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G74-142 Harvesting and Preserving Hay Crop Silage

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Harvesting and Preserving Hay Crop Silage

This NebGuide describes principles of successful hay crop harvest, silage preservation, management techniques to obtain high quality hay crop silage, and proper use of silage storage facilities.

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Most hay (legume and grass) crops can be ensiled, or made into silage, successfully. For best feeding value and preservation, consider the special requirements for ensiling each crop.

Hays to be ensiled should be selected on the basis of economics. Which are the most profitable for supplying nutrients? For example, legumes have a relatively higher value for dairy herds than for beef finishing operations because of dairy cows' higher requirement for protein (*Table I*).

	Dry matter yield	Net energy for milk^a	Net energy for grain^b	Digestible protein
	(Ton/Acre)	(Mcal/Acre)	(Mcal/Acre)	(lb/Acre)
Alfalfa hay	5	4600	2500	1600
Small grains silage	4	3400	2300	560
Corn silage	6	6200	5040	600
Sorghum silage	6	5400	4200	600

^aAfter maintenance energy needs are met, 1 Mcal of net energy is required to produce about 3 lb. of milk.
^bAfter maintenance energy needs are met, 1 Mcal of net energy for gain is required to produce .67 lb gain per day on a

Earlier harvesting can increase the crude protein level of legumes and grasses. Nitrogen fertilization has a marked effect on increasing the crude protein of grass hay crops and, to a lesser extent, of grain crops.

Maturity at Harvest

Time of harvest has a major influence on the quality of hay crop silage. Available energy, digestible protein and daily intake decrease with advancing crop maturity.

Because acreage dry matter yields are lowered by early harvest, time of harvest is a compromise between quality and yield. High prices for protein and energy tend to favor earlier cutting, in spite of lower yields. *Table II* gives recommended stages of harvest of crops for silage.

Crop	Recommended stage for harvest
Alfalfa	1st cutting, bud stage or earlier if new shoots appear from crown. Other cuttings, early bloom or bud stage if new shoots appear from crown.
Legume-grass mixture	Legume, early bloom
Bromegrass	Early head
Orchard or timothy	Early head
Clovers	3/4 bloom
Cereal grains	Boot stage ^a
^a If crop has advanced to milk stage, delay cutting until the dough stage	

Forage Moisture Level

It is important to control forage moisture to reduce nutrient losses, obtain good packing in the silo, prevent seepage, and permit proper fermentation of the silage.

The moisture content of perennial hay crops at the optimal stage for harvest may be 80 percent or higher. Seepage and excessive fermentation losses, as well as foul odors, result from storage at such high moisture levels. Wilting the crop prior to ensiling is necessary.

Wilting. Moisture problems can be avoided by wilting the crop to approximately 65 percent moisture. Wilting beyond 65 percent moisture may increase leaf loss.

The short time (usually three to six hours) required to wilt to 35 percent dry matter practically eliminates the potential for rain damage in most of Nebraska, depending on the time of year. When it is impossible or impractical to wilt the crop, it may be helpful to add a preserving agent.

The moisture level of a crop at ensiling should promote the best preservation and handling for the structure in which it will be stored. For example, 77 percent moisture produces a much better pack in a 500 ton stack than does 65 percent moisture, and produces less seepage.

In a tall concrete stave, 65 percent moisture is better because higher moisture forage produces considerable seepage and has higher fermentation losses. *Table III* gives recommended moisture levels for forages stored

in various types of silos.

Table III. Ideal forage moisture for various types of silos	
Type of silo	Ideal forage moisture
Gas-Limiting silo	40-50%
Conventional upright ^a	60-70%
Bunker or trench	
Height, 12 ft or less	70-75%
Height, more than 12 ft	65-70%
Stack ^a	
Height, 12 ft or less	72-77%
Height, more than 12 ft	68-73%
^a Top 2-3 ft should be 70-75 percent moisture	

Moisture tests. Farmers making hay or silage should have a small dryer or microwave oven for rapid moisture determination. From actual test results you can soon learn the "feel" of forage when it is at the desired moisture level.

To estimate moisture content you can use a "squeeze test." Squeeze a handful of chopped forage into a ball and hold it 20 to 30 seconds; then quickly release your grip. The condition of the ball shows how much moisture it contains. *Table IV* is a guide for estimating moisture content using this technique.

Table IV. Guide for estimating forage moisture	
Condition of forage ball	Estimated forage moisture
Ball holds shape, considerable free juice	over 75%
Ball holds shape, little free juice	70-75%
Ball falls apart slowly, no free juice	60-70%
Ball falls apart readily	below 60%

Harvesting the Crop

After the crop is cut and windrowed, the main concern is to get the forage into the silo with minimal losses. This means getting the crop out of the field as soon as possible. Wilting the crop to 70-75 percent moisture takes as little as two hours during hot, dry, windy days.

Turning the windrow before chopping may result in considerable leaf loss. Windrows should not be disturbed until picked up, unless turning is necessary to prevent molding.

If forage becomes too dry before chopping, waiting until night or early morning when dew has accumulated may help prevent leaf loss. Another means of increasing moisture level is to mix some later cut windrows in with the dryer ones.

Forage for dairy operations should be chopped 3/8 to 1/2 inch theoretical length if wilted, or 1/2 inch to 1 inch if direct-cut. Beef operations usually use a slightly smaller forage cut. Flail harvested forage needs to be recut before storage because stems are too long for effective packing. After chopping, the crop should go directly into storage without delay.

The Ensiling Process

The goal of silage preservation is conversion of a moist, chopped forage with a short storage life to a preserved silage that can be fed to livestock as needed.

The key to good silage management is *air exclusion*. To obtain the best preservation of forage as silage, air (oxygen) contact with the ensiled forage must be minimized.

The forage crop entering the silo continues to respire, using oxygen and plant sugars to produce carbon dioxide, water and heat. This process of respiration results in loss of nutritionally valuable dry matter and energy.

Subsequent anaerobic (without oxygen) fermentation of the ensiled forage develops the necessary acidity for effective silage preservation in conventional silos. When anaerobic conditions are achieved, bacteria ferment plant sugars to ethanol, acetic and lactic acids. The build-up of lactic acid results in a decline in silage pH (increased acidity).

Under optimal ensiling conditions, the majority of plant sugars are fermented to lactic acid, resulting in maximum preservation of silage energy and dry matter.

Potential Nutrient Losses During Ensiling

Along with the respiratory losses that occur during the initial stages of the ensiling process, several other events may occur that decrease the quality of the hay crop silage:

- A. **Clostridial spoilage.** Clostridial bacteria grow under anaerobic conditions and usually are found in manure and soil. These microbes ferment silage acids, sugars and proteins to butyric acid, putrescine, and cadaverine--all foul-smelling compounds.

Clostridial activity results in dry matter and energy losses, elevated silage pH, and decreased intake by cattle fed the silage. The best way to avoid clostridial growth is to maintain forage moisture content between 60 and 70 percent, and to achieve a rapid and extensive reduction in silage pH. Crops such as grasses and corn are less susceptible to clostridial fermentation than legumes, due to their lower buffering capacity.

- B. **Protein solubilization.** The action of plant enzymes released during harvesting and ensiling and microbial enzymes degrade protein in the forage crop during silage fermentation. Hay crop silage that has undergone extensive protein degradation may exceed the rumen bacterial requirement for degradable protein.

Forage protein that escapes fermentation at ensiling is usually more slowly degraded in the rumen. More protein may bypass to the lower gut, resulting in better animal production. The best means to inhibit protein solubilization is a rapid reduction in silage pH.

- C. **Effluent production (seepage).** If the moisture content of the forage is too high, effluent will flow from the silage mass. Silage effluent contains approximately 5 percent dry matter and represents a loss of plant sugars and soluble proteins.

In general, the moisture content of the silage should be below 70 percent for bunker or trench silos, below 50 percent for gas-limiting silos, and approximately 60 percent for upright (tower) silos and silage bags (*Table V*).

- D. **Browning reactions.** Even when proper silage pH is obtained, air entry into the silage mass must be minimized to avoid excessive decomposition and heating (browning).

Silage heating forms indigestible protein-sugar linkages in the forage crop, resulting in loss of nutrients and decreased crude protein digestibility when fed to cattle. Browning reactions are usually associated with forages ensiled in the range of 20-40 percent moisture. Increases in silage temperature due to aerobic activity stimulate this reaction. Browning reactions themselves release heat, and this increased heat accelerates the reactions further, potentially causing spontaneous combustion (silo fires).

To avoid these problems, ensile forages at proper dry matter content, fill silo quickly, and seal the silo well to exclude oxygen.

Silo height (feet)	Silo diameter (feet)				
	10	15	20	25	30
20	22	24	26	26	26
30	24	28	29	30	31
40	26	30	32	34	35
50		32	34	37	38
60		33	37	39	40

Adapted from Pitt and Parlange. 1987. Trans. Amer. Soc. Agric. Engin. 30:1198.

Minimizing Silage Losses

The decline in silage quality associated with respiratory losses, clostridial activity and silage heating is minimized by limiting air contact with the silage mass. The amount of air within the ensiled forage mass can be reduced and the chance for air to enter the mass from the outside minimized by the following management practices:

- A. **Harvest less mature crops** (fewer hollow stems). Harvesting forages at the correct stage of maturity and moisture content maximizes nutritive value of silage. Refer to *Table II* for complete information concerning proper stage of maturity for forage harvest.
- B. **Avoid over-wilting.** Wilting helps fill spaces which might otherwise entrap air. Water also provides weight for more effective packing. *Tables III, IV, and V* give detailed information concerning proper moisture content for forages at time of ensiling.
- C. **Chop forage to proper length.** Forage chopped too coarsely (greater than 1/2 inch theoretical cut length) has a greater amount of air entrapped, more heat development, and more indigestible protein formed compared to silage chopped at 1/4 - 3/8 inch theoretical cut length. Silages chopped too coarsely pose a major problem for silo unloading equipment, as well.

Forage chopped too finely, however, may accumulate in feedbunk corners, eventually spoiling and reducing feed intake. Finely chopped forage also may lower rumen pH, increase the potential for metabolic disorders, and depress milk fat in dairy cows consuming this silage.

- D. **Even distribution and compaction of silage.** A uniformly compacted silage mass aids in air exclusion, ensures equalized force against silo walls, and results in better unloader operation.

- E. **Rapid uninterrupted filling.** Rapid filling reduces exposure time of ensiled forage crop to oxygen. If filling a silo is delayed for more than one day, covering the surface of the ensiled forage with a plastic seal may be beneficial, although it usually is not practical.
- F. **Sealing exposed silage surfaces completely.** Plastic material should be completely covered with weighting material to provide a good seal and prevent wind and air from getting underneath.
- G. **Removing silage properly.** With open silos, a minimum amount of silage must be removed daily to avoid winter freezing and summer spoilage. Average minimum removal rates are 3 inches/day for tower silos and 4 inches/day for bunker (trench) silos.

Other factors known to influence the ensiling process include: content of fermentable sugars in the forage crop, buffering capacity of the forage crop, microbes such as lactic acid bacteria on the forage crop and harvesting equipment, and ambient temperature at time of ensiling. Forages, such as alfalfa, that are typically low in fermentable sugars and higher in buffering capacity have slower rates of pH decline during ensiling. They require strict adherence to the suggested guidelines for proper silage making. *Table VI* summarizes management practices necessary to minimize silage losses.

Table VI. Recommended ensiling practices			
Tower Silo	Bunker Silo	Silo Bag	Silage Stack
Harvest crop at proper stage of maturity Chop at 3/8 inch TLC ¹			
Top-off	Compress forage with tractor	Use good filling machine	Pack from all directions
Cover top with plastic	Cover with plastic	Seal ends carefully	Plastic cover
Apply sealant as needed	Maintain air-tight sides	Repair punctured bags	
Leave silo sealed for at least 14 days			
TLC ¹ theoretical length of cut			

Ensiling Requirements for Different Types of Silos

The silo selected for storing hay crop silage should be practical for storage and feed out. It must effectively preserve the forage.

- A. **Gas (O₂)-limiting silos.** These silos present minimum hazard from air entry because of type of construction. Because limited air is present, forages can be preserved with less attention to packing. In these structures forages usually are preserved at 35-50 percent moisture, resulting in a low level of fermentation. Consequently, these silos hold both fermentative and oxidative losses to low levels. But the operator must maintain the air seal. *Shut doors securely when not in use.*
- B. **Conventional upright silos.** Maintain structure to minimize leaks; keep doors in good repair; apply sealant to interior as needed; assure continuous, even distribution when filling. Mechanical distributors are generally effective and inexpensive.

If the silo is less than 40 feet tall, manual packing may be required after every two to three loads, especially if the forage moisture level is less than 65 percent and no mechanical distributor is used.

Allowing overnight settling is especially important before "topping off" taller silos. These silos also

require trampling for the last several loads to minimize top loss. (**WARNING:** Do not enter a silo that has set overnight unless toxic gasses are first removed. Run the blower at least five minutes before entering.)

With a good plastic seal, top losses should be minimal. Commercially produced plastic sleeves or silo caps also can be used for this purpose.

- C. **Trench or bunker.** Maintain smooth, air-tight sides; to obtain a good pack in trenches or bunkers, the moisture level should be higher. Shallow silos require higher levels of moisture for effective packing. A heavy-wheel tractor with wide-set front wheels and blade serves well for distribution and packing. A heavy track-type tractor with blade is frequently used for large silos.

The largest potential loss from trenches and bunkers is top spoilage. However, top losses are minimal when these silos are carefully covered with plastic. A 6 mil sheet is recommended. Weighting down the plastic is vital.

Effective covering materials include chopped forage (10-12 inches), dirt (2-3 inches) or limestone (1 inch). Chopped fresh forage (10-12 inches) may be the most practical to handle and is readily available. Feed-out is simplified if the covering material can be fed along with the silage.

Additional losses result from molding and heating during feed-out. These losses are reduced by uniform removal of 3-5 inches of forage per day from the face of the silo. A mechanical unloader is ideal for obtaining uniform removal, especially from deep silos.

- D. **Silo bags.** Silage must be compacted into the plastic bag uniformly, and the bag sealed to prevent oxygen penetration. Bags should be placed on a smooth, hard surface such as concrete to avoid puncturing the bag. Small punctures in the silo bag should be repaired quickly to limit extent of silage deterioration due to contact with oxygen.
- E. **Silage stack.** Large amounts of silage are stored in simple stacks on top of well-drained areas or on concrete slabs. Efforts to control losses are similar to those needed for trenches or bunkers.

Side losses are generally a serious problem. This is due to slippage of forage during distribution and packing, and the inability to pack the steep sides. This type of loss is reduced by building wide stacks with steep slopes to permit packing from all directions.

Such stacks seem impractical except for very large stacks. Small stacks (less than 500 tons) generally suffer a much higher percentage of loss than very large stacks because a larger percentage of the forage is near the surface. Stacks are more practical when large numbers of cattle are fed.

Plastic covers are of less potential value on stacks because of the problem of weighting down the plastic. Generally the flatter the stack, the more practical a plastic cover. With large, deep stacks, plastic covers offer a relatively lower potential for reducing loss.

Silage Additives

Several types of additives are available to potentially enhance the quality of hay crop silage. The most popular additives include: ammonia, acids, and microbial inoculants. Nearly any forage suitable for ensiling can be properly fermented without using additives, provided recommended silage management practices are followed.

In some instances, use of additives may improve a silage's nutritional value, stability, and/or production potential, depending upon the hay crop fermented.

- A. **Ammonia.** The most consistent benefits of ammonia addition are with corn silage. For hay crop forages, the greatest benefit of ammoniation would be at a 1 percent addition rate with lower quality grasses and not high quality alfalfa. The crude protein content of the grass increases with the added protein equivalent from ammoniation.
- B. **Acids.** Acids such as formic acid are popular additives to hay crop silage in Europe, but not widely available in the United States.
- C. **Bacterial inoculants.** Use of bacterial inoculants supplements the lactic acid producing bacteria already present on forage. Research results have been variable, perhaps due to the wide variability in bacterial populations naturally present on the forage. The most consistent benefits of silage inoculants accrue when adverse weather or poor management result in poor conditions for ensiling. *Use of inoculants should never replace good silage making practices.*

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B-7, Forages

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