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Practical Corn Silage Harvest and Storage Guide for Cattle Producers

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Photo: Steve Patton.

Corn silage is often referred to as the "king of forages" and for good reason. With adequate and timely rainfall and normal environmental temperatures during the growing season, corn silage can yield 20 to 25 (or more) tons as fed per acre. Even in years with limited soil moisture, this crop still can provide needed forage when harvested and stored properly although whole plant yield and/or grain content is often reduced.

To make corn silage, the whole corn plant, excluding the bottom 6 to 12 inches of the stalk, is harvested and ensiled as a combination of stalks, leaves, cobs, husks, and corn kernels and allowed to ferment. Corn silage easily lends itself to be custom harvested, if one wishes, as it is harvested once per growing season. Harvesting technology (i.e., use of a kernel processor) and our understanding of the fermentation process have advanced over the years and resulted in improvements in efficiency during harvest, storage, and feed-out resulting in a feedstuff which provides more and better nutrition for beef and dairy cattle.

Corn silage makes an excellent feed for beef and dairy cattle when fed as part of a properly balanced diet. Compared to other grass forages, corn silage contains more starch and thus more energy. (The corn kernels contribute starch.) With normal ear development, the ear and associated corn kernels account for approximately half of the biomass when the whole plant is harvested. Corn silage is typically below an animal's protein requirement, and thus, often needs to be supplemented with a higher protein feed, such as soybean meal, to support optimal growth or milk production. Often, the nutritional value of corn silage is greater than the costs associated with raising and harvesting this crop. For example, with corn grain at $5/bushel and soybean meal at $550/ton, corn silage contains nutrients that are worth over $100/ton in high-producing dairy cow diets, much greater than costs associated with growing and storing the crop. Even with lower corn and soybean meal prices, corn silage is very valuable as a forage and energy source and proper harvest, storage, and feedout practices can help preserve this feeding value for both beef and dairy cattle.

Figure 1. Kernel processed corn silage. *Photo: Nick Roy.*

Reporting Results on a Dry Matter Versus As Fed Basis

When evaluating yield, nutrient content, and recommendations as to when to harvest corn for silage, one needs to understand the difference between dry matter, as fed, or a set moisture content basis. Dry matter content of a forage reflects the weight or nutrient content with all the moisture or "water" removed. The weight of a particular forage is always greater when reported on an as fed versus dry matter basis. To allow for comparisons between varieties, fields, growing years, cattle feeding programs, and farms, yields and nutrient densities are standardized either on a dry matter or to a set amount of dry matter or moisture content.

To convert between ways of expressing yields, intakes, and moisture content, remember the following:

1. Converting dry matter content to moisture content and vice versa

   Dry matter (DM) % + Moisture % = 100%

   Example: 35% dry matter is equal to 65% moisture

2. Yields can be reported on a dry matter basis (weight without moisture) or an as fed basis (moisture included). Agronomists may report yields on an as fed basis at a standard percentage of dry matter or moisture to allow comparison between varieties. Dry matter yields are always lower than those reported on an as fed basis.

   Example: 20 tons of silage at 35% dry matter = 7 tons of dry matter

   (20 tons x 0.35) = 7 tons dry matter

3. Packing densities of silages can be reported on a dry matter (DM) amount per cubic foot or amount of "as fed" silage per cubic foot. Densities reported on a dry matter basis are always lower than those reported on an "as fed" (with moisture or water included) basis.

   Example: Packing density of 44 lb as fed/ft^3 at 35% dry matter = 15.4 lb DM/ft^3

   (44 lb/ft^3 x 0.35 (dry matter %/100) = 15.4 lb DM/ft^3

4. Nutrient density always should be compared between crops and within a crop on a dry matter basis, not as fed. Dry matter density of nutrients should be greater than those reported containing water/moisture. They are more nutrient dense per unit when reported on a dry matter basis.

   Example: 8% crude protein on a dry matter basis = 2.8% crude protein on an as fed basis at 35% dry matter.

Estimating Silage Yield

Various methods are commonly used to estimate the total yield of corn silage for the purpose of determining storage space needs, meeting forage demands of cattle, or for calculating the total price when buying or selling a standing field of corn for silage. The method selected should be based on a grower's preference or use of the estimate. Silage yield across a field and between fields can vary greatly, similar to variation seen in grain yield. Thus, multiple samples per field are needed to estimate silage yield regardless of the method chosen.

Yield estimate based on plant height. An older method for estimating silage yield was based on plant height. Assuming a good plant population and good ear development, a general rule of thumb is each foot of plant (excluding the tassel) will produce approximately 2 tons of corn silage at 35% dry matter or 65% moisture. Plants without ears will yield approximately 1 ton per foot or half the yield of well-eared corn. Based on these assumptions, a 12-foot, well-eared plant will yield 24 tons per acre. Corn silage yields with extremely good grain yield will be underestimated using this assumption while yield in fields with poor grain development will be overestimated.

Row spacing, plant populations within a field, soil type, and variety may impact yield along with growing conditions. In corn hybrid trials harvested as silage, the height of corn plants did not correlate to silage yield as the weight of leaves and stalk were similar. Thus, yield is best estimated by collecting samples and weighing selected, representative plants in a defined area.

Yield estimate based on sampling and weighing. A more accurate method to estimate silage yield is to weigh a representative number of plants. Anticipated silage yield per acre can be calculated by harvesting and weighing corn plants found in 1/1000th of an acre. To estimate yield per acre, follow these steps.

1. Randomly select five locations from the field.
2. Weigh the tarp or tub to be used to collect samples. This is your tare weight or weight without plants. This weight will need to be subtracted from the weight of the tarp or tub containing your harvested plant material. Record this weight.
3. Measure the spacing between rows to determine the length of the row needing to be harvested at each of the five selected locations using the following chart (Table 1).

Table 1. Length of row of corn plants to harvest and weight to estimate tonnage found in 1 acre of standing corn based on row spacing.

Row spacing (inches)	Row Length (1/1000th of an acre)
15	34 ft 10 in
20	26 ft 3 in
30	17 ft 5 in
36	14 ft 6 in

4. For each selected location, harvest the corn stalks in the given length of row starting at a height of 8 to 12 inches above the ground (chopping height). Weigh the stalks cut from each location in the field making sure to subtract/account for the tare weight of the tarp or tub.

5. Average the weight for the stalks from the five locations in the given field.
6. Divide the average weight by 2 to get silage yield (as fed) per acre.

Sources: Steinhilber et al., 2016. and Master Choice Seed Corn publications.

Value of Corn Silage Prior to Harvest and Storage

Forage grower standpoint. Different methods exist to determine the starting point when pricing corn silage. Generally, the crop is sold as a standing crop and the cattle producer harvests the crop. If the dry matter content of the whole plant is greater than 38%, the crop needs to be harvested as grain and not as corn silage. Determining the potential silage yield and value of the crop should be determined using multiple methods. These values then should be compared while taking into consideration what the estimate actually determines. For example, the value for feeding the crop to cattle is different than the salvage value of poorly eared corn to a grain farmer. Pricing options per acre outlined below can be used as a starting point for negotiations. More than one estimate should be used to calculate the value of the crop and these results compared to one another.

> *Enterprise budget used to estimate total cost associated with growing corn.* Budgets can be used to calculate the cost to grow a crop for corn silage or corn grain. These budgets can be used as a starting point along with anticipated yields to calculate a starting price for the standing crop. Remember that costs associated with harvest (also drying if needed) and transportation need to be subtracted from these budgets, as these costs will not be incurred if the crop is sold standing in the field. In addition, the lost fertilizer value of crop vegetation remaining in the field after harvest needs to be reflected in the final value.
>
> *Value estimated using the crop's estimated corn grain yield and current corn price.* Another means for estimating the value of a standing crop is to estimate the yield of corn grain and multiple by the value of a bushel of corn, if sold. The costs associated with harvest, drying, transportation and lost fertilizer value of plant material left in the field need to be taken into account.
>
> *Value estimated using corn price and a "factor."* Another method to determine the value of corn for silage at 35% dry matter (65% moisture) is to multiple the value of a bushel of corn, if sold, by a set value. For yields less than 100 bushels/acre, a value of six to eight times the cost of a bushel of corn can be used. With yields above 200 bushels/acre, the price of corn is multiplied by a factor of 8 to 10. If the silage is harvested, a factor of 10 to 12 is multiplied by the price of a bushel of corn grain as harvest costs need to be considered.

Cattle feeder standpoint. The value of corn silage should reflect the value as a feed ingredient in diets fed to a particular group of cattle. Generally, the value relates to the availability and prices of other forages and the relative prices of corn and soybean meal. Computer programs, such as Feedval, are available to calculate the nutritive value of corn silage. Some computer programs take into consideration the contribution of energy, protein, and fiber of byproducts, other than just corn grain and soybean meal. The calculated nutritive value should be greater than you can purchase the crop, thus economically favorable to purchase the silage. Others calculate an economic value by multiplying the value of corn grain by a factor of 8 to 12, depending on grain yield and whether the crop is already in storage or is a standing crop. Corn silage made from corn plants with limited ear set has approximately 70% of the feeding value of normal-eared silage. When pricing the value of silage to be fed to cattle, one needs to consider the amount of shrink related to harvest, storage and feeding losses. Depending on the management of storage structures and feeding practices, these can be substantial. For example, storage losses can range from 10% to 25% or more depending on management practices at harvest and storage.

Determining When to Harvest

Harvest based on moisture/dry matter content. Harvesting corn plants at the correct moisture promotes favorable fermentation in the stored silage crop and decreases storage losses. Thus, the moisture or dry matter content of the chopped plant should be the major determining factor for when to harvest corn for silage. Silage should contain between 35% to 38% dry matter (62% to 65% moisture) and the crop should be harvested, enter the storage structure, and be packed as quickly as possible. Agronomists generally estimate that a healthy corn plant dries down 0.5% to 1.0% per day. During "normal" growing conditions, corn is harvested approximately 40 to 49 days after silking or tasseling.

Historically, corn silage harvested at the 35% to 38% dry matter (62% to 65% moisture) content would have corn kernels (if present) that are at the ½ to ¾ milk line. (See figures 2 and 3 for description of milk line.) Newer varieties of corn harvested as silage stay green longer and the corn kernels can be more mature (approximately ¾ milk line) at the optimal harvest-moisture resulting in more starch in the harvested crop. Weather, growing conditions, and plant disease can change the optimum stage of maturity of corn kernels for harvest as corn silage. An experiment showed that the stage of maturity of the corn plant only correctly predicted harvest moisture content 68% to 85% of the time. Thus, the strong

Figure 2. To determine the milk line, break a representative ear of corn in half. Look at the milk line on the kernels in your hand holding the tip of the ear. Kernels dry down as starch is laid down in the kernel and progress from the outside of the ear inward toward the cob. Note change in color of the corn kernel and the texture becomes "harder." *Source: UK ID-13: Comprehensive Guide to Corn Management. Photo: Chad Lee.*

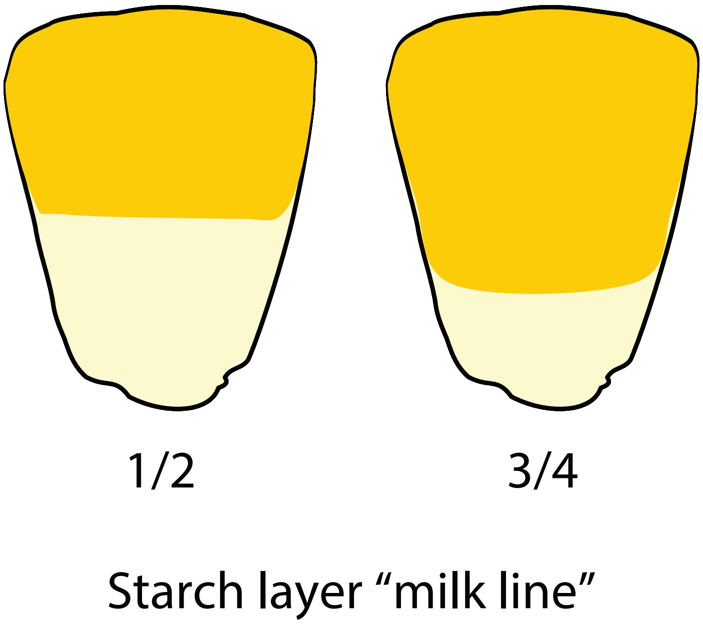

Figure 3. Schematic of the starch layer(known as milk line) progressing from the top of the kernel (dented area) to the base. *Source: UK AGR-79: Producing Corn for Silage.*

Figure 4. Corn kernel at black layer. Note black area at the base of the kernel. *Photo: Chad Lee.*

recommendation is to actually measure the moisture or dry matter content of representative chopped corn plants along with stage of milk line (ideally no greater than ¾ milk line). A partial load of silage can be chopped and the dry matter/moisture content determined using the procedures outline in the following section, "How to Determine Moisture Content of Silage or Fresh Chopped Forage Plants."

Harvesting corn for silage either too dry or too wet can result in a decrease in feed quality and performance by cattle fed the crop. In research studies, harvesting corn silage at 40% dry matter or greater (60% moisture or less) resulted in decreased milk yield of 4.4 lb milk/dairy cow/day. Silage that is too dry will have more and larger air pockets at time of storage which results in poorer fermentation with less beneficial acids for cows to use to make milk and meat.

Silage that is harvested too wet (< 30% dry matter in bunkers/trenches/piles or < 32% for upright silos) results in higher concentration of butyric acid during the fermentation process. Cattle offered this feed often have a decreased feed intake and feeding this feed can result in higher incidence of ketosis in early lactation dairy cows. Also, silage harvested too wet results in more seepage from the storage structure resulting in an increased loss of nutrients. This effluent needs to be contained and not allowed to enter waterways as it is considered even more toxic than manure runoff.

Recommendations. Ideally, corn silage should be harvested at 35% to 38% dry matter (62% to 65% moisture). However, the moisture content of corn plants will vary by location within and between fields and most times harvest cannot be completed or initiated when the dry matter is at this precise concentration. Another factor that must be considered is the amount of time needed to complete harvest. Harvest may take place over several days or a week(s) with the crop continuing to dry down. Thus, the recommendation is to start a little wetter so that harvest is completed before the crop becomes too dry. If a custom harvester is used, one needs to continuously communicate with the custom harvester regarding planting and silking dates early in growing season and moisture content as harvest nears. One may need to harvest a little wetter than ideal to avoid getting the crop too dry resulting from "waiting your turn."

When to Harvest Corn Silage

Ideally, corn silage should be harvested at 35% to 38% dry matter (62% to 65% moisture).

- For bunkers and trenches to accommodate a longer harvest window, silage should contain between 32% (at start of harvest window) to 38% dry matter (62% to 68% moisture).
- Upright silos and silage bags can be a little drier at 35% to 38% dry matter (62% to 65% moisture).
- Best to start harvest at a wetter (32% dry matter/68% moisture) than at ideal (38% dry matter/62% moisture) if harvest will take place over more than a day or two or one has to "wait for your turn" for the custom or shared corn harvester.

Table 2. Stages of growth of the corn plant as it relates to the physiological development of the kernels on the ear.

Appearance of ear or corn kernels	Growth stage	Approximate days after silking	Comments
Silking	R1	-	One or more silks extending from the husk leaves.
Blister	R2	12	Kernels are white blisters filled with clear fluid.
Milk	R3	20	Kernel fluid is milky white as starches accumulate
Dough	R4	26	Kernel contents develop dough-like consistency as starches increase. Begin monitoring whole plant moisture.
Dent	R5	38	Kernels begin denting. Continue to monitor whole plant moisture and harvest accordingly.
Mature (black layer)	R6	60	Depending upon structure, whole plant moisture may be below target content.

Sources: AGR-202: *Corn Growth Stages and Growing Degree Days* and *Determining Corn Growth Stages*, Bayer.

Estimating harvest based on planting date. Most seed companies estimate the number of days a particular variety of corn for silage will take to reach maturity or harvest time. These estimates are based on the average growing degree days needed to reach maturity. The majority of the difference between early maturing versus later maturing corn harvested as silage is the number of growing degree days or units needed between emergence and silking, not after silking. Since environmental temperatures can vary by location and from year to year, especially early in the growing season, expected maturity and harvest date can vary from the expected date when based on a planting date. Thus, this estimate is just that, an estimate of a time frame the crop may be ready to harvest and is best only used for planning purposes.

Estimating harvest based on growth stage. Most varieties of corn will be ready to harvest for silage approximately seven weeks after silking. If the date of silking initiation is known, count forward seven weeks to estimate harvest date and make machinery preparations. If silking date is unknown, kernel development can also help estimate harvest date. Again, this estimation is just for planning purposes and dry matter/moisture content should be the determining factor when to harvest corn as silage.

How to Determine Moisture Concentration of Silage or Fresh Chopped Forage Plants

The moisture or dry matter concentration of fresh corn plants can be determined by chopping a small amount and using a microwave or Koster tester to determine the moisture or dry matter content. A small digital scale that measures weight in grams helps obtain accurate results and simplifies the procedure.

Procedure for Microwave Oven

Cautions

- Do not use the microwave in the house, as odors can linger. Use only a designated microwave for this purpose especially for fermented silages (smell will linger in microwave and make the room smell) and
- **Do not leave the microwave unattended** during the procedure as the material can ignite.

1. Weigh out 100 grams of forage on a paper plate to determine the initial wet weight. (If the weight reflects the plate plus chopped corn plants, you will need to remember to subtract the weight of the plate from all measured weights or tare the scale to zero prior to weighing the material (make sure it stays tared.)
2. Place an **8 oz glass of water (3/4 full)** in the back right corner or on the rotating plate in the microwave. Try to keep the water level constant during microwave use. (Glass of water is a necessary step here.)
3. For silages or feeds with 25% to 50% dry matter:
   a. Heat for 5 minutes on high power.
   b. Stir feed, rotate plate, and return to oven.
   c. Heat for an additional 3 minutes on high power.
   d. Weigh plate and record weight.
   e. Stir feed, rotate plate, and return to oven and heat for an additional minute.
   f. Re-weigh plate and compare to previous weight.
   g. Continue to weigh, stir, rotate plate, and reheat sample until sample weight does not change more than 1 to 2 grams and/or feed starts to char.
4. To calculate the percentage of moisture and dry matter. (Remember to subtract the tare weight of the plate from both the wet and dry weights.)

$$\text{Percent Moisture} = \frac{\text{Wet Weight - Dry Weight}}{\text{Wet Weight}} \times 100$$

$$\text{Percent Dry Matter} = 100 - \text{Percent Moisture}$$

Figure 5. Koster tester available from farm supply companies, such as Nasco. Sample of fresh or fermented corn silage is added to the basket, weighed, and then placed on top of the Koster tester for drying. After sample is dry, the sample is reweighed and dry matter or moisture concentration is calculated. *Photo: Nick Roy.*

Procedure for the Koster Tester

1. Weight the empty basket to get a tare weight. Record tare weight.
2. Add 100g of chopped forage to the basket and place basket with chopped forage on top of the Koster tester.
3. Plug in the Koster tester and make sure that no flammable material is located close.
4. After 30 minutes, weigh the basket with dried material. Record weight.
5. Replace the basket on the Koster unit and let dry for an additional 5 to 15 minutes. Reweigh. If the weight does not change from the previous weight, the result is the dry matter of the forage sample (after subtracting the tare weight of the basket).

Moisture % = 100 - dry matter %

Grab method. An approximation of the moisture or dry matter concentration of corn silage can be made using the grab method. This involves obtaining a handful of silage and squeezing the chopped material in one's hand as tightly as possible for 90 seconds. After releasing one's grip, the ball of material should expand slowly and no dampness should appear on your hand. The chopped forage contains 30% to 40% dry matter (see Table 3). This method only allows for a general estimation of the moisture or dry matter concentration.

Plant appearance. In the past, the appearance of brown leaves near the lower part of the corn plant was used as a factor in determining the optimum harvest window. With today's corn genetics, corn plants stay green longer and this target is not an appropriate benchmark. The stalk of the corn plant can contain quite a bit of moisture even when the leaves appear to be dry. Also, the corn kernels account for most of the drying effect on the total plant when harvested.

Table 3. Determining the moisture/dry matter of corn chopped for silage using the grab method where a handful of silage is tightly squeezed in one's hand for 90 seconds.

Moisture percentage	Dry matter percentage	Characteristics after handful squeezed
75% to 85% moisture	15% to 25% dry matter	Liquid runs freely or shows between fingers
70% to 75% moisture	25% to 30% dry matter	Ball holds shape and hand is moist
60% to 70% moisture	30% to 40% dry matter	Ball expands slowly and no dampness appears on hand
Less than 60% moisture	Greater than 40% dry matter	Balls springs open in an opening hand.

Source: Chamblee and Green (1995).

Can I add water at harvest if silage is too dry?

Over the years, some have tried adding water to dry, chopped corn silage at the silo or blower using a garden hose. To increase the moisture content 1% unit (i.e., 60% to 61% moisture), 5 to 7 gallons of water must be added per ton of silage. At normal unloading speeds, adding a sufficient amount of water to increase the moisture content is difficult, if not impossible. **If the dry matter of corn for silage will be greater than 38% to 40%, shelling for corn grain alone is the best use for the crop.** It's best to monitor the moisture content, and harvest at proper moisture/dry matter for the best quality feed. To prevent silage from becoming too dry at harvest time, one may want to start harvest at a slightly wetter moisture content.

Example of Amount of Water Needed to Increase Moisture Content of Too Dry Corn Silage

Amount of water needed for 4-ton load of silage to increase moisture from 55% moisture (45% dry matter) to 62% (38% dry matter)

- ✓ For each 1% increase in moisture for each 4-ton load of silage need to add 20 to 28 gallons of water (or 4 to 6 "5-gallon" buckets)
- ✓ To increase moisture from 55 to 62% moisture (seven 1% units) need 140 to 196 gallons for a silo wagon with 4 tons of dry silage—
- ✓ Not realistic to add an adequate amount of water to make a difference. Best to shell the crop!

Sizing a Storage Structure (or Calculating Amount Stored in Silo)

When sizing a silage storage structure, the amount of feed that will be fed daily needs to be considered. In order to keep the silage face fresh, prevent spoilage, and optimize intake by cattle, a minimum of 12 inches of the silo face should be removed daily during the warmer months and 6 to 8 inches in the winter. As an example, an 8-ft diameter silage bag would contain 1 ton of silage (as fed) per foot. If livestock are fed 20 lb silage per animal daily, 100 cattle would need to be fed daily to remove 1 ft of silage or 50 cattle fed to remove 6 inches daily. Dry matter losses during storage and harvest need to be considered when determining acreage needed to provide an adequate amount of feed for the entire cattle feeding period. Dry matter losses due to "normal" silage fermentation account for about a 10% dry matter loss. Dry matter losses can exceed 25% if silage is not harvested at the correct dry matter, packed, and covered correctly.

Silo bags. The amount of silage that can be stored in a silo bag can be calculated from the volume in the bag multiplied by the estimated density of the packed silage. To calculate an estimation for the volume of a round bag and then the estimated tonnage:

Volume (ft^3) = 3.14 x ($Diameter^2$ /4) x Length (ft)

(For the length, subtract 2 times the diameter of the bag to account for sealing the plastic at both ends.)

(Volume (ft^3) x Density (lb dry matter or as fed/ft^3))/2,000 lb = estimated tonnage

Density of corn silage can vary between 11 to 15 lb dry matter/ft^3 (31 to 44 lb as fed/ft^3@ 35% dry matter). Recommendations are to use the higher end of this range (14-15 lb DM/ft^3 or 40-44 lb as fed/ft^3) assuming the crop is harvested at the proper moisture content, packed well, and no holes develop in the bag during storage.

Table 4. Estimated storage capacity of different diameter silo bags and the number of acres needed to fill a particular size silo bag.

	Storage capacity [2]		Acreage needed to fill		
	Tons dry matter	Tons as fed [3]	15 tons[3]/acre	20 tons[3]/acre	25 tons[3]/acre
8 Ft Diameter Silo Bag					
100 ft length[1]	30	84	6	4	4
150 ft length[1]	47	135	9	7	6
200 ft length[1]	65	185	12	9	8
300 ft length[1]	100	286	19	14	12
9 Ft Diameter Silo Bag					
100 ft length[1]	37	104	7	5	4
150 ft length[1]	59	168	11	9	7
200 ft length[1]	81	232	16	12	10
300 ft length[1]	126	359	24	18	15
10 Ft Diameter Silo Bag					
100 ft length[1]	44	126	9	6	5
150 ft length[1]	71	204	14	10	9
200 ft length[1]	100	283	19	14	12
300 ft length[1]	154	440	29	22	18

[1] To calculate length of silo bag, subtract 2 times the diameter from stated length to account for closing the ends of the bag.
[2] Capacity calculated as volume of a round bag times a density of 14 lb dry matter/cu ft or 40 lb as fed/cu ft. *Does not* account for storage losses of 10% to 25% and slopes at start and end of filled bags.
[3]Dry matter assumed to be 35% or 65% moisture. Harvest and storage losses are not taken into account in these calculations. Assuming good harvest and storage practices are in place, losses of 10% to 15% are normally seen and are associated with the fermentation process itself.

Bunkers, trench (earthen sides), or pit silos. When sizing bunkers or trench silos, one needs to account for the width needed to maneuver the packing tractor. In order to effectively pack silage with a tractor (tire spacing is 8 ft), silos should be a minimum of 17 to 18 ft wide or at least twice the width of the packing tractor. It is always best to have a longer (or multiple silo structures) verses a wider silo. Too wide of a silo will not allow an adequate amount of silage to be removed daily to maintain feed quality and prevent heating of feed at the silo face.

Excluding the slope at the face of these storage structures, they are essentially a rectangle and an estimated volume can be calculated as such.

Volume (ft^3) = length (ft) x width (ft) x height (ft)

Capacity (as fed tonnage) = (Volume (ft^3) x silage density (40-44 lb as fed/cu ft))/2,000 lb/ton

Example: A 40 ft wide, 100 ft long silo with 10 ft walls could hold 800 tons as fed filled level with the top of the side walls.

(40 ft wide x 100 ft long x 10 ft walls x 40 lb silage as fed/cu ft)/2,000 lb silage/ton = 800 tons as fed

For those wanting to calculate the capacity of a bunker silo while taking into account the slope of silage at the front (and back) of a silage structure and the rounded dome of silage on top, Dr. Brian Holmes, professor emeritus from the University of Wisconsin, has designed a spreadsheet which takes these calculations into account. (https://fyi.extension.wisc.edu/forage/harvest/#sstorage – Under the heading "Bunkers and Pile Silos," see downloadable spreadsheet entitled "Bunker Silo Volume and Weight Calculator").

Estimating capacity of tower (upright) silos-top unloading. When calculating the amount of silage in an upright silo, one needs to remember that the silage stored in the bottom of the silo has a higher density than that stored at the top of a silo. Thus, more silage would be stored in the lower part of the silo versus the top. When calculating the amount of silage left in an upright silo, this needs to be taken into consideration (see Table 8 for an example). The University of Wisconsin has a spreadsheet that allows the user to take this important concept into consideration. (https://fyi.extension.wisc.edu/forage/harvest/#sstorage – Under the heading "Tower Silos," see downloadable spreadsheet entitled "Tower Silo Capacity Calculator.")

Table 5. Approximate storage capacity[1] in tons (as fed – 35% DM) for bunker, trench, or pit silos not accounting for slope of silage at openings.

Length (ft)	Width (ft)	Height (ft)			Approximate acreage needed to fill silo to 8 ft height		
		6	8	10	Tonnage expected/acre		
		Tonnage (as fed)			15 tons/acre	20 tons/acre	25 tons/acre
100	30	360	480	600	32	24	19
150	40	720	960	1200	64	48	39
200	50	1200	1600	2000	107	80	64

[1]Assumes silage density of 40 lb as fed/cu ft, does not account for slope at open faces, and harvest and storage losses are not taken into account.

Table 6. Amount of corn silage (as fed) needing to be fed daily (tons) to remove 6 (minimum winter feeding rate) or 12 (minimum summer feeding rate) inches from the face of a bunker, trench, or pile.[1]

Silo width (ft)	Silo depth (Height)[2]					
	6 ft		8 ft		10 ft	
	Amount of face removed daily (inches)					
	6 in.	12 in.	6 in.	12 in.	6 in.	12 in.
	Amount of silage (tons as fed) removed daily					
30	1.8	3.6	2.4	4.8	3.0	6.0
40	2.4	4.8	3.2	6.4	4.0	8.0
50	3.0	6.0	4.0	8.0	5.0	10.0

[1] During the warmer times of the year, at least 12 inches should be removed daily from the face of the silo. During the winter (cold temperatures), at least 6 to 8 inches should be removed daily to keep a fresh face and maintain intake by cattle.
[2] Assumes 40 lb of silage (as fed)/cubic ft and silo is leveled to height specified.

Table 7. Estimated capacity of various sized top-unloading upright silos.

Upright silo size (inside diameter x height)	Estimated tonnage (as fed)
16 ft x 70 ft	300 tons
18 ft x 70 ft	375 tons
20 ft x 60 ft	390 tons
24 ft x 70 ft	670 tons

[1]Estimated tonnage when silo is filed within 5 ft of the top with corn silage at 38% dry matter.
[2]Calculated using spreadsheet as modified by Dr. Brian Holmes https://fyi.extension.wisc.edu/forage/harvest/#sstorage – under the heading of "Tower Silos" and see downloadable spreadsheet entitled "Tower Silo Capacity Calculator").

Table 8. Estimated amount of corn silage left in an 18 ft x 70 ft upright silo at varying heights.

Height of silage left in silo[1] (ft)	Estimated tonnage of dry matter left in silo	Estimated tonnage left on an as fed[2] basis
10	24	63
20	48	126
30	75	197
40	99	261
50	120	316
60	137	361

[1]Height measured from bottom of upright silo.
[2]Tonnage at 38% dry matter.
[3]Calculated using the University of Wisconsin spreadsheet, "Tower Silo Capacity Calculator."

Should You Use a Kernel Processor on the Silage Chopper?

Kernel processors are essentially an on-board roller mill attachment for corn choppers which helps break the cob and corn kernel into smaller pieces. Cattle are great sorters of their feed and will leave the round pieces of cob behind in the feedbunk. When corn cobs are not consumed, cattle do not consume the amount of fiber intended which may result in health and performance issues. Also, when corn kernels are broken into smaller pieces, the rumen bacteria can better digest the starch found in the corn kernel. Improvements in performance, milk production or weight gain, are not always seen, but their use may be more important with drier corn silage (38% dry matter versus 32%) and thus more mature corn kernels. Use of a kernel processor will reduce feed sorting by all cattle and is advised when possible. In dairy cattle, the use of kernel processors is recommended to improve digestion of starch within the rumen, when available.

Chop Length and Kernel Processor Settings

Choppers without kernel processors. For choppers without kernel processors, silage should be chopped to a ½-inch theoretical length of chop and harvested a little wetter (32% to 35% dry matter) than general recommendations. By harvesting silage that is wetter, generally the corn kernel is less mature, contains more moisture, and usually results in kernels broken up as chopping occurs. Knives should be sharpened as needed throughout the harvest period such that corn husks are adequately chopped and no long pieces are seen in the chopped material.

Choppers using kernel processors. To optimize starch digestion by the cow and provide adequate effective fiber, the recommendation when using a kernel processor on a corn chopper is to cut silage to ¾-inch theoretical length of chop with an initial roller clearance of 1 to 2 mm (clearance of a dime).

Figure 6. Sample corn silage to insure proper kernel processing at time of harvest. *Photo: Nick Roy.*

To test on farm whether adequate kernel damage is occurring, collect a silage sample in a 32 oz. cup. Pick out and count the number of whole and half kernels. No more than two or three half or whole corn kernels should remain after sorting the contents of the 32 oz. cup and corn cobs should be broken into 8 pieces. If kernel breakage is not adequate, the roller clearance should be decreased. Achieving this degree of kernel breakage does require more horsepower and a small increase in fuel usage, but results in better use of nutrients by cows; an area we need to consider as this practice impacts profit margins. Repeat this procedure throughout the harvest to ensure kernel processors continue to work properly.

Managing Storage Structures at Harvest Time for Best Quality Corn Silage

Regardless of the storage structure used, silos should be filled as quickly as possible. Silage should be added to all structures in layers and packed while filling (in uprights, gravity does the job of packing) to occlude as much oxygen as possible. During the filling process, silo distributors in upright silos need to operate correctly for ensiling silage is added in somewhat level layers. Both uprights and bunkers/trenches/piles need to be covered with silo plastic and the plastic remains in direct contact with the silage surface until time fed out.

For bunkers/trenches and piles. When filling a bunker/trench silo, silage should be added quickly and then packed correctly with adequate tractor weight to occlude as much oxygen as possible. To pack, silage should be spread in thin layers of less than 4 to 6 inches thick. Tractors with blades versus buckets do a better job in spreading the silage out into thin layers. Total packing tractor weight required for effective packing should equal 800 times the number of tons of forage delivered hourly. Another way to look at this is the total packing tractor(s) weight in tons multiplied by 2.5 is the number of tons of forage that can be brought to a bunker/pile hourly. To increase packing capacity, weights can be added to the tractor as well as fluid within the inside tires of dual wheels.

Question #1. How much total tractor weight is needed to effectively pack a bunker/trench/pile of silage?

Example A: 4 trucks per hour, 5 tons silage per truck or dump bed

800 x 5 tons/truck x 4 trucks = 16,000 lbs tractor weight

Example B: 25 tons silage delivered per semi-trailer, 4 trucks per hour

800 x 25 tons/trailer x 4 trucks = 80,000 lbs tractor weight or 2 heavy packing tractors

Question #2. How much silage can be packed hourly by a particular tractor?

Example:

20,000 lbs packing tractor = 10 ton packing tractor weight

10 ton packing tractor x 2.5 = 25 tons silage delivered to bunker/trench/pile per hour

Silage should be packed with a tractor at a speed of 1.5 to 2.5 mph. Spread silage in 4-inch-thick layers over the pile in a wedge configuration. Do not turn around on the surface and operate the tractor in a forward and backwards motion. Packing is complete when the surface is covered with tire tracks and is smooth. If the silo will be filed within 1 to 2 days from start to finish, the silage can be layered versus using a progressive wedge configuration.

Prior to filling, line the sides of the bunker walls with plastic with extra plastic overlapping the outside silo walls. Drainage tile can be slit and then attached to the top of the bunker walls to prevent tearing of the plastic while filling and pulling the plastic over the sidewalls. Plastic should line the entire inside wall of the bunker and be weighted with feed at the bottom (inside) of the bunker to prevent movement of the plastic when filling. Enough plastic should overlap the walls on the outside to allow at least 3 to 4 feet of overlap of the top-covering plastic on the top of the silo.

Once filling is complete take the excess plastic overlapping the walls and pull this plastic over the top of the bunker. Place another piece of 6 to 8 mm plastic over the top of the silo. These two pieces of plastic should overlap by 3 to 4 feet and the overlap weighted down to ensure the plastic stays in direct contact with silage throughout the time silage is in storage. Tires/tire walls that touch or gravel/sandbags should be used to weight down the entire surface of plastic such that the plastic stays in contact with the silage surface until time of fed out. If an additional oxygen barrier film is used and is not an integral part of the plastic covering, it should be applied before covering the silage pile with plastic. (The plastic on the inside walls also should be lined with oxygen-barrier film.)

Planting wheat or another crop on top of a pile

The purpose of placing plastic on the top and sides of a bunker, trench, or silage pile is to prevent water and oxygen infiltration into the silo pile resulting in spoilage and increased feed loss. Planting a "green crop" does not achieve this objective and feed losses will be very high on the top of the silo with this practice and is not recommended. Research has shown that oxygen will penetrate 3 feet into well-packed silage that has not been covered adequately with plastic, reducing the nutritional content of that feed and increasing the amount of shrink or feed loss.

For drive-over piles: Side slopes should not exceed a 3:1 slope (3 feet wide by 1 foot tall). This allows for water to drain off the pile and for safer packing with equipment. When covered, plastic should extend 4 to 6 feet off the forage surface around all 4 sides and be weighted down with a 6- to 12-inch layer of sand, soil, or sandbags for the entirety of the plastic edge to exclude air from getting under the plastic and causing spoilage. The plastic over the pile should be weighted down with tires/tire walls that touch or gravel-filled bags.

Bags: Make sure the bagger is working properly at the time of filling to allow for effective packing of silage (watch stretch marks on the bags). Place bags on solid surface, ideally concrete or asphalt, to minimize mud at feedout. Mud decreases feed quality and increases the possibility of unwelcome bacterial contamination of feed. Ends of the bags should be closed and sealed using dirt or other such products. Check often for holes in the plastic and when found reseal with silo-repair tape.

Immediately after filling, the end should be sealed as soon as possible. During the first 48 hours, gas will develop that will need to be vented to prevent damage to the bag. Take caution completing this practice as inhaling silage gases may cause severe sickness. To reduce build-up of gas, vent the bag after sealing following manufacturer recommendations. Typically, this involves cutting a small hole on the sealed end. After 48 hours, the hole can be resealed with silo-repair tape. To get a good seal, the area where the vent was cut should be cleaned before applying the repair tape. Only silo-repair tape should be used to reseal holes to prevent spoilage from occurring. Duct tape and other types of tape will not allow for a good seal and prevent spoilage of silage. (Source: Ag Bag Plastic Silage Mounting Instructions 2021)

Uprights: Fill as quickly as possible. After filling is complete, silos should be leveled and covered with plastic. Limit access by raccoons and other varmints that can cause damage to silage surfaces (i.e., digging holes) resulting in increased spoilage. During silo filling and for at least three weeks after, special care should be taken when working around or entering these silos as silo gases accumulate (a human health hazard). Even after this time frame, run the forage blower for 15 to 20 minutes with the door closest to the top of the silage open before entering the silo.

Are Oxygen Barrier Films for Covering Silage Worth Their Cost?

Oxygen barrier films can be applied as either a separate layer of plastic with a covering of "silage plastic" or incorporated into the "silage plastic" covering itself. Research has shown that the proper use of oxygen barrier plastic to cover silage decreases oxygen infiltration into the upper layers of silage reducing dry matter losses. Most farmers notice the reduction of spoiled silage that needs to be discarded from the top and sides of piles, bunkers, and trenches when using oxygen barrier plastic. Researchers have estimated that silage losses within the top 2.5 feet of silage were reduced by half when an oxygen barrier film was used. Even when evaluating dry matter losses within the entire silo, dry matter losses were reduced 8% over those using just a standard plastic covering. This reduction in dry matter loss is the average of the results from 41 research trials of which only two studies showed a negative result. Additional studies have shown that the use of oxygen barrier film to line the sides of bunker/trench silos reduces dry matter losses close to the sidewalls.

Figure 7. Bunker silo with plastic covering the top weighted down with tire walls. *Photo: Donna Amaral-Phillips.*

To make the best use of these plastic coverings, the plastic (oxygen-barrier plus plastic layer or oxygen barrier film incorporated into the plastic) must remain in contact with the silage surface throughout the storage period. To accomplish this task, tire walls or sandbags that touch must be placed over the entire top surface of the covered silo. Wind or varmints (i.e., raccoons) cannot disturb the plastic layer and the weight holding the plastic in place. If this does happen, repairs should be made immediately. Plastic used to cover silage should be UV resistant.

Will it pay?

Oxygen barrier films do increase the cost associated with covering silage over using just a single non-oxygen barrier plastic. But the real question is: Do they pay for themselves? If we decrease the amount of silage lost by 8% in a silo holding 350 tons of corn silage (approximately 20 ft wide x 100 ft long x 8 ft tall), we have an additional 28 tons of silage to feed. This amount of silage is enough to feed 19 additional beef cows (20 lb/animal/day) for 150 days or 2.5 dairy cows for a year. At today's feed prices (high corn, SBM, and byproduct costs), corn silage has a nutritive value in excess of $100/ton. Thus, that additional feed is worth $2,800 for a dairy cow operation. Even if we value the corn silage at $50/ton, that feed is still worth an additional $1,400. These feed savings are over and above those associated with using a traditional plastic silage cover. With these feed savings, use of oxygen barrier films will pay dividends.

Frost Damaged Corn

Corn can withstand temperatures down to 32°F for up to four hours with only minimal plant damage, but significant damage to the plant can occur with only a few minutes of exposure at temperatures 28°F or below. With a light frost, more than likely the corn plant will recover and reach maturity and dry matter needed for harvest. However, severe frost damage will result in death of the leaf tissue, browning of the leaves, and leaf losses which decrease dry matter yield depending on the stage of maturity of the corn plant. (The more mature the corn plant, i.e., milk line versus dough, losses are lower.) If the leaves around the ear are healthy, the plant will continue to mature and accumulate starch in the corn kernel.

The greatest challenge with immature, frost damaged corn is that the stalk still retains moisture and, as such, the crop may be too wet to be ensiled. Thus, one should check the moisture content before deciding when to chop the affected crop. Waiting for the whole plant to continue to dry down to at least 30% dry matter or 70% moisture may require the plant to remain in the field to dry down before ensiling. This practice could result in significant leaf loss during harvest. Straw, hay, or grain can be mixed with the harvested crop at ensiling to absorb some of the excess moisture. To result in a 1% unit of moisture reduction, 30 lb of dry matter from a "dry" feed ingredient needs to be mixed per ton of fresh silage. Frost damage to the corn kernels may allow access by fungi, resulting in an increase in molds and the possibility of mycotoxins.

Another concern when frost occurs at the milk stage of corn ear development is high nitrate levels. High concentrations of nitrate are toxic to cattle and will occur most frequently when the corn has been under drought stress prior to the frost. Ensiling will reduce nitrate levels 30 to 50%. To reduce the risk of nitrate toxicity, allow the ensiling process to occur for at least 21 days before feeding and submit fermented samples to a forage lab for nitrate testing prior to feeding to cattle. Increasing the chopping height will decrease the nitrate levels as higher concentrations of nitrates are found in the lower stem of the corn plant. Also, delaying harvest seven days or more can help decrease the concentration of nitrates as this allows the plant to convert nitrates into ammonia or other non-toxic forms.

For more information on frosted corn, see UK Publication AGR-183: *Late-Season Frost Damage to Corn Grown for Silage*.

Drought-stressed Corn

Elevated environmental temperatures or lack of adequate amount of water at silking and tasseling result in drying of pollen on the tassels and silks resulting in a reduction of fertilization of ovules that develop into corn kernels. Thus, grain yield is reduced as less to no kernel development occurs. Timing in relation to tasseling/silking and duration of drought-stresses determine the resulting decrease in ear development and forage yield.

At harvest time, drought-stressed corn plants often are higher in moisture than those grown under normal growing conditions and determining harvest moisture content is even more critical than under normal growing conditions. A higher percentage of the total plant is made-up of the stalk, which retains moisture, as total grain yield is reduced. The starch found in the corn kernels (greater than 1/4 milk-line) is responsible for decreasing the moisture content of the total plant. Thus, the total plant often is higher in moisture when limited ear development occurs.

Drought-stressed corn plants can accumulate nitrates. Consumption of high amounts of nitrates by cattle can cause sudden death. To avoid potential poisoning, the crop should be tested before feeding as green chop, before harvesting, or before being fed as an ensiled feed. Nitrates accumulate in the lower part of the stalk and higher chopping heights in relation to soil surface may be necessary to reduce the nitrate concentration in the ensiled crop. Depending on the nitrate concentration, delayed harvest may be needed, but proper moisture content at harvest must be observed. Ensiling the crop for at least 30 days reduces the concentration of nitrates by approximately 30 to 50% under proper fermentation conditions. For more information on nitrate poisoning, see ID-217: *Forage-related Disorders in Cattle: Nitrate Poisoning*.

Figure 8. Ear of corn illustrating the lack of kernel development at the tip end. The silks are still attached to the area on the ear where kernel development did not occur. *Photo by Chad Lee.*

Important Steps during the Silage Fermentation Process

A general understanding of what occurs during the fermentation process is critical to implementing sound management practices when storing and feeding silages. The fermentation process involves both aerobic (oxygen needing) and anaerobic (non-oxygen needing) bacteria and is generally dividing into six different phases. Aerobic fermentation occurs when the silo or bag is being filled (Phase 1) and at feedout (Phase 6). The remainder of the phases (phases 2 through 5) occur under anaerobic conditions.

Good silage management practices can help minimize losses in forage dry matter. Often, these losses in dry matter go undetected unless the amount of forage ensiled and feed being removed from the storage structure is measured accurately. Most farms do not complete and summarize these measurements. Also, well-fermented silages are more readily consumed by dairy and beef cattle. At harvest, good silage management practices include harvesting the crop at the proper moisture and stage of maturity, rapid filling of the storage structure, firm packing of the ensiled material, and then properly sealing the structure with plastic. What happens during the fermentation process determines the quality and quantity of stored feed that will be available at feedout.

Phase 1: Phase 1 starts at harvest and under ideal conditions of moisture, chop length, and firm packing lasts only a few hours. This initial phase continues until either the oxygen supply or water-soluble carbohydrates have been depleted. The most notable feature of this phase is the increased temperature of the newly fermenting crop resulting from ongoing cell respiration where carbon dioxide, water, and heat are produced. In poorly sealed and/or packed silos, bunk life of the resulting feed can be reduced since the initial growth of aerobic spoilage organisms (yeasts and bacillus species) occur during this phase and energy value of the resulting feed reduced. Once feedout occurs, yeasts can rapidly increase in numbers causing heating in the feedbunk and lowered feed consumption.

Phase 2: Phase 2 begins when the trapped oxygen supply is depleted and generally lasts no longer than 24 to 72 hours. During this phase, anaerobic (without oxygen) heterofermentation occurs. The primary bacteria during this phase is *Enterobacteria*. They can tolerate the heat produced during the aerobic phase and are viable

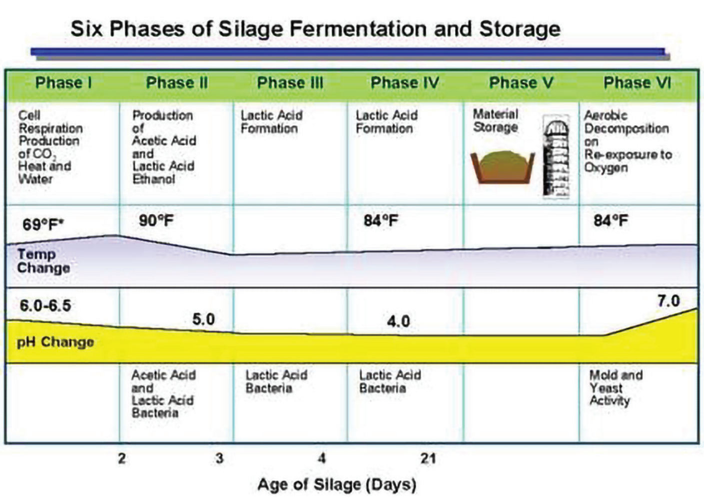

Figure 9. Six phases associated with silage fermentation and storage. *Source: Seglar, W. 2003. Fermentation Analysis and Silage Quality Testing. Proceedings from Minnesota Dairy Health Conference. Pg. 119.*

in a pH range of 5 to 7 which is found in the fermenting forage at this time. These heterofermenters produce both acetic and lactic acid, but tend to be inefficient at producing these acids relative to nutrients lost in the fermenting crop. The final proportions of these acids depend on the crop maturity, moisture, and natural bacterial populations. When the pH drops below 5, homofermenters predominate and phase 3 of silage fermentation begins.

Phase 3: Phase 3 is a transitional phase that generally lasts only 24 hrs. During this phase, the homofermentative bacteria, which are more efficient than the heterofermenters, rapidly drop the pH of the fermenting forage by efficiently producing lactic acid as an end-product. As the temperature of the silage mass decreases and the pH continues to drop, the bacteria in this phase become inhibited and Phase 4 lactic acid bacteria increase.

Phase 4: This phase is a continuation of Phase 3 with a stabilization of temperature of the fermented crop. Homofermentative bacteria convert water-soluble carbohydrates to lactic acid, which is very effective at dropping the pH which helps preserve silage. In well-fermented silages, lactic acid can account for over 65% of the total volatile fatty acids.

The final pH of an ensiled crop depends on the type of forage and moisture content of the ensiled forage. Legumes, i.e., alfalfa, have less water-soluble carbohydrates, a higher buffering capacity, and generally reach a final pH of about 4.5. Corn silage, in contrast to grasses and legumes, has a lower buffering capacity, more water-soluble carbohydrates, and generally reaches a pH around 4.0. When the terminal pH is reached, the forage is preserved within the silo. Silage pH does not indicate the rate or quality of the resulting fermentation. To determine the quality of the fermentation, a fermentation analysis is needed where the amount of acetic, lactic, and other acids is determined.

Phases 2, 3, and 4 generally are completed within 10 days to three weeks from harvest. Thus, the general recommendation is to wait at least three weeks before feeding newly harvested forages. The length of this fermentation process will vary depending on the crop harvested (related to buffering capacity), moisture, and maturity of the ensiled crop. Properly applied, high-quality inoculants may decrease fermentation time required.

Phase 5: This phase lasts through the remainder of storage where the fermentation process is stable as long as oxygen does not penetrate silage, i.e., through silo walls, with final temperature of well-preserved silage being 75 to 85° F. However, changes do occur in the digestibility of the nutrients found in these forages. Studies show that with longer storage times, starches become more quickly degraded in the rumen and, as such, corn silage (and high-moisture corn and earlage) stored for 2 months does not have the same feeding value as that stored for 6 months post-harvest.

Phase 6: This phase occurs during feed out, is just as important and often neglected part of the fermentation process and can result in substantial dry matter losses as oxygen is reintroduced into the fermented crop. Proper management of the silage face and at the feedbunk can minimize dry matter losses and optimize feed intakes by cattle.

Take-home messages: When applying these concepts on-farm regarding the fermentation process for silage:

1. Harvesting ensiled forages at the proper moisture and stage of maturity, rapidly filling, and properly packing and covering harvested silages directly impact the fermentation process. Well-fermented silages result in less dry matter losses, more feed being available for feeding dairy and beef cattle, and a higher quality feed (more lactic acid) which could improve feed intake, milk production, growth, and profitability.
2. Changes do occur in the nutritive value of forages after the fermentation process is complete. These changes may help partially explain why dairy cows produce more milk on corn silages fermented longer than two to three months from harvest.
3. The fermentation process takes 10 days to three weeks for the initial stages to be completed. Silages should not be fed until after these initial fermentation processes are completed for the best milk production and feed intake outcomes. Thus, the recommendation is to wait at least 3 weeks before feeding new crop silages. Digestibility of the starch continues to increase with storage for approximately six months post-harvest.
4. To extend bunk life, minimize the exposure of fermented feed to oxygen at the silo face (Phase 6). By properly handling silage at feed out, the feed will heat less in the feedbunk and be more acceptable to cattle.

Fermentation Analysis of Silages

Most commercial laboratories can analyze forages for the concentrations of various acids produced during the fermentation process. These values can be used to determine the quality of fermentation that has occurred. However, these results cannot be used to balance rations. Taken in combination with nutrient concentrations, they can help explain what did or did not occur during the fermentation process and possibly may explain feed intake problems in dairy or beef herds. For accurate results, samples of forage need to be frozen immediately after being collected and shipped on ice for next day delivery to the forage testing laboratory.

These reports typically analyze several end products of the fermentation process with expected ranges given in Table 9.

pH. Generally, the lower the pH the better the fermentation (assuming pH is within expected ranges) and is one of the criteria when evaluating the quality of a silage fermentation. When pH is higher than expected, fermentation may not be optimum. One possible cause for a higher silage pH is drier silages as fewer acids are produced. In addition, silages that are undergoing *clostridial* fermentation have a higher pH as the lactic acid is being converted to butyric acid.

Lactic acid. Lactic acid is the predominant fermentation acid and should comprise 65% to 70% of the total acids in the silage. Generally, the presence of high levels of lactic acid indicates efficient fermentation and minimal dry matter losses.

Acetic acid. Acetic acid provides silages with the characteristic vinegar odor and taste and helps maintain aerobic stability, i.e., extend bunk life. Some microbial inoculants (*Lactobacillus buchneri*) added at time of ensiling increase the amount of acetic acid in silage and help extend bunk life once the silage is exposed to air.

Propionic acid. Propionic acid produces a sharp, sweet smell and taste. Generally, this acid is found in low concentrations in well-preserved and fermented silages.

Butyric acid. Butyric acid produces a rancid butter smell. High concentrations (greater than 0.5%) indicate the silage has undergone an undesirable, *clostridial* fermentation and the resulting silage is lower in nutritive value because soluble nutrients have been degraded. These silages may result in lower feed intakes in all class of cattle and lower milk production in dairy cattle. The butyric acid concentration in *clostridial* silages increases over time. Butyric acid may induce ketosis in cattle and silages with high concentrations should not be fed to early lactation and transition dairy cows. Cows later in lactation can handle 100g butyric acid daily in their total diets and use of these high butyric acid silages may need to be limited so as not to exceed these amounts.

Ethanol. Ethanol produces an alcohol smell and is primarily an indication of yeast activity. These silages are more prone to spoilage and, as a result, heat quicker with a shorter bunk life. Yeast numbers can double within two hours, thus numbers can increase rapidly, further deteriorating the quality of silages being fed.

Ammonia nitrogen. High concentrations of ammonia in silages are an indication of excessive breakdown of proteins caused by a slow drop in pH or *clostridial* fermentation. Proper balancing of rations for ruminally degradable protein (RDP) can help minimize problems with dairy cattle at feedout.

Table 9. Typical concentrations of fermentation end products in legume, grass, and corn silages and high moisture corn without inoculants added at time of ensiling.

End Product	Legume Silage (30-40% DM)	Legume Silage (45-55% DM)	Grass Silage (30-35% DM)	Corn Silage (30-40% DM)	High Moisture Corn (70-75% DM)
pH	4.3-4.7	4.7-5.0	4.3-4.7	3.7-4.2	4.0-4.5
Lactic Acid (%)	7-8	2-4	6-10	4-7	0.5-2.0
Acetic Acid (%)[1]	2-3	0.5-2.0	1-3	1-3	< 0.5
Propionic acid (%)	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1
Butyric acid (%)	< 0.5	0	0.5-1.0	0	0
Ethanol (%)	0.2-1.0	0.5	0.5-1.0	1-3	0.2-2.0
Ammonia-N (% CP)	10-15	< 12	8-12	5-7	< 10

DM= dry matter, CP= Crude protein
[1] Silages without hetero-fermentative silage inoculants
Source: Kung and Muck. 2017. Silage harvesting and storage. Large Dairy Herd Management, third edition.

Use of Silage Inoculants – Are They Worth the Money?

Ensiled forages form the foundation of many rations fed to dairy and beef cattle, providing many nutrients necessary to support milk production, reproduction, and growth. When forages are correctly ensiled, water-soluble carbohydrates are converted into organic acids by bacteria naturally found on the leaves of plants. These organic acids—mostly lactic acid—lower the pH of the ensiled crop, thus preserving the forage crop and inhibiting the growth of spoilage and pathogenic bacteria. Once these silages are exposed to oxygen during feeding and at the exposed open face of a silo, yeasts and molds can grow, allowing for heating and deterioration of silage quality. Two different types of silage inoculants have been developed and studied as they relate to controlling each of these two processes. The question then becomes: On what crops and under what field and storage conditions are these inoculants the most beneficial.

Lactic Acid Bacterial Inoculants

Inoculants containing lactic acid (LAB) bacteria, such as *Lactobacillus plantarum*, are some of the older types of bacterial silage inoculants. These bacteria ferment carbohydrates in ensiled plants to primarily lactic acid and, as such, were known as homofermentative lactic acid bacteria. Today, they are classified as facultative heterofermentative lactic acid bacteria, but still produce predominately lactic acid, an acid that decreases the pH of the ensiled crop. These inoculants were developed to cause a quicker drop in the pH of silage crops shortly after ensiling, as well as decrease the pH of the crop during the entire fermentation process. This drop in pH inhibits the growth of undesirable microbes, such as molds or *clostridia* (cause of botulism in cattle) and prevents the loss of nutrients in the ensiled crop.

Responses to an inoculant vary by ensiled forage type (i.e., corn versus alfalfa), bacterial species and strains used in the silage inoculant, application rate of LAB, and other silage management practices. In alfalfa and grass silages, silage inoculants decrease the final pH of silages, increase lactic acid concentration, increase dry matter recovery, decrease mold counts; thus improving silage fermentation. However, these responses were not consistently seen in corn or sorghum silages. Scientists speculated the lack of response was due to the harvested corn or sorghum plants already containing sufficient water-soluble carbohydrates to support adequate lactic acid synthesis resulting in an adequate drop in silage pH, lower buffering capacity of the forage itself, and the inability of the added LAB bacteria to outcompete those already present in the harvested crop. If these conditions were not met, a positive response might be seen; thus providing insurance during the ensiling of a corn or sorghum crop.

One positive response across forage types and in most studies was a small, but significant, increase in daily milk production (0.8 lb/day) and a tendency for an increase in milk fat and protein percentage and dry matter intake. Scientists could not easily explain this increase in milk production but speculated that it might be related to an inhibition of detrimental molds and toxins and changes in rumen fermentation.

Forages treated with a LAB-type of inoculant generally have lower acetic acid content and, consequently, contain higher yeast counts. Acetic acid acts as an anti-fungal agent and higher lactic acid concentrations act as a growth substrate for spoilage yeasts. These changes decrease the stability of silages at time of feedout resulting in heating at the feedbunk or open face of the silo.

Inoculants to Extend Bunk Life

Different from LAB bacteria, the group of bacteria, known as obligate heterofermentative bacteria, improve the stability of silages at time of feedout and on the face of an opened silo. The most common example of this type of silage inoculant is *Lactobacillus buchneri*. These bacteria convert lactic acid found in the silage to acetic acid, thus lowering yeast counts with the result of less heating of silage in the feedbunk and at the exposed face of silos. These increases in acetic acid content take 30 to 60 days post-ensiling before they are detected. Combining results across multiple studies, aerobic stability of corn silage (measured as silage temperature increased no more than 2° to 3.5°F, considered stable) was 25 hours for untreated silage and increased to 503 hours for silage treated with *L. buchneri* at application rates greater than 100,000 cfu/g. Feed placed in a feedbunk should be consumed before these times. However, this longer stability is more important in helping maintain the quality of silage found just interior to the exposed face of silos. Removing silage from the face allows oxygen to enter the stored pile just interior to the exposed face. The depth of this oxygen infiltration is dependent on how deep from the face packed silage is disturbed when removing silage for feeding. Researchers also noted that silage pH increased somewhat in silages inoculated with *L. buchneri*, but still within an acceptable range (i.e., 4.2 vs 4.4 pH for grass and small grain silages). Just like the LAB inoculants, effects are strain and dose dependent.

Combination Inoculants

Commercial products are available that combine both types of inoculants. The LAB bacteria would help control the early fermentation process resulting in a more rapid drop in pH, suppressing undesirable microbes, reducing the breakdown of proteins, and decreasing losses of dry matter, especially in grass and alfalfa silages. The *L. buchneri* bacteria (or similar acting bacteria) would improve the stability of the ensiled forage at feedout and at the open face of the silo. When selecting a product, one needs to request research showing the product works as advertised. Different species and strains are used in different products along with various inclusion rates. Limited peer-reviewed, published data are available showing the effects on animal performance as to whether the effects seen with the LAB bacteria separately are found when used in combination with *L. buchneri*.

Should You Use Inoculants?

Success when using a silage inoculant starts and is dependent on one practicing sound silage preservation management practices. Preserving quality silages starts with harvesting the crop at the proper stage of maturity and moisture, adequately packing to exclude as much oxygen as possible, and covering the silage to prevent water and oxygen infiltration. In addition, the inoculant must be handled as directed and applied at the correct concentration. Poor handling and storage of inoculant account for many on-farm failures.

From the published research trials, the use of LAB bacterial inoculants seems to be prudent for alfalfa and grass silages. With corn and sorghum silages, the effects with the use of LAB bacterial inoculants are less definitive as they relate to changes in the fermentation process. Use of these products may act as an insurance policy for times when conditions are not optimal for successful fermentation. The question becomes, is that cost justified? The use of *L. buchneri*, a different type of inoculant, extends the stability of silages at feedout irrespective of crop.

The response from any product depends on the species and strains included as well as the inclusion rates of stated bacteria. To determine whether a particular product is effective, one should request research supporting the product's effectiveness. These results should be compared to a control where no product was used, and the untreated ensiled silage was treated identically to the treated silage. Multiple studies should show that the product is effective with the crop in question and was conducted over multiple years and in multiple locations.

Managing Silage Storage at Time of Feeding

Management practices related to how silage is removed at feedout from all types of storage structures directly impact the quality and amount of silage fed. The key principle is to remove an adequate amount of silage every day to keep the silage face "fresh" while preventing heating. At the same time, silage needs to be removed such that the area directly behind (or under) the new silo face is not disturbed to prevent the infiltration of oxygen. If oxygen is allowed to enter the silo face, the silage heats while still in storage (often initiated by growth of yeasts), quality of the silage deteriorates rapidly at or before feedout, and then less dry matter or feed may be consumed by cattle.

Maintain smooth face on bunkers. When removing silage from a bunker, trench, or pile, always maintain a smooth face and minimize "digging" into the face of the silage. If tractor buckets are used for removing silage, they should remove feed carefully from the top down and not by "digging" into the pile from the bottom or middle of the pile's face. Mechanized silo facers minimize oxygen infiltration into the packed face beyond the amount to be fed and can be cost effective. When removing silage from the face of the pile, only the amount needed for the current feeding(s) should be removed. Unfed, excess feed quickly heats and deteriorates in quality. Plastic covering the top of the bunker should be removed as the pile is fed. Extreme care is needed to prevent human injury or death from falling silage.

Silos with poor face management generally have a higher pH and temperature at the face compared to 2 to 3 feet behind the face. These findings indicate aerobic instability with aerobic yeast activity resulting in silage heating. Generally, the bunk life of this feed is shortened and once heated, cattle usually eat less of this silage. To determine the pH or temperature of a silo face versus 2 to 3 feet inside the face, measurements should be taken at several locations throughout the silo face. Because of the potential instability of the silo face, extreme caution should be taken by those making these measurements and always have another person close with necessary equipment in case of a silage avalanche. A non-contact thermometer along with a 2- to-3-foot temperature probe (compost temperature probe) or thermal imaging (infrared) camera can be used to compare the temperature of silage at the face versus 2 to 3 feet behind the face. The temperature inside the pile should be within 15°F of ambient temperature at harvest and within 15°F of the temperature of silage at the surface. pH paper or a pH meter can be used to measure the pH of silage when 1 to 2 ounces of silage is mixed with equal amounts of distilled water in a disposable cup. For corn silage, pH should be between 3.7 and 4.2 and for grass, alfalfa, or clover silage (30-40% DM) pH should be between 4.3 to 4.7.

Silage sampling—safety first. Samples of silage to determine dry matter and nutrient content should not be collected at the face of the silo to ensure the safety of those taking these samples. Instead, silage should be removed across the face of the silo using the normal method of removing silage (i.e., tractor or skid steer bucket with or without a silo defacer), added to the TMR wagon without any other ingredients, allowed to mix, and then discharged on the feeding pad away from the face of the silo. Then, samples can be safely collected for nutrient analysis. Individuals should not be standing closer than 2.5 to 3 times the height of the storage structure to prevent human injury or death.

Upright silos. Just like bunkers, the top of the silo "face" needs to be kept level and an adequate amount of feed fed daily to prevent feed from heating.

Summary

Harvest and storage practices for corn silage impact the quality of feed at feedout, cattle performance, and profitability of cattle operations. Corn silage needs to be harvested at the correct moisture (62 to 65% moisture, 35 to 38% dry matter) content, stored in a properly sized and sealed storage structure, harvested rapidly, packed adequately to occlude oxygen, and allowed a minimum of three weeks to ferment. Ultimately, adherance to these silage management practices impact the growth, reproduction, or milk production of cattle. Practices at feed-out, irrespective of the storage structure, also directly impact cattle performance and potential profit for cattle operations and must be practiced to deliver quality feed to cattle.

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