Harvesting and Storage

Harvest Timing

Corn should be harvested for silage at a moisture content that will ensure good storage in the silo. Harvesting within the ranges shown in table 3 will promote good packing and will minimize losses due to heating or runoff. Silage ensiled too wet may ferment poorly and seep. Seepage removes nutrients, particularly soluble nitrogen and carbohydrates, and can damage the silo. Silage that is too dry will have air pockets that prevent anaerobic fermentation and allow molds to develop. In addition, the kernels become harder and less digestible. As harvest is delayed from full dent to black layer (no milkline) crude protein levels decline, fiber levels either remain constant or decline, and digestibility remains relatively constant (table 4).

Table 3. Recommended moisture contents for corn silage stored in various types of silos.

Silo type	Recommended moisture content (%)
Upright silo	60-65
Upright “oxygen-limiting”☐ silos	50-60
Horizontal silos	65-70
Bag silos	60-70

Table 4. Effect of harvest stage on yield and quality of corn silage.

Maturity stage	Moisture (%)	Dry matter yield (tons/acre)	Crude protein (%)	NDF[1] (%)	Digestibility (%)
Early dent	73	5.6	9.9	48.0	79.0
½ milkline	66	6.3	9.2	45.1	80.0
¾ milkline	63	6.4	8.9	47.3	79.6
No milkline	60	6.3	8.4	47.3	78.6

[1]NDF = neutral detergent fiber
Source: Wiersma and Carter, University of Wisconisn, 1993.

In dry, overmature corn silage the stove is less digestible and contains lower amounts of vitamins A and E. Often, adding water to a dry forage becomes impractical because of the amount of water needed. For example, using the equation below, a 4000 lb load of silage at 45% dry matter would require 137 gallons of water to get it to 35% dry matter.

Amount of water needed to raise moisture content of forage to 65% moisture (35% dry matter):

Gallons to add = ([(FW x DM)Ã·FDM]- FW)/(8.33)

Where:
FW = forage weight in wagon
DM = dry matter of forage in wagon
FDM = desired final dry matter (e.g., 0.35)

Measuring moisture content with a microwave oven

To test the moisture content of corn silage with a microwave oven, weigh out exactly 100 grams of fresh silage on a paper plate (Don’t forget to adjust for the weight of the paper plate). Spread the forage evenly on the plate and place in a microwave oven. Heat on high for 4 minutes. Remove the silage, weigh and record. Heat the sample again on high for 1 minute. Weigh and record. Repeat this procedure until the weight remains the same. At this point, the weight in grams represents the dry matter content of the silage. To calculate the moisture content, subtract the dry matter content from 100. Example: After several heating cycles, the sample weight stabilizes at 34 grams. Thus, the dry matter is 34% and moisture is 66% (100-34). Harvest timing can be estimated using the kernel milkline (figure 4). When the milkline is ½ to 2/3 of the way down the kernel, silage moisture will often be in the range of 65%. Silage moisture varies depending on region, growing season, and hybrid so this technique should be used only as a rough estimate of moisture content. Whenever possible, measure the moisture content with a commercial forage moisture tester or in a microwave oven before harvesting.

Other considerations for timing the harvest of corn silage are that as the corn plant matures, the composition of the plant changes. More mature corn silage will have more, drier grain with harder seed coats, more starch and less sugars, and less digestible fiber than earlier harvested corn. Therefore, harvesting early will yield more digestible stover and less starch (from lower percentage of kernels), while harvesting later (2/3 to ¾ milk line with some brown leaves) will mean about the same whole plant digestibility but now the energy is coming from an entirely different source (starch from the kernels) that changes rumen dynamics. The desired feeding program may influence the maturity and storage facility you choose for you corn silage (See “Feeding Silage”).

Harvest Height

Harvest height is typically set at 4 inches. Increasing the height to improve silage quality is usually not profitable, since the improvement in quality rarely offsets the yield loss. In a Wisconsin study, increasing the harvest height from 6 to 18 inches reduced yields up to 0.6 tons per acre while reducing the NDF from 59.9 to 59.4% (table 5). In another study, increasing the harvest height to 6 to 8 inches may be justified since nitrate levels are highest in the lower portion of the stalk

Table 5. Effect of cutting height on yield and forage quality of corn harvested at 75% silk.

Planting date	Cutting height (inches)	Yield (tons/acre DM)	NDF	ADF	CP
	6	10.3	59.9	34.3	12.2
Early	12	10.0	59.6	33.9	12.4
	18	9.7	59.4	33.6	12.6
	6	7.6	52.4	36.5	14.8
Medium	12	7.3	51.9	36.2	15.1
	18	7.0	51.4	36.0	15.6
	6	5.6	55.7	33.0	14.1
Late	12	5.3	55.3	32.5	14.4
	18	5.1	54.6	31.8	14.8

Abbreviations: DM =dry matter, NDF = neutral detergent fiber, ADF = acid detergent fiber, CP = crude protein.

Source: Ballweg, University of Wisconsin, 1984.

Frosted Corn

Occasionally, corn is damaged or killed by frost before it reaches the desired maturity for ensiling. If the frost is early and green leaves remain on the plant, the crop will continue to accumulate dry matter and should be left in the field until it reaches the appropriate moisture content. Partially frosted corn often appears to be drier than unfrosted at the same moisture. If the plants are killed and still immature, they will likely contain too much moisture for immediate ensiling. Plants will dry slowly and dry matter losses will increase as the dead plants lose leaves in the field. The best strategy is to leave the crop in the field to dry down to an acceptable level unless dry matter losses become too high. When a crop that is ready to be ensiled is frosted, harvest it immediately. If the crop becomes too dry, consider a finer chop and adding water or a wet forage during silo filling. Harvesting losses will likely increase, but a reasonable quality silage can still be made.

Drought-Stressed Corn

When corn is so drought stressed that it may not resume growth, t should be ensiled. Corn in this condition usually has few ears and has leaves that have turned brown and are falling off. Be careful not to harvest prematurely because corn with ears and some green leaves may still be able to resume growth and accumulate dry matter later in the season. The net energy content of drought-damaged corn often is 85 to 100% of normal, and it sometimes contains slightly more crude protein. If drought stress is moderate, corn can often have higher than average energy in drought years because of a high grain content and high stover digestibility.

One concern with drought-stressed corn is the potential for high nitrate levels in the silage. High nitrate levels are found most frequently where high nitrogen rates were applied or when a drought-stressed crop is chopped within three days following a rain. Ensiling crops that are suspected to have high nitrate levels is preferred to green chopping since the fermentation process will decrease nitrate levels by about 50%. When in doubt, have the forage analyzed before feeding. High nitrate feedstuffs can be diluted by feeding with another feedstuff.

Drought can also affect the whole plant moisture content. When drought slows plant growth and delays maturity, the moisture content will be higher than suggested by the appearance of the crop. When a drought occurs at the end of the season, moisture levels may be lower than normal. Consequently, measuring the moisture content of drought-stressed corn before ensiling is recommended.

STALKLAGE

Corn plant residue following grain harvest can also be used as a forage. About 40 to 50% of the energy of the corn plant is in the leaves, stalks, cobs, and husk. Corn residue makes acceptable silage (stalklage) if moisture content is brought to about 65% by adding water or wet forages and if chopped between 1/8 and Â¼ inch theoretical length of cut which should be fine enough to pack tightly. Grain and protein supplementation is often required, which make the economics of feeding stalklage less attractive other than as a maintenance feed. For the highest quality stalklage, plan in the spring to harvest and handle high moisture corn, since the feed quality of stalklage declines as grain harvest is delayed. Also, less water will need to be added to silage at harvest. Hybrids vary in the feeding quality and moisture content of stover after grain harvest but there is little data available to compare hybrid. Holstein replacement heifer have shown adequate gains using stalklage as the forage in rations (table 6).

Table 6. Performance of replacement Holstein heifers fed a corn stalklage ration.

Ration Component	Dry Matter (%)
Corn stalklage	70.1
Grain mix	29.9
Shelled corn	65.1
Soybean meal	32.3
Other	2.6
Animal performance	
Average daily gain (pounds per day)	1.66
Feed conversion (pounds dry matter fed per pound of gain)	10.96
Feed cost (dollars per pound of gain)	0.54

NITRATES IN CORN SILAGE

High levels of nitrates in corn silage can be toxic to animals. The level of nitrate in plant tissues varies greatly and depends on many factors. Enzymes in plant leaves convert nitrates into protein. Nitrates accumulate in the plant tissue during unfavorable conditions when growth is slow and yet nitrates are plentiful. While nitrate accumulation in corn silage is typically not a problem, it's important to understand the factors that affect nitrate accumulation.

- **Nitrogen availability.** Nitrate content of corn increases as nitrogen increases. Sources of nitrogen include fertilizers, legumes, manure, and high soil organic matter
- **Drought.** Long, sustained droughts are not as likely to cause accumulation of nitrates in corn as are brief, intense droughts. Nitrate accumulation is highest after a drought-ending rain.
- **Cloudy weather.** Cloudy days often cause elevated nitrate levels because the enzyme that converts nitrates to protein is less active.

- **Extremely high plant populations.** Thick stands can produce barren stalks which prevents movement of materials into kernels. Nitrates accumulate in the stalk and leaves.
- **Nutrient deficiencies.** Deficiencies of nutrients such as phosphorus, potassium, molybdenum, and manganese increase the concentrations of nitrate. Root uptake of nitrate continues, but growth is limited causing nitrates to accumulate.
- **Plant age and plant part.** Nitrates accumulate most in the lower, older pars of plants. The stem and roots have higher concentrations than the leaves and ears.

Fermentation in the silo will reduce nitrate levels by 30 to 50%. In addition, a number of management options can be used to reduce or prevent high nitrate levels in corn silage.

- Apply nitrogen at recommended rates. Be sure to subtract residual soil nitrogen and manure applications from the total recommended amount.
- Minimize plant stresses due to nutrient imbalances, diseases, insects, weeds, and insufficient moisture.
- Harvest on bright, sunny days.
- Dilute high nitrate corn silage with feed grains or legume hay.

Harvest and Storage

Harvesting

In well-planned operations, silo structure type I based on cost and unloading considerations. Machinery for harvesting then should be sized based on required fill rates of silos and on distance of fields from silos.

RATE OF FILLING

In general, the faster the silo is filled the better. Rapid filling (1) minimizes the risk of feed losses due to inclement weather and advancing maturity of the crop, (2) reduces labor and overall ensiling costs, and (3) improves fermentation by minimizing exposure of the chopped forage to oxygen. Slow filling encourages fungal growth which can result in unstable silage at the time of feed out. When silage is stored in small-diameter silage bags (8 ft), the rate of fill may range from 50 to 200 tons per day. The filling rate of large-diameter silage bags (10 ft), and bunkers silos (1000+ tons) can range from 100 tons to 500 tons per day.

FIELD EQUIPMENT

The ideal capacity of field harvesting equipment ill depend on the acrege or total tons of forage to harvest. In general, tractor-drawn forage harvesters are used for silage capacities up to 2000 tons. Self-propelled forage harvesters are more common when chopping more than 5000 tons of forage.

Travel time is an important component of moving forage from the field to the silo. Forage is generally moved with one of two types of wagons (high-dump or self-unloading) or by truck. Self-unloading wagons require an additional tractor or truck to move the forage from the field to the silo. This type of system is typically used when hauling less than 2 miles. Self-unloading wagons are required when using upright silos and certain models of silage baggers. High-dump wagons and truck hauling are preferred when forage must be transported farther than 2 miles. Large hydraulic cylinders on the dump wagon raise the loaded wagon box and dump the forage into a truck. This operation proceeds more quickly since the wagon does not have to be disconnected from the tractor-chopper unit. A consideration with the use of high-dump wagons is the need for an additional 20 hp of tractor power to pull the wagon across average fields. Truck ca efficiently transport forage over long distances and unload rapidly at the silo; however, a greater capital investment is necessary. The purchase cost and capacity of several harvest systems are show in figure 5.

FILLING AND PACKING EQUIPMENT

Once the forage arrives at the silo, it should be transferred and packed quickly to exclude oxygen and promote the onset of fermentation. Forage should be delivered to the silo daily until the silo is full. Delaying silo filling over a weekend is strongly discourages as this will lead to significant forage losses during ensiling and unstable silage at the time of feedout.

Techniques for packing vary depending on the silo type. Upright silos rely on the weight of the silage to supply the packing pressure. Silage bags require special bagging equipment that is adjusted to provide even tension to form a firm tube of silage. Uneven tension results in loosely compacted silage and inefficient use of the silage bag. When ensiling forage in bunker silos, compact it in progressive wedges (figure 6) using a wheel tractor with a front end loader or blade to move and pack silage. This technique minimizes exposure of silage to air before covering. Crawler-type tractors do not provide enough downward compaction pressure and are not recommended. Tractor size should be dictated by the overall needs on the farm and size of the silo.

The amount of time spent compacting the silage affects fermentation. Running the tractor across the surface many times leads to better fermentation than when the forage is only leveled off with minimal compaction. Ideally, allow 5 minutes packing time per ton of wet forage.

Troubleshooting silage harvester problems

Problem	Possible causes
Poor or ragged cut stalks Excessive cob lengths	Dull knives, worn stationary knife, excessive stationary-to-cutterhead-knife clearance
Ragged stubble	Improper knife register on row crop unit; knives not centered on rov
Lack of fan or spout blow	Hole in spoiut liner; excessive blade to band clearance
Excessive power requirement	Dull knives; dull or misaligned stationary knife

Storing

SELECTING A SILAGE STORAGE STRUCTURE

Major considerations in selecting a silo type are speed of loading and unloading, volume of storage needed, and structural cost. Other considerations may include silo longevity, initial investment cots, and potential to purchase feed or share with a neighbor. Characteristics of the major types of silage storage structures currently used and their costs are outlined in tables 7 and 8.

Table 7. Comparison of silo structure types

Silo structure type	Advantages	Disadvantages
Horizontal silos	• Holds large capacity • Can be filled with conventional farm equipment • Requires less energy to move the forage • Offers faster unloading rates	• Requires greater care in filling and packing
Upright silos	• Smaller exposed surface area of silage • Requires less area for construction • Allows greater mechanization during filling and feedout • Convenient to unload in winter	• High initial cost • Unloads more slowly • Silage cannot be stored at as high a moisture content as for other silo types
Plastic bags	• Flexible storage system, allows you to increase capacity as needed • Low initial investment costs	• Bags must be protected to prevent rips and tears
Silage piles	• Inexpensive	• Greatest loss of dry matter during storage (up to 35% of the total forage harvested) • Large amount of exposed surface area • Difficult to pack

Table 8. Typical costs of various silage structures, 1991.

Silo type, size	Capacity dry matter (tons)	Useful life[a] (years)	Initial cost[b] ($)	Average cost per year[c] ($)	Cost per ton dry matter Filled once ($)	Filled twice ($)
Metal, oxygen-limiting (used)						
20 x 50	100	30+	23,000	3,565	36	18
20 x 70	190	30+	34,500	5,348	28	14
25 x 88	385	30+	47,000	7,285	19	9
Concrete stave, oxygen-limiting29						
16 x 60	95	20	36,000	5,580	59	29
20 x 70	180	20	53,000	8,215	46	23
30 x 80	480	15	134,000	20,770	43	22
Poured concrete, oxygen-limiting						
16 x 60	100	30+	59,000	9,145	91	46
20 x 72	200	30+	72,000	11,160	56	28
30 x 76	515	30+	110,000	17,050	33	17
Concrete stave						
16 x 60	95	20	25,500	3,953	42	21
20 x 70	180	20	36,000	5,580	31	16
30 x 80	480	15	77,000	11,935	25	12
Poured concrete39						
16 x 60	100	30+	25,000	3,875	39	19
20 x 70	200	30+	32,000	4,960	25	12
30 x 76	515	30+	55,000	8,525	17	8
Concrete bunker						
20 x 80 x 10	85	20	25,000	2,754	32	16
20 x 105 x 12	200	20	32,000	4,442	22	11
50 x 150 x 12	490	20	55,000	7,189	15	7
Baggerd						
1 bag (8 x 150)	45	20	20,400	2,331	52	-
2 bags (8 x 150)	90	20	32,900	2,745	30	-
4 bags (8 x 150)	180	20	53,250	3,753	20	-
Pile						
Small	7	-	-	100 [e]	24	-
Large	24	-	-	600 [e]	14	

[a] Typical life depends on use as well as structure type. Any life beyond 20 years requires excellent management and care of the structure.
[b] Includes cost of unloader in all cases, except bunker and bagger which require a loader tractor for unloading.
[c] Average annual use cost is based on zero salvage value after a useful life of 20 years; a 10% interest rate on half of the initial cost; typical costs for taxes (1.5%), insurance (2% for tower silos), and repairs (2%) expressed as a percentage of the initial cost.
[d] Bags cost %400 each, bagger costs $14,200.
[e] Cost of plastic to cover silage.

Source: Ishler et al., Pennsylvania State University, 1991.

SILO PLACEMENT

Once you've decided which type of silage storage structure to purchase, you'll need to determine where to place it. When evaluating sites, look for places that are (1) convenient for both loading and unloading, (2) in an area where expansion is not limited, and (3) positioned to collect effluent and avoid environmental concerns.

SILO CAPACITY

Data presented in the appendix (figure 1 and table 1) can be used to estimate the storage capacities of silos of different types and dimensions. The storage capacity of the bag system is estimated at 1.2 tons of wet silage per linear foot (10 ft diameter bag), 1 ton per linear foot (9 ft diameter bag), and 0.8 ton per linear foot (8 foot diameter bag) when forage is ensiled at 40% dry matter. In addition, data are available in appendix table 2 which account for variation in the density of the silage stored in bunker silos and its effect on silo capacity. Good packing practices can substantially increase the capacity of horizontal silos, reducing the cost per ton of stored silage.

MINIMIZING SILAGE LOSSES

The most important practices for minimizing silage losses are to

- Harvest at an appropriate dry matter,
- Fill the silo quickly with appropriate packing,
- Seal it well,
- Feed at an appropriate rate, and
- Maintain a firm silo face.

Dry matter loss during ensiling is an important factor to consider when placing a value on the cost of a selected storage system. Figure 7 illustrates typical storage dry matter losses for various silo systems. The capacity of the silo has a significant effect on dry matter losses during storage feed out due to the relationship of "exposed" surface area to volume (see figure 8) - the smaller the silo, the higher the loss.

Excess moisture content at harvest can cause considerable loss of nutrients in effluent which hurts the fermentation process and the nutritive value of the silage. The minimum dry matter content required to prevent effluent loss from upright silos of different sizes vary depending on the silo height and width (figure 9). If corn silage is harvested and stored above 75% moisture, dry matter losses during storage can exceed 10 to 15%. The loss of effluent from corn silage stored in bunker silos is minimal if the moisture content is less than 75%. Absorbent materials such as beet pulp and alfalfa hay cubes can be added to wet silage at 5 to 15% of the wet weight of silage or 50 to 150 pounds (depending on moisture of silage) per ton to eliminate loss of nutrients as effluent.

Covering and sealing forage can prevent substantial losses of dry matter during ensiling (see figure 10). In addition, the resulting silage has a higher digestibility. It has been estimated that covering a bunker silo with plastic can return $8 for every dollar spent due to reduced losses and increased animal productivity. Use 4 mm plastic if storing longer. Place 15 to 20 tires per 100 square feet to hold down the plastic. The average losses of dry matter associated with harvest, storage, and feeding vary depending on moisture content (table 9). Consideration of total losses can be helpful when considering cropping decisions and how much feed will need to be purchased off-farm. The amount of field tonnage needed to obtain 1 ton of feedable silage can be calculated for different combinations of harvest storage and feeding losses using the following formula and number shown in table 9.

Tons to grow = (tons needed after losses)/((1-HL/100) x (1-SL/100) x (1-FL/100))

Where:
HL = harvest loss, %
SL = storage loss, %
FL = feeding loss, %

Table 9. Expected dry matter losses in forage harvest, storage, and feeding.[1]

Corn silage moisture (%)	Harvest	Storage	Field tonnage to feeding	total	Tons to grow to obtain 1 ton feedable silage
	----------------------------Dry matter losses (%)[2]--------------- ---------------------				
70+	4.0	13.7	4.0	21.7	1.26
60-69	5.0	6.3	4.0	15.3	1.17
Under 60	16.2	6.3	4.0	26.5	1.33

[1] Considers dry matter losses only. Loss of quality was disregarded, but could vary considerably

[2] Chore Reduction for Confinement Stall Dairy Systems. Hoard's Dairyman, Fort Atkinson, WI 1978, pp 12-13.

Source: University of Minnesota, 1980.

CALCULATING SILAGE USAGE

Upright Silos

Determining silage dry matter intake of cattle

Example: You feed 100 cows 6 inches per day from a 20 x 60 ft upright silo. The silo was filled initially and has 20 ft of silage remaining. The depth of silage removed is 40 ft (60 ft - 20 ft). Using appendix table 3, there are 13 ton of dry matter in the next 4 feet. How much silage dry matter intake will this provide?

Silage DM intake per cow (lb/day)=((tons of DM in next 4 ft)x (inches per day fed))/((number of cows)) x 41.67

Silage DM intake per cow (lb/day)=((13 tons)x (6 inches per day fed))/((100 cows)) x 41.67=32.5 lb/cow per day

Determining how many cattle you can feed

Example: You plan on feeding 35 lb/cow per day from a 20 x 60 ft upright silo. The silo was filled initially and has 20 ft of silage remaining. You need to remove 6 inches per day to prevent spoilage. The depth of silage removes is 40 ft (60 - 20 ft). Using appendix table 3, there are 13 tons of dry matter in the next 4 feet. How many cows will this feed?

Number of cattle=((tons of DM in next 4 ft)x (inches per day fed))/((silage DM intake per cow, lb per day)) x 41.67

Number of cattle=((13 tons)x (6 inches per day))/((32.5 lb per cow per day)) x 41.67=100 cows

Bunker Silos

Determining silage dry matter intake of cattle

Example: You have 120 cows to feed. At 6 inches fed per day out of a 24 ft wide x 12 ft deep bunker, how much silage is each cow getting? Corn silage dry matter density is 14.4 lb/cu ft (â€œas isâ€□ silage density from appendix table 2 divided by silage dry matterâ€”36 lb/cu ft Ã· 40%).

Silage DM intake per cow (lb/day)= ((silo width,ft) x (silo vertical depth,ft)x (inches per day fed))/((number of cows)) x ((DM density))/12

Silage DM intake per cow (lb/day)= ((24 ft) x (12 ft) x (6 inches per day fed))/((120)) x ((14.4 lb DM density per cu ft))/12=17.3 lb per cow per day

Determining how many cattle you can feed

Example: You decide to feed 15 lb of corn silage dry matter per cow each day from a 24 ft wide, 12 ft deep bunker silo. How may cows do you need to feed? Corn silage dry matter density is 14.4 lb/ cu ft (â€œas isâ€□ silage density from appendix table 2 divided by silage dry matterâ€”36 lb cu ft Ã· 40%).

Silage DM intake per cow (lb/day)= ((silo width,ft) x (silo vertical depth,ft)x (6 inches per day fed))/((silage DM intake per cow,lb per day)) x ((DM density))/12

Silage DM intake per cow (lb/day)= ((24 ft) x (12 ft)x (6 inches per day fed))/((15 lb per cow,lb per day)) x ((14.4 lb DM per cu ft))/12=138 cows

At feed out, removing silage from the whole silo face at a rate of at least 4 to 6 inches per day reduces losses due to poor aerobic stability. Calculate the number of cows to feed or the amount of dry matter to feed per day in order to use 6 inches of silage each day using the equations on page 20. Slow feedout rates allow more time for losses due to the growth of yeasts, molds, and aerobic bacteria. This, in turn, decreases dry matter intake. For example, when a corn silage that had been exposed for four days was fed to dairy cows, their dry matter intake dropped 38% , from 60 lb to 37 lb per day. Feedout rate is a function of the number of animals being fed. The amount of silage fed in the diet, and the silo design. Thus, silo design and size should be matched with the feeding rate in order to minimize silage losses during feedout.

Silo face management is also important in managing aerobic deterioration in silage. Loose silage is more porous and allows greater air infiltration, increasing the rate of aerobic growth. Figure 11 illustrates the dramatic differences in dry matter losses associated with different levels of silo face management. Maintaining a firm face and cleaning up loose silage that has fallen to the floor of the silo on feedout will help minimize aerobic losses. Keeping an even, clean face on bunker silos is an important management factor. To remove silage from a bunker, use the edge of the bucket on a front-end loader to pull the silage down the face of the silo (figure 12). Then scoop and load. This method will minimize infiltration of oxygen into the silo face and eliminate loose and unpacked silage at the bunker floor. Silage should never be scooped from the face as this allows more air to enter, resulting in unnecessary spoilage.

Safety and Silage making

Silage making has the potential for causing serious accidents. As with any operation involving large equipment, the key to safety begins with prevention. This section describes the precautions to take to avoid injury during harvesting and while working on or around silos.

Safety rules for all silage harvesting equipment and operations

1. Properly maintain the equipment. Poorly maintained equipment will not function properly, which increases the risk of an accident.
2. Study the operator’s manual before each harvesting season, especially the safety instructions.
3. Make certain that all guards and shields are in place.
4. Always turn off equipment before making any adjustments. Never try to adjust or unclog a machine while its parts are in motion.
5. Space tractor and equipment wheels as far apart as possible to increase stability.
6. Make certain the RPM of the tractorâ€™s PTO (540 or 1,000 RPM) match the design RPM of the equipment.
7. Inspect the field for stumps, stones, washouts, ditches, and other obstacles which might damage the equipment or cause an overturn.
8. Never permit riders
9. Keep children, uninformed adults, and pets away from the machinery.
10. Wear close-fitting clothes and sturdy slip-resistant work shoes
11. Never operate equipment if you are ill, tired, or have alcohol or medications in your system. You must stay alert.

Safety rules for working around silos

1. Wear slip-resistant shoes; crepe or rubber soles are much safe than leather or synthetic material soles.
2. Always have one firm hand and foot hold.
3. If you must do some work high up on a silo, wear a safety belt secured to a rung of the ladder.
4. Keep others away from the bottom of the ladder, should a tool or part slip and fall.
5. Do not climb a silo if afraid of heights

Silo ladders are perpendicular and the rungs do not provide the same foot hold as a regular ladder set at an angle. Climb slowly with secure holds. Practice descending from low levels. Many people find the descent from a silo more difficult than the climbing.

SILO GASES

During silo filling and for about 2 weeks after, take special care when entering or working around a silo. Protect yourself and your livestock from injury and death due to silo gas.

The fermentation of green plant material produces nitrogen dioxide (see figure 13). After more oxidation and contact with water - such as the moisture in the lungs - nitrogen dioxide turns into highly corrosive nitric acid.

Low concentrations of nitrogen dioxide will cause a burning sensation in the nose, throat, and chest. Heavy concentrations can cause death within seconds. Even brief exposures to moderated concentrations can cause extensive lung damage and pneumonia.

Carbon dioxide is produced in quantity in the silage fermentation process. It is odorless, colorless, and tasteless and is 53% heavier than air; thus, it also settles into low spots. It is not toxic, but it displaces the air, lowers the oxygen level and causes a person to gasp for air and become asphyxiated (death from a lack of oxygen).

Follow these precautions to reduce the danger of silo gas:

1. Silo gas forms shortly after filling and persists for 2 to 3 weeks. Stay clear of the silo for at least 3 weeks, and even after this time, run the forage blower for 15 to 20 minutes with the door closest to the top of the silo open before entering the silo.

2. Beware of bleach-like odors or yellowish-brown fumes at the silo base, the telltale signs of nitrogen dioxide.
3. Ventilate silo feed rooms with open windows and fans during the 3-week danger period. Keep the door between the silo feed room and barn closed tightly to protect livestock
4. Properly adjust the distributor so that silage will be well-distributed in the silo and will not require anyone entering the silo during or after filling.
5. Keep children and visitors away from the silo area during the danger period.
6. If you should experience even slight throat irritation or coughing around a silo, move into fresh air at once. See your doctor immediately if you suspect you've been exposed to nitrogen dioxide.
7. If you must enter a silo during the 3-week danger period, wear and approved, self-contained breathing apparatus and ventilate the silo for 20 minutes before entering. You should also be attached with a lifeline to someone outside the silo.

Silage additives

A wide variety of silage additives are being marketed to improve corn silage. The principal additives are (1) bacterial inoculants, (2) nonprotein nitrogen sources such as anhydrous ammonia and urea, (3) enzymes, and (4) organic acids such as propionic acid.

Each of these four major groups affects ensiling differently. Consequently, knowledge of how these products work is an essential part of determining which silage additive, if any, would be advantageous. Choice of an additive should be based on meeting a particular goal or solving a particular problem in ensiling as well as increasing profitability. Additives should never be considered as substitutes for good silo management but as tools for improving silage quality beyond that obtainable by good management.

BACTERIAL INOCULANTS

The most common silage additive is the bacterial inoculants. Most inoculants contain homofermentative lactic acid bacteria and supplement the natural lactic acid bacteria on the crop to guarantee a fast and efficient fermentation in the silo. Each product usually contains one or more strains, usually of the following species: Lactobacillus plantarum, other Lactobacillus species, Pediococcus species, or Streptococcus (or Enterococcus) faecium. These bacteria grow rapidly under a wide variety of conditions and produce mostly lactic acid when growing on the main sugars in the crop.

When the inoculant bacteria dominate the silage fermentation, they change the end-products formed during ensiling. While naturally occurring lactic acid bacteria produce acetic acid, alcohol, and carbon dioxide in addition to lactic acid, inoculant bacteria produce a much greater proportion of lactic acid. This shift in fermentation products lowers silage pH and reduces dry matter loss during ensiling by approximately 2%.

Some inoculants can improve animal performance by increasing intake, weight gain, milk production, and/ or feed efficiency. These improvements are likely due to increased digestibility, but other factors may contribute as well. Reduced levels of acetic acid and alcohol improve the palatability of the silage and help improve microbial growth in the rumen. Inoculated silage may also increase retention of dietary nitrogen in cattle.

These additives have had little effect on heating and spoilage of silage at feedout (bunk life or aerobic stability), a common problem in corn silage. Manufacturers are looking for microorganisms that will consistently improve bunk life. Currently, however, you should not expect significant improvements in bunk life from using an inoculant unless a manufacturer can provide independent research data to verify such claims.

Inoculants are inexpensive, and consequently small gains in dry matter recovery from the silo and small improvements in animal performance can easily provide the financial incentive for their use. Unfortunately, these products don't always work, particularly in corn silage. A recent survey of research results found that inoculants affected fermentation approximately 40% of the time in corn silage in contrast to 70-75% in grass and legume silages. And significant improvements of animal performance occurred only 20% of the time in corn silage. The poorer results with corn silage appear to be due to higher natural levels of lactic acid bacteria on corn at ensiling. When the natural population is much higher than the number of bacteria supplied by the inoculant, it is more difficult for the inoculant to dominate fermentation and improve silage quality. At the present time, the factors affecting lactic acid bacteria numbers on corn at harvesting are not known. Evidence suggests that populations increase on the plant as it matures while freezing and thawing may reduce populations.

Inoculants vary in their effectiveness, so choose products with independent research data to back their claims of lowered pH, increased dry matter recovery, better aerobic stability, or improved animal performance. Because of the high natural levels of lactic acid bacteria on corn, select an inoculant that supplies at least 100,000 bacteria/g crop and has been developed for use on corn. If possible, apply the inoculant at the forage harvester to mix the product more thoroughly with the corn and give the inoculant an early start.

NONPROTEIN NITROGEN

Anhydrous ammonia is commonly used in making corn silage in some regions of the United States. A more costly means of applying ammonia is through aqua-ammonia. An alternative to ammonia is urea, which is not as popular and is more expensive. The primary reasons for using these additives are to increase the crude protein content of the silage and to increase silage bunk life. The addition of ammonia immediately raises crop pH. Urea also increases pH as urea is broken down to ammonia and carbon dioxide by plant enzymes. Ammonia plus the high pH kill many of the yeasts, molds, and bacteria that cause heating and spoilage. This should improve bunk life if the silo remains well sealed prior to feeding.

Typically, these additives have little effect on the final pH in corn silage because normally there are plenty of sugars for the lactic acid bacteria to ferment. Because the crop starts out at a higher pH, ammonia treatments increase both the total amount of acids produced and the amount of acetic acid relative to lactic acid. These changes inhibit mold and yeast growth. However, this shift in fermentation can decrease dry matter recovery.

Ammonia improves dry matter and fiber digestibilities by breaking down hemicellulose and other components in plant cell walls. This should improve animal performance but research trials have yielded mixed results. Research with urea on corn silage has typically found small but consistent improvements in weight gain, milk production, and feed efficiency compared with silages supplemented with urea at feeding. Research trials with anhydrous ammonia, however, have found results ranging from positive effects on animal performance to a significant number of cases with negative effects.

Typical application rates for either urea or anhydrous ammonia raise the crude protein content of corn silage by 5 percentage points. This requires varying amounts of additive depending on the moisture content of the silage. For example, 6.5 lb/ton anhydrous ammonia is needed if the silage dry matter is 33%, while approximately 8 lb/ton anhydrous ammonia is needed if the silage dry matter is 40%. The decision to use urea or ammonia hinges on the primary goal for using such an additive. If the primary objective is raising the crude protein content of the silage, urea has a more consistent, positive effect on animal performance. If reducing heating and spoilage is the main objective, anhydrous ammonia is more effective. Precautions must be taken to apply anhydrous ammonia safely.

ENZYMES

Enzymes are one of the newest classes of silage additives. Enzymes reduce fiber content by degrading cell walls and carbohydrates. These additives usually contain a variety of enzymes including cellulases, hemicellulases, pectinases, and amylases. Some inoculant products have enzymes included in their formulation although enzyme concentrations in inoculant products are often much lower than in straight enzyme products. Enzyme additives are marketed primarily for hay crop silages with the goal of making a more mature grass or legume silage feed like an immature one.

These products reduce fiber content in grass but are less effective in legume silages. There is insufficient evidence to indicate their effectiveness in corn silage. Enzymes work most effectively when the moisture content is greater than 55%. The upper limit for moisture content is determined by when seepage occurs in a particular silo type (see table 3). The reduction in fiber affects dry matter recovery either negatively or positively depending on the moisture content of the crop. When the crop is at or near a moisture content where seepage or effluent is produced, the breakdown of fiber causes more seepage losses and reduces dry matter recovery. In drier silages, the loss of fiber helps compress the crop which reduces oxygen levels and increases dry matter recovery.

Despite the reduction in fiber content, improvements of animal performance with straight enzyme products have been reported in only a small percentage of research trials. The current enzyme products apparently degrade fiber that is readily digested by ruminants. As these products develop, improvements in animal performance should be seen.

Overall, enzymes currently do not appear to be a useful additive for making corn silage. First, high fiber content is not usually a problem in corn silage. Second, if corn silage is made at the appropriate moisture range for enzymes, increased seepage losses are likely, especially in upright silos. Finally, there appears to be little opportunity for recovery of the additive's cost in corn silage.

PROPIONIC ACID MIXTURES

Propionic acid and mixtures of propionic acid with other acids such as acetic are used to reduce spoilage and increase bunk life. Both propionic and acetic acids inhibit the growth of yeasts and molds. Propionic acid is a stronger inhibitor; however, it is considerably more expensive than acetic acid. As a result, mixtures of the two acids help reduce the cost of the additive.

These products may be added at ensiling, typically at rates of 0.2 to 1.0% of fresh weight. Do not apply these products at less than the recommended rates as this reduces their effectiveness.

Often these additives are used when emptying a silo in situations where the silage is heating in the silo and/ or in the feed bunk. In such cases, the product is sprayed on the silage face. This will not prevent spoilage losses in the silo during feedout, but it will reduce the rate of loss and help keep the silage cooler in the feed bunk. When a silage is overheating during feedout, it is also important to use it faster, if possible, to minimize spoilage.

Further Reading

Wisconsin

Note: Web resources for Wisconsin are maintained by Mike Rankin and Team Forage. Please see http://www.uwex.edu/ces/crops/uwforage/Silage.htm for an up-to-date listing.

Wisconsin Corn Silage Dry Down Results
Results from county corn silage dry down programs. Sort by county or region.

The Relationship between Corn Grain Yield and Forage Yield: Effect of Moisture, Hybrid and Environment
by Dr. Joe Lauer,UWEX Agronomy Advice , December 2006

Calculating Grain Yield Utilizing a Corn Silage Forage Test
by Matt Lippert, Wood County UW-Extension Agriculture Agent

Adjusting the Forage Harvester for Corn Silage Particle Size
by Dr. Ron Schuler, UW Extension Ag Engineer

Crop Processor Adjustment for Corn Silage
by Dr. Ron Schuler, UW Extension Ag Engineer

Crop Processing and Chop Length of Corn Silage: Effects on Intake, Digestion, and Milk Production by Dairy Cows
by Dr. Randy Shaver, UW Extension Dairy Scientist, et al.

Rehydration of Corn Forage Standing in the Field
by Dr. Joe Lauer, Wisconsin Crop Manager Article, January, 2004

Keys to Higher Corn Forage Yields
by Joe Lauer, UW Extension Corn Agronomist.

Uneven Maturity at Corn Harvest - Handling Silage and Grain
by Dr. Joe Lauer, Wisconsin Crop Manager Article, September, 2001

Estimating the Weight of Forage in a Forage Wagon
by Dan Wiersma, Marshfield Ag Research Station. A "Focus on Forage" fact sheet

On-farm Moisture Testing of Corn Silage
by Dr. John Peters, Director- UW Soil and Forage Testing Lab, Marshfield Ag Research Station. A "Focus on Forage" fact sheet

Predicting Corn Silage Harvest Dates
by Dr. Joe Lauer, Wisconsin Crop Manager Article, August, 2000

Contract Feed Production Arrangements
by Joe Stellato, former Shawano County Crops and Soils Agent

Working Successfully with a Custom Operator
by Joe Stellato, former Shawano Co. Crops and Soils Agent and John Biese, former Outagamie Co. Crops and Soils Agent

What Can We Learn From the Corn Forage Drydown During 1998?
by Dr. Joe Lauer, Wisconsin Crop Manager Article, March 1999

Timing Corn Silage Harvesting and Custom Operators
by Dr. Joe Lauer, Wisconsin Crop Manager Article, August 1997

Corn Silage Yield and Quality Trade-Offs When Changing Cutting Height
by Dr. Joe Lauer, UWEX Agronomy Advice, December, 1998

Kernel Milkline: How Should We Use It For Harvesting Silage?
by Dr. Joe Lauer,UWEX Agronomy Advice , April 1999

Corn Harvest in Wisconsin During "Cool" Growing Seasons
by Dr. Joe Lauer, Agronomy Advice Article, December 1996

Harvesting Silage at the Correct Moisture
by Dr. Joe Lauer, Wisconsin Crop Manager Article, September 1996

Calculating the Value of Normal and Immature Corn Silage
by Dr. Joe Lauer, Wisconsin Crop Manager Article, September 1996

Custom Harvesting Spreadsheet - download as an Excel (*xls) file
This spreadsheet, developed by Dr. Gary Frank, allows you to help determine your forage harvesting costs vs. custom operator charges.

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