Getting the Most from Your Bunker/Pile Silo

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Dry Matter Losses

Exposure to oxygen is a major cause of dry matter loss and silage deterioration. The oxygen supports aerobic organisms that use readily available carbohydrates in forage as an energy source, thus depleting the silage of the energy cows use to produce milk. Table 1 summarizes estimates of losses that occur in the process of harvesting, storing and feeding out hay and whole plant corn used for silage. With appropriate management, forage producers can preserve most (85-90%) of the dry matter made into silage. However, those who fail to apply excellent management may only recover 60-85% of the dry matter they have harvested.

Table 1. Dry Matter Loss for Forage Harvest, Ensiling and Feedout

	Dry Matter Loss Range (%)	Normal (%)
Mowing/Conditioning Haylage*	1-4	2
Respiration Haylage*	1-7	4
Rain (Haylage only)*	0-50	varies
Raking Haylage*	1-20	5
Merging Haylage*	1-3	1
Chopping Haylage*	1-8	3
Chopping Whole Plant Corn***	0-1	0.5
Storage Filling**	2-6	
Ensiling, Storage & Feedout (bunker)*	10-16	12
Haylage Total	17-64+	
Whole Plant Corn Total	12-23	

* Rotz and Muck, 1994
** Forage: the Science of Grassland Agriculture, 4th Edition, quoted in Bickert, W. G. et al, 2000
*** Personal communication with Dr. Kevin Shinners, Biological Systems Engineering Department, UW Madison.
+ Rain Loss not included

Table 2 can be used to estimate the value of feed lost based on quantity placed into storage, the estimated dry matter lost and forage worth \$100/T DM. If forage is worth more than \$100/T DM multiply the table value by a proportionally higher value. For example when feed is worth \$300/T DM, multiply the table value by 3. If 5,000 tons of dry matter were stored, forage was worth \$300/T DM and estimated loss was 20%, the expected value lost would be \$300,000 [(5,000 T DM/1,000 T DM) x (\$300/T DM/\$100/T DM) x \$20,000].

Table 2. Value of Dry Matter Loss

Feed Placed into Storage (T DM)	100	200	300	400	500	**1,000**
Dry Matter Loss (%)	Value of Feed Lost (\$)					
10	1,000	2,000	3,000	4,000	5,000	10,000
15	1,500	3,000	4,500	6,000	7,500	15,000
20	2,000	4,000	6,000	8,000	10,000	**20,000**
25	2,500	5,000	7,500	10,000	12,500	25,000

Size Silo Properly

Bunker silos and silage piles should be sized so as to remove silage at a high rate. This helps to keep ahead of the spoilage rate. This will be discussed in more detail later. Size the silo to achieve at least a 12" per day removal rate. Thus if a silo must store feed for a 365 day feeding period, it must have an average length of at least 365 ft. Stack silage so it is no higher than the unloading equipment can reach (no overhangs to avoid avalanches). With these two constraints and an assumption about silage density, one can calculate a face cross section based on volume removed each day. An example may be helpful. Assume a 1,000 cow herd is being fed 15 lbs of forage dry matter per cow per day from a particular storage. The storage has a silage dry matter density of 17 lbs DM/ft^3, a 1 ft/day removal rate and is limited to 16 ft height by the reach of the unloading equipment. The volume removed from storage is 882 ft^3/day (1,000 cows x 15 lbs DM/cow/day/17 lbs DM/ft^3). The face cross section area of the volume removed is 882 ft^2 (882 ft^3/day/1 ft/day). The average width then becomes 55 ft (882 ft^2/16 ft).

Prepare the Bunker Silo

Concrete is pervious to oxygen penetration. Cracks and holes in bunker silo walls allow a much higher rate of oxygen penetration than does solid concrete. Seal wall cracks and holes with spray/trowel on concrete, epoxy or grout. Plastic film is used to enhance the oxygen retarding features of walls. Select a plastic sheet so it is at least as wide as the wall is tall plus an additional eight feet. Line the wall with the plastic sheet extending about two feet onto the bunker floor. Use forage to hold the plastic on the bunker floor. Extend the extra plastic over the top of the bunker wall. Care should be taken to avoid the plastic being punctured by the wall top. Placing gravel filled bags between the concrete wall and the plastic can help. Some have used a split drain tile fitted on top of the concrete wall to provide a rounded top surface. When the bunker is full, the wall plastic is extended over the forage surface before the cover plastic is applied. The wall plastic helps to provide a good air and water seal at the wall edge. Water draining from the cover plastic is diverted away from the silage and down the wall. The edge seal goes a long way toward eliminating the "shoulder spoilage" commonly seen in bunker silos.

Harvest at Correct Moisture and Maturity

High levels of readily available carbohydrate (sugars) are needed to ferment into acids. Mowing alfalfa in the early to mid bloom stage optimizes plant sugars and protein content. The crop should then be dried to the 35-40% dry matter range to optimize fermentation and to limit porosity in storage. Porosity is a measure of space between forage particles (see Porosity discussion below). The rate of drying and the rate of chopping needs to be matched to avoid large variation in crop moisture content as it is placed into the storage. Data and experience shows the variation in moisture content at harvest is much higher in hay silage than in whole plant corn silage. Comparing the dry matter values in Tables 3 and 4 confirm this. Jones et. al., 2004, point out the wide variation in results of fermentation as seen in Tables 3 and 4. The preferred pH of alfalfa silage should be in the range of 4.0-5.5. The data of Table 3 suggest that has been generally achieved over the range of dry matter contents. Lactic acid is the preferred acid with 60% of total acids being desired. In the case of alfalfa silage, the trend is for lactic acid concentration to increase slightly with increasing dry matter content while the other acids decline in concentration with increasing dry matter content. Butyric acid is an indication that a clostridial fermentation has occurred. Clostridial fermentation tends to predominate at lower dry matter contents and in alfalfa which has a higher buffering capacity than whole plant corn. Lower initial levels of sugar can limit lactic acid and acetic acid production, thus limiting the rate of pH drop. This can also enhance a clostridial fermentation.

Harvest whole plant corn at 1/3 – ½ half milk line for optimum moisture and to have sufficient sugars for good fermentation. Be sure to test the plant moisture content as this stage of maturity is approached. For good fermentation of corn silage, the recommended dry matter content is 30-35%. The preferred pH of whole plant corn silage should be in the range of 3.5-4.5. The data of Table 4 suggest that has been generally achieved over the range of dry matter contents with a tendency for higher pH as dry matter increases. In the case of whole plant corn silage the trend is for Lactic acid concentration to decrease slightly with increasing dry matter content while the other acids decline in concentration with increasing dry matter content. The generally high level of sugars and low buffering capacity discourages clostridial fermentation with resultant butyric acid production. This is seen in Table 4.

Seepage of cell contents occurs when forage moisture content is above 70% and/or forage is driven over too much. Seepage contains about 5% dry matter and as the liquid leaves the storage dry matter is lost.

Dry matter losses increase during storage and feedout if the forage is harvested too dry. Lower moisture content contributes to higher porosity which allows faster oxygen penetration into the silage when exposed to air. Lower moisture content can contribute to reduced acid production with resultant higher pH and faster aerobic microbial growth rates. The lower moisture content also reduces the thermal mass of the silage which contributes to more rapid heating for each molecule of sugar decomposed. Dry, poorly fermented silage can heat in the feed bunk contributing to dry matter loss during feeding. Corn silage is more susceptible to heating in the feed bunk because there are likely to be higher levels of readily available carbohydrates in corn silage than in legume silage.

Harvest at High Enough Rate to Fill the Silo Quickly and Continuously

While silos are being filled, forage is exposed to oxygen thus supporting microbial deterioration. Exposed forage is also susceptible to precipitation which can leach soluble carbohydrates. When forage is continuously being added to the storage surface, the rate of oxygen penetration is reduced. When the surface is exposed to the air for extended periods (overnight, precipitation

Table 3. Typical Fermentation Profile of Mixed Mostly Legume Silage at Various Dry Matter Contents. (Jones et al, 2004)

	< 30% Dry Matter		30-35% Dry Matter		>35% Dry Matter	
	n[1]	Range[2]	n[1]	Range[2]	n[1]	Range[2]
Dry Matter, %	65	24.0-29.2	45	32.0-34.3	122	36.00-54.4
pH	65	4.0-5.8	41	4.2-4.9	99	4.2-5.4
Lactic,% of DM	47	0.3-6.8	29	3.0-7.6	46	1.6-5.5
Acetic, % of DM	47	1.6-5.1	29	0.9-3.3	46	0.4-2.6
Propionic, % DM	43	퇘퇘퇘퇘	21	0.1-0.5	29	0.1-0.5
Iso-Butyric, % DM	30	0.1-0.5	13	0.1-0.6	18	0.1-0.6
Butyric, % DM	32	0.2-3.3	12	0.2-0.9	19	0.0-1.0
Ammonia, CP Equiv. % DM	47	0.4-5.3	29	0.6-1.8	46	0.5-2.1
NH_3-N, % DM	34	0.7-19.6	28	2.3-5.6	42	1.4-5.0

Source: Data provided by Cumberland Valley Analytical Services, Inc.
[1]Number of samples
[2]Range was calculated by subtracting or adding one standard deviation to the average obtained for all samples

Table 4. Typical Fermentation Profile of Corn Silage at Various Dry Matter Contents. (Jones et al, 2004)

	< 30% Dry Matter		30-35% Dry Matter		>35% Dry Matter	
	n[1]	Range[2]	n[1]	Range[2]	n[1]	Range[2]
Dry Matter, %	483	25.7-29.4	570	31.9-34.2	669	35.1-43.2
pH	477	3.5-4.4	551	3.5-4.5	603	3.7-4.8
Lactic,% of DM	383	2.9-8.0	351	2.7-7.0	314	2.1-5.9
Acetic, % of DM	386	1.6-6.0	351	0.9-4.1	315	0.4-2.9
Propionic, % DM	310	0.1-1.0	252	0.1-0.7	200	0.0-0.6
Iso-Butyric, % DM	127	0.0-1.3	116	0.1-0.9	112	0.2-0.7
Butyric, % DM	106	0.0-0.8	78	0.1-0.7	91	0.1-0.6
Ammonia, CP Equiv. % DM	386	0.0-1.6	352	0.0-1.8	315	0.0-1.8
NH_3-N, % DM	290	1.0-9.6	282	0.0-9.0	237	0.0-7.7

Source: Data provided by Cumberland Valley Analytical Services, Inc.
[1]Number of samples
[2]Range was calculated by subtracting or adding one standard deviation to the average obtained for all samples

event), the forage at the surface undergoes extended aerobic deterioration. This is often seen as a discolored line across the feedout face. Significant heating and dry matter loss has occurred in this zone. Harvesting as continuously as possible and covering the surface with plastic during stoppage periods are ways to reduce this loss. Sizing smaller silos allows for each to be filled more quickly which allows for more frequent covering and sealing. Providing enough equipment and labor to harvest and transport forage quickly allows the storage to be filled quickly. However, increasing the harvest rate also requires an increased storage filling and packing capacity. This is discussed more fully later.

Set knives to obtain 3/8th inch TLC for hay and unprocessed whole plant corn
and ½-3/4 inch TLC for processed whole plant corn. Shorter particles pack better and release more soluble carbohydrates which enhances fermentation.

Pack Forage to a High Bulk Density

Bulk density is a measure of the weight of forage particles and water within a given volume of silage. High bulk density (> 44 Lbs AF/ft^3) has low porosity which limits the rate of oxygen transmission through silage. For the same packing effort, higher moisture forage will pack to a higher bulk density. To achieve high bulk density, harvest at the recommended moisture content, use heavy packing tractor(s), pack continuously, pack the whole surface (keep packing slope shallow) multiple times, and use multiple packing tractors if the harvest rate is high.

For many years, specialists have recommended filling the storage unit as quickly as possible to avoid the effects of precipitation, over drying of wilted forage, extended periods of crop respiration and exposure to aerobic decomposition during the filling process. Forage harvesting equipment has been increasing in capacity to meet this need. Self propelled forage harvester estimated capacity as a function of machine horse power is shown in Figure 1. Power requirements of 2.4 – 3.0 HP-hr/T were used to develop the upper and lower bounds for the harvest rate (Shinners, 2009). The horse power values used in developing the graph were obtained from web sites for the four major manufacturers of self-propelled forage harvesters (April 2009).

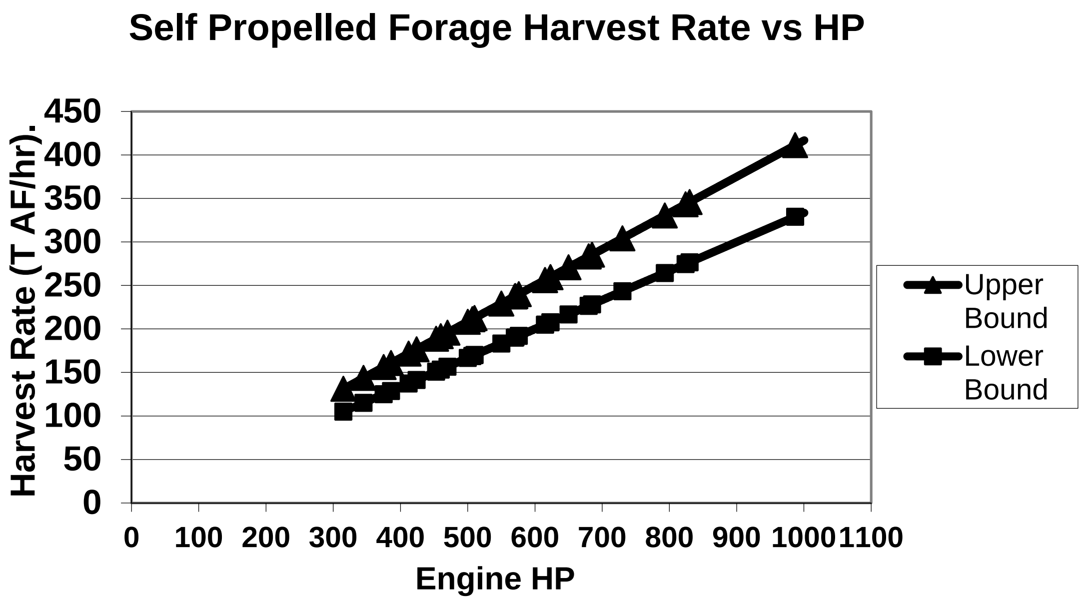

Figure 1. Maximum Estimated Harvest Rate for Self Propelled Forage Harvesters

The harvest rates are the maximum expected under ideal conditions. Factors that reduce actual capacity are: (1) forage available is limiting due to not bringing enough windrows together to satisfy the throughput capacity of the harvester; (2) transport vehicles limiting by vehicle exchange or not enough vehicles available to present to the harvester; (3) field capacity constraints presented by small fields, (4) reduced speed due to obstructions or ground surface conditions, or (5) service and maintenance etc. Even with these possible limitations to achieving full capacity, it is reasonable to assume forage could be arriving at the storage unit at 75% of these values under certain harvest conditions. As new harvesters with these high harvest rates are introduced, the harvest/storage team often is not prepared to deliver and pack the forage into the silo at these rates. Frequently, filling and packing machines for the bunker or pile are insufficient in numbers and weight to get the forage packed to the desired density. Using the “Bunker Silo Density Calculator” spreadsheet of Holmes and Muck, 2007, with the assumptions of 14-ft sidewall, 18 ft peak height, 35% dry matter forage, 6-inch packing layer thickness and a harvest rate of 60 T AF/ hr, a 32,000 lb tractor is needed to push and pack the forage to achieve about a 44 lbs AF/ ft^3 density with a porosity of 0.40. The values in Table 5 were developed using the range of harvest rates reduced to 75% of the upper bound of Figure 1 and the “Bunker Silo Density Calculator” spreadsheet trying to achieve a similar 44 lbs AF/ft^3 density and a porosity of 0.40. The values in Table 5 suggest current high capacity harvesting can be accommodated when enough tractors of sufficient weight are employed to pack in the bunker silo. The bunker silo must be of sufficient width to accommodate the numbers of tractors operating safely or more than one bunker must be filled simultaneously to allow the tractors to operate.

Table 5. Number of Packing Tractors Required in a Bunker Silo at Different Harvest Capacities

Harvest Capacity (T AF/hr)	Number of Tractors	Tractor Weight (lbs/tractor)
98	1	42,000
213	2	42000
248	3/2	38,000/47,000
308	3	42,000

The conventional pushing and packing tractor used in the United States is an agricultural tractor with four wheel drive or front wheel assist and weighted with one or more of; steel wheel weights, front end weights, 3-point hitch weight, liquid in tires weight. Fully weighted tractors are usually in the range of 40-50,000 lbs. Tractors often use dual wheel arrangements with well lugged tires for good traction. Pushing tractors use tall and wide blades. Some producers have experimented with alternative packing vehicles. Industrial wheel loaders are heavier than agricultural tractors on a per horse power basis, Figure 2. They are often used for silage feed out from the bunker/pile silo. This makes them prime candidates for alternative packing vehicles. The tires on industrial loaders are not as well lugged as farm tractors which allows them to slide more easily on wet sloped silage surfaces. This makes the operators much less comfortable about their safety while packing. Transmissions may be prone to overheating due to constant changes in direction. Tracked industrial dozers have been tried. Their naturally heavy weight and some vibration may contribute to good packing but research showing densification effectiveness of tracked industrial dozers is lacking. Tracked vehicles are likely more stable on wet sloped surfaces than wheel loaders. Some producers have used loaded dump trucks and concrete mixing trucks as packing vehicles. These vehicles may be loaded up to 80,000 lbs Gross Vehicle Weight (GVW) on many state highways but on farms they may be loaded up to 100,000 lbs GVW with sand, gravel, stone or concrete. With these kinds of loads, silage could be packed to very good densities. Some concerns about these vehicles are 1) the failure of bunker silo sidewalls due to loads imposed, 2) the likelihood of roll over due to high center of gravity and 3) lack of traction on sloped wet silage. Industrial rollers and sheeps foot rollers and rollers designed for packing silage receive strong producer testimonials, however, there is no research data to verify improved silage density with this equipment. There is currently a study being conducted by the University of Wisconsin and the US Dairy Forage Research Center comparing a conventional tractor to the same weight tractor towing a silage packing machine. Expect results in summer of 2013.

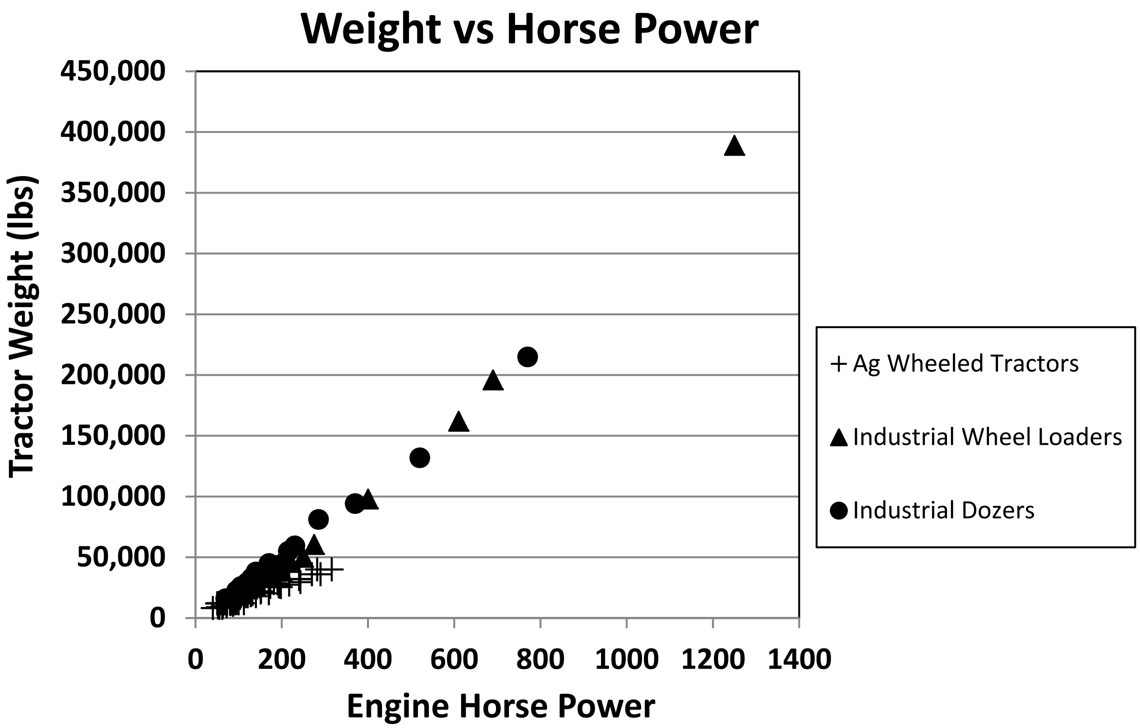

Figure 2. Tractor Weight vs Horse Power for Agricultural, Industrial Wheel Loader and Tracked Industrial Tractors.

The rate at which forage harvesters have increased capacity has begun to outstrip the capacity to properly place forage into horizontal silos and get them packed to an adequate bulk density. Those who have increased forage harvest rate without increasing packing capacity, have discovered their bulk density is reduced compared to the past and their dry matter loss is higher. Methods for increasing bulk density in the face of high harvest rates include: increasing tractor weight, increasing number of packing tractors, spending more time per ton packing, and increasing the moisture content of silage.

Holmes, 2006 summarizes some of the research and field trials related to density achieved in bunker/pile silos. Many field trials are finding:

1. **Dry matter density is greater at the bottom of the silage than toward the top.** This may be due to self-compaction and more time spent packing the lower layers.
2. **Dry matter density is lower next to the wall and on the sloped sides of piles than in the center of the bunker/pile silo.** This may be due to reduced packing time next to the wall and the lower depth on the sides of piles.
3. **Average dry matter density is higher for hay than for corn silage.** This may be the result of faster harvest rate for whole plant corn than hay with resultant lower packing time for whole plant corn. Hay is often harvested at a higher dry matter than corn silage. Research has shown dry matter density to be directly related to dry matter content.
4. **Increasing packing tractor weight, number of packing tractors and reducing layer thickness result in increased dry matter density.**

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 at a minimum of 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.

Muck and Holmes, 2000 reported dry matter densities were positively correlated with the height of silage above the core, indicating the effect of self-compaction in bunkers and the effect of previous compactions on the lower layers. Dry matter density was also positively correlated with average packing tractor weight, packing time, and dry matter content. Density was inversely correlated with the initial depth of the crop layer when spread in the silo. Use of rear duals or all duals on packing tractors had little effect on density. Other factors such as tire pressure, crop, and average particle size were not significantly correlated with density.

One practical issue is packing time relative to crop delivery rate. Assuming one packs continuously with one tractor throughout filling, packing time per ton (1 to 4 min/T AF) is high under low delivery rates (<30 T AF/h) and generally declines with increasing delivery rate. This result suggests farmers using high capacity harvesters need to pay particular attention to spreading the crop in a thin layer and would benefit from using several heavy packing tractors simultaneously. If a satisfactory bulk density is not being achieved, a producer can select one or more of the following options to increase bulk density:

a. Reduce delivery rate of silage to the storage.
b. Decrease dry matter content.
c. Increase depth of silage in the bunker/pile silo.
d. Increase average tractor weight by adding more weight to each tractor, or replace existing tractors with heavier tractors.
e. Add more packing tractors. Use heavier rather than lighter tractors so the average weight is not reduced when adding a tractor.
f. Spend more time packing per ton.

Items a. to c. are somewhat difficult to accomplish if the harvest rate and bunker silo capacity are currently being pushed to the limit. Few will be willing to slow the harvest rate so packing can be accomplished. Fermentation occurs best in the range of 30-40% dry matter. Decreasing dry matter content beyond 30% to improve bulk density is counterproductive for good preservation. If the bunker is full, adding silage depth above the full mark can be dangerous. Items d. to f. are more often within the control of the producer. Producers achieving high packing density have adopted the use of very heavy tractors and spend adequate time packing. When the delivery rate to the silo is quite high (as with self-propelled harvesters operating in corn silage), one or more additional packing tractors are needed. In a well-packed silo, all tractor tires pass over the entire packing layer surface at least once. More passes are beneficial. Because density near the wall of a bunker silo is frequently lower than toward the interior, packers should make more passes near the walls.

Recommendations for many years have included distributing forage in thin layers before packing. Preliminary research by Muck and Holmes, 2007 has not confirmed the value of thin layers when packing time per ton is kept constant. However, when a given weight of forage is distributed in thin layers, each pass of the packing tractor results in more packing time per ton when the layer is thin than when the layer is thicker.

Porosity

Porosity is a measure of the voids between the solid particles of a material. Pore space can be filled with fluids including gas and/or water in silage. The "air filled" porosity allows gases to move within the material. For gases to move throughout the material, the pores must be continuous. Closed pores do not contribute to gas flow. Figure 3 shows a graph of porosity as calculated using the equations of Richard et al, 2004. From Figure 3, porosity is most influenced by bulk density (as fed density) over the range of dry matter contents recommended (0.30-0.40) for ensiling. Figure 4 was developed using a modified version of the spreadsheet for calculating average density in a bunker silo by Holmes and Muck, 2007. From Figure 4, it is apparent porosity increases with harvest rate and increasing dry matter content. To keep porosity below 0.4, multiple heavy tractors and lower dry matter content are needed when the harvest rate is high. A minimum bulk density of 44 lbs AF/ft^3 keeps porosity below 0.4 within the recommended range of DM content.

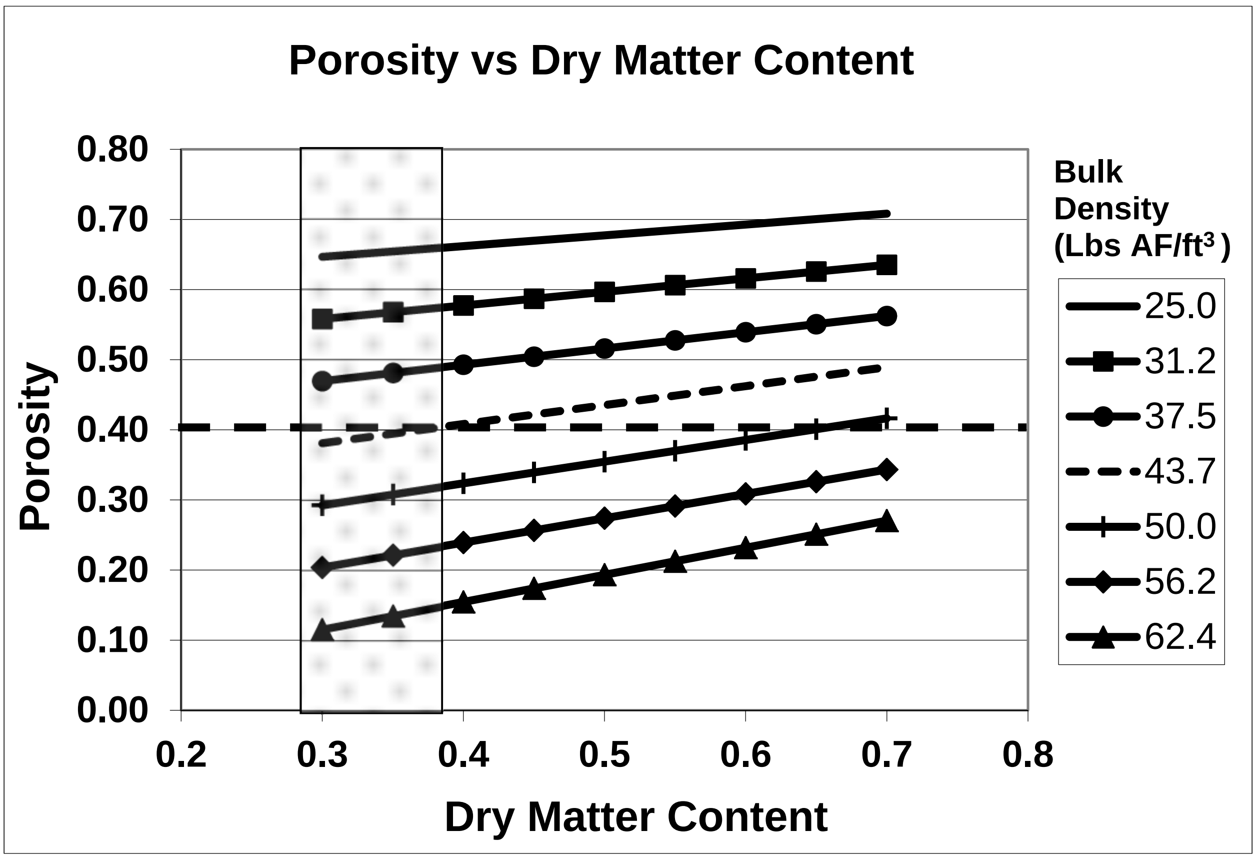

Figure 3. Graph of Porosity (decimal) vs. Dry Matter Content (decimal) for Various Bulk Densities

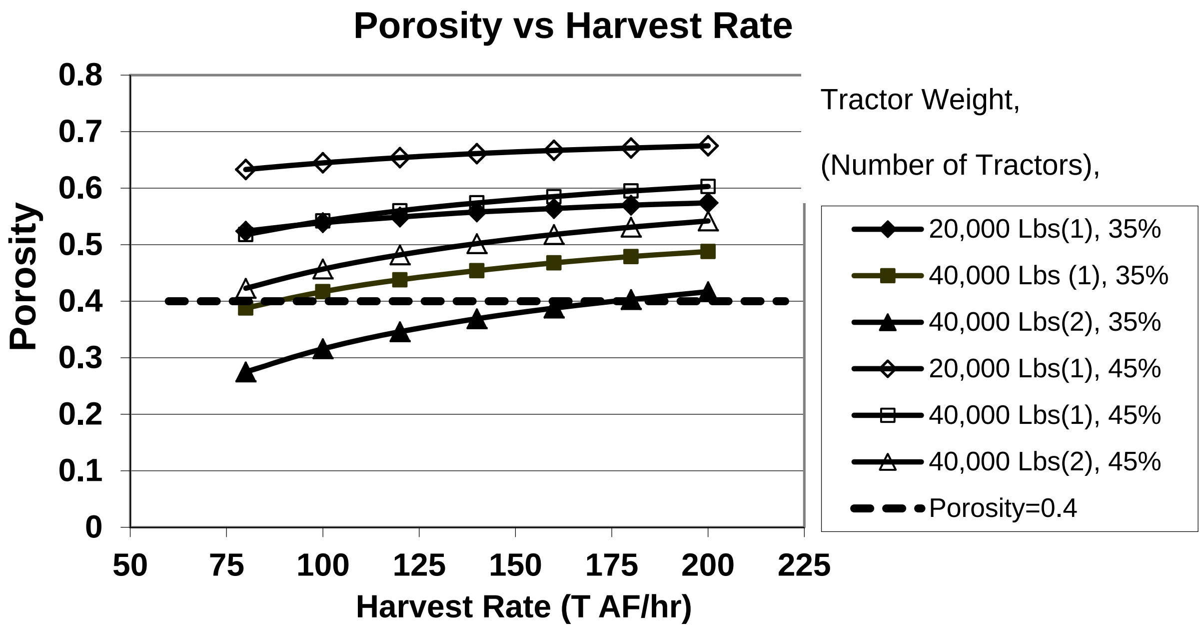

Figure 4. Porosity vs Harvest Rate for Different Combinations of Tractors and Dry Matter

If forage DM exceeds 40%, packing effort needs to be much higher to produce high bulk density and to keep porosity at or below 0.40. In recent years, there has been an increase in factors leading to lower bulk density and higher porosity. These factors include the increased harvest rates without increased packing effort mentioned above, as well as a trend for field-wilted forages to be harvested drier. Arguments for dryer forage at harvest include: desire to avoid a clostridial fermentation and desire to increase the DM content of the ration when other feed ingredients are high in moisture. When field mowing and raking rates exceed harvest rate, the drying occurs too fast (drying gets ahead of harvest rate). Drier forage also lowers bulk density. Whatever the reasons for ensiling forage too dry, the nutrient losses will increase but the recognition of those losses does not occur until sample analyses document the reduced feed quality.

Sloping the Top Surface

Sloping the top surface of the forage, while filling, allows for precipitation to be drained from the plastic cover. Slopes greater than 3 horizontal to 1 vertical (3:1) run the risk of tractor roll over. Many producers use steep sloped surfaces in an attempt to store more forage in a limited space. Steep slopes are usually not packed properly because the operator is fearful of driving on the sloped surface. Weighting materials used to hold the plastic close to the forage are less effective on slopes steeper than 3:1. Extra time is required to tie tire sidewalls so they don’t slide down a steep sloped surface. Frequently, silage losses are higher on the steep sloped surface than they are on shallower slopes where the silage is packed well and the plastic is held close to the silage. These losses are visible as blackened silage which must be removed before feeding. So the extra costs associated with steep slopes include: added labor to secure the weighting material, higher dry matter losses and extra labor to pitch off the waste feed. Potential dangers include tractor roll over and falling from the feedout face while pitching waste feed.

Covering

Dry matter losses occur in storage due to exposure to oxygen and precipitation. This exposure can occur through any or all of: Holes/cracks in walls, No plastic cover, Plastic not applied immediately after filling, Plastic cover not weighted uniformly, Plastic edges not well sealed, Plastic sheet joints not sealed, Holes in plastic not sealed in a timely way. Polyethylene is the conventional material used to cover silage to exclude oxygen. It should be applied immediately after filling the storage. Weighting material should be uniformly applied to limit plastic billowing in the wind. Joints in the plastic and where the plastic joins the walls or ground should be sealed to limit oxygen from entering the silage at the joint. Perimeter edges of plastic should be sealed with windrows of soil or gravel filled bags touching each other. Overlap plastic at least 4 feet at joints with upslope plastic on top of the down slope plastic sheet. Weight joints with gravel filled bags or a double layer of tires. Place tires or tire sidewalls uniformly on plastic so tire edges touch to keep the plastic in intimate contact with the silage. In very windy sites, consider a double layer of tires/sidewalls to limit billowing and plastic blow off. Tarps are available to protect the plastic from ultraviolet light and punctures. Tarps can distribute weighting forces to keep the plastic in contact with the silage thus not requiring so many weighting objects. Rows of gravel filled bags should be applied at 10-20 foot intervals along the length of the storage top surface to hold the tarp down. Using tires and/or sidewalls to weight the plastic/tarp between the rows of bags can provide an added weighting to the plastic.

Other methods for uniformly weighting the plastic that have been tried include the application of; soil, wet straw, waste silage, wet sawdust etc. These materials can do an effective job of sealing the silage if enough material is applied. Problems with this technique include the difficulty of removing the weighting material and contamination of the silage with spilled weighting material. Snow and ice can complicate the use of these alternative weighting materials and the tarps.

Polyethylene is the most common plastic used to protect silage from oxygen and precipitation. It can be obtained in a variety of thicknesses from 4-9 mils (thousandths of an inch). The thicker the film, the higher its resistance to oxygen infiltration and the more resistant to tearing. Polyethylene comes in black on black and white on black colors. When using polyethylene with the white surface exposed to the atmosphere, the plastic reflects more of the solar radiation and does not become so hot as the black colored plastic. This helps to keep the silage in direct contact with the silage slightly cooler. The effect is however limited to the top inch of silage. Polyethylene exposed to the sun becomes brittle and deteriorates quickly. Manufacturers of polyethylene used for silage protection add ultraviolet (UV) radiation protectants to the plastic to give it a longer life when exposed to the sun. Select plastic with enough UV protection for the expected storage period. If the storage period could be up to 24 months, make sure the UV protection level is that long.

Polyethylene comes in a variety of sheet sizes and forms (folded bundles, rolls). Select sheet size so as to minimize the number of joints in the sheets but not so large the package cannot be handled by the application crew. In cases where very large sheets are applied, plan to use a tractor with a 3-point hitch dispenser to carry a roll of film across the silage surface. Workers report 8 mil polyethylene is easier to apply and walk on than is 4 mil plastic. The thicker plastic is less susceptible to wind blowing the plastic out of control. The 8 mil plastic is less likely to be torn during application.

Oxygen barrier film is a relatively new product for protecting forage from oxygen and precipitation. There are several types of these films available on the market. Some are single polymer films and some are multiple layers of different polymers in one sheet. Some films are not manufactured with UV protection. Those films should be covered with a tarp or polyethylene film containing UV protection to help hold down the film and protect it from solar radiation. For a film to do its job, it must exclude oxygen and precipitation as continuously as possible. Research has shown oxygen barrier films can reduce dry matter loss and increase the concentration of fermentation byproducts in the silage below this plastic compared to polyethylene. However, research has also shown the oxygen barrier plastic must be used in such a way so as to limit oxygen penetration at laps and walls and to patch holes or the benefits will not be completely realized. Inspection and patching of holes in any plastic covering should be done on a weekly basis so oxygen is excluded from the aerobic organisms for as long as possible. Use a specially designed patching tape supplied by the plastic distributor when patching holes.

Studies comparing polyethylene and oxygen barrier films have frequently found very limited visible spoilage under oxygen barrier films and limited to some visible spoilage under polyethylene. Often times, when the plastic is properly applied, dry matter loss under each film is the same and quite low in the top six inches. Silage under oxygen barrier film usually has higher levels of fermentation products compared to a polyethylene cover. Where increased pH, dry matter loss, spoilage and reduced fermentation products are found in silage under either film, there is a high likelihood the film has not been sealed as well as it should have been. Research and experience shows improved silage quality when the plastic film is held closely to the silage.

Once the storage is opened for feeding, the edge of the cut plastic should also be sealed to limit oxygen penetration under the plastic. Gravel filled bags work well to seal the edge of plastic at the feedout face.

Feedout

During the feedout process, the feeding face is exposed to oxygen continuously. The higher the porosity and roughness of the feedout face the more quickly and deeply into the silage oxygen penetrates. Packing the forage to a high bulk density (>44 lbs/ft^3) limits the porosity. Proper use of a front end loader bucket and/or a facer helps to achieve a smooth feedout face with limited porosity. The rate (inches/day) at which silage is removed from the feedout face determines how long silage (within 3 feet of the feedout face) is exposed to oxygen. At the rate of 12 inches per day, the silage is exposed for only 3 days while a feedout rate of 3 inches per day exposes the silage to oxygen for 12 days. Silage can heat and loose a high level of dry matter in 12 days of oxygen exposure. The key is to manage the storage so silage is removed at no less than 6 inches per day to limit the time silage is exposed to oxygen. This is done by limiting the feedout face cross section area by selecting silos that are long and narrow compared to short and wide. See the discussion about sizing bunker/pile silos “Size Silo Properly” above. In Figure 5, the dry matter loss is less than the goal of 3% when bulk density is greater than 40 lbs AF/ft^3 and the face removal rate is greater than 6 inches per day.

A ragged silage feedout face has larger surface area exposed to oxygen and fissures and cracks allow oxygen to penetrate deep into silage. The method for removing silage from the bunker/pile silo should leave a smooth tight feedout face. Methods that can be used to achieve a smooth feedout face include:

1. Scraping silage at feedout face in a downward motion with the loader bucket edge.
2. Scraping silage at feedout face with the loader bucket side while driving parallel to the face.
3. Use a rotating facer.
4. Use a silage rake. This method leaves a corrugated face which is not as smooth as the other methods.

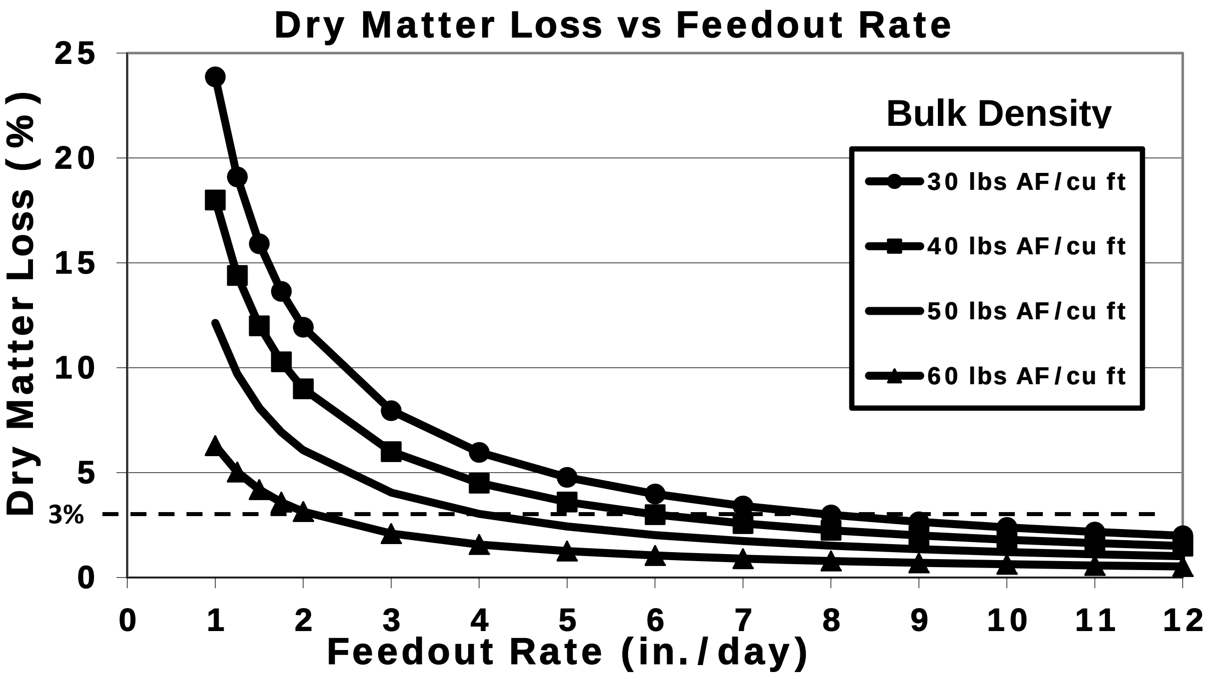

Figure 5. Dry Matter Loss vs Feedout Rate (Derived from Pitt and Muck, 1993)

Silage removed from the feedout face and residing on the storage floor has low density which allows oxygen to penetrate quickly and deeply. This can result in rapid silage heating with resultant dry matter loss. Remove only the amount of feed that will be used in one feeding so excess feed is not left on the floor for extended periods.

Practice Safety

Injury and death are expensive and personally devastating! It can happen to you. There should be protocols to reduce the likelihood of injury and death. Enforcement of the protocols is needed to ensure compliance. Some practices that limit injuries and deaths include but are not limited to:

Four wheel drive packing tractor
Roll over protection on tractor and **use** seatbelts
Experienced packing tractor driver
Keep pedestrians (especially children) away from work areas.
Keep packing surfaces shallower than at 3:1 slope
Don't fill higher than the unloader can reach (reduced overhangs)

Face wall side of silo when covering and weighting (don't back up to edge),
Consider guard rails at wall top.
Use trailer dump while parked only on solid surfaces
Avoid approaching the feedout face while on the ground (avalanches are real)
Avoid standing/walking on top of silo near the feedout face (avalanches are real)
Don't place forage on top of plastic cover when adding new feed (pull back the plastic first)

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Notes: