Preventing Silage Storage Losses

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This article is one in a series of three that addresses the issue of forage loss in harvest, storage, and feeding of animals. Forage loss occurs primarily by two modes: 1) escape of forage from the mass of forage as it moves through handling and storage processes and 2) microbial deterioration. Escape of forage can often be observed as forage lying on the ground or on top of equipment surfaces. Most microbial deterioration is invisible and may only be detected by a temperature rise in the forage or a darkening as the forage oxidizes. The obscurity of microbial deterioration has led many producers to believe they have minimal forage loss. In fact, they may experience appreciable (5-20%) losses before they see visual evidence of molds on forage. Table 1 lists estimates of dry matter loss for filling, storage and emptying a variety of silage storages. This article addresses the modes of loss experienced and provides recommendations for minimizing these losses for each of the major silage storage systems

Storage Filling

Top Unloading Tower Silos

Dry, lightweight forage particles (alfalfa leaves) can become suspended in the air while blowing forage into a tower silo. Some of these particles can be blown from the silo and lost. This loss is evident as forage particles in the air outside the silo while filling and as a deposit of forage particles on barn roofs and the ground following filling. Harvesting at the correct moisture content minimizes the amount of lightweight particles, thus reducing the quantity of particles suspended in the air and lost. Harvesting when dew is on the hay and/or adding some water at the blower can help reduce alfalfa leaf loss.

Forage in a tower silo is packed by the weight of the forage above. Consequently, forage near the top of the mass is low-density, porous material. Such material traps air between particles and lets air penetrate the mass easily. This air supplies oxygen to aerobic organisms as well as for plant respiration that both consume readily available carbohydrates. Forage heating results from both processes. A tower silo that is filled slowly has more low-density forage exposed to the air for longer periods than does a rapidly filled silo. Thus, equipment to harvest, transport and fill the silo, as well as labor, should be available to fill a tower silo rapidly (within 3 days). At the end of each day's filling process, the top surface should be leveled and walked on to compact the forage. The denser top surface limits air infiltration. Remember to keep the blower operating to dissipate silo gas, which may be present.

Forage spilled on the ground while feeding the blower deteriorates if left for any length of time. Cleaning up around the blower and delivering the spilled forage into the silo at the end of each day minimizes the loss.

Oxygen Limiting Tower Silos

The moisture content of forage placed into oxygen limiting silos is usually lower than that of top unloading tower silos. Consequently, dry matter loss as forage particles is apt to be greater with oxygen limiting silos during filling. Cleaning forage from the silo roof at the end of each day's filling can help to reduce this loss. Cleaning up around the silo filling blower at the end of each day and placing the spilled feed into the silo limits dry matter loss.

The oxygen-limiting nature of the silo requires the filling hatch to be closed and sealed at the end of each day of silo filling.

Silo Bags

Forage spilled during bag filling can be lost if allowed to remain on the ground. Since bag filling machines move as a bag is filled, it is probably most convenient to clean up feed as it spills or at least after each wagon/truck load is emptied. Silo bags protect forage from exposure to air once they are sealed. Consequently, equipment to harvest, transport and fill a bag, as well as labor, should be capable of filling and sealing a bag quickly. Forage packed uniformly against the plastic bag minimizes pockets of entrapped air. Harvesting forage at 60-70% moisture with 3/8-inch theoretical length of cut and 15% or less of hay particles longer than 1.5 inches minimizes the development of air pockets within the bag.

Bunkers/Piles

The recommended procedure for filling a bunker silo or silage pile is to spread the forage in thin layers on the sloped filling face and driving over it several times with one or more heavy tractors. The top of the forage mass is a large area exposed to air and precipitation during filling. Penetration of air and precipitation supports aerobic organisms, which cause forage deterioration throughout the top surface of exposed forage. The progressive wedge technique of filling continually covers previous layers of forage, thus reducing exposure to air. Packing the forage to form a high-density mass reduces entrapped air and limits penetration of air into the forage mass. Filling the storage quickly (within 3 days) limits the forage exposure to air throughout filling. Consequently, equipment to harvest, transport and fill the storage as well as labor should be capable of filling the storage rapidly. Each of two smaller bunkers/piles can be filled more quickly than one large one. When sizing a storage, select several smaller storages so you can fill each more quickly, thus reducing exposure of forage to the elements.

Silage piles should be built so the entire surface can be driven upon to obtain high-density forage throughout. The side slopes of the pile should be sloped at 3 units of run for each unit of rise (3:1) to obtain a surface which can be driven over with minimal risk of tractor roll over.

Plastic is the recommended material to cover forage in bunker silos and piles to exclude air and precipitation. The sooner this cover is installed, the less time forage is exposed to aerobic conditions. Once the rear portion of the forage mass is placed and packed, the plastic cover should be installed. If precipitation is expected, the sloped filling face should also be protected by rolling the plastic over the surface. This practice will prove extremely valuable at protecting the forage if the precipitation event lasts for an extended period.

Storage Period

Top Unloading Tower Silos

Concrete walls of tower silos are porous to air exchange into the forage. However, cracked concrete and cracks in and around silo doors are much more porous to air movement. If the amount of spoilage around walls and doors has been steadily increasing from year to year, this indicates the need for maintenance even if cracks are not visible. Walls and doors must be maintained on a regular basis to limit the number and size of cracks if air exchange and losses are to be minimized.

Forage moisture content is very important for limiting losses in tower silos. Above 65% moisture, silage compaction causes juice to be expressed from the forage. In large tower silos, seepage may be a problem unless forage moisture content is less than 60%. The seepage of juice carries away soluble carbohydrates that cattle could have used. Forage lower than 40% moisture does not pack as densely as wetter material (more porous) and is susceptible to spontaneous combustion if exposed to air (Tormoehlen et al., 1989). Spontaneous combustion can cause not only a large loss of forage, but also the silo and/or unloader can be destroyed.

The roof on a tower silo is used to exclude precipitation. Inspect and repair the silo roof periodically and close openings to assure proper water exclusion from the silo.

As with bunker silos and silage piles, plastic should be used to cover the top surface of a tower silo after filling. While the silo is still being ventilated by the blower, level the forage surface and walk on the surface to compact the forage. Excavate a 2-ft deep trench in the forage around the perimeter of the silo. Then cover the forage and insert the edges of the plastic into the trench. Blow 12 inches of wet forage, sawdust or straw on top of the plastic to weigh it down, and pack the material into the perimeter trench to form a tight seal. Allow the silo to remain capped for 30 days to permit good fermentation and silage stabilization.

Oxygen Limiting Tower Silos

During the storage period, the filling and emptying hatches must remain closed to limit entry of air to the interior of the silo. Where the breather bags are outside the silo, inspect them for punctures at monthly intervals.

Silo Bags

The higher the density of forage in a silo bag, the lower the amount of entrapped air and the lower the rate of air infiltration as the bag is opened or if the bag is punctured. Thus, the bagging machine should be adjusted to form a tightly packed bag.

Silo bags are punctured by a variety of causes including but not limited to equipment, people, animals (domestic, wild), hail, etc. Punctured bags allow air to enter, which can cause significant deterioration of feed. Take measures to protect bags from punctures. Locate bags away from woods and treed fencelines. Mow weeds around the storage pad and provide an unvegetated, 3-ft perimeter around the storage pad to discourage rodents from approaching the bags. Clean up spilled feed to avoid attracting vermin. Fence the storage pad area to exclude domestic animals. Admonish children not to play on or around bags. Take care when operating equipment (front end loaders) near the side of a bag. Inspect each bag weekly and repair holes with tape supplied by the bag distributor. The tape should have low oxygen permeability.

Bunkers/Piles

The walls of bunker silos help to exclude oxygen from the forage. The walls must be free of cracks to be effective. Before filling a bunker silo, inspect walls for cracks and make needed repairs to wall cracks and wall panel joint cracks.

Seepage of forage juice can occur from a bunker/silo pile if the forage is harvested at moisture content greater than 70%. The juice carries a high concentration of soluble carbohydrate, which represents a significant loss of valuable feed energy (Graves and Vanderstappen, 1993; Wright, 1997). Clostridial fermentation can be a problem at these levels as well. Harvesting at 40% moisture or less exposes forage in a bunker silo/pile to the risk of spontaneous combustion (Tormoehlen et al., 1989).

Good packing during filling produces a dense silage mass. Dense silage limits air penetration while the forage is stored.

The plastic cover placed on top of forage in a bunker/pile excludes oxygen and precipitation. Use at least 6-mil thick plastic. Thicker plastic is easier to handle and more resistant to tears and to oxygen infiltration. For the plastic to be most effective, it should be held tightly to the silage surface and tightly sealed at the edges. If tires are used to weigh the plastic down, they should touch each other to provide uniform weighting and to prevent plastic billowing in the wind. This billowing can act as a bellows, drawing air into the silo. Loose soil or sand bags have been used to give a tight seal at the edges of the plastic. Use specially designed tape to repair punctures after the plastic is installed. Inspect the plastic cover weekly and repair holes with oxygen excluding tape.

Water entering silage can carry oxygen to supply aerobic organisms and can wash sugars and acids out of the silage. If percolating water causes seepage, the feed value of the sugars and acids are lost. The pH of forage exposed to percolating water will be higher than well-fermented silage. High pH forage will deteriorate at a fast rate when exposed to oxygen. Consequently, plastic covers should be installed in such a way to exclude precipitation from silage. Consider:

1. Sloping the forage top surface to drain water away from the silage feed out face.
2. Sloping the forage top surface to drain water without letting it pass between silage and bunker silo wall.
3. Sloping the bunker/pile floor so water drains away from the silage face.
4. Installing drains below walls to intercept/remove groundwater.
5. Diverting surface water runoff so it doesn't enter the storage.
6. Weekly inspecting for and repairing holes in the plastic cover to exclude air and water.

Emptying Storage

The face from which forage is removed from any storage system is an area exposed to aerobic deterioration for an extended period of time. Removal processes that cause exposed silage to be rough and/or have cracks in the forage cause higher losses than do processes that leave smooth, undisturbed surfaces. Density and feed out rate affect the amount of air exposure prior to feeding.

In loosely packed silage, oxygen may move several yards into the silage from the open face. In contrast, densely packed silage limits the rate of oxygen diffusion into the feed out face. Practices and systems that promote high silage density should be used during filling to help minimize losses at feed out (Holmes and Muck, 1999a).

The feed out rate (inches removed from the silage face per day) can influence the average loss during feed out. If most dry matter loss occurs within 1-2 inches of a silage feed out face and the feed out rate is one inch per day, then all of the silage fed will have had some loss before being fed. Let's say as an example, 10% of that one inch of material was lost. Then all feed removed will have a 10% loss. On the other hand, if the removal rate is 4 inches per day and only the first inch experiences the 10% dry matter loss and the other 3 inches are unaffected, the average dry matter loss for the feed removed is 2.5%. Thus, it is important to size and manage the feed out rate for adequate rates of removal to minimize spoilage losses at the feed out face.

Pitt and Muck (1993) determined the dry matter loss during feed out of bunker silos as a function of silage removal rate. They determined the dry matter loss was 3% at the recommended removal rate of 6 inches per day for 35% dry matter silage with a density of 14 lbs DM/ft^3. They also concluded dry matter loss was reduced as silage density increased. Muck and Pitt (1994) state that dry matter loss is proportional to silage porosity. Porosity is inversely related to dry matter density and dry matter content. Based on this information, Figures 1-3 were developed to establish the dry matter loss as a function of dry matter density, silage removal rate, and dry matter content. In Figure 1 (9 inches per day removal rate), the dry matter loss during removal is less than 3% when the dry matter density is greater than 14 lbs DM/ft^3 and forage is ensiled at less than 40% dry matter. For the forage ensiled at 50% dry matter, the dry matter density must be greater than 17 lbs DM/ft^3 before the removal dry matter loss is 3% or less. Note that porosity must be less than 55% for the removal dry matter loss to be less than 3% when the removal rate is 9 inches per day.

In the situation where the silage face removal rate is 6 inches per day (Figure 2), the porosity must be 43% or less for the removal dry matter loss to be 3% or less. As the forage dry matter content increases, higher and higher dry matter densities are needed to keep the removal dry matter loss under 3%. If the dry matter density is less than 13 lbs DM/ft^3, it will be difficult to keep dry matter loss under 3% for any dry matter content graphed with a 6-inch silage face removal rate.

Figure 3 presents the removal dry matter loss as a function of dry matter density when a 3-inch silage face removal rate is used. Under these conditions, the porosity must be less than 23% to keep the removal dry matter loss under 3%. The dry matter density must be greater than 16 lbs DM/ft^3 for this to occur. Face removal losses will be higher than 4.5% when the dry matter density is less than 14 lbs DM/ft^3. In fact, dry matter loss can be as high as 10% when forage is 50% dry matter and density is 10 lbs DM/ft^3.

As the silage face removal rate decreases from 9 inches per day to 3 inches per day, forage must have a lower dry matter content (more moist) and/or a higher dry matter density to assure dry matter loss is kept under 3%.

Table 2 lists the recommended minimum removal rates for different types of storage. When designing a storage, plan to remove at least twice the minimum value. The implication is that you

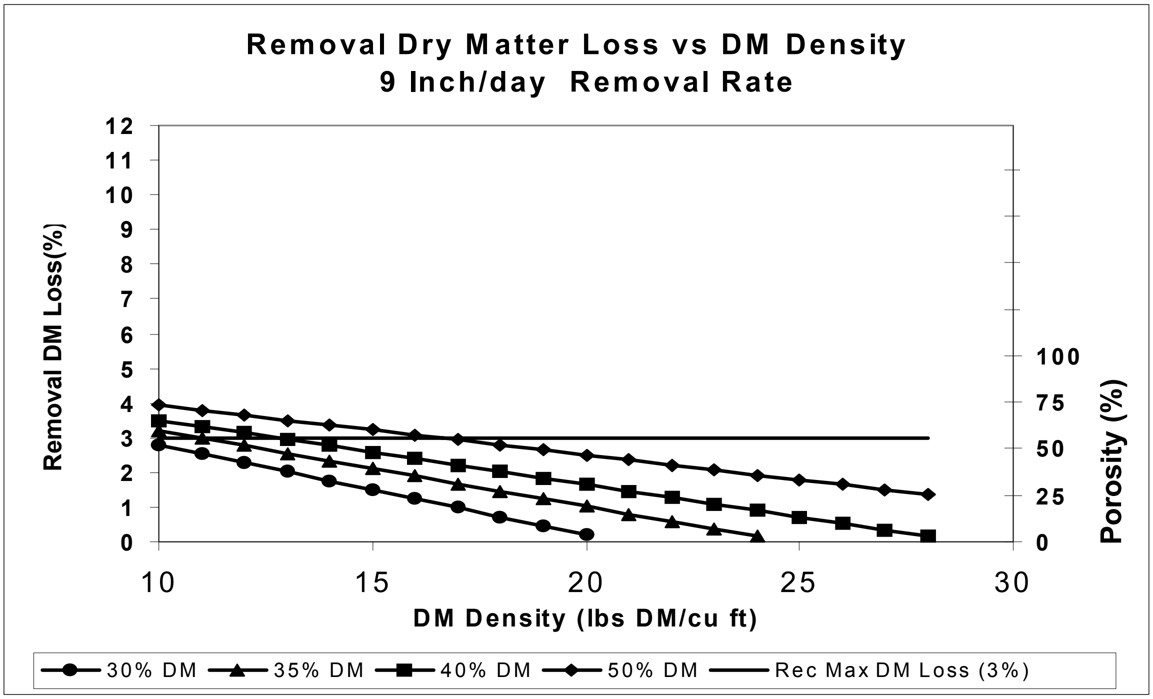

Figure 1. Dry Matter Loss vs Silage Density During Silage Removal From a Bunker Silo Face at the Rate of 9 Inches/Day.

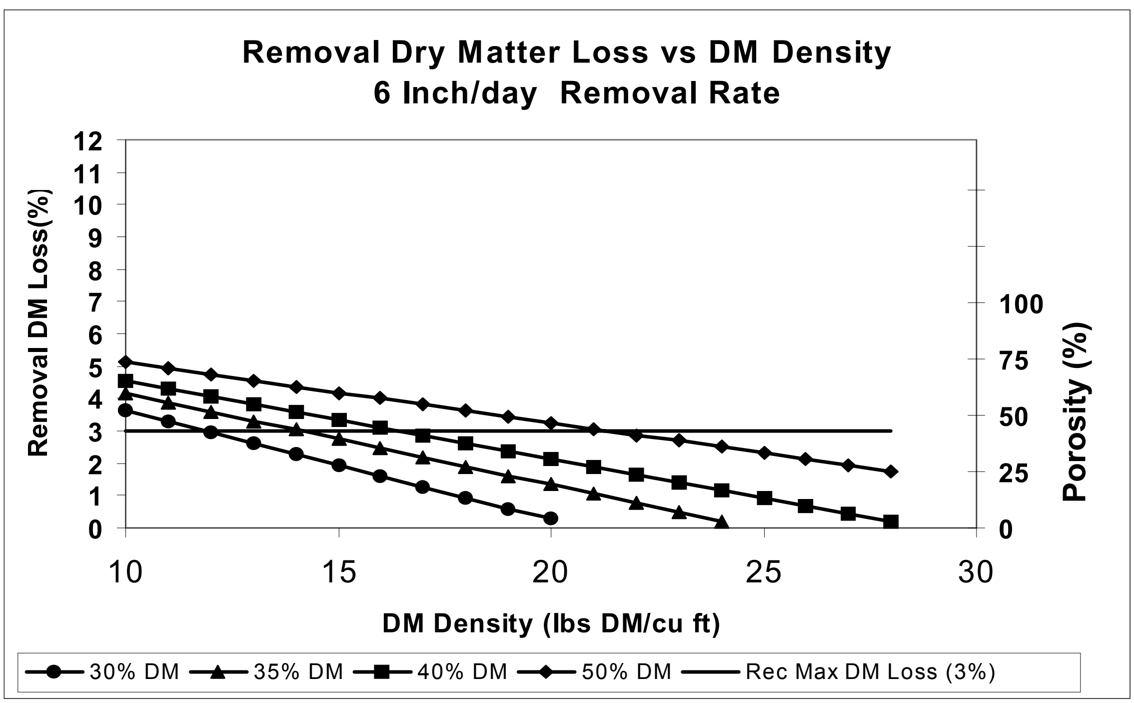

Figure 2. Dry Matter Loss vs Silage Density During Silage Removal From a Bunker Silo Face at the Rate of 6 Inches/Day.

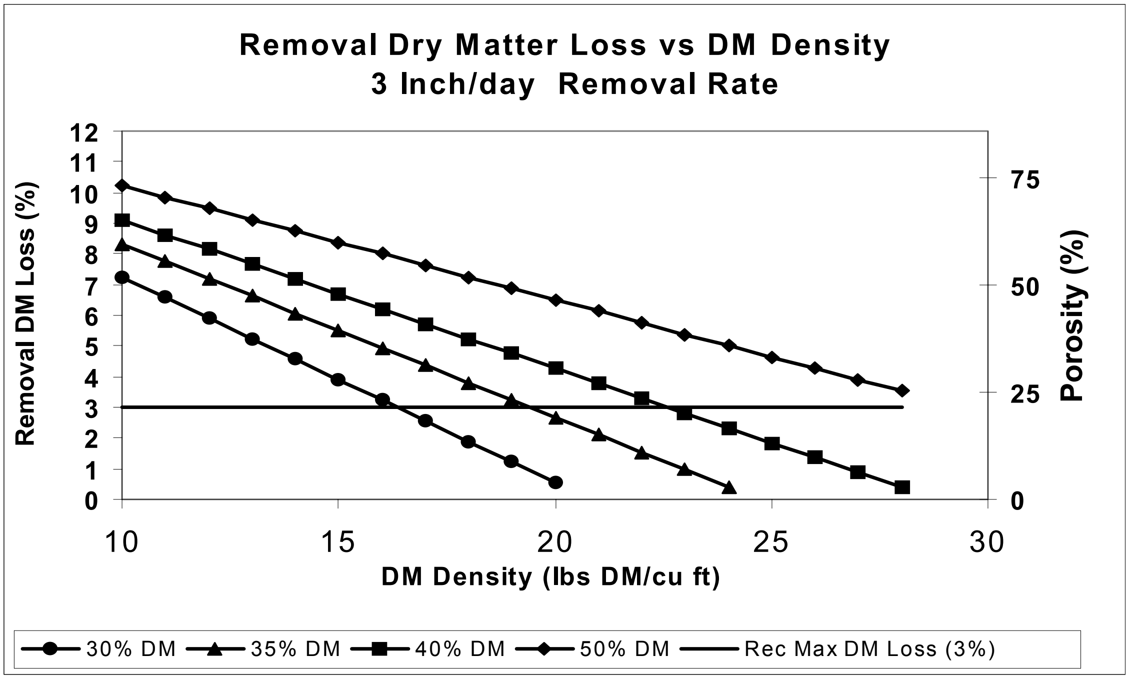

Figure 3. Dry Matter Loss vs Silage Density During Silage Removal From a Bunker Silo Face at the Rate of 3 Inches/Day.

will design for a smaller face removal area and a longer/taller storage and experience lower dry matter loss at feed out.

Silage removed, but not fed immediately, is exposed to air for an extended time period. Aerobic deterioration can occur more rapidly during this exposed condition. This is of special concern in warm weather. Remove only that quantity of forage needed for the current feeding.

Top Unloading Tower Silos

Most silo unloaders leave a smooth feed out face when operated properly. Consult the owner's manual for recommended adjustments to the unloader and the removal rate that produces the smoothest silage surface. Remove only the amount of silage needed for a feeding. Loose silage accumulated at the base of the silo may heat up with subsequent loss of feed value.

Forage accumulates on surfaces within the silo chute. Cleaning these surfaces each time you climb the silo makes the climb safer and reduces the rate of accumulation on these surfaces.

Oxygen Limiting Tower Silos

The emptying hatch must remain open only during the operation of the silo unloader. Close and seal the hatch following unloading.

Silo Bags

Silo bags are usually emptied with a front end loader. This equipment does not operate well on muddy surfaces. When unloading a bag under muddy conditions, feed will be lost as it falls into the mud and becomes unavailable. Consequently, bags should be placed on an all-weather base such as macadam (Janni et al., 1999), asphalt or concrete (Friday et al., 1989) to aid in forage removal and to minimize losses during feed out.

The feed out face of a bag should be kept as tight as possible and minimal excess feed (removed from the bag) left at the bag between feedings. Remove only as much plastic from the bag as will be needed for 3 days of feeding.

The face removal rate from a silage bag is usually not a problem, even for smaller herds. For example, a 40-cow herd being fed 25 lbs forage dry matter per day with a third as corn silage will need about 333 lbs corn silage dry matter per day. An 8-ft diameter silo bag packed to a density of 13 lbs DM/ft^3 will yield that much feed by removing about 5.7 inches per day. Thus no more than 18 inches of plastic should be removed each time.

Bunkers/Piles

As with bags, the floor of a bunker silo must have a driveable surface (Janni et al., 1999; Friday et al., 1989). In fact, much of the seepage and runoff water may pass through the feed out area in a bunker/pile, depending on design. This, combined with the fact that silage prevents the ground from freezing, can cause the unloading area of a bunker/pile to become much muddier than that of bags if an all-weather surface is not used.

Losses throughout the filling, storage and feed out process in bunkers/piles are strongly correlated with silage density. A dense, well-maintained feed out face has much lower dry matter loss than a more porous feed out face. To assure limited dry matter losses at feed out, use design (Bodman and Holmes, 1997; Roach and Kammel, 1990) and packing practices (Holmes and Muck, 1999a, 1999b) which promote high density.

There is a temptation to use a loader bucket to lift silage up when unloading from the face of a bunker/pile. This process loosens the whole face, causing fissures to penetrate deep into the silage mass. Such a practice should be avoided to minimize aerobic deterioration at the feed out face. Methods for face removal that have been proposed to maintain a tight feed out face include:

1. scraping down the face with the bucket edge;
2. shearing across the face with the side of the bucket;
3. undermining the face and using the bucket to scrape silage down into the void;
4. using a machine designed to remove silage while leaving a smooth face.

Whatever removal practice is used, the silage face should remain tight and smooth.

Care should be taken to remove only that forage needed for a given feeding. Feed accumulated at the base of the feed out face will aerobically deteriorate (heat) before being used in the next feeding.

Remove no more plastic from the top of the bunker/pile than will expose 3 days of feed. In fact, plastic overhanging the face will shed rainfall and snow melt onto the storage floor, thus reducing the addition of water to the silage and possible seepage with consequent nutrient loss.

The minimal face removal rate of Table 2 should be maintained while feeding to minimize dry matter loss. When sizing bunkers/piles, plan the removal rate to be at least twice these values.

TABLE 1. **Estimate of silage losses during filling, storage and feed out**

Silo Type	Moisture (%)	Filling	Seepage	Gaseous	Top Surface	Feed Out	Total
		DM Loss (%)					
Conventional Tower	80**	1-2	7*	9*	3*	1-5	21-26
	70**	1-2	1*	8*	4*	1-5	15-20
	65	1-3	0*	8*	3*	1-5	13-19
	60	1-3	0*	6*	3*	1-5	11-17
	50	2-4	0*	5*	3*	1-5	11-17
Gas-tight Tower	70**	0-1	1*	7*	0*	0-3	8-12
	60	1-2	0*	5*	0*	0-3	6-11
	50	2-3	0*	4*	0*	0-3	6-12
	40	2-4	0*	4*	0*	0-3	6-13
Trench or Bunker, no cover	80**	2-5	6*	10*	6*	3+-10	27-37
	70**	2-5	1*	9*	9*	3+-10	24-34
	60	3-6	0	10	12	5+-15	30-43
Trench or Bunker, covered	80**	2-5	4*	9*	2*	3+-10	20-30
	70**	2-5	1*	7*	3*	3+-10	16-23
	60	3-6	0	6	4	5+-15	18-31
Stack, no cover	80**	3-6	7*	10*	11*	3+-10	34-44
	70**	3-6	1*	11*	19*	3+-10	37-47
	60	4-7	0	12	24	5+-15	45-58
Stack, covered	80**	3-6	5*	8*	2*	3+-10	21-31
	70**	3-6	0*	7*	4*	3+-10	17-27
	60	4-7	0	6	6	5+-15	21-34
Silage Bags	80**	1-2	2	6	2	1-5	12-17
	60-70**	1-2	0	5	2	1-5	9-14
Wrapped Silage Bales	60**-70**	1-2	0	8	5	1-5	15-20
	50-60**	2-3	0	6	6	1-5	15-20

*Based on *Forages: The Science of Grassland Agriculture*, 4th ed. See Bickert et al (1997).

+Feed out loss is 3-5% with good management on concrete floor. Use 4-6% for asphalt, 6-8% for macadam, and 8-20% with earth floor assuming good face management. With less than good management, add up to 7% additional loss.

**Avoid ensiling hay crop above 70% moisture in structures and above 60% moisture in wrapped bales to prevent clostridial fermentation.

TABLE 2. **Minimum silage removal rates***

Storage Type	**Cold Weather** (in/day)	**Warm Weather** (in/day)
Tower Silo, top unloading	2	4
Tower Silo, oxygen limiting	2	2
Bunker Silo/Silage Pile**	4	6
Silo Bag**	4	6

*From Bickert, et al., 1997.
**Greater removal rates are needed if silage density is less than 13 lbs/ft^3.

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