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FEEDING CORN SILAGE TO DAIRY CATTLE

J. G. Linn, Extension Animal Scientist—Dairy Nutrition
D. E. Otterby, Professor, Department of Animal Science
N. P. Martin, Extension Forage Agronomist
AGRICULTURAL EXTENSION SERVICE UNIVERSITY OF MINNESOTA

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Corn silage is a high energy, palatable forage that fits well into many dairy rations. Over 25 percent of the forage dry matter fed to dairy cows in Minnesota each year is corn silage. The easy mechanization of harvesting, storing, and feeding of corn silage along with high yields per acre are some of the reasons for its widespread usage. However, good harvesting, preservation, and feeding practices are necessary to attain optimal animal performance from corn silage based dairy rations.

Harvesting and Preserving Quality Corn Silage

Quality corn silage is more than silage with a high grain content. How well corn silage nutrients contribute to and are utilized in maximizing animal performance is the best measure of silage quality. Harvesting and storage conditions have a significant effect on silage quality.

Maturity

Maximum grain and silage dry matter (DM) will be harvested when corn is chopped at physiological maturity or black layer stage. Check for black layer development by splitting kernels lengthwise or cutting off the tip (Figure 1).

Kernels will contain 62 to 65 percent DM, ear corn will be 55 to 60 percent DM, and the whole plant will be 32 to 38 percent DM at physiological maturity. Most upper leaves will still be green but lower leaves will be in various stages of drying. Harvesting at this time minimizes field losses as well as seepage losses from the silo. No further grain development occurs once physiological maturity is reached. Delaying harvesting only increases field losses and the possibility of molding and heating occurs in corn silage ensiled too dry (Figure 2).

Corn plants harvested for bunker or trench silos should be slightly higher in moisture, lower DM (28 to 32 percent), than corn for upright silos. The higher moisture level is necessary for good packing. Begin harvesting the corn about one week earlier for bunker silos than for upright silos, but don't start too early.

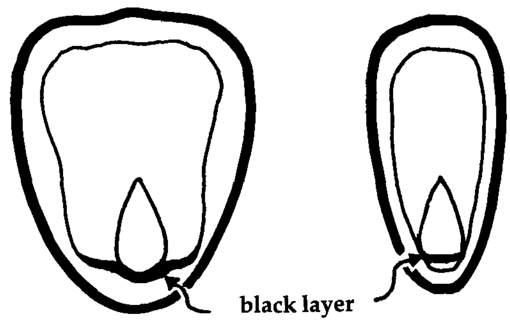


Figure 1. Black layer indicator of physiological maturity.

Length of chop

Chop length is important as it affects both storage losses and feeding quality. Wisconsin research indicates a 1/4 to 3/8 inch theoretical length of cut is ideal for corn at physiological maturity. Over 90 percent of the kernels will be scarified at this chop and passage of kernels into manure will be minimum. Finer chopping is recommended for drier silages to aid packing in the silo. In contrast, wetter silages can be chopped slightly longer and still attain good packing in the silo. The effect of different chop lengths at different corn silage DM levels on kernel scarification and passage into manure is in table 1.

The length of chop dictates particle size of corn silage which affects chewing and saliva production in cows. The more cows chew, the more saliva is produced to help buffer the rumen and maintain normal milk fat tests. A 1/4 inch chop is suitable when corn silage is fed with other forages. A 5/16 to 3/8 inch chop is recommended when corn silage is the major or only forage in the diet.

Table 1. Effect of chop length on whole kernels in silage and passage into manure.

Chop	Silage DM	Whole kernels in silage	Whole kernels in manure
(inches)	*(%)*	*(% of DM)*	*(% of whole kernels fed)*
1/8	28	.02	0
1/4	26	.10	93
1/8	34	.31	68
1/4	32	.53	66
1/8	48	1.40	63
1/4	50	2.10	66

Source: University of Wisconsin.

Fermentation

The objective in silage making is to promote a bacterial fermentation which produces sufficient quantities of lactic acid to preserve the forage and inhibit spoilage losses from other bacterial, mold, or microbiological activity. The conditions necessary for good fermentation are: 1) correct moisture content of the crop; 2) availability of crop carbohydrates and other nutrients to support bacterial fermentation; 3) right type of bacteria; and 4) anaerobic or oxygen free conditions. The process of fermentation can be divided into four phases.

Phase 1 The living cells of freshly-chopped corn plants continue to respire and use oxygen after ensiling. In well-packed forages, the amount of oxygen trapped in the silo is minimal and used up rapidly. Carbon dioxide and heat are produced during this phase.

Phase 2 Within a few hours after ensiling, the oxygen should be depleted and anaerobic bacteria will begin to predominate. Acetic acid producing bacteria are the first to appear. As they convert forage sugars and carbohydrates to acetic acid, the pH of the ensiled forage declines from approximately 6.5 to 5.

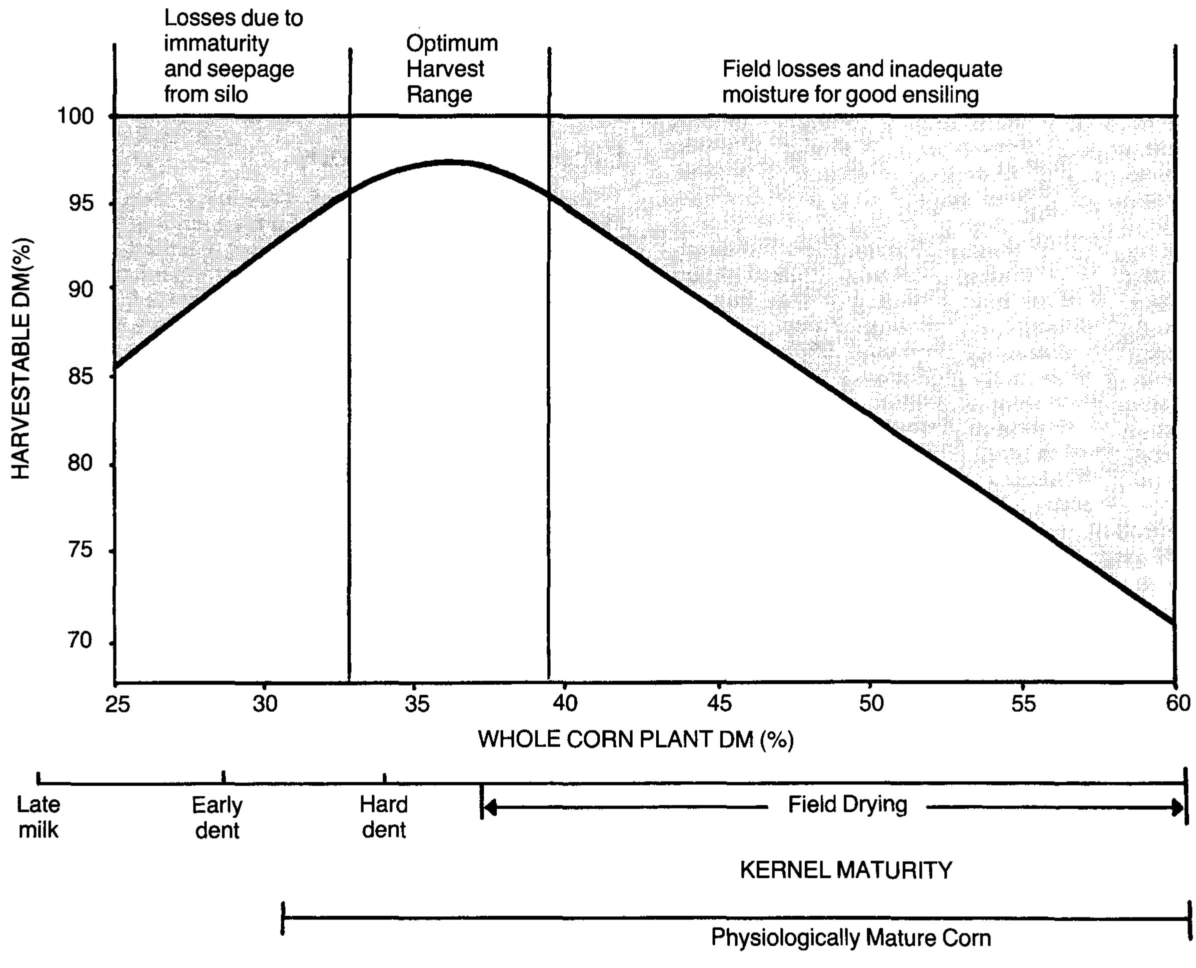
Phase 3 As pH declines, lactic acid producing bacteria begin to predominate. Corn silage contains ample sugars and carbohydrates for fermentation and, therefore, lactic acid production is enhanced.

Phase 4 Lactic acid production continues until pH 4 is reached or the carbohydrate supply for fermentation is depleted. This is normally achieved within four to five days after filling. Final lactic acid concentrations of well-preserved corn silage will be from 4 to 10 percent, DM basis. If the corn silage remains undisturbed and anaerobic conditions remain, the silage will stay well preserved and stable for months and even years. However, if oxygen or air invades the ensiled material from leaky silos, if the pack is disturbed from feeding or moving silage between silos, or if lactic acid concentration is diluted by rain or snow, heating and molding will begin reducing silage quality.

Silage additives

Silage additives can be classified into four categories: nutrient additives, fermentation stimulants (microbial and enzymatic), acids, and preservatives. The most commonly used additives in corn silage are nutrient, primarily nonprotein nitrogen, and fermentation stimulants. Since corn is high in carbohydrates and ferments relatively easy, the use of acids or preservatives to inhibit corn silage fermentation has received little attention.

Figure 2. Relationship between corn plant maturity and DM harvested.



Nonprotein nitrogen The general recommendation is to add five pounds of actual nitrogen per ton of 32 to 38 percent DM corn at the time of ensiling. This will increase the crude protein (CP) content of corn silage about four percentage units, from about 8 to 12 percent, DM basis. Some nonprotein nitrogen (NPN) additives are listed in table 2.

Several commercial products for adding nitrogen to corn at ensiling are available. Most of these are molasses based and contain essential minerals in addition to a nitrogen source. These products are easy to apply and safe to handle.

The recommended rate for adding urea to corn silage at ensiling is 10 pounds per ton. Urea must be mixed into the silage thoroughly, either by metering on at the blower or spreading appropriate amounts on top of silage in wagons before unloading. When urea is added to silages, check other ration ingredients for urea content and make sure the total intake of urea is less than four-tenths of one pound per cow per day.

Ammonia can be applied to corn silage at ensiling in several forms: anhydrous ammonia (cold-flow method), water-anhydrous ammonia mixture, aqua ammonia, or through a commercial product. All forms have been successfully applied, but ammonia mixtures with either water or molasses are the safest and easiest method of application. However, these products are usually more expensive than application of anhydrous ammonia through the cold-flow method.

The recommended application rate of anhydrous ammonia by the cold-flow method is seven pounds per ton of wet corn silage. Application requires a condensation chamber, regulator, hoses, and storage tank. *Be careful* when handling ammonia. Wear rubber gloves and goggles, and always have a large supply of water available for washing if skin contact occurs.

Corn silage between 30 and 40 percent DM will have the highest retention of NPN additives. Water is necessary for absorption of ammonia into silages; however, excess moisture, above 70 percent, alters fermentation and increases ammonia losses. Likewise, adding urea or other NPN to silage below 30 percent DM results in high nitrogen losses through seepage. Very dry silages do not ferment well and NPN losses are high also.

Ammonia acts as a buffer to extend fermentation, increasing lactic acid concentrations in silages. Ammonia treated silages generally are more stable or have a longer bunk life than untreated silages. Ammonia also has antifungal properties which reduce mold growth in silages. Approximately 50 percent of the urea or other non-ammonia NPN products added to silages are converted to ammonia during fermentation, however, these levels are probably not high enough to attain the same stability benefits as when ammonia is used directly.

The application of NPN at ensiling appears to reduce the degradation of corn plant proteins during fermentation and thus, more true plant protein is retained. Urea and other non-ammonia NPN products provide some sparing action to plant protein degradation but are probably not as effective as ammonia additions. Ammonia treated corn silages are 25 to 50 percent higher in true protein content than untreated silages.

Other nutrients Limestone, steamed bone meal, or other calcium-phosphorus supplements may be added at ensiling. The added minerals may provide some buffering to extend fermentation and increase acid production, as well as enhancing the mineral content of corn silage. The general rate of addition for most calcium phosphorus supplements is 10 pounds per ton.

Fermentation stimulants Bacteria, primarily *Lactobacillus* species, and enzymes are the two most common stimulants. The mode of action for bacteria is to direct fermentation towards more lactic acid production, while enzymes should increase the availability of carbohydrates for fermentation.

The effects of Lactobacilli additions to corn silages were recently reviewed by Minnesota workers. In general, Lactobacilli additions did not improve lactic acid concentrations or alter silage temperature or pH over control silage. However, Lactobacilli treated silage appeared to be slightly more stable on exposure to air than untreated silages. In another review of 10 research trials comparing inoculated corn silages to controls, inoculation only improved dry matter recovery of silages by 2 percent.

The effects of corn silages treated with fermentation aids on milk production is inconclusive.

There are currently too many commercial bacterial and enzyme silage additives to generalize in a conclusive statement. However, no matter what type of silage additive, be it nutrient, fermentation stimulant, or other, is applied, the cost benefits must be considered. To be cost effective, the additive should be economically feasible through improved milk production, reduced spoilage or fermentation losses, and/or replacement of nutrient(s) from other sources.

Drought stressed corn

Corn subjected to drought, hail, insect damage, or other stresses may be high in nitrates. Ensiling reduces nitrate toxicity dangers as approximately 50 percent of the nitrate in plants will be converted to other products during fermentation. Also, the highest nitrate levels in corn plants are found in the bottom one-third of the stalk. Cutting higher than normal will help reduce nitrate levels.

Silo gas (nitrogen dioxide) is always dangerous, but concentrations may be higher when plants high in nitrates are fermented. Stay out of silos during filling and for at least the following three weeks.

Limestone or other nutrient additions which extend fermentation may be advantageous when high nitrate plants are ensiled. Extending fermentation should increase the amount of nitrates converted to other products.

Table 2. Some nonprotein nitrogen additives for corn silage.

Additive	Form	Nitrogen	Level added	Estimated loss
		------ %------	---*lb/wet ton*--	----------- % -----------
Ammonia-water mix	liquid	20-30	25	10-20
Anhydrous ammonia	gas	81	7	5-20
Commercial ammonia-molasses-mineral	liquid	13.6	45	Less than 5
Commercial urea-molasses-mineral	liquid	17.6	38	Less than 5
Urea	dry	45	10	5-15

Ruminant animals can convert small amounts of nitrate into ammonia, however, silages high in nitrates should be fed with other feeds to dilute out the nitrates. High energy feeds such as grains are best to feed in conjunction with high nitrate silages. Nitrate levels and feeding guidelines are listed in table 3.

Analysis may be reported several ways. Convert to nitrate-nitrogen by:

Nitrate (NO_3) × .23 = Nitrate nitrogen
Potassium nitrate (KNO_3) × .14 = Nitrate nitrogen
Sodium nitrate ($NaNO_3$) × .16 = Nitrate nitrogen

Symptoms of nitrate toxicity (where nitrates are converted to nitrites, tying up blood oxygen-carrying ability) in animals are: increased pulse rate, quickened respiration, heavy breathing, muscle tremble, weakness, staggered gait, and blindness. If these symptoms occur, change feed source.

Frosted corn

Corn killed by frost will have a similar feeding value to normal corn of the same maturity. Frosts occurring after physiological maturity is reached only increase plant drying rates. This corn should be harvested and ensiled as soon as possible to prevent high field losses and ensiling of excessively dry corn silage. Immature corn killed by frost should be allowed to dry down to recommended moisture levels (62 to 68 percent) before ensiling. The effect of frosts on the nutritive value of corn silage is shown in table 4.

Table 3. Nitrate-nitrogen levels and corresponding feeding guides.

Nitrate nitrogen (NO_3N)		
Percent*	Parts per million (PPM)	Feeding guide
0 to .3	3,000	Gradually introduce feed
.3 to .5	3,000 to 5,000	Limit to 1/2 of the total ration DM
Over .5	5,000	Limit to 1/4 of the total DM or lower (depending on level)

*DM basis

Table 4. Effect of frost on nutritive value of corn silage.

	Dough	Number of frosts		
Item	stage	1	2	6
Dry matter, %	24.0	27.6	30.8	54.4
Acid detergent fiber, %	33.3	28.5	28.7	30.4
Crude protein, %	9.4	8.9	9.0	8.6
Calcium, %	.54	.34	.32	.25
Phosphorus, %	.17	.17	.19	.19

Source: Department of Agriculture—Canada.

Feeding Corn Silage

Nutrient content

The average nutrient content of corn silage is listed in table 5. However, no two corn silages are ever identical in nutrient content. To obtain optimal animal performance, corn silages should be analyzed for dry matter, crude protein, fiber, calcium, and phosphorus when being incorporated into feeding programs.

Table 5. Average nutrient content of late dent corn silage.

Nutrient	As fed	100% DM
Dry matter, %	35	100
Crude protein	2.8	8.0
Net energy lactation, Mcal/cwt	24	68
TDN, %	24.5	70
Crude fiber, %	8.4	24
Acid detergent fiber, %	10.8	31
Neutral detergent fiber, %	17.8	51
Calcium, %	.09	.27
Phosphorus, %	.07	.20
Potassium, %	.37	1.05
Magnesium, %	.10	.28
Sulfur, %	.03	.08
Sodium, %	.004	.01
Cobalt, ppm	.02	.06
Copper, ppm	4.6	13.2
Iron, ppm	224.0	640.0
Manganese, ppm	11.9	34.0
Zinc, ppm	7.4	21.0

Protein

Corn silage is a relatively low protein feedstuff. Well-eared, physiologically mature corn silage normally contains 8 to 9 percent crude protein, DM basis. The crude protein content of corn silage can be effectively raised by 4 or 5 percentage units through the addition of nonprotein nitrogen compounds at ensiling (see Silage Additive Section).

Before harvesting, most of the nitrogen in corn is in the form of true proteins. Upon ensiling, about one half of the plant protein is broken down to amino acids. In well-made silage, further conversion of amino acids to ammonia and other undesirable nitrogen compounds is minimal. However, the net result of fermentation is that over 50 percent of the original plant proteins will be converted to amino acids or other compounds categorized as NPN. The addition of anhydrous ammonia at ensiling protects plant proteins from breakdown during fermentation, resulting in silages containing 30 to 50 percent more true protein than untreated silages after fermentation.

Energy

Good, well-eared corn silage is a mixture of about 50 percent grain and 50 percent forage, DM basis (table 6). Thus, the energy value (TDN or net energy) of corn silage is less than corn but higher than most forages. Cows fed only corn silage can consume enough energy to meet maintenance requirements and produce about 35 pounds of milk per day.

Highly digestible sugars and starches make up about 60 percent of the DM in corn silage. Crude fiber represents about 24 percent of the DM and is approximately 55 percent digestible. The main fiber fraction in corn silage is cellulose, followed closely by hemicellulose.

Immature corn plants are equal in digestibility to physiological mature plants because of high starch and sugar contents in the stalk (table 6). As plants mature and grain development occurs, sugars and starches are removed from the stalk and deposited in kernels, reducing the digestibility of the stalk but not of the whole plant.

Minerals

Corn silage, because of its grain content, is relatively low in minerals compared to other forages. Calcium and possibly phosphorus, potassium, and sulfur will need to be supplemented in diets containing corn silage. Sulfur should particularly be evaluated when corn silage diets contain NPN. Adding 5 to 10 pounds of calcium sulfate, sodium sulfate, potassium sulfate or potassium-magnesium sulfate, or 2 pounds of elemental sulfur per ton of grain mix is an acceptable way to meet requirements. Calcium sulfate or potassium-magnesium sulfate can be added at 5 pounds per ton of wet silage at ensiling as another alternative.

The trace minerals, iodine, manganese, cobalt, and zinc, are low in corn silage and should be supplemented. Adding trace mineralized salt to grain mixes at 20 pounds per ton is a common way of supplementing these minerals.

Vitamins

Green corn plants contain carotene but the quantity decreases with maturity. Frosted or drought-stressed corn is devoid of carotene. Drought-stressed corn also contains nitrates which interfere with conversion of carotene to vitamin A. Supplementing 50,000 international units of vitamin A and 15,000 international units of vitamin D per cow per day is good insurance against deficiencies.

Feeding management

Intake The highest DM intake of corn silage in dairy cows will occur when corn is harvested at physiological maturity (32 to 40 percent DM). Higher moisture corn silages depress intakes as a result of undesirable acids and nitrogen products produced during fermentation. Excessively dry corn silages are not readily digestible and may limit intake because of gut fill.

Feeding recommendations Corn silage can be used as the only forage in lactating dairy cow rations; however, the ration should not contain less than 45 percent corn silage on a DM basis. Be sure the ration is balanced for all nutrients but particularly for protein and calcium. Adequate protein is required for both rumen digestion of feedstuffs and milk production. Dairy rations containing both legume and corn silage forages are probably best and the two forage sources are complementary in their nutrient contents. If all or nearly all the forage in rations comes from corn silage or other fermented forages, dry grains rather than high-moisture grains may be advisable to prevent depressions in DM intake. When total ration moisture was over 50 percent, depressed intakes have been observed.

The passage of whole kernels into the manure of cows fed corn silage is often a concern. In general, less than four percent of the kernels in silage are recoverable in the manure when plants are chopped at recommended lengths. This has a negligible effect on corn silage digestibility. Chopping fine enough to break up all kernels will not improve digestibility and may cause milk fat depressions. Finely chopped silages reduce chewing and saliva flow in cows. The addition of buffers to finely chopped rations may be of benefit in preventing milk fat depression and maintaining feed intake.

Animal health When quality corn silage is fed under good management conditions, corn silage rations will not adversely affect the health of dairy cattle. Higher incidences of displaced abomasums, off-feeds, reproductive and other metabolic problems have been observed with finely chopped corn silage or corn silage feeding programs not matched to meet animal requirements. Excess feeding of corn silage to late lactation and dry cows is a primary cause of fat cows.

Deterioration of corn silage results in the breakdown of nutrients to carbon dioxide and water and leads to a considerable DM loss. Silo DM losses can be minimized by removing two inches of silage daily during winter and four inches in summer. Feeding also can result in considerable DM losses. In warm weather, spoiling and mold growth occur rapidly. More frequent feeding of smaller portions will help minimize palatability problems caused by yeasts and mold growth. Their exact effects other than reducing palatability on dairy animals is relatively un-

Table 6. Changes in grain content and digestibility of corn silage with increasing maturity.

Dry Matter content	Grain content	Dry Matter digestibility
---- % ----	--% *of DM* --	---- % ----
24	35.5	71.2
28	44.0	70.7
33	46.7	70.0
40	51.3	70.4

Source: University of Guelph—Canada.

known, although diarrhea, off-feed, respiratory and reproductive problems have all been reported. Ensiling and fermentation will not destroy or detoxify aflatoxins and are not always a safeguard against possible disease producing organisms. Pesticides will survive ensiling also.

Abnormal corn silages are caused by improper fermentation conditions. Ensiling corn too wet results in a slimey, high butyric acid silage. Combining this material with some other quality feeds may improve but will not completely overcome palatability problems. When corn is ensiled at high DM contents, heating may occur which will tie up protein and reduce energy availability. A dark brown, caramelized appearance with a burnt odor are characteristics of heated silages. Palatability is usually no problem. Excessive additions of NPN will prevent fermentation and cause silage to have an ammonia smell, especially when applied to material above 40 percent DM. Silage pH will often be above six, enhancing ammonia release and discouraging animal consumption.

Other Corn Silages and Crop Residues

Other types of corn silages which have been fed to dairy animals are brown midrib, high lysine, and waxy. Most research trials have shown no production differences when these silages were compared to regular corn silages. Modification of these new corn varieties are small and the alteration and dilution of feeds in the rumen probably negates any potential benefit from them.

Silage made from sweet corn or sweet corn cannery waste is often available for feeding. Sweet corn silage should be made the same as regular corn silage. Sweet corn will be slightly higher in sugar content but will have the same feeding value as regular corn silage (table 7). Canning waste from sweet corn processing generally consists of husks, cobs, and some ears. The high water content may restrict feed intake in high producing cows when fed in large amounts.

Corn crop residue (stalks, husks, and cobs) which remain after harvesting corn may contain 35 to 40 percent of the total digestible nutrients and one-half the DM in the whole corn plant. Timely harvest of corn stalks is important to ensure adequate moisture for ensiling. Corn stalk silage properly supplemented with protein, minerals, vitamins, and energy, as needed, can be a good forage for heifers and dry cows.

Table 7. Average nutrient content of other corn silages and crop residues.

Item	Crude protein	Crude fiber	TDN
		%, DM basis	
Normal corn silage	8.0	24	70
Other corn silages			
Brown midrib	8.2	22	65
Grainless corn silage	9.6	33	65
High lysine	7.4	20	65
Sweet corn	9.5	29	66
Sweet corn cannery waste	8.8	27	70
Crop residues			
Cobs	3.2	36	50
Stover	6.5	34	58

Summary

Good ensiling techniques and feeding management will minimize corn silage losses and maximize animal production. Avoid large nutrient losses from harvesting and ensiling by:

- harvesting at physiological maturity (32-38 percent DM),
- chopping between 1/4 and 3/8 inch,
- storing in good sound structures,
- filling rapidly,
- distributing silage evenly in silos and pack tightly, and
- sealing exposed surfaces.

The following guidelines will help optimize corn silage utilization in dairy cattle rations:

- Know nutrient content of forages—test for DM, CP, fiber, calcium and phosphorus.
- Balance rations for all required nutrients.
- Feed fresh, high quality corn silages.
- Suggested forage DM ratios in dairy cattle rations are:

1) early lactation—1/3 corn silage, 2/3 legume forages,
2) mid to late lactation—2/3 corn silage, 1/3 legume forages,
3) dry cows—1/2 corn silage, 1/2 grass forage, and
4) yearling heifers—1/2 corn silage, 1/2 legume-grass forage.

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