"Software applications for sizing silos to maximize silage quality"

Brian J. Holmes
Professor and Extension Specialist
Biological Systems Engineering Department
University of Wisconsin-Madison
Madison, WI.

Introduction

Producers considering a new silage storage frequently have three criteria that influence their decision about the storage size. They often want to minimize the space requirements because of space limitations on the farmstead. There must be sufficient volume to contain the stored crop. Finally, the initial investment should be as low as possible. These criteria influence the size of the storage resulting in high and wide bunker and pile silos. A square silo has the lowest initial investment compared to a long narrow rectangle when storing the same volume of feed. Since bunker silo walls are quite expensive, producers tend to use piles over bunker silos to keep the initial investment low. Wide and tall silos will have a lower feed removal rate for a given volume of feed removed compared to a feed out face which is narrower and shorter. Low feed out rates result in higher dry matter losses (Figure 1). Higher dry matter losses contribute to increased annual costs.

One method of reducing dry matter loss at the feed out face is to have a large enough feed out rate. Establishing the feed out rate is the first step in the design process. Selecting a feed out rate of 0.31 m/day assures a feed out dry matter loss rate of less than 3% for a wide range of bulk densities (Figure 1). Since feed out rates may have to change over the life of the storage structure, selecting a high design feed off rate allows a significant reduction of feed out rate down to about 0.15 m/day without incurring losses greater than the desired value of 3% for most bulk densities. The next design step is to establish the maximum height of the feed out face. The maximum height should be limited by the reach of equipment available to safely remove silage while maintaining a smooth feed out face. The feed out face should not be undermined causing an overhang. Overhangs can collapse on people causing injury and death. Collapsed faces leave rough and fissured faces prone to aerobic deterioration with consequent high dry matter loss and feed value loss. Front end loaders can reach 3.7-4.9 m from the floor of the silo while telehandlers might reach as high as 9 m from the floor. The taller the feed out face, the narrower the silo will be but the farther any avalanching silage will fall away from the feed out face. The third step in design is to establish the volume of silage to be removed from the storage each day. This volume is determined by the weight of this particular silage fed to each animal per day, the number of animals fed from the silo and the bulk density of the silage in the storage. Once the daily volume stored is determined, the width of the silo can be calculated by Equation 1.

$$W = V/(H \times RR) \qquad (1)$$

W = silo width, m
V = volume per day, m^3/day
H = height assumed, m
RR = removal rate, m/day

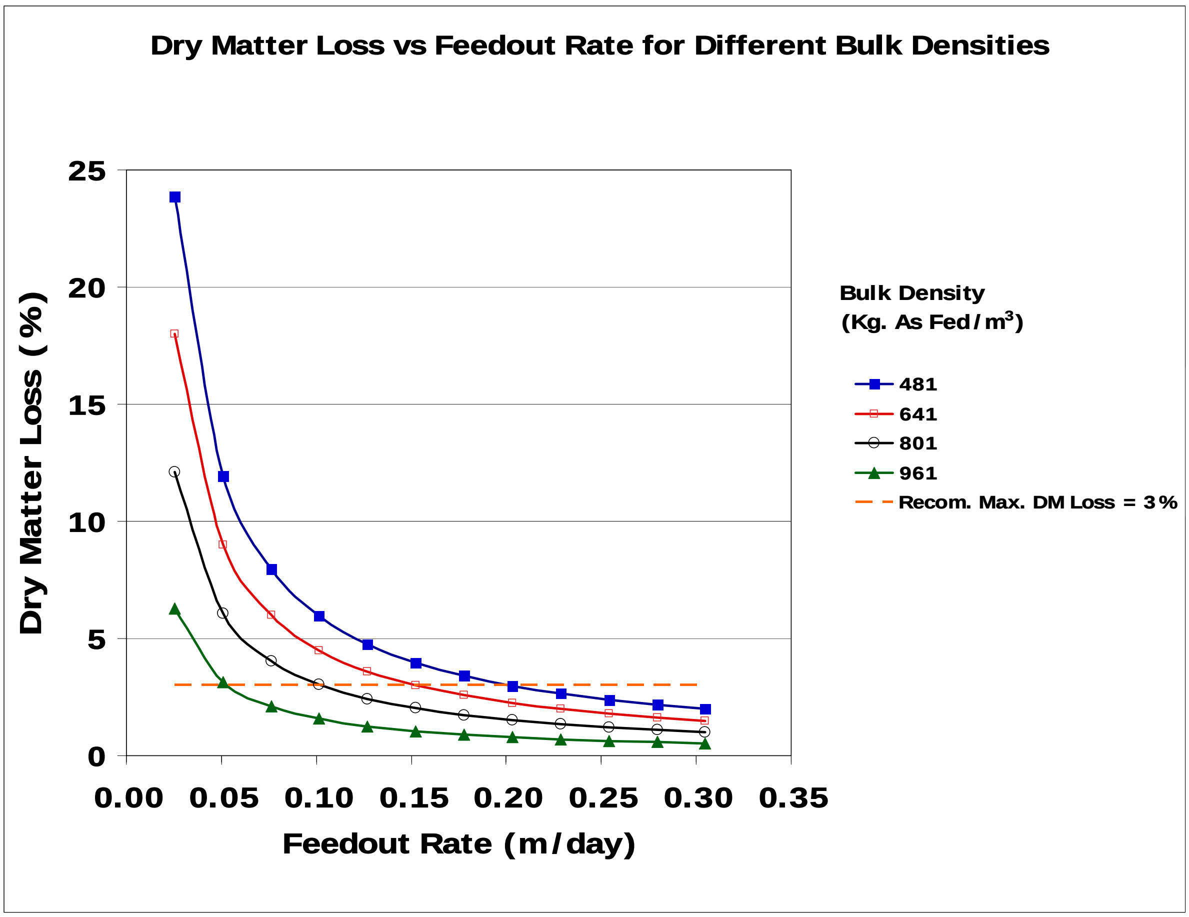

Figure 1. Dry matter loss as a function of feed out rate on the face of a silo. Derived from Pitt and Muck, 1993.

This procedure, examples and a manual worksheet are given in a fact sheet by Holmes and Muck, 2004. Consider the example of a 200 cow herd fed 19.5 Kg AF/cow – day of corn silage and the silage has a bulk density of 705 Kg AF/m^3 where AF means as fed. Assume the equipment on the farm can reach a maximum height of 3 m and the deign feed out rate is 0.31 m/day. The daily quantity of corn silage removed from the silo is 3,900 Kg AF/day (200 cows x 19.5 Kg AF/cow-day). The volume removed is 5.53 m^3 (3,900 Kg AF/day / 705 Kg AF/m^3). Using equation 1, the average width is 6 m (5.53 m^3 / (3 m x 0.31 m)). Since the width is greater than 5 m which is twice the width of a typical packing tractor, the whole surface can be packed and the width is acceptable for a bunker silo. For the silo to store enough feed, the total average length must be determined by equation 2.

$$AL = SP \times RR \qquad (2)$$

AL = Average Length, m
SP = Storage Period, day
RR = removal rate, m/day

In our example, assume a 365 day storage period. The Average Length is calculated as 113.2 m (365 d x 0.31 m/d). Since the maximum recommended bunker silo length is 46 m, plan to use three bunker silos of 38 m average length each to satisfy the storage requirement. Thus in our example, we need three silos with average width of 6 m, depth of 3 m, average length of 38 m and a face removal rate of 0.31 m/day. A similar procedure would be used to size storage for hay silage for this herd. The overall footprint for the storage is about 18 m x 38 m. This is far from a square storage shape but will result in far less than 3 % dry matter loss at the feed out face because the removal rate is 0.31 m/day. Note: actual bunker silo floor length will be greater than 38 m. Each end may have a sloping silage surface of 3:1 slope ratio representing an additional 9 m of floor length. There will also be a filling apron of 13-15 m. Thus the total floor length might be 60-62 m (38m + 13m + 9m).

Steps to Successful Silage Making

Harvest At the Correct Moisture and Stage of Maturity

- Harvest hay at 60-65% moisture to assure good bulk density and good fermentation. Higher moisture runs the risk of clostridial fermentation (Butyric Acid). High moisture also contributes to leachate losses. Low moisture results in low acid production resulting in a higher pH and reduced microbial inhibition. Lower moisture causes high porosity and rapid oxygen penetration at the feed out face. High levels of oxygen penetration support aerobic organisms that deteriorate silage dry matter. Low moisture reduces thermal mass which contributes to rapid heating when oxygen is present.

- Harvest whole plant corn at 65-70% moisture to assure good bulk density and good fermentation.
- Harvesting at the correct stage of maturity assures adequate sugars are available for fermentation to lactic acid. Harvest Alfalfa at early to mid bloom and whole plant corn at 1/3 – ½ kernel milk line.

Chop to Correct Particle Length

- Shorter particles pack better and release more soluble carbohydrates
- Set knives to obtain 0.95 cm theoretical length of cut (TLC) for hay and unprocessed whole plant corn and 1.27-1.91cm TLC for processed whole plant corn.

Size Storage for Large Face Removal Rate and Optimal Top Surface Area

- Design for 0.31 m/day removal rate to reduce the time silage is exposed to oxygen during feed out and to keep ahead of spoilage organisms. This generally means narrower bunkers and piles vs what is commonly seen.
- The forage at the top of a silo is typically of lower bulk density than that below it. Lower bulk density silage has higher porosity and high oxygen penetration rate when exposed to oxygen. Bolsen et. al. (1993) showed silage at the top of bunkers has a higher loss rate in the top 0.9 m than that below. The exclusion of oxygen by plastic films helps to control this loss compared to no cover. Deciding to use a silage pile over a bunker silo exposes more top area and consequently more silage in the top 0.9 m and can thus be expected to have higher dry matter loss in storage and feed out all other factors being equal.
- Use Bunker, Pile and Bag sizing software .

Use Additives to Improve Silage Quality and/or Remedy Problems

If quality has been a problem in the past, consider additives designed to remedy these problems. Plan to apply these materials at the chopper so good mixing can be accomplished before entering the silo.

- Adding Homofermentative organisms increases the likelihood of a rapid and complete fermentation and low acetic acid levels. They reduce dry matter loss on average 2-3% and increase animal performance 3-5% when effective.
- Use *Lactobacillus buchneri* to reduce heating at feed out and extend bunk life. Buchneri reduces dry matter loss on average 1-2%.
- Propionic acid reduces heating at feed out and extends bunk life.
- Sugar (molasses) reduces pH at a faster rate when inadequate sugar is available naturally.
- Urea reduces heating at feed out and extends bunk life and adds non-protein nitrogen
- Ammonia reduces heating at feed out and extends bunk life and adds non-protein nitrogen.

Fill Storage Quickly

- Harvest at a high enough rate to fill silo in fewer than three days. The quicker forage is placed in the silo, the quicker fermentation can begin to exclude oxygen. While silos are open, forage is exposed to oxygen thus supporting microbial deterioration. Exposed forage is also susceptible to precipitation which can leach soluble carbohydrates. Oxygen exclusion halts plant and microbial respiration which consume readily available dry matter. Size silos small and/or provide enough equipment and labor to harvest, transport forage and fill storage quickly.
- Cover surface of forage with plastic when filling must be stopped. This helps exclude oxygen and precipitation which can hasten dry matter loss.

Pack Forage to High Bulk Density

- Aim for greater than 705 Kg/m^3 bulk density and less than 0.4 porosity. Minimize porosity to limit oxygen penetration into the silage. Oxygen supports aerobic organisms which decompose silage quickly, causing heating and dry matter loss.
- Keep silo bag surface smooth to limit pockets of low density silage.
- Place forage or bags on all weather surface of gravel, asphalt or concrete.
- Pack bunkers and piles with heavy tractors in thin layers (<0.15m). Use a shallow slope on the filling surface to keep layer thickness thin. Multiple tractors may be needed with high forage delivery rates (more than 72.6 t AF/hr).
- While packing, make at least two passes over silage surface with both sets of wheels. This will require extra passes near the wall compared to interior of the storage.

- Use bunker/pile packing software to investigate “what if” scenarios before harvest.
- Slope the top surface to drain water from the silo without draining into the silage.

Cover Forage with Plastic to Exclude Oxygen and Water

- Cover silage immediately (<24 hr) upon completing filling. The longer forage is exposed to air, the higher will be the dry matter loss.
- Use 8 mil plastic or oxygen barrier plastic with tarp and weighting to hold plastic to forage surface. Joints in plastic should be sealed by overlapping sheets by 1.5 - 2 m, Berger and Bolsen (2006). Overlap in such a way as to shed water away from the silage. Use gravel filled bags or soil piles at perimeter to seal edges. Use tires or tire sidewalls touching to hold plastic against the forage uniformly.
- On bunker silos, use wall plastic to exclude runoff water and oxygen from penetrating the silage. On silage piles, extend the plastic past the silage and onto the ground a distance of 1.5 - 2 m to keep water away from the silage and to exclude oxygen, Berger and Bolsen (2006).
- Develop a vermin control program to limit damage to the plastic cover.
- Examine the integrity of plastic film on a weekly basis. Patch holes in plastic as they occur with tape designed for that purpose.

Feed Out So As to Minimize Deterioration

- Remove no more than three days of plastic cover. Consider leaving plastic to cover the top of silage near the feed out face. This may result in plastic overhanging the feed out face at times. This remaining plastic will shed precipitation.
- Weight the edge of the plastic at the feed out face to prevent billowing. Billowing of cover plastic draws air under the plastic.
- Remove visibly spoiled silage. Spoiled silage causes cattle to reduce their dry matter intake and can cause health problems due to mold spores and toxins.
- Ragged silage has larger surface area exposed to oxygen and fissures and cracks allow oxygen to penetrate deep into silage at the feed out face. With a front end loader or facer, remove at least 0.15 m per day from the silo face leaving a smooth surface. High face removal rates reduce the time silage is exposed to oxygen. A smooth face with no fissures reduces the surface area of silage exposed to oxygen. Techniques for front end loader operation that help to maintain a smooth feed out face include: downward force with the

edge of the bucket scraping the face of silage; use the side of the bucket to shave the face while driving parallel to the face; removing a cavity near the floor and then breaking the face into the cavity with the edge of the bucket. Practices that should not be used include: jamming the bucket edge into the feed out face and lifting the silage up; undermining the silage near the top creating an overhang; tunneling through the silage leaving a long exposed wall of silage.

- Remove from the face only that amount of silage to be fed in one feeding. Removed silage has low density which allows oxygen to penetrate deeply. Rapid heating can result in feed left at the base of the feed out face.

Software for sizing and managing bunker and pile silos

Bunker and pile silo sizing and management can benefit from many mathematical calculations to consider some of the "What if?" scenarios. Multiple calculations using the same set of equations can benefit from the use of computer software. Many software packages have been developed in spreadsheet format and are available for download from the Harvest and Storage page of the University of Wisconsin-Extension Team Forage web site located at URL:

www.uwex.edu/ces/crops/uwforage/storage.htm

Bunker Silo Sizing Calculator

The bunker silo sizing spreadsheet uses the principals described in the Introduction of this paper. It is designed with three major areas within the spreadsheet. The first area allows the operator to list the number of animals in various animal groups within the herd and the amount of dry matter for each animal in three hay silage categories and one corn silage category. The section then calculates the total quantity of each of the four forages required to be fed to the herd each day. These values are then entered by the user one at a time into the second (Input) section of the spreadsheet. The user also enters values for storage loss, feeding loss, bulk density, moisture content, face removal rate, storage period and maximum storage length. Finally, the results are tabulated in section three (Results) as a listing of bunker silo average dimensions that will satisfy the design criteria. To use the Results table, one selects a wall height that is the maximum his/her feed out equipment can reach. On the same line as the wall height, one selects the average bunker width, number of bunker silos, and bunker length. Also listed on this line are estimates for the quantity of dry matter placed into storage, quantity of feed dry matter lost to spoilage, and the percent dry matter lost from storage and feeding losses.

Bunker Silo Volume and Weight Calculator

Often the question arises about the quantity of silage in a constructed bunker silo. This is usually needed as part of a feed inventory process. In this spreadsheet, the operator is asked to enter bunker silo dimensions, silage moisture content and dry matter density. The spreadsheet output includes the dry matter and as fed weight and the volume of silage in the bunker.

Silage Pile Dimension Calculator

This spreadsheet uses operator information to determine dimensions of a drive over pile. The number of animals and the quantity of silage fed per animal each day from the pile are used to calculate the quantity of this silage fed to the herd each day. The peak height, side wall slope and daily removal rate is used to determine the bottom and top width of the pile. The daily removal rate, length of feeding period and end slopes are used to calculate the top and bottom lengths of the pile. Other information reported by the spreadsheet include quantity of dry matter and as fed silage being placed into the storage and that removed assuming a 20% loss of mass during storage and feed out.

Silage Pile Capacity and Cost Calculator

Often the question arises about the quantity of silage in a constructed pile silo. This is usually needed as part of a feed inventory process. In this spreadsheet, the operator is asked to enter pile dimensions, silage moisture content and dry matter density. The spreadsheet output includes the silage dry matter and as fed quantity in each pile and total quantity of silage. By including dimensions of the buffer space of the storage pad around the pile and the cost per unit area of the pad, an estimate of the initial investment of the storage pad is calculated.

Average Density of Silage in Storage

The average density of silage in storage is very important for limiting oxygen penetration into silage and for determining the quantity of silage in the storage. This spreadsheet determines average bulk density and dry matter density in bunker, pile, bag and tower silos. It uses the principle of weight of silage removed divided by the volume removed to calculate the density. The weight is determined by summing weights placed in the feed mixer wagon during feeding. The volume is calculated after the user enters the dimensions of the volume of feed removed from the storage. Accuracy is influenced by precision with which weight is recorded and how much feed volume is removed during the test period. Dimensions will be difficult to measure accurately if the test period is only a few days. However, measurement accuracy increases if the test period is greater than one week. This method has the possibility of giving more accurate values than the face probing method used by many researchers in that the point density can vary quite a bit over the face of a storage and the probing method can have inaccurate results if a bore hole is made into a non-representative site on the feed out face.

Silo Bag Sizing Calculator

This spreadsheet determines the number of silo bags and the pad needed to store them for three hay silage qualities, corn silage and high moisture corn. The user enters the following data: quantity of dry matter fed to the herd each day for each feed ingredient, dry matter density, bag diameter, bag length, storage period, distance between bags, pad buffer length on the ends of each bag and the dry matter loss. Output of the spreadsheet includes: number of bags for each forage type, quantity of feed dry matter placed into storage and that removed, storage pad length, storage pad width and pad area.

Silage Bag Capacity Calculator

Often the question arises about the quantity of silage in a silo bag. This is usually needed as part of a feed inventory process. The operator is asked to enter bag dimensions, silage moisture content and dry matter density. The spreadsheet output includes the silage dry matter and as fed weight stored in the bag.

Bunker Silo Density Calculator

Packing bunker silos to achieve high bulk density is important to limit the silage porosity and subsequently the penetration of oxygen into the top surface, under the plastic, and at the feed out face (Holmes and Muck, 2007b). Attaining a high silage density is important for two primary reasons. Most importantly, density and dry matter content determine the porosity of the silage.

Porosity, in turn, sets the rate at which air moves into the silage and subsequently the amount of spoilage which occurs during storage and feed out. The higher the density, the greater is the capacity of the silo. Thus, higher densities generally reduce the annual cost of storage per tonne of crop by both increasing the amount of crop entering the silo and reducing crop losses during storage. General recommendations have been to spread the crop in 0.15 m layers and pack continuously with heavy, single-wheeled tractors. Holmes (2006a) summarizes some of the research and field trials related to density achieved in bunker/pile silos. Many field trials are finding:

Dry matter density is greater near the bottom of the silage than toward the top. (Muck and Holmes, 2000; Visser, 2005; Craig and Roth, 2005; D'Amours and Savoie, 2004; Oelberg et al, 2005) This may be due to self-compaction and more time spent packing the lower layers.

Dry matter density is lower next to the wall than in the center of the bunker/pile silo. (Visser, 2005; Craig and Roth, 2005; D'Amours and Savoie, 2004; Oelberg et al, 2005) This may be due to reduced packing time next to the wall and the lower depth on the sides of piles.

Average dry matter density is higher for hay than for corn silage. (Visser, 2005; Oelberg et al, 2005) 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.

Increasing packing tractor weight, number of packing tractors and reducing layer thickness result in increased dry matter density. (Muck and Holmes, 2000; Visser, 2005; Craig and Roth, 2005; D'Amours and Savoie, 2004; Oelberg et al, 2005).

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 drive over it several times with one or more heavy tractors. The progressive wedge technique of filling continually covers previous layers of forage, thus reducing exposure to air. 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, minimizing the exposure to oxygen during filling.

One practical issue is packing time relative to crop delivery rate. Assuming one packs continuously with one tractor throughout filling, packing time per tonne (1 to 4 min/t As Fed) is high under low delivery rates (<30 t As Fed/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 dry matter density is not being achieved, a producer can select one or more of the following options a-g to increase density;

a. Reduce delivery rate of silage to the storage.
b. Increase dry matter content by allowing longer crop field drying time.
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. Reduce packing layer thickness.
g. Pack for additional time.

Items a. to c. are somewhat difficult to accomplish if the harvest rate and bunker silo 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. Increasing dry matter content beyond 40% to improve density is counterproductive for good preservation because of incomplete fermentation, heating, and increased porosity. If the bunker is full, adding silage depth above the full mark can be dangerous.

Items d. to g. are more often within the control of the producer. Producers achieving high packing density have adopted the use of very heavy tractors and are using a shallow (< 0.15 m) packing layer thickness. 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 will be needed. In a well-packed silo, all tractor tires will 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 that toward the interior, packers should make additional passes near the walls.

The “Spreadsheet to Calculate the Average Silage Density in a Bunker Silo” (Holmes and Muck, 2007a**)** was developed to guide producers as they consider how they can increase bulk density in their bunker silos. User provided inputs to the spreadsheet include: bunker wall height and peak height, harvest rate, dry matter content, tractor weight and percent of filling time each of up to four tractors spend packing. Outputs of the spreadsheet include: an estimate of bulk and dry matter density following packing and fermentation, maximum achievable bulk and dry matter density and porosity. The operator can use this spreadsheet to try some “what if” scenarios by changing the input variables over which he/she has control to try to reach a desired density and porosity.

The “Spreadsheet to Calculate the Average Silage Density in a Silage Pile” (Holmes and Muck, 2008**)** was developed to guide producers as they consider how they can increase bulk density in pile silos. User provided inputs to the spreadsheet include: pile height, pile top and bottom width, harvest rate, dry matter content, tractor weight and percent of filling time each of up to four tractors spend packing. Outputs of the spreadsheet include: an estimate of bulk and dry matter density following packing and fermentation, maximum achievable bulk and dry matter density and porosity. The operator can use this spreadsheet to try some “what if” scenarios by changing the input variables over which he/she has control to try to reach a desired density and porosity.

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 2 shows porosity as calculated using the equations of Richard et al (2004). From Figure 2, porosity is most influenced by bulk density (as fed density) over the range of dry matter contents recommended (0.30-0.40) for ensiling in bunkers, piles, and bags. Bulk density in silage is affected by the same packing practices as dry matter density: tractor weight, packing time and spreading layer thickness as well as depth of silage, however, the same packing practices result in a lower bulk density as dry matter content increases. This trend is the opposite of what occurs with dry matter density. Figure 3 was developed using a modified version of the spreadsheet for calculating average density in a bunker silo by Holmes and Muck (2007a). From Figure 3, 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.

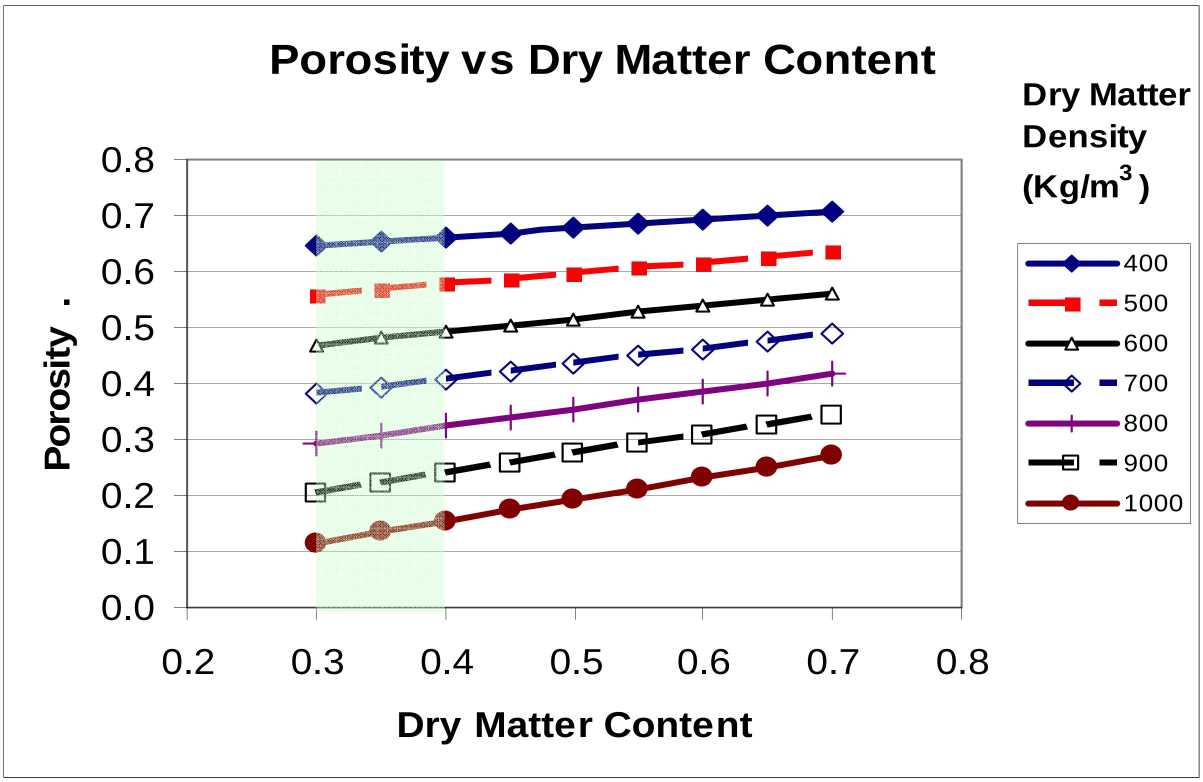

Figure 2. Graph of porosity (decimal) vs. dry matter content (decimal) for various bulk densities

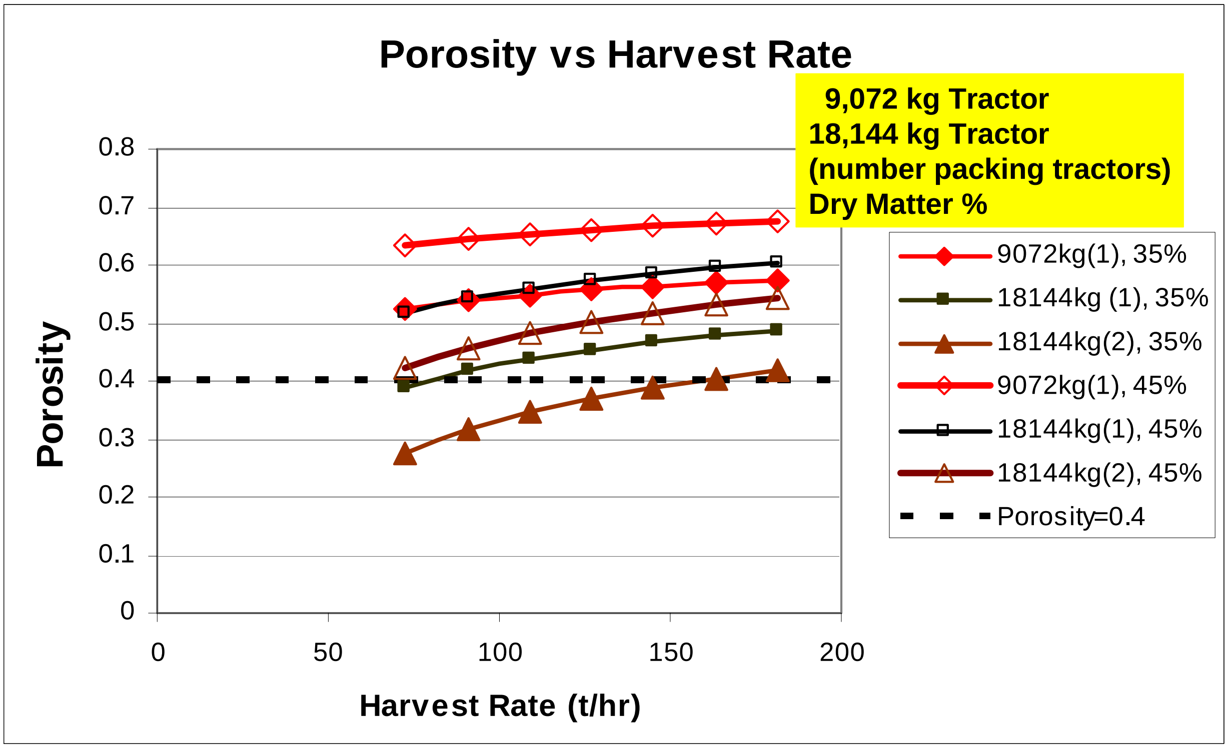

Figure 3. Porosity vs Harvest Rate

Calculator to Determine Length on Bunker/Pile Silo Floor to Achieve a Given Forage Layer Thickness

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 tonne 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 tonne when the layer is thin than when the layer is thicker. Consider this example for determining the length of the filling slope when one load is pushed onto the filling slope at a layer thickness of 0.15 m:

Example 1.

Assume:

Weight per load = 6804 Kg DM/ Load = 6.8 tonne/Load
Forage density on filling slope = 80.1 Kg DM/m^3
Forage Dry Matter = 32% DM
Bunker height = 3.7 m
Packing Speed = 4.8 Km/hr
Tractor width = 3 m
Bunker width = 12.1 m
Packing layer thickness = 0.15 m
Tire width per trip = 0.5 m/trip

Packing Area = (6804 Kg DM/ 80.1 Kg DM/m^3) / (0.15 m) = 566 m^2
Length of Packing Surface = 566 m^2 / 12.1 m = 46.8 m, (Figure 4)
Packing Trips = (12.1 m -3 m)/0.5 m/trip = 18 trips per pass across the packing surface
Total Packing Length = 46.8 m/trip x 18 trips = 842 m
Time/Pass = 842 m/4800 m/hr = 0.18 hr = 10.5 min = 10.5 min/load
Packing Time per tonne = 10.5 min/laod/6.8 t DM/load = 1.55 min/t DM= 0.5 min/t AF

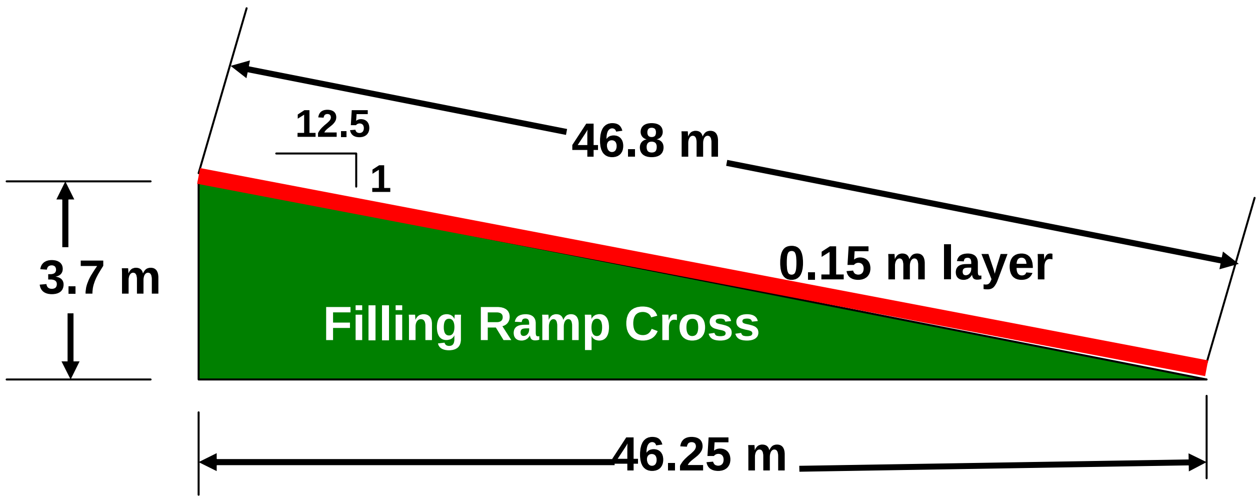

Figure 4. Cross section of progressive filling wedge for Example 1.

The more conventional recommendation is to use a 3:1 progressive wedge filling slope. In Example 2, a filling slope ratio of 3:1 is used and the remaining assumptions of Example 1 are used. The resulting layer thickness and the time spent packing that layer for one packing pass is developed in Example 2.

Example 2

Assume:

Length of Packing Surface = 11.6 m
Layer Thickness = (6804 Kg DM/ 80.1 Kg DM/m^3)/(12.1 m x 11.6 m) = 0.61 m
Total Packing Length = 11.6 m/trip x 18 trips = 208.8 m
Time/Pass = 208.8 m/4800 m/hr = 0.044 hr = 2.6 min = 2.6 min/load
Packing Time per tonne = 2.6 min/laod/6.8 t DM/load = 0.38min/t DM= 0.12 min/t AF

By selecting the longer filling slope of Example 1, the layer thickness becomes about one fourth that of Example 2 and the packing time per tonne becomes four times larger.

A spreadsheet is available to calculate the length of floor needed to achieve a given layer thickness while filling bunker and pile silos (Holmes 2006b). The user enters; average bunker/pile fill height and width, desired unpacked forage layer thickness, unpacked dry matter density, and truck/wagon load dimensions.

How much value can be saved by implementing good silage management practices?

The answer to this question depends on current management practices. If a producer can be viewed as doing a moderate job of management, some savings can be obtained. If on the other hand, large improvement in practices are needed, much greater savings are possible. To help address this issue, a spreadsheet is available (Holmes, 2006c). This spreadsheet was used with the following assumptions and those in Table 1 to estimate the benefit of moving from "not so good management" to "good management":

100 cow herd with replacements

Hay Silage Value = $138/t DM, 40% of cow ration, 50% of heifer ration

Corn Silage Value = $110/t DM, 60% of cow ration, 50% of heifer ration

Table 1. Dry matter loss percentage assumed for analysis of management economics

	Dry Matter Losses with Good Management		Dry Matter Losses with Not So Good Management	
Forage Type	Hay	Corn	Hay	Corn
Loss Category	(%)	(%)	(%)	(%)
Feeding Loss	5	5	7	7
Feed Out Loss	3	3	5	5
Storage Loss	10	10	15	15
Filling Loss	1	1	3	3
Harvest Loss	6	1	8	2

Results of the economic analysis using the spreadsheet are found in Table 2. With these assumptions and those not presented about the ration formulation, the value of moving from not so good management to good management is $13,795/year ($33,571-$19,766). You can use this spreadsheet to enter your own assumptions about herd size, rations and estimated losses to find a savings for your situation for each management change you attempt and for the total savings.

Table 2. Economic loss for good and not so good management

	Economic Loss with Good Management		Economic Loss with Not So Good Management	
Forage Type	Hay	Corn	Hay	Corn
Loss Category	($)	($)	($)	($)
Value Lost	11,204	8,572	18,649	14,9927
Total Value Lost	19,776		33,571	

Conclusions

There are many opportunities to improve silage management and by doing so improve economic profitability for the producer. There are many spreadsheets available to help make decisions about proper silage storage management. Use of these spreadsheets to help guide silage storage management should help improve silage management and consequently profitability.

References

Berger, L.L. and K.K. Bolsen. 2006. Sealing strategies for bunker silos and drive-over piles. Pg. 266-283. *In*: Proc. Silage for Dairy Farms: Growing, Harvesting, Storing, and Feeding. NRAES Publ.181. Ithaca. NY.

Bolsen, K.K., J.T. Dickerson, B.E. Brent, R.N. Sonon, Jr., B.S. Dalke, C.J. Lin, and J.E. Boyer, Jr. 1993. Rate and extent of top spoilage in horizontal silos. J. Dairy Sci. 76:2940-2962.

Craig, P. H. and G. Roth. 2005. Penn state university bunker silo density study summary report 2004-2005. Pennsylvania State University.

D’Amours, L. and P. Savoie. 2004. Density profile of corn silage in bunker silos. ASAE Paper 041136.

Holmes, B. J. 2006a. Density in silage storage. Silage for Dairy Farms: Growing, Harvesting, Storing and Feeding Conference Proceedings (NRAES-181), Natural Resource, Agriculture and Engineering Service, Ithaca, New York

Holmes, B. 2006b. Floor Length to Achieve Bunker/Pile Silo Filling Layer Thickness Calculator. University of Wisconsin Extension. http://www.uwex.edu/ces/crops/uwforage/storage.htm

Holmes, B. J. 2006c. Determining Value of Improved Silage Management. University of Wisconsin Extension. http://www.uwex.edu/ces/crops/uwforage/storage.htm

Holmes, B. J. and R. E. Muck. 2004. Managing and designing bunker and trench silos (AED-43). MidWest Plan Service. Ames, IA. http://www.mwps.org

Holmes and Muck. 2007a. Spreadsheet to Calculate Average Silage Density in a Bunker Silo. University of Wisconsin Extension. http://www.uwex.edu/ces/crops/uwforage/storage.htm

Holmes, B. J. and R. E. Muck. 2007b. Packing Bunkers and Piles to Maximize Forage Preservation. Proceedings of the Sixth International Dairy Housing Conference. ASABE. and Harvest and Storage page of Team Forage web site. URL: *www.uwex.edu/ces/crops/uwforage/storage.htm*

Holmes and Muck (2008). Spreadsheet to Calculate Average Silage Density in a Silage Pile. University of Wisconsin Extension. http://www.uwex.edu/ces/crops/uwforage/storage.htm

Muck, R. E. and B. J. Holmes. 2000. Factors Affecting Bunker Silo Densities. Applied Engineering in Agriculture. 16 (6) 613-619.

Muck, R. E. and B. J. Holmes. 2007. Bunker Silo Management: Spreading Layer Thickness and Plastic Film Effects. Power Point Presentation. ASABE Annual Meeting. Unpublished ASABE Paper 071025

Pitt, R. E. and R. E. Muck. 1993. A diffusion model of aerobic deterioration at the exposed face of bunker silos. J. Agricultural Engineering Research. 55:11-26.

Oelberg, T., C. Harms, D. Ohman, J. Hinen, and J. Defrain. 2005. Survey shows more packing of bunkers and piles needed. Monsanto Dairy Business and Hubbard Dairy Services

Richard, T. L., A. H. M. Veeken, V. de Wilde and H. V. M. Hamelers. 2004. Air-filled porosity and permeability relationships during solid-state fermentation. *Biotechnology Progress.* 20 (1372-1381)

Visser, B. 2005. Forage density and fermentation variation: a survey of bunkers, piles and bags across Minnesota and Wisconsin dairy farms. Four-State Dairy Nutrition and Management Conference Proceedings. (MWPS-4SD18). MidWest Plan Service. Ames, IA.