Documentation

Bunker Silo Silage Density Calculator

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Purpose:

This spreadsheet was designed to inform producers and those advising producers about factors that are important for achieving high silage density when filling a bunker silo. Another spreadsheet that performs similar calculations for silage piles is available at URL:
http://www.uwex.edu/ces/crops/uwforage/storage.htm

The spreadsheet (dated August 5, 2007) has an English language and units page, English language with metric units page and a Spanish language with metric units page. Click the tab at the bottom of the spreadsheet screen for the units or language you desire. This documentation is specific to the English language and units page.

Computer Software Requirements:

The spreadsheet was designed to operate with Microsoft Excel-97. Set the screen size **%** in the upper toolbar so column **R** is visible on the screen.

Inputs:

User changeable values can be entered into spreadsheet cells with a yellow background color. Intermediate values calculated by the spreadsheet are printed in cells with a green background color. The output cells have a pink background color. Some advisory notes use a blue cell background color. Only yellow background cells should be changed by users. The other cells are protected from being changed .

A graphic appears to the right of cell H12. The graphic explains the meaning of wall height and maximum silage height. Values printed below these terms are those entered by the user in column F.

The following variables must be entered by users:

1. **Bunker silo wall height** (cell F7) is the height of the bunker silo wall measured in feet from the bunker silo floor to the top of the wall. The assumption is that silage is filled to the top of the wall. Typical values are 6 to 16 ft. If the bunker is not filled to the top of the wall, enter the height of silage at the wall.

2. **Bunker silo maximum silage height** (cell F9) is the maximum height of the silage measured in feet from the bunker silo floor to the top of the silage. This maximum height of silage is assumed to be midway between each wall.

3. **Silage delivery rate to bunker** (cell F11) is the average rate at which silage is pushed into the bunker silo by the filling tractor(s). The units are Tons of silage As Fed per hour (TAF/hr). Typical values for field harvest rate are given in Table 1. Actual delivery rate may be less than these values if transportation does not keep up with the harvester. Actual delivery rate may be larger than the values in Table 1 if the forage harvester has higher engine horse power or there are multiple harvesters operating. The larger the delivery rate, the lower the estimated density when all other factors remain the same.

TABLE 1. Typical Harvest Rates for Forage Harvesters

Crop	Harvest Rate (TAF/hr)*	
	Towed by 250 hp Tractor	Self-propelled 450 hp engine
Hay	60	110
Corn	100	180

* Personal communication with Dr. Kevin Shinners, Biological Systems Engineering Dept., UW Madison. Larger capacity machines are available.

4. **Silage dry matter content** (cell F13) is the average dry matter content of the forage entering the silo expressed in decimal form. Typical values are 0.3 to 0.4. The larger this number, the higher the estimated dry matter density but the lower the bulk density when all other factors remain the same. Dry matter content less than 0.3 can cause the Maximum Achievable DM Density (cell F36) to control estimated dry matter density (cell F35) as the forage becomes saturated following good packing. For good fermentation and bulk density, keep dry matter content in the range of 0.3-0.4.

5. **Silage packing layer thickness** (cell F15) is the depth of forage (measured in inches) as deposited in the bunker silo before being packed by driving on the forage with the packing tractor(s). Values vary in the range of 2 to 36 inches. The recommended value is 6 inches or less. The smaller this number, the higher the estimated density when all other factors remain the same. Layer thickness is hard to measure or estimate, but it is one variable producers can control and highly influences silage density.

   The "Floor Length to Achieve Bunker/Pile Silo Filling Layer Thickness Spreadsheet" was developed to help producers determine how to place forage on a filling surface in thin layers. Obtain a copy from URL:
   http://www.uwex.edu/ces/crops/uwforage/storage.htm

6. **Packing tractor weight** (cells F19-F22) is the weight of each tractor (measured in lbs) used to pack the forage during filling. The weights of as many as four tractors can be entered.

Typical values fall in the range of 10,000 to 60,000 lbs/tractor. The larger the tractor weight, the higher the estimated density. Tractor weight is one variable producers can control and will highly influence silage density. Plan to increase tractor weight to increase silage density.

7. **Tractor packing time** (cells H19-H22) is expressed as the ratio of time a tractor spends packing to the time it takes to fill the bunker silo. Typical values are between 0 and 100%. For example, if tractor #1 is used to push up forage and pack forage continuously between loads, its packing time is 100%. If tractor #2 is used to pack forage when there is an operator available, say half the time the bunker silo is being filled, the packing time for tractor #2 is 50%. A value greater than 100% is possible if a tractor packs beyond the filling time. The larger this number, the higher the estimated density.

   Error messages (cells I19-I22) will appear as red text on screen if an incorrect value is entered in either cell groups F19-F22 or H19-H22. When an error message appears, enter realistic values for cells in columns F and H.

Intermediate Output (green background):

1. **Proportioned total tractor weight** (cell F23) is the time weighted total weight of tractors used to pack the forage. This value is used in the Packing Factor (cell F28), which relates density to tractor weight. The larger this number, the higher the estimated density. More accurate estimates of density result when tractors of similar weight are used. (For example when a second tractor is much lighter (<40%) than the first, the second tractor will not improve density. We are uncertain of the prediction accuracy when this condition is used.)

2. **Average silage height** (cell F24) is the calculated average depth of forage across the entire width of the bunker silo. The larger the average height, the larger the estimated density.

Output (pink background):

1. **Packing factor** (cell F28) is directly related to average packing tractor weight, silage dry matter content and sum of tractor packing time and inversely related to silage packing layer thickness and silage delivery rate to the bunker. Increasing the packing factor results in increased average density.

2. **Estimated average wet density (Bulk Density)** (cell F29) is measured in lbs. of forage as fed (AF) per cubic foot of packed forage following the fermentation stage. The desired range of values is 44 to 75 lbs AF/cu ft. Silage gas filled porosity (cell F31) increases with decreasing bulk density. High gas filled porosity contributes to rapid oxygen diffusion through the silage. The larger the bulk density, the lower the expected losses of forage due to aerobic deterioration resulting from oxygen entry into the forage during storage and feed out. If the estimated bulk density is less than 44 lbs AF/cu ft, try increasing tractor weight, tractor packing time or number of tractors packing, or decreasing silage packing layer thickness and dry matter content into the range of 0.3 to 0.4. When using this spreadsheet, producers may want to aim for an estimated bulk density greater than 44 lbs AF/cu ft to improve the

likelihood of achieving an adequate average bulk density. If the bunker silo has not yet been constructed, consider adding wall height as a method of increasing estimated density. See maximum achievable bulk density below to be aware of the upper limit placed on this value.

3. **Maximum achievable bulk density** (cell F30) is measured in lbs. of forage AF per cubic foot of packed forage following the fermentation stage. This is the density which could be achieved if the forage is packed to the point of moisture saturation. At this value, gas filled porosity would likely be very close to zero. The forage can be packed no more densely than this value for a given moisture content of forage as it is placed into the silo. The "Estimated Average Wet Density" (cell F29) is limited to this maximum value in the spreadsheet. When the "Estimated Average Wet Density"(cell F29) is lower than the "Maximum Achievable Bulk Density" (cell 30), one can assume the average moisture content of the forage in the storage is less than saturation. However there still may be seepage or effluent coming from the silo at average densities approaching the maximum value because density at the bottom of the silo may have reached the maximum.

4. **Gas Filled Porosity** (cell F32) is a decimal value which is the ratio of open volume to total volume occupied by the silage. It is important to limit this value to less than 0.4 so as to limit the rate of oxygen diffusion into the silage. High gas filled porosity contributes to rapid oxygen diffusion through the silage. The lower the gas filled porosity the lower the expected losses of forage due to aerobic deterioration resulting from oxygen entry into the forage during storage and feed out. Increasing bulk density by the methods mentioned above decreases the gas filled porosity.

5. **Estimated average dry matter density** (cell F35) is measured in lbs. of forage dry matter per cubic foot of packed forage following the fermentation stage. The desired range of values is 15 to 28 lbs DM/cu ft. Silage gas filled porosity (cell F32) increases with decreasing dry matter density. High gas filled porosity contributes to rapid oxygen diffusion through the silage. However, porosity is also a function of dry matter content. A forage with dry matter density greater than 15 lbs DM/cu ft may have a gas filled porosity greater than 0.4 if forage is too dry. The larger the dry matter density, the lower the expected losses of forage due to aerobic deterioration during storage and feed out provided the air filled porosity is less than 0.4. If the estimated dry matter density is less than 15 lbs DM/cu ft, try increasing tractor weight, tractor packing time or number of tractors packing, or decreasing silage packing layer thickness and dry matter content into the range of 0.3 to 0.4. When using this spreadsheet, producers may want to aim for an estimated dry matter density greater than 15 lbs DM/cu ft to improve the likelihood of achieving an adequate dry matter density. If the bunker silo has not yet been constructed, consider adding wall height as a method of increasing estimated dry matter density.

   See Maximum achievable dry matter density below to be aware of the upper limit placed on this value.

6. **Maximum achievable dry matter density** (cell F36) is measured in lbs. of forage dry matter per cubic foot of packed forage following the fermentation stage. This is the density which

could be achieved if the forage is packed to the point of moisture saturation. The forage can be packed no more densely than this value for a given moisture content of forage as it is placed into the silo. The "Estimated Average Dry Matter Density" (cell F35) is limited to this maximum value in the spreadsheet. When the "Estimated Average Dry Matter Density"(cell F35) is lower than the "Maximum Achievable Dry Matter Density", one can assume the average moisture content of the forage in the storage is less than saturation. However there still may be seepage or effluent coming from the silo at average densities approaching the maximum value because density at the bottom of the silo may have reached the maximum.

Changes Made Since the April 7, 2000 Version of the Spreadsheet

1. Maximum Achievable Dry Matter Density and its limitation on the Estimated Average Dry Matter Density were added.

2. Error limiting checks were added to the combination of Tractor Weight and Tractor Packing Time.

3. The Percent Packing Time influence on Proportioned Number of Packing Tractors was changed to 100% from the maximum value entered into that column.

4. The Packing Factor equation is now based on the maximum value achievable based on combination of packing tractor weight and packing time values entered.

5. Typical harvest rates (Table 1) were increased.

Changes Made Since the April 25, 2001 Version of the Spreadsheet

1. Proportioned Number of Packing Tractors was removed. This value was not used to make calculations in the spreadsheet and could contribute to confusion of the user.

2. Proportioned Average Tractor Weight was removed. This value was not used to make calculations in the spreadsheet and could contribute to confusion of the user.

3. A page using metric units was added. Click on the “Metric Units” tab at the bottom of the spreadsheet screen.

4. A Spanish language page was added. This page also uses metric units. Click on the “Espanol- (unidades metricas)” tab at the bottom of the spreadsheet screen.

Changes Made Since the April 23, 2005 Version of the Spreadsheet

1. A graphic of a bunker silo cross section showing “Wall Height” and “Maximum Silage Height” was added.

2. The opportunity to use the spreadsheet with bunker silos and pile silos was dropped. A second spreadsheet should be used for silage piles.

Changes Made Since the February 28, 2006 Version of the Spreadsheet

1. The Estimated Average Wet Density (Bulk Density), Maximum Achievable Bulk

Density, and Gas Filled Porosity were added.