

Documentation
Bunker Silo Sizing Spreadsheet
Brian J. Holmes, Extension Agricultural Engineer
Department of Biological Systems Engineering
University of Wisconsin-Madison
460 Henry Mall
Madison WI 53706
608 / 262-0096 (voice) 608 / 262-1228 (FAX)
Date: August 25, 1998

This spreadsheet will help you design a bunker silo(s) which uses nearly vertical walls. The spreadsheet is organized into three sections. The INPUT section (cells A15-E36 which are boxed in Figure 1 and in blue text in the spreadsheet) gives you the opportunity to enter information about your needs and wants in a bunker silo silage storage system. As you enter input, you may need some assistance to determine the Herd Daily Feed Need. The SILAGE DRY MATTER CALCULATOR in section two provides assistance in determining the values you will feed each day. You can enter the number of animals in each group in your herd (cells J14-J39 which are boxed in Figure 1 and in blue text in the spreadsheet) and the quantity of each feed type and quality (cells L14-O39 which are boxed in Figure 1 and in blue text in the spreadsheet). 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. Once the values in the INPUT section have been entered, proceed to section three which is labeled RESULTS and appears in cells A40-G60.

Throughout the spreadsheet text which is shaded blue are values the operator 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 file name for this spreadsheet is BSILOSIZ and is available in Excel (xls), QuatroPro (wb2) and Lotus (wk3) format. You may change any of the following input variables as they apply to your situation.

Forage Type (cell E17): is the type of feed to be placed into this storage(s). This is for information only. The spreadsheet does not use this for any calculation.

Herd Daily Feed Need (cell E19): is the total quantity (lbs dry matter) of this type of forage which will be fed to the herd each day. It includes all animal groups, mature and replacements. It should be emphasized that this Herd Daily Feed Need is for one type of forage and, in fact, 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, the bunker silos 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 quality being stored. See SILAGE DRY MATTER CALCULATOR (cells I6-T44) below for help in estimating Herd Daily Feed Need. The combination of silage density, wall height, and removal rate with daily feed needs determines the width of the bunker silo.

Storage Loss (cell E22): is the percentage of dry matter lost during the fermentation and storage phases. With excellent management and a reasonable storage period, this value can be as low as 13%. 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.

Feeding Loss (cell E25): is the percentage of the dry matter lost during feed mixing and delivery and feed refusal. This value can be in the 3-15% range. A loss during the feed out phase is programmed into the spreadsheet. It is a function of face removal rate, moisture content and density, with the face removal rate being significant for removals less than 4 in/day.

Daily feed needs and storage and feeding losses determine the total amount of forage which must be placed into the bunker silo(s).

Silage Wet Density (cell E28): is the density achieved after packing the bunker silo during the filling process. With excellent management, this value can be as high as 60 lbs silage/ft³. Typical management will achieve 40 lbs silage/ft³, while poor management will produce silage in the 20-25 lbs silage/ft³ range.

Silage Moisture Content (cell E30): should be in the range of 60-65% for hay silage and 65-70% for corn silage. Excessive moisture causes dry matter loss by juice expression, while low moisture content limits the ability to exclude oxygen by packing tightly.

Face Removal Rate (cell E32): is the thickness of the slice of silage removed from the face of the silage mass each day. Minimum removal rates are 3 in/day in winter and 4 in/day in summer. A good design value is 6 in/day or greater. See Feeding 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 14-21 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.

If you plan to feed from this storage only during the winter, the length of the winter storage period should be entered here. 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). This value will typically be in the range of 100-200 feet, with 150 feet being a reasonable value to enter.

Once you enter the necessary input values, the spreadsheet displays some of the viable silo sizes in the table labeled RESULTS (cells A40-G60). From the table, you can select a wall height from column

one and then read other information about the design from the other columns on the same line. 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 (45° angle) silage surface at the rear and a sloping (30° angle) silage surface at the filling end. The taller the sidewall, the longer these surfaces will be, and the more feed will be stored in those wedges compared to shorter walled bunkers. The relationships have been established so the maximum silo length you specified will often occur for bunkers with a 10- 12-foot wall height.

The FORAGE PLACED INTO STORAGE is the sum of that needed to feed the herd and the losses that occur during storage and feeding. 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 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 will display the words "Don't Use" in the rows where the width is less than 16 feet. 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 tractor would actually require 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 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 O44-T44. One of these totals is then manually entered as an input value in cell E19 as the Herd Daily Feed Need. The totals in the SILAGE DRY MATTER CALCULATOR are not linked to the INPUT section, so you must enter that value yourself.

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, 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:

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

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.

BUNKER SILO SIZING
 August 22, 1998
 Brian J. Holmes
 Professor and Extension Specialist
 Biological Systems Engineering Dept.
 University of Wisconsin-Madison
 Madison, WI 53711
 Voice: (608) 262-0096
 FAX: (608) 262-1228
 bjholmes@facstaff.wisc.edu

INPUT	=	=	=	=	=	=	=
Forage Type (hay, corn, oats&peas etc):	=	corn	=	=	=	=	=
Herd Daily Feed Need (Lbs DMI/Herd-Day)	=	4000.0	=	=	=	=	=
This Forage	=		=	=	=	=	=
Storage Loss (%)	=	10.0	=	=	=	=	=
Fill through Storage	=		=	=	=	=	=
Feeding Loss (%)	=	5.0	=	=	=	=	=
Feed Removal through Refusal	=		=	=	=	=	=
Silage Wet Density (40 Lbs/cu ft)	=	40.0	=	=	=	=	=
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	=	=	=	=	=

RESULTS	=	=	=	=	=	=	=
AVERAGE	NUMBER	BUNKER	FORAGE	FORAGE	PERCENTAGE		
WALL HEIGHT (FEET)	BUNKER WIDTH (FEET)	of BUNKER SILOS	LENGTH (FEET) (EACH)	PLACED INTO STORAGE (TDM)	LOSS Refusal (TDM)	DM LOSS Fill through (%)	
4	91	3	125	902.4	190.9	21.1	
6	61	3	128	882.7	166.5	18.9	
8	45	3	131	872.8	154.6	17.7	
9	40	3	132	869.5	150.7	17.3	
10	36	3	134	866.9	147.6	17.0	
12	30	3	136	862.9	143.0	16.6 *	
14	26	3	139	860.1	139.7	16.2	
16	23	3	142	858.0	137.2	16.0	
18	20	3	145	856.3	135.3	15.8	
20	18	3	147	855.0	133.8	15.7	
22	17	3	150	853.9	132.6	15.5	
24	Don't Use	Don't Use	Don't Use	Don't Use	Don't Use	Don't Use	

* 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 area effects.

SILAGE DRY MATTER CALCULATOR (herd totals do NOT transfer to Herd Daily Feed Need in INPUT section)										
=	=	=	=	=	=	=	=	=	=	=
Group	Number per Group	TOTAL	Hay1 Silage	Hay2 Silage	Hay3 Silage	Corn Silage	Hay1 Silage	Hay2 Silage	Hay3 Silage	Corn Silage
		L	LBS DM/ANIMAL-DAY				LBS DM/GROUP-DAY			
DRY		68								
Transition	8		0	0	20	0	0	0	160	0
Dry1	22		0	10	15	0	0	220	330	0
Dry2	22		0	10	15	0	0	220	330	0
Close-up	16		0	20	0	3	0	320	0	48
Maternity	20	20	15	10	0	3	300	200	0	60
Fresh	6	6	10	5	0	10	60	30	0	60
Two-year-olds	110	110	10	0	0	15	1100	0	0	1650
THREE YRS & OLDER		226								
High Producers	90		10	0	0	15	900	0	0	1350
Medium Producers	68		15	5	0	10	1020	340	0	680
Low Producers	68		10	10	0	10	680	680	0	680
Sick Cows	10	10	25	5	0	5	250	50	0	50
MATURE COWS	TOTAL	440								
HEIFERS										
3-5 months	48		5	0	0	2	240	0	0	96
6-8 months	48		10	0	0	3	480	0	0	144
9-12 months	72		10	5	0	4	720	360	0	288
13-15 months	48		10	10	0	4	480	480	0	192
16 months-freshening	156		15	10	0	10	2340	1560	0	1560
HEIFERS	TOTAL	372								
HERD TOTAL							8570	4460	820	6858

Figure 1. Bunker silo sizing spreadsheet (input values within boxes).