management practices to produce silage and grain may reduce silage feed quality. Good corn silage hybrids have high yields, high energy, high digestibility, and good animal performance.

Critical to maximize silage yields is the selection of the right variety. With lower corn silage yields, there is a greater need for livestock supplementation, which increases feed costs. However, because grain provides needed starch, it is unlikely that corn grain will be completely removed from the ration. Since starch is deposited in the kernels, the amount of grain in the ration is associated with the energy content of the silage. In the past, the rule of thumb for the corn silage grain-to-forage ratio was 50:50. The improved grain yield per unit area of modern corn hybrids is because of the increased optimum plant population rather than the improved grain yield per plant.

For example, hybrid 1 produces 150 bu/acre or 20 tons/acre of corn silage at 65% moisture. This hybrid has a grain equivalent per ton of corn silage of 7.5 bushels, and the proportion of grain per ton of dry silage as percent of the whole plant is 420 lbs (7.5×56) divided by 700 (350×2) or 60% grain per ton of dry matter.

Hybrid 2, produces 200 bu/acre or 29 tons per acre at 65% moisture. This corn hybrid has a grain equivalent per ton of corn silage of 6.8 bushels, and the proportion of grain per ton of dry silage as percent of the whole plant is 380 lbs (6.8×56) divided again by 700 (350×2) or 54% grain per ton of dry matter.

By difference, one can infer that the forage fraction of 150-bushel corn yielding 20 tons of silage per acre is 40% (100-60), whereas the forage fraction of the 200-bushel corn is 46% (100-54). If we estimate, 0.7 megacalories (MCal) of net energy for gain (NEg) per pound of corn grain the 150-bushel produces:

0.7×56×150 = 5,880 MCal NEg per acre, whereas the 200-bushel corn produces: 0.7×56×200 = 7,840 MCal NEg per acre or 33% more energy. These calculations show trade-off often seen between hybrids.

Desirable hybrid characteristics for grain production, such as hard and fast-drying kernels, are exactly the opposite of what are needed in corn silage. Corn hybrids for silage need to have both high yields and increased starch and fiber (NDF) digestibility.

Corn Silage Planting Date, Population, Fertilizer, and Insect Control

Where possible, select corn silage hybrids that have a slightly higher maturity rating that grain hybrids, and cultivate early at rates 2,000 to 3,000 plants/acre higher than for grain producation. Row spacing should be approprate for the agricultural system, and harvesting corn for silage removes more N, P, and K than harvesting corn for grain (Chapter 24). If the field is routinely harvested for silage, consider increasing the amount of fertilizer or manure applied to the field.

Climatic conditions can impact silage quality. Dry conditions during stalk development generally increase digestibility, but drought conditions can result in silage with very high nitrate concentrations. However, because much of the nitrate is contained in the lower portions of the stalk, high nitrate concentrations can be minimized by raising the chopper cutter blade. The concentration of nitrate that causes toxicity in ruminants depends on total intake (diet + water), the acclimation of the animal to the nitrate, and its overall nutritional and health status. As a rule of thumb, forage with less than 5,000 ppm nitrate (mg NO_3/kg dry silage) or 1130 ppm NO_3-N is considered safe. Forage containing 5,000 to 10,000 ppm NO_3 (1130 to 2260 mg NO_3-N/kg dry silage) is considered potentially toxic when it is the only source in the diet (Whittier, 2014). If the forage has more than 10,000 ppm NO_3 (2260 mg NO_3-N/kg dry silage) it can be fed to nonpregnant, healthy ruminants provided it's diluted with other safe, nitrate-free forages. Generally, pest control practices are similar in corn grown for silage and grain. However, if pesticides are applied to the field, it is important to follow labeled rates for silage.

Improving the Nutritive Value

Starch Digestibility

The energy value of corn silage is highly dependent on the content and digestibility of starch and fiber components. The digestibility of both fractions in ruminants differs. Fiber is mostly fermented in the reticulo-rumen and the products of this fermentation are utilized by rumen microorganisms. There are corn silage varieties that have higher starch digestibility. In general, corn silage hybrids with softer and slower drying kernels, preserve better in the silo and have higher total starch digestibility. Starch is mostly fermented in the rumen. However, some may escape and potentially be digested and its end products absorbed in the lower digestive tract. Its high water-resistance allows some starch to escape rumen fermentation before bacteria can degrade it. This "protection" from degradability can also reduce accessibility to starch-degrading enzimes in the small intestine. With corn silage starch of lower digestibility (i.e. flinty), a portion can end up in the manure, particularly with higher rates of passage typical of animals with high feed intakes. Thus, it is important to understand the consititutional factors influencing grain digestion.

Table 18.1 The relationship between prolamin percent and starch classification.

Prolamin percent of starch classification	
10	
9	Very high
8	
7	High
6	
5	Moderate
4	
3	Low
2	
-	Very low

Source: AgriAnalysis Inc. 2010

In a University of Wisconsin study, Hoffman and Shaver (2014) showed that starch digestibility decreased 0.86 percentage units per percentage unit increase in prolamin content when expressed as percent of the starch. This negative relationship was attributed to the prolamins interfering with starch digestion. Corn hybrids with a more diffuse protein matrix allow for greater water penetration and improved starch accessibility (Hoffman and Shaver, 2014). During the fermentation process, prolamin protection of starch is reduced.

Fiber Digestibility

Corn silage nutritive value is affected by its content of grain, stalks, cobs, leaves, and ash (natural minerals from the plant and/or soil contaminant). Relative proportions of these plant components in corn silage will determine the amount of fiber (neutral detergent fiber; NDF), starch, and protein content. Corn silage is low in protein and provides fermentable starch, energy, and relative amounts of effective fiber (depending on its particle size). Fiber has a greater negative impact on nutritive value because of its lower digestibility compared with starch.

When confronted with high corn prices, livestock producers need to decide whether the corn should be harvested for silage or sold as a cash crop. To address this question one important consideration is forage digestibility. More tonnage means more grain but also more plants and, consequently more fiber-rich stems that dilute energy concentration. To make the most out of corn silage, it is very important to select varieties not only with more grain, but also with increased fiber digestibility (NDF). This is particularly important in diets for milking cows where forage fiber represents the largest nutrient fraction.

In ruminant diets, the fiber fraction is reported as neutral detergent fiber (NDF) and acid detergent fiber (ADF). The residue in the NDF is negatively correlated with feed intake and thus with energy uptake. Analyzing samples for NDF digestibility (NDFD) provides an estimation of the amount of energy the ruminant is able to obtain from that forage (see "Assesing Quality" below). For example, an increase of 1 percentage unit in NDFD can result in 0.37 lb increase in forage dry matter (DM) intake per day (Oba and Allen, 1999a; 1999b). Jung et al. (2004) reported that dairy cows ate 0.26 lb/day more feed DM when in vitro NDFD of corn silage increased by one unit. Cows fed corn silage with greater NDFD are able to eat more and obtain more total energy. This is the result of a faster emptying of the rumen, which reduces distension and allows for additional feed to be consumed. As a result, energy requirements can be fulfilled with less grain.

Brown midrib (BMR) is a natural mutation that occurs in corn and other crops. Brown midrib varieties have lower lignin concentrations and greater NDFD. Research has shown that NDFD of BMR corn silage varieties ranges from 64.4% to 72.8%, whereas NDFD in normal corn silages ranges from 44% to 63.8% (Hoffman and Combs, 2004). One other concern of BMR varieties is that they can have approximately 10% to 20% lower DM yields than normal varieties. Recent results (Darby et al., 2014) reported by the University of Vermont showed that 22 tons of corn silage at 35% DM per acre (44.8 fresh) were achieved with one BMR corn silage variety.

Research has shown that although BMR varieties have slightly less starch than forage-quality hybrid counterparts, they can be up to 30% more digestible. This is the reason, livestock producers should evaluate corn silage hybrids not only by tonnage and yield, but more importantly by animal performance. In dairy cows, a milk-per-acre index can aid in this evaluation. The University of Wisconsin has the milk-per-acre selection index that combines yield and quality into a single term allowing an easier ranking of forages and hybrid selection. Using this information, the milk-per-ton of corn silage is estimated, and then multiplied by the silage yield to calculate the amount of milk produced per acre of corn silage. Research conducted by Penn State University together with the W.H. Miner Agricultural Research Institute (Roth et al., 2001) suggest that improved plant digestibility can compensate for reductions in DM yields of BMR varieties. Researchers from the latter institution reported that NDF ratio is lower in the BMR hybrid, whereas starch content is higher. These findings suggest that the quality of the BMR hybrid is better than that of the conventional corn hybrid. This is true, however, only when cows respond with production. Several studies have shown that milk production can be increased by BMR corn (Oba and Allen, 1999a, 1999b; Nennich et al., 2000; Stone et al., 2012; Ballard et al., 2001).

Based on forage quality, BMR corn should be targeted to fresh and peak lactation cow groups to maintain intake and reduce rumen fill, leading to greater production and feed efficiency. This underscores the economic importance of assigning the right forage to the right animal group regardless of corn silage hybrid.

Kernel Processing
Harvesting corn silage at the black layer stage maximizes starch content in the kernels. Research has shown that digestibility decreases with increasing maturity. Bal et al. (1997) reported that corn silage moisture content decreased from 69.9% to 58% and NDF of the silages decreased from 52% to 41.3% as corn matured from early dent to black layer. Milk production was maximized at the 2/3 milk line stage, when the silage was 64.9% moisture. A second trial by the same research group evaluated silages at early dent (71% moisture), half milk line (64% moisture), and black layer (48% moisture). In this trial, milk production was highest at the early dent stage. The researchers found that starch and fiber digestibility decreased at the black layer stage. Based on these results, there is limited benefit in harvesting after the half milk line stage. The authors concluded that a target of 65% moisture seemed best, but that producers should begin harvesting at 70% moisture to avoid silage drying down excessively. Roth (2015) reported that corn silage moisture contents have increased from 58% to 63% from 2000 to 2010.

To harvest corn silage at higher maturities and maintain animal performance, the protein matrix that encapsulates the starch needs to be disrupted. This has sparked the interest in feeding processed (rolled) corn silage. Processing is a harvesting method where corn silage harvesters are equipped with post-cutting processing rolls. These rolls consist of two opposing, groove-ridged cylinders that roll to crush and physically damage grain and forage outer layers, which improves digestibility. For the system to work properly, the separation between roll surfaces is critical. It needs to be close enough to allow for proper "damage" of the plant material, yet not so close as to create excessive friction that wears the rolls. Self-propelled forage choppers are now available in the market.

In an early trial, Bal et al. (1997) compared corn silage harvested at half milk line, 67% moisture, and chopped at 3/8" theoretical length of cut (TLC) using a pull-type chopper and no rollers with other silages that were rolled. The other corn silages were harvested at 3/8", 9/16", and ¾" TLC and were rolled using the same pull-type chopper but fitted with a crop processor (1 millimeter roll spacing). On the unrolled silages, whole and half cobs were retained in the upper sieve of the Penn State particle separator, which could result in feed sorting in the feedbunk. Cows fed the rolled silages ate 1.5 lbs more dry matter per day compared with those fed unrolled silage. Cows fed the rolled silage also produced 2.5 lbs more milk and 3.5 more fat-corrected milk (FCM) daily. Milk fat was also 0.10% units higher on these cows, which could possibly be explained because of less sorting of the cobs in the bunk. The authors recommended a ¾" TLC with 1-mm roller clearance, except on wetter silages where the clearance could be expanded to 2 to 3 mm. Longer chop lengths are not recommended because of the potential for equipment wear and less packing in the silo. On a posterior trial, the same authors found that processing corn silage harvested later (at black layer) did not improve the digestibility of the fiber in the corn silage, which was reduced. From these results it does not appear that harvesting should be delayed.

New silage processors handle grain better than previous ones, allow for greater flexibility at harvest, and reduce feed sorting by the cows. In 2010 a new method of harvesting corn silage was developed in South Dakota. The system, named "Shredlage®" (Scherer Corrugating & Machine, Inc. Shredlage® LLC, Tea, SD) consists of cross-grooved crop-processing rolls mounted on a conventional corn silage harvester. According to the developer, Shredlage® silage has a number of benefits compared with traditional kernel processing silage as follows:

1. Longer chopped particles (26 to 30 mm vs. the traditional 19 mm), which reduce other forage fiber sources in the total mixed ration (TMR).
2. Longer plant stems, which increase the disrupted surface area. This enhances rumen microbial accessibility to cell contents, improves total tract digestion, and results in an overall enhanced rumen fermentation.
3. Stalks ripped lengthwise into planks and strings allowing for better packing.
4. Prolonged window for silage harvesting since it allows processing at greater maturities without losing too much digestibility.

In general, Shredlage® manufacturer guidelines show (Table 18.2) the higher the forage moisture, the longer the cut and wider the roll gap, whereas at lower moistures, the cut will be shorter and the roll gap narrower. Brown midrib (BMR) corn silage has spongier stalks and as a result may require a narrower roll setting than the current recommendations for conventional corn.

Table 18.2 Length of cut and roller gap suggestions for different corn silage moistures.

Forage Moisture (%)	Length of Cut (mm)	Roller gap (mm)
70	26-30	2.25
69	26-30	2.25
68	26-60	2.25
67	26-30	2.25
66	26-30	2.25
65	26-30	1.75
64	23	1.75
63	23	1.75
62	21	1.5
61	21	1.5
60	21	1.5

(Source: Shredlage.com)

Figure 18.1 Corn silage harvested with Shredlage® technology.

The use of Shredlage® as part of the total mixed ration for dairy cows was tested recently (Ferrareto and Shaver, 2012; Fig. 18.1). In one trial, Shredlage® and conventionally processed corn silage were harvested using self-propelled forage harvesters. The Shredlage® processing rolls were set for a 30-mm length of cut (LOC) (half of the knives removed). The processor gap spacing was set at 2.5 mm, whereas the conventional silage was set for a 19-mm LOC, with conventional processing rolls with 3-mm separation. The percentage starch passing through a 4.75-mm screen was greater for Shredlage® than conventional (75.0% vs. 60.3%) silage. The proportion of coarse particles retained on the Penn State top sieve was greater for the shredded silage (31.5% vs. 5.6%). Packing density in the silo bags was similar and averaged 272 kg of DM/m3 (17 lbs /ft3). Feed sorting was minimal and not different between silage processing methods. Cows fed TMR with Shredlage® tended to consume more feed but there was no difference in average milk yield (95 lbs/day). Milk component concentrations and yields were not affected by the type of silage. Cows fed Shredlage®, however, tended to have greater yields of 3.5% fat- and energy-corrected milk (2.2 and 2 lbs/day, respectively). Starch digestibility in the rumen was greater in cows fed Shredlage®.

Ferrareto and Shaver (2012) suggested that feeding Shredlage® may be a potential tool for dairy producers and their nutritionists desiring to feed higher corn silage diets without compromising kernel breakage for corn silage chopped at a greater LOC. The research also suggests that shredded silage maintained an adequate packing density of 17.5 lbs of DM per cubic feet compared with 17.2 of the conventional kernel-processed corn silage. The proportion of coarse particles retained on the 19-mm screen of the Penn State Particle Separator at feed-out was 31.5% vs. 5.6% for the Shredlage® and kernel processed corn silage, respectively. Once the shredded and kernel-processed corn silages were fed, milk yield tended to be greater (100.1 lbs/day) in cows fed shredded vs. those fed kernel processed corn silage (97.8 lbs/day). The key to successful application of this technology would be to determine whether feeding shredded corn silage results in less risk of acidosis in high-producing cows. In addition, it will be necessary to ensure that Shredlage® allows for adequate processing of the corn kernel to ensure maximum starch utilization by the cow. Being able to maximize the inclusion of corn silage in the diets of high-producing dairy cows will allow for the reduction of highly priced corn grain.

Preservation and Utilization

There are some critical aspects to the production and utilization of corn silage as a livestock feed. In very broad terms, they can be classified as plant, procedure, and feeding.

Plant

Adapting animal and plant genetics to the environment (soil or climate) makes more sense environmentally and economically than attempting to modify the environment to fit the genetics. Harvesting the hybrid at the optimum time is determined by a compromise between yield and livestock performance. It makes little economical sense to sacrifice silage yield and maximize quality, if the livestock producer will have to add wheat straw to the TMR to increase effective fiber and make it a safer diet.

Procedure

Corn silage is chopped to improve silo preservation and enhance animal performance. From this perspective a one-size-fits-all chopping strategy is not available. More mature, drier corn silages (i.e., those harvested at black layer) may have more starch stored in their kernels, however this starch is not as accessible as in those harvested earlier. If too dry it will not pack and ferment well, and thus heating and molding are possible. Drier, mature silages may benefit from post-chopping kernel processors or Shredlage®, described previously.

On the other hand, corn silage with moisture levels higher than 70 percent, may lead to butyric acid fermentation. If the odor of the silage changes because of butyric fermentation, it may result in reduced palatability and total feed intake, as well as feed sorting at the feed bunk. This may result not only in reduced milk production or weight gains, but also in increased incidence of other disorders, such as acidosis and displaced abomasum as a result of feed sorting. Extremely wet silages also have more seepage with high nutrient loss, and they make it more difficult to remove silage for feeding during the cold winter months because of freezing. In addition seepage from fermented silage has a very high biochemical oxygen demand (BOD). The BOD is the oxygen required for bacteria to convert biologically available nutrients into energy and new cells. To avoid problems from too wet or too dry corn, it should be periodically tested for moisture content. If it is too wet, chopping should be delayed several days.

Feeding

The low protein concentration in corn grain and corn silage could be considered a disadvantage from a nutritional standpoint. However, this feature turns out to work in favor of the nutritionist. One of the constraints with feeding corn and its associated feedstuffs is that its protein is deficient in the amino acid lysine. As a result, there is oftentimes a need for higher-quality forages (e.g., alfalfa) and other feedstuffs that will supply additional lysine in the diet. This is particularly true when feeding high-performance animals such as the dairy cow in early lactation. If low-protein corn grain and silage did not dilute the protein supplied by alfalfa and other high-protein feeds, the protein requirements of the ruminant would be exceeded and the excess nitrogen excreted in the urine and feces. Corn and corn silage can thus be considered "ideal" feedstuffs particularly in the Midwest.

When corn prices increase sharply, livestock producers consider replacing corn grain in livestock diets with other forages. In this scenario, corn silage may become the primary forage in the ration. Corn silages with greater percentage of leaves usually have greater digestibility as the higher lignified stalks represent a smaller portion of the total silage mass. This is the reason that leafy corn hybrids are more digestible. Researchers conducted two trials evaluating hybrid differences (Roth, 2015). In the first trial they compared a conventional hybrid with a leafy hybrid. Hybrids were evaluated at two plant populations—24,000 plants per acre or 32,000 plants per acre. These were chopped at ¾" TLC without a processor and fed in a ration that consisted of 2/3 of the forage from corn silage and 1/3 from alfalfa. They observed lower ADF digestibility and higher starch digestibility with the leafy hybrid. The higher starch digestibility was presumably due to the softer kernel texture of the leafy hybrid. They found no milk production difference among hybrids or population treatments. Silages varied in these trials by 2 units in NDF and 2.8 units in digestibility, yet no milk response was noted. These results are similar to another trial recently conducted by the University of Minnesota (Roth, 2015). Based on these results, the authors suggested that hybrid selection for leafy and normal hybrids could be based on yield per acre and agronomic performance.

Digestibility of corn silage can be increased by adjusting corn silage height to prioritize ears and leaves over stems. Cutting corn plants at 8 inches (normal cut) compared with 24 inches (high cut) and chopped at 0.4 inches reduced total silage dry-matter yield by 8.3%, increased grain content by 11.6% and decreased stalks by 38.5% (Dominguez-Diaz and Satter, 2004). With the high-cut silage, the concentration of dry matter, protein and starch increased 9.1%, 4.8% and 22.3%, respectively, while the fiber fractions and lignin were reduced. Feed intake was similar between the normal and high-cut corn-silage diets (53.7 and 54.1 lbs/day). However, the high-cut silage diet increased production and 3.5% fat-corrected milk (88.9 vs. 86.5 and 91.5 vs. 89.8 lbs/day, respectively). Feed efficiency (pounds of feed intake per pound of milk produced) increased with the high-cut treatment (1.66 vs. 1.62). Cutting corn silage higher, although reducing total forage yield by 8%, resulted in increased total milk and fat-corrected milk production, and improved efficiency of feed utilization. Leaving 16 additional inches of cornstalks in the field can also be an advantage when high nitrate concentrations might pose a problem.

Frost-damaged or Immature Corn Silage

Harvesting frost-damaged and (or) immature corn as silage is similar to producing silage from more mature corn. However, it is difficult to estimate the moisture content of damaged corn because it appears drier than it actually is. Leaves that have been damaged by frost will brown and dry rapidly; however, the stalk, ears, and undamaged leaves are still wet. Milk line alone should not be used as an indicator of moisture content in frost-damaged, immature corn. When determining the appropriate time to harvest silage, it is important to ponder the moisture content of the whole plant against the potential reduction in dry matter because of leaf loss (Seglar, 2012). If extensive leaf loss has already occurred, the nutritive value and amount of dry matter remaining should be carefully evaluated to determine whether it is economically feasible to harvest the crop as silage.

The nutritive value of corn silage from immature plants depends on plant growth stage. Drought-stressed corn or corn that has not been pollinated will produce little or no grain crop for the crop farmer to sell, but producers can use the nonpollinated corn for silage. On a dry-matter basis, the drought-stressed corn may be nearly equal in feeding value to normal corn silage. The best way to determine the feeding value of drought-stressed silage is to test the forage. Forage analysis is useful for buying, selling, or using the silage for ration balancing. Buyers of drought-stressed silage high in crude protein and slightly lower total digestible nutrients values may be willing to pay a price similar to that of well-eared silage of equal dry matter content.

Silage from corn that has had some ear and kernel development can have similar energy content as that produced under normal conditions. According to the University of Minnesota, corn in the blister stage can be as high as 80% moisture. To ensure proper fermentation in a horizontal silo, the moisture content should be between 63% and 68%. For upright silos, moisture should be between 60% and 65%. Silage that is too wet, may have excessive seepage and off odor. The effluent (fluid that seeps out of the silo) contains high nutrient concentration, which reduces the nutritive value of the forage and could potentially contaminate the environment. In terms of N, P and K, the nutrient concentration of silage effluent is similar to typical liquid dairy manure. The effluent has an approximate pH of 4.0, as it contains organic acids that are necessary for proper ensiling and preservation. This acidity is another potential pollution issue that can be observed as characteristic burnt/dead plants surrounding ensiled material. Silage effluent ranks among the highest sources from a contamination standpoint because of its high biological oxygen demand. The oxygen demand of silage seepage is approximately 50,000 mg of oxygen per L of effluent, 100 times more than raw domestic sewage. From a biological impact standpoint, a gallon of silage effluent can deplete the amount of oxygen needed for fish to survive in 10,000 gallons of freshwater.

Finally, the fermentation that occurs at higher moisture concentrations can result in the production of butyric acid, which gives silage a sour smell that can reduce palatability and potential feed intake. In contrast to immature corn, mature corn will dry very rapidly after a killing frost. It is suggested to consider cutting the silage as soon as possible after the frost, setting the equipment to chop the silage as fine as possible. Harvesting silage that is too dry can create packing problems that can lead to heating and mold development. Silos that contain silage of questionable moisture content should be monitored closely and care should be taken when opening the silo for feeding. Both pH and dry-matter content are used as criteria for measuring silage quality. In silages with more than 35% dry matter, low pH becomes less critical from the point of view of preservation, as limited availability of water will inhibit proliferation of undesirable bacteria. Silages that undergo limited fermentation, as measured by pH and acid content, tend to show heat damage more frequently. This is also true for high dry-matter silages, which tend to be higher in pH and "brown" more frequently. As dry-matter loss increases, there is an increase in the pH as a result of losses of sugars that are not available for lactic acid production. It has been demonstrated that low pH by itself is not enough to prevent aerobic deterioration, as there are yeasts that can grow under acid conditions. Silage that has undergone heating can be a safety concern. When opening a heated silo, there is potential for spontaneous combustion that could result in personal injury or property damage.

Assessing Silage Quality

Corn silage test results are of little value unless they are understood and used appropriately. Results can be used to balance rations and to improve future crop management. Results of analysis are expressed on an "as received" and on a "100% dry matter (DM)" basis. As-received is sometimes referred to "as-fed" or "fresh." The as-received basis includes the water or moisture contained in the feed. Nutrients expressed on this basis represent the nutrient content of the feed when it was received at the lab. Dry matter basis means all moisture has been removed. The nutrient concentration is that which is contained in the dry-matter portion of the feed. Values reported on a dry-matter basis are always larger than the as-received values. To convert from an as received to a dry-matter basis, use the following formula:

Nutrient (as received basis) x 100 = Nutrient (DM basis) % DM

For example, if a sample of corn silage (30% DM) contains 2.7% crude protein (CP) on an as-received basis, it contains 9.0% (CP) on a dry-matter basis: 2.7% CP x 100 = 9% CP 30% DM

Moisture/Dry Matter (DM)

Moisture content is the amount of water in the feed. Percent moisture = 100 - % DM. Dry matter is the percentage of feed that is not water. Percent DM = 100 - % moisture. A sample of corn silage with 30% dry matter contains 70% water. Knowing moisture content of corn silage is critical to balancing rations properly. Lower moisture contents are usually associated with more mature plants, which can alter its digestibility and energy content. Adequate fermentation is also highly dependent on adequate moisture content, which for corn silage should be between 60% and 70%. If ensiled in an upright silo, 60-65% moisture is desirable to minimize seepage. Knowing the moisture content of forages is essential for making and preserving high-quality hay and silage.

Using a microwave oven can be a fast and reliable method to determining moisture content. Changing weather conditions can oftentimes make adequate predictions of moisture in corn plants to be ensiled difficult. Testing the plants for the right moisture content is critical to determine the ideal conditions for an adequate fermentation. Oetzel et al. (1993) evaluated on-farm methods to determine the dry-matter content of ensiled feeds. In this study, the authors looked at ease of use, time required to conduct the determination, repeatability, and accuracy relative to a standard drying method (drying oven). The methods evaluated were: sequential drying in a microwave oven, Koster tester method, and the electronic moisture tester method. All methods produced repeatable results. Although the microwave-oven method was more accurate than the standard method, it also required the most time. The Koster tester tended to leave some moisture on the feeds and was not as repeatable as the microwave. The procedure for measuring crop moisture content using a microwave oven was described by Tidwell et al. (2002). Regardless of the method used, it is critical to obtain a representative sample of the silage. About 2 gallons of silage should be collected from random locations of the exposed surface, avoiding areas close to the top, bottom, and sidewalls. The measuring procedure requires a paper plate, a glass of water, a small scale, and a microwave oven. Follow these simple directions:

1. Dry the paper plate on high power for 1 1/2 to 2 minutes and weigh it.
2. Weigh (precisely) about 100 grams (3 ounces) of forage sample and spread it evenly on the plate.
3. Place a glass of water in the back corner of the microwave oven to protect the oven magnetron when sample moisture is low (if not, the sample and the oven may catch fire!).
4. For corn silage or chopped corn plant samples, dry for 5 minutes at 50 percent power.
5. Repeat this step as needed, shortening the drying period to 2 minutes once the sample dries substantially.
6. Continue until weight change between dryings is less than 2 grams.
7. If the sample is charred, discard and repeat the test.
8. Calculate % moisture content with the equation.

$$\% \text{ moist} = 100 \times \frac{(\text{wet sample weight}+\text{dry paper weight})-(\text{dry sample weight}+\text{dry paper plate})}{[(\text{dry sample weight}+\text{dry paper plate})-\text{weight of dry paper plate}]}$$

The rest of the nutrient fractions analysis should be performed in a reputable forage testing laboratory. These laboratories can use wet chemistry or near infrared reflectance spectroscopy (NIRS) to determine quality. In wet chemistry, a feed sample is chemically analyzed to determine the nutrient fractions. In the NIRS analysis, a dried ground feed sample is subjected to infrared light and the divergence of this light is measured and used to calculate the feed composition. The chemical analysis is more time-consuming and expensive than the NIRS analysis.

Crude Protein (CP)

Crude protein is an estimation of total protein based on nitrogen in the feed (nitrogen x 6.25 = crude protein). Crude protein includes true protein and nonprotein nitrogen (NPN) such as urea nitrogen and ammonia nitrogen. The crude protein value provides no information about amino acid composition, intestinal digestibility of that protein, or the rumen degradability of that protein.

Acid Detergent Fiber (ADF)

ADF consists primarily of cellulose, lignin, and acid detergent fiber crude protein. It is closely related to indigestibility of forages and is the major factor in calculating energy content of feeds. The greater the ADF, the less digestible the feed and the less energy it will contain.

Neutral Detergent Fiber (NDF)

The total fiber content of a forage is contained in the NDF or cell walls. This fraction contains cellulose, hemicellulose, and lignin. NDF gives the best estimate of the total fiber content of a feed and is closely related to feed intake. As NDF values increase, total feed intake will decrease. Grasses will contain more NDF than legumes at a comparable stage of maturity.

Digestible NDF 48 (dNDF 48)

The importance of measuring dNDF 48 has been recently recognized. Fiber digestibility differs between legumes and grasses harvested at a similar stage of maturity, and even for the same species when grown under different weather conditions. By digesting NDF more rapidly, ruminants can move feed through their rumen faster, thus allowing for enhanced animal performance. Decreases in dNDF 48 are usually a reflection of higher lignin content in the NDF fraction. DNDF 48 is measured from an in vitro NDF digestion for 48 hours.

Lignin

Lignin is a polymer component of the plant cell walls that provides rigidity and structural support to plants. It cannot be digested by animal enzymes. It increases as plants mature and is higher for a same plant species grown under warm weather conditions. The higher the lignin content of a forage, the lower the dNDF.

Crude Fat

Also known as ether extract (EE). This term comprises all substances that are soluble in ether (thus the

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term ether extract). Although it will mainly contain lipids, it will also include other fat-soluble substances such as chlorophyll and fat-soluble vitamins, and it is high in energy when the fraction represents primarily lipids.

Neutral Detergent Fiber Digestibility (NDFD)
NDFD is dNDF expressed as a percent of NDF. Therefore, NDFD = dNDF/NDF × 100.

Ash (ASH)
Ash is the remaining residue after all organic matter present in a sample is completely incinerated, thus 100 – ASH = organic matter. It comprises all inorganic matter (or mineral matter) in the feed, as well as inorganic contaminants, such as soil or sand.

Minerals
Calcium (Ca), phosphorus (P), magnesium (Mg), and potassium (K) values are expressed as a percentage of each in the feed.

Total Digestible Nutrients (TDN)
TDN represents the sum of digestible crude protein, digestible carbohydrates, and digestible fat (fat is multiplied by 2.25 to compensate for its higher energy content). Since feeds are utilized differently by different species, percent TDN in a feed is different for each species, and it is highly correlated with the energy content in feeds. TDN is estimated in many different ways. TDN in SDSU lab reports is estimated from the NEL value, which in turn is calculated from the ADF content of the silage. The equation for calculating TDN is: TDN = 31.4 + (53.1 × NEl)

Net Energy for Lactation (NEl)
Net energy for lactation is the term used by the NRC (National Research Council) for assessing the energy requirements and feed values for lactating cows. It is expressed as megacalories per pound (Mcal/lb) or megacalories per kilogram (Mcal/kg). Corn silage NEl is calculated from ADF with the following equation: NEI = 1.044 - (0.0124 × ADF)

Net Energy for Maintenance (NEm) and Net Energy for Gain (NEg)
The net energy system used by NRC for beef cattle assigns both energy values to each feedstuff and similarly subdivides animal requirements for energy. Feed energy is used less efficiently for depositing new body tissue than for maintaining existing body tissue. NEm is the net energy value of feeds for maintenance. NEg is the net energy value of feeds for the deposition of body tissue, growth, or gain. Both NEm and NEg are needed to express the total energy needs of growing cattle. They are usually expressed as megacalories per pound (Mcal/lb) on SDSU lab reports and can also be expressed as megacalories per kilogram (Mcal/kg).

NEm = -0.508 + (1.37 × ME) - (0.3042 × ME2) + (0.051 × ME3)
NEg = -0.7484 + (1.42 × ME) - (0.3836 × ME2) + (0.0593 × ME3)

Where ME (metabolizable energy) = 0.01642 * TDN.

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