Documentation
Bunker Silo Sizing Spreadsheet

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This spreadsheet will help you design a bunker silo(s) which uses nearly vertical walls. Throughout the spreadsheet, blue text with yellow cell background are values the user is expected to enter or change. Text which is black should NOT be changed. Doing so may change the appearance of the spreadsheet or destroy formulas which are programmed into those cells. These cells are protected from inadvertent change.

The spreadsheet is available with seven pages including English with English units, English with Metric units, Portuguese, Russian, Spanish (Mexican dialect), Spanish (Castilian dialect), and Hungarian. Select the language you desire from the colored tabs at the tool bar at the bottom of the spreadsheet. The spreadsheet is organized into three sections. The INPUT section (Figure 1below - pink cell background cells A12-F38) gives you the opportunity to enter information about your needs and wants in a bunker silo silage storage system. Enter the values in the cells with yellow backgrounds. If you know the daily quantity of silage dry matter to be fed to the herd from a particular bunker silo, click on cell E17 and then click the down arrow that appears to obtain a drop down list of silages. Select "My Silage" from the drop down list. Enter your known silage dry matter to be fed to the herd each day in cell F21. The value used in design will appear in cell E19.

If you need assistance determining the Herd Daily Feed Need (cell E19), the SILAGE DRY MATTER CALCULATOR in Figure 2 below (brown cell background) provides a procedure for determining the values you will feed each day. You can enter the number of animals in each group in your herd (cells J14-J39) (yellow cell background with blue text) and the quantity of each feed type and quality (cells L14-O39) to be fed to each animal in a group (yellow cell background with blue text). The output for each group in this section is found in cells Q14-T39. The HERD TOTAL values for each type and quality of silage is found in cells Q44-T44. Only one of these values at a time should be entered in cell E19 as the Herd Daily Feed Need value for the bunker silo sizing process. To select one of these values, click on cell E17 and then click the down arrow that appears to obtain a drop down list of silages. Select the type/quality of silage from the drop down list. The total dry matter for that particular silage type/quality will be automatically inserted into cell E19 from the appropriate cell in row 44.

Once the values in the INPUT section have been entered, proceed to section three which is

labeled RESULTS in Figure 3 below and appears in cells A40-G62 (cells with blue backgrounds). Select a bunker silo height from column A and read the other design information across that same row.

Meaning of variables used in the spreadsheet:

Forage Type (cell E17): is the type/quality of feed to be placed into this storage(s). This is for identifying the silo and the type/quality of feed to be stored in it. The spreadsheet uses your selection from the drop down list to determine the quantity of a particular feed to be fed daily from the storage (see discussion above).

Herd Daily Feed Need (cell E19): is the total quantity (lbs dry matter) of this **Forage Type** which will be fed to the herd each day. It includes all animal groups, mature and replacements. It should be emphasized the Herd Daily Feed Need is for one type of forage and it may be for a specific quality of a given type of forage. For example, corn silage is usually uniform in quality and is fed from one storage structure at a time. Consequently, the value to enter is the total amount of corn silage fed per day. On the other hand, two or more qualities of hay silage may be fed to the herd each day. In that case, each bunker silo should be sized separately, based on the quantity of each being fed to the herd each day. Operate the spreadsheet changing this value for each feed type/quality being stored. See SILAGE DRY MATTER CALCULATOR (cells I6-T44) for help in estimating Herd Daily Feed Need (as discussed above). The combination of silage density, wall height, and removal rate and daily feed needs determines the width of the bunker silo. Cell E19 is protected and should not be changed by editing the cell. Change the value in cell E19 by clicking on cell E17 and selecting the type of forage to be stored from the drop down menu. See instructions at the beginning of this documentation.

Storage Loss (cell E22): is the percentage of dry matter lost during the fermentation and storage phases, but not including losses during feed out, feeding and feed refusal. With excellent management and a reasonable storage period, this value can be as low as 8 - 10%. With moderate management and/or a long storage period, it can be as high as 28%. This loss is affected by packing, exposure during filling, top surface sealing, top surface area, moisture content, and storage period length. A loss during the storage feed out phase is programmed into the spreadsheet but is not displayed to the user. It is incorporated into total loss in cells G48-G59. It is a function of face removal rate, moisture content and density, with the face removal rate being significant for removals less than 6 in/day.

Feeding Loss and Feed Refusal (cell E25): is the percentage of the dry matter lost while feed sits at the base of the feedout face and during feed mixing and delivery and feed refusal. This value can be in the 3-15% range.

Daily feed needs and losses during storage, feed out and feeding determine the total amount of forage which must be placed into the bunker silo(s) to assure adequate quantities of feed are available to feed to the herd.

Silage Wet Density (cell E28): is the density achieved after packing the bunker silo during the filling process and is sometimes referred to as Bulk Density. With excellent management, this value

can be as high as 60 lbs As Fed silage/ft^3. Good management will achieve greater than 44 lbs AF silage/ft^3, while poor management produces silage < 44 lbs AF silage/ft^3.

Silage Moisture Content (cell E30): should be in the range of 60-65% for hay silage and 65-70% for corn silage. Excessive moisture (>70%) causes dry matter loss by juice expression, while low moisture content limits the ability to pack silage to a high density. Low moisture contributes to high silage porosity which allows easier oxygen penetration when the silo face is opened.

Face Removal Rate (cell E32): is the average thickness of the slice of silage removed from the whole face of the silage mass each day. A minimum removal rate is 6 in/day or greater. A good design value is 12 inches/day or greater. See **Storage Loss** above.

Storage Period (cell E34): is the length of time you plan to feed from the storage. If no other storages exist for the feed being considered, the storage period is the amount of time between annual harvests (360 ± days). Where other storages are available or where refilling part of this storage is possible, the storage period can be proportionately less than 360 days. Since silage should ferment for 30 days before being used, you may want to reduce the storage period by this much as you feed the animals from other sources during fermentation. In the case of corn silage, extended storage increases the digestibility of corn kernels. Consider adding 30-90 days of additional storage period in a different storage to increase carryover to promote kernel digestibility. A few examples may help understand this concept.

Example 1.

Corn silage is to be fed over a 360 day period but an additional storage period of 90 days is needed to increase kernel digestibility. Use the spreadsheet using a 360 day storage period to establish the size of bunker(s) for the feeding period. Next use the spreadsheet using a 90 day storage period to determine the size of an extra bunker silo(s) to accommodate the extra feed needed to keep on hand. Depending on the size of the operation or availability of other storages on the farm, this 90 days of storage could be placed in silo bags, silage piles or tower silos instead of building additional bunker silos.

Example 2.

Hay silage is to be fed over a 360 day period but the first part of the storage period (30 days) is needed to allow for fermentation to be completed. In the spreadsheet select a 360 day storage period to establish the size of bunker(s). Since the 30 day fermentation occurs with each cutting, the first cutting may be the most critical time to allow the fermentation to occur. Access to fermented feed can occur if more than one bunker silo is used. For example, first cutting can be placed into Bunker silo #1 while feeding from Bunker silo # 2 or #3. In the spreadsheet, vary Face Removal Rate and/or Maximum Silo Length to assure more than one bunker silo is selected in cells C48-C59.

Example 3.

A producer uses grazing practices but needs hay silage is to be fed over a 240 day winter period. Hay will be harvested in the spring and stored as "Hay #1" in a bunker silo(s). Since the 30 day fermentation period occurs well prior to the start of feeding from the storage, the 240 day storage period can be used to establish the size of bunker(s) for Hay #1.

If you plan to feed from this storage only during the winter, the length of the winter storage period should be entered. You may consider decreasing the face removal rate for winter-only feeding. However, this may reduce your flexibility of extending the use of this storage into warmer periods in the future.

Maximum Silo Length (cell E36): is the maximum distance you are willing to drive to get feed into and/or out of the bunker silo(s). It may also reflect the space available to locate the bunker silo(s). This value will typically be in the range of 100-200 feet, with 150 feet being a reasonable value to enter. Selecting longer silo length tends to reduce the number of silos needed in the design. The spreadsheet accounts for a sloping filling surface and a sloping back surface. Wedges of feed are longer for taller silos than for shorter silos. These wedges contribute to the Bunker Length in cells D48-59.

Once you enter the necessary input values, the spreadsheet displays some of the viable silo sizes in the table labeled RESULTS (cells A40-G62 with blue backgrounds), Figure 3 below. From the table, select a wall height from column A and then read other information about the design from the other columns on the same row. The AVERAGE WIDTH is the distance measured between the interior wall surfaces at a height halfway up the wall. The NUMBER OF BUNKERS is established based on the removal rate, storage period, and maximum bunker silo length you specified as inputs. The bunker length accounts for a sloping (3 horizontal to 1 vertical) silage surface at the filling and back ends of the storage. The taller the sidewall, the longer these surfaces, and the more feed will be stored in those wedges compared to shorter walled bunkers. Wall height selection should be based on the sizes of available walls and the maximum height your emptying equipment can reach. From the table (Column G), you can see losses are estimated to increase with decreasing wall height. Select a reasonable wall height to minimize losses caused by oxygen exposure through the top surface area.

The FORAGE PLACED INTO STORAGE is the sum of that needed to feed the herd and the losses that occur during storage, feeding and refusal. You have specified a storage loss in the INPUT section. The spreadsheet provides an adjustment in that value, increasing the loss for wall heights less than 12 feet and decreasing the storage loss for wall heights greater than 12 feet. This adjustment emphasizes the importance of top surface area on the amount of loss one might experience.

The values in the column titled FORAGE LOSS - Fill Through Refusal are the actual feed dry matter losses for this forage. These losses occur during the fermentation and storage periods as well as during feeding and after the feed manger is cleaned out. There is a built-in face removal dry matter loss which is based on face removal rate, moisture content, and bulk density.

The PERCENTAGE DRY MATTER LOSS column expresses the total forage loss as a percentage of the total amount of feed which must be placed into storage.

Using the RESULTS table (cells A40-G62), select a bunker silo size which gives reasonably sized bunker silos. Those with exceptionally tall sides will be difficult to empty without adequately sized equipment for removing feed from the face. Selecting a short wall height results in bunker silos which are quite wide. This contributes to a large top surface area with resulting higher feed storage loss. For medium sized dairies, bunker wall height is often in the 8- to 16-foot range.

The spreadsheet displays the words "Don't Use" in the rows where the width is less than twice the width of the packing tractor. A packing tractor cannot produce complete packing coverage between the walls of a bunker that is narrower than twice the width of the tractor. A 10-foot wide packing tractor requires a bunker width of at least 20 feet.

If the width of the bunker calculates to be exceptionally wide (greater than 40 feet) for the wall height you prefer, consider a slightly taller wall or increase the face removal rate in the INPUT section which results in a new set of bunker silo sizes in the RESULTS section. The number of bunkers may increase. More bunker silos will cost more but will increase your flexibility of feed storage. You may be able to refill some of the storages with other forages, thus reducing the total amount of feed storage capacity needed for the farm.

If the Number of Bunker Silos appears to be excessive, increase the value you entered for Maximum Silo Length and/or decrease the Face Removal Rate in the INPUT section. Be sure to keep the Face Removal Rate larger than 6 inches/day to assure face removal dry matter loss within a reasonable range. Decreasing the Storage Period may also reduce the Number of Bunker Silos.

Silage Dry Matter Calculator (Cells I6-T44)

If you are not clear how much of a given forage is or will be fed and should be included as input for Herd Daily Feed Need, a dry matter calculator is provided within the spreadsheet in cells I6-T44. Enter the number of animals in each group under the column heading Number per Group. The spreadsheet will calculate the totals for each group and list them in the TOTAL column. Under the columns labeled Hay 1, Hay 2, Hay 3 and Corn, enter the pounds of forage dry matter coming from each of the storages representing different feed types and quality. You need not use all columns. Enter zero for each group in a column where that feed doesn't exist on the farm. Generally, milking cows consume forage for a total of 20-30 lbs-DM/animal-day. Other groups may consume more or less.

The spreadsheet uses the information on the number of animals in each group and the dry matter consumed per animal to establish a group daily consumption rate for each forage which is listed in cells Q14-T39. These group values for a specific forage are summed to produce a total for each type/quality of feed. These totals are listed in cells Q44-T44. One of these totals is then automatically entered as an input value in cell E19 as the **Herd Daily Feed Need** after selecting the feed type/quality in the drop down list of cell E17. See instructions for selecting from the list in **Herd Daily Feed Need.**

Since the SILAGE DRY MATTER CALCULATOR establishes only the quantity of feed that must be fed, the total values should not be used to establish cropping acres needed to feed the herd. These values must be modified to include losses which occur in harvest, storage, feedout, feeding, and feed refusal. For that reason, the values in the RESULTS section are more useful. The FORAGE PLACED INTO STORAGE value does take all losses into consideration except for harvest/transport losses. For example, if the forage placed into storage for Hay 1 is 1500 TDM (from the RESULTS section), harvest/transportation loss is 5%, and yield is 4 TDM/acre-yr. The number of acres needed to feed Hay 1 to the herd is:

$$\frac{1500\ TDM}{(4\ TDM\ /\ acre\text{-}yr)^{*}\ (1 - 0.05)} = 395 \text{ acres}$$

REFERENCE

Bodman, G.R. and B.J. Holmes. 1997. *Managing and Designing Bunker and Trench Silos* (AED-43). Published by MidWest Plan Service and available through county extension offices in states of the midwest.

User input values are in blue text with yellow background

INPUT

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Maximum Packing Tractor Width (feet) =	8.0	
Forage Type (hay, corn, oats&peas etc):	**My Silage**	Click on Cell E17 then down arrow select feed from displayed table
Herd Daily Feed Need (Lbs DMI/Herd-Day) =	6,000.0	
My Silage, if not from Silage Dry Matter Calculator Table (Row 44) (Lbs DMI/Herd-Day)	6,000.0	**My Silage**
Storage Loss (%) =	10.0	
Fill through Storage		
Feeding Loss and Feed Refusal (%)	3.0	
Silage Wet Density (minimum 44 Lbs/cu ft)	44.0	
Silage Moisture Content (%) =	67.0	
Face Removal Rate (min. 6 In/Day) =	12.0	
Storage Period (days) =	360.0	
Maximum Silo Length (150 ft) = for about 10 foot wall height	150.0	

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Figure 1. Input Section (input values within yellow cell backgrounds).

SILAGE DRY MATTER CALCULATOR

Animal Group	Number per Group	TOTAL	Hay1 Silage	Hay2 Silage	Hay3 Silage	Corn Silage	Hay1 Silage	Hay2 Silage	Hay3 Silage	Corn Silage
			LBS DM/ANIMAL-DAY				LBS DM/GROUP-DAY			
DRY		68								
Transition	8		0	0	20	0	0.0	0.0	160.0	0.0
Dry1	22		0	10	15	0	0.0	220.0	330.0	0.0
Dry2	22		0	10	15	0	0.0	220.0	330.0	0.0
Close-up	16		0	20	0	3	0.0	320.0	0.0	48.0
Maternity	20	20	15	10	0	3	300.0	200.0	0.0	60.0
Fresh	6	6	10	5	0	10	60.0	30.0	0.0	60.0
Two-year-olds	110	110	10	0	0	15	1100.0	0.0	0.0	1650.0
THREE YRS & OLDER		226								
High Producers	90		10	0	0	15	900.0	0.0	0.0	1350.0
Medium Producers	68		15	5	0	10	1020.0	340.0	0.0	680.0
Low Producers	68		10	10	0	10	680.0	680.0	0.0	680.0
Sick Cows	10	10	25	5	0	5	250.0	50.0	0.0	50.0
MATURE COWS	TOTAL	440								
HEIFERS										
3-5 months	48		5	0	0	2	240.0	0.0	0.0	96.0
6-8 months	48		10	0	0	3	480.0	0.0	0.0	144.0
9-12 months	72		10	5	0	4	720.0	360.0	0.0	288.0
13-15 months	48		10	10	0	4	480.0	480.0	0.0	192.0
16 months-freshening	156		15	10	0	10	2340.0	1560.0	0.0	1560.0
HEIFERS	TOTAL	372								
						HERD TOTAL (Lbs DM/Herd/day)	**8570.0**	**4460.0**	**820.0**	**6858.0**

Figure 2. Section for Determining Daily Feed Needs (input values within yellow cell backgrounds).

RESULTS

WALL HEIGHT (FEET)	AVERAGE BUNKER WIDTH (FEET)	NUMBER of BUNKER SILOS	BUNKER LENGTH (FEET) (EACH)	FORAGE PLACED INTO STORAGE (TDM)	FORAGE LOSS Fill through Refusal (TDM)	PERCENT DM LOSS (%)
4	103	3	152	1316.8	247.5	18.8
6	69	3	158	1288.4	213.1	16.5
8	52	3	164	1274.3	196.5	15.4
9	46	3	167	1269.5	191.0	15.0
10	41	3	170	1265.8	186.6	14.7
12	34	4	141	1260.1	180.1	14.3 *
14	30	4	147	1256.0	175.5	14.0
16	26	4	153	1253.0	172.0	13.7
18	23	4	159	1250.6	169.4	13.5
20	21	4	165	1248.8	167.2	13.4
22	19	5	150	1247.2	165.5	13.3
24	17	5	156	1245.9	164.1	13.2

* Forage DM Loss is the sum of the Storage Loss and Feeding Loss (entered above) at 12 foot wall height plus a feeding face loss. Losses will be greater for wall height less than 12 feet and less for higher walls due to top surface area effects.

Figure 3. Results Section