Importance of Silage Density and How to Pack Silage for Good Density

Dr. Dan Undersander

(University of Wisconsin, USA)

Silage density is important because it determines the porosity (pore space) in silage. The amount of pore space controls how fast and how far from the face that air moves into the silage when the bunker or pile is opened for feeding and, consequently, the amount of energy loss from heating and spoilage. This is shown in the table from Rupple (1992) where greater silage density resulted in less dry matter loss.

Table 1. Dry matter loss as influenced by silage density

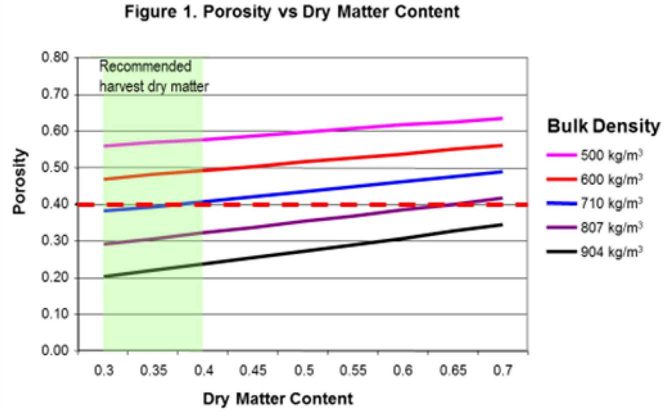
Silage Density (kg of DM/m^3)	DM loss at 180 days (% of the DM ensiled)
161	20.2
226	16.8
242	15.9
258	15.1
290	13.4
355	10.0

Higher silage density also increases the capacity of the silo. More silage dry matter can be stored in the same volume if the density is higher.

Thus, higher silage densityreduces the annual cost of silage storage by increasing the amount of crop that can be stored in a silo and reducing the crop losses during storage. It is important to note that the factors affecting silage density and porosity are the same for corn silage, alfalfa, grass, small grain and all other crops that may be ensiled. Neither does the storage type affect silage density/porosity characteristics - the same information applies to bunkers, piles and tubes of silage.

Porosity is the factor of concern. It is a measure of the voids (open space) between solid particles of silage. Pore space can be filled with either gas or water in silage. If porosity is high then pores may be continuous and allow air to move through the silage which can increase aerobic microbial activity when feeding the silage out of the bunker or pile. Microbial activity is indicated by heating in the silage. If it occurs for some time it can result in increased fiber, crude protein, higher ammonia and elevated pH. In extreme cases it may result in moldy gray to black silage.

Figure 1. Porosity vs Dry Matter Content



When pore space is high air moves into the silage from the feed out face by a combination of several methods. The first is diffusion. If the oxygen content of the silage is 0% and the oxygen content of the air at the face of the silage is 20%, oxygen will move from areas of high concentration (outside the pile) to the area of low oxygen concentration (inside the pile). The greater the air space (porosity), the faster the oxygen will flow into the silage and the greater the microbial growth will be. A second method that oxygen moves into the silage is by gravity. Carbon dioxide is heavier than oxygen so it settles through the silage and emerges at the bottom of the vertical feedout face. The carbon dioxide moving out of silage draws air containing oxygen into the silage which supports spoilage organisms.

The goal should be to pack silage to 0.4 porosity or less. This is 40% air space at 35% dry matter as shown in figure 1.

It is not possible to measure porosity on the farm so the most practical estimate of porosity is bulk density (weight of silage per unit volume). Note, also from figure 1, that silage density must increase as forage dry matter content increasesto get the 0.4 or less porosity.

However, over the recommended dry matter range (32 to 40%)for ensilingto get good fermentation, a silage bulk density of 690 to 717 kg/m3 will generally give the needed porosity.The remainder of this discussion will pertain to silage in this dry matter range as forage ensiled wetter will tend to ferment poorly, possibly containing butyric acid and/or clostridia, and may have seepage losses of protein and soluble carbohydrates. Forage ensiled at higher dry matter content will tend to have reduced fermentation and higher pH resulting in greater heating losses on feedout.

We will focus on 35% dry matter silage for the rest of this paper which requires a bulk density of 705 kg/m3to achieve 0.4 porosity.When porosity is greater than 0.4, air moves rapidly into the face of the silage in a bunker or silo and heating and white mold spots will form. The face of a bunker or pile with less than 0.4 porosity should be very firm and should not give half a cm when pushed against with a fist.

It is possible to measure silage bulk density using a 10 cm diameter piece of stainless steel pipe approximately 60 to 70 cm long. The pipe should have serrated edges on one end for cutting into the silage and be able to be attached to a drill on the other end. The pipe is forced into the silage face a known distance and then removed. The contents are weighed and divided by the volume of the pipe to determine silage density.

Another way to determine silage density is to keep track of the number of truckloads going into a bunker or pile, to weigh an average truckload and then calculate the weight of silage in the bunker or pile as the number of truckloads times the average truckload weight (this should be done anyhow for feed inventorying). This weight of silage can be divided by the volume of the bunker or pile to determine the silage density.

A third way to estimate density is during feedout. One can weigh the silage as it is removed for feeding from a measured distance of bunker length. Bulk density is the weight of removed silage divided by the volume of silage removed.

Density is primarily a function of the packing practices used to fill the bunker or build the pile. The main factors are the rate of silage delivery to the bunker/pile, packing layer thickness, the number and weight of tractors, packing time, crop dry matter content and height of the bunker or pile. Other factors, such as chop length and species of silage crop, have much less effect on packing density.

You can determine the management needed for good packing density using the spreadsheets developed at the University of Wisconsin. Spreadsheets for calculating both bunker and silage pile density are available athttp://fyi.uwex.edu/forage/harvest/#silageHE.

Some differing management scenarios are presented in table 2. If we start with a bunker with 3 m side walls that is filled 3.5 m high at the rate of 100 tons 35% moisture silage/hr and it is packed in 15 cm layers with two tractors weight 16000 and 12000 kg, both operating 100% of the time, the silage density would be expected to be 660 kg/m3 and have a porosity of 0.44 as shown in table 2 “Standard” column. This is less density than recommended and would be expected to heat during feedout with resulting dry matter and quality loss. Note that, if the packing tractors are running 80% of the time rather than 100%, the density of silage would be reduced another 30 kg/m3 (not shown in table).

One option to increase silage density is to reduce the delivery rate of silage to the bunker or pile so that more packing time is allowed per ton of forage. This is shown in the column labeled “Slower delivery” where reducing silage delivery rate to 75 t/hr increased packing time per ton to achieve the desired bulk density 705 kg/m3). This option may not be desired but is presented to show the importance of knowing actual silage delivery rate so that management can be adjusted accordingly to achieve good silage density.

A more practical option is to keep all factors the same except to spread and pack thinner layers at the bunker or pile. Packing density is very sensitive to packing layer thickness. As shown in table 2,decreasing the packing layer thickness from 15 cm to 13 cm resulted in a density increase of 44 kg/m3 and an acceptable silage density of 704 kg/m3.

Another option is to increase the weight of the packing tractors. In the table 2 example, increasing the weight of one tractor by 4000 kg resulted in an acceptable packing density of 701 kg/m3. It may be possible to get a heavier tractor but also consider the option of adding weight to existing tractors. It may be possible to add wheel weights, make a concrete block that can be attached to the 3-point hitch, or to add concrete blocks to loader. Always do whatever possible to add weight to packing tractors. Also consider that single wheels apply more weight per square meter than dual wheels.

The last column shows the effect of not running the packing tractors all the time. Reducing tractor operating time 20% (to 80) required significantly heavier tractors to result in similar packing density.

Table 2 Effect of Silage Making Parameters on Silage Bulk Density and Porosity

(Yellow box is item changed from standard column and green boxesare resulting silage density and porosity)

Factor	Standard	Slower delivery	Thinner packing layer	Heavier packing tractor	Heavier packing tractor/less time
Bunker wall height (m)	3	3	3	3	3
Maximum silage height (m)	3.5	3.5	3.5	3.5	3.5
Delivery rate to bunker (t AF/hr)	100	75	100	100	100
Silage dry matter (decimal)	.35	.35	.35	.35	.35
Packing layer thickness (cm)	15	15	13	15	15
Packing tractor #1 weight, kg /% time operating	16000/100	16000/100	16000/100	16000/100	18000/80
Packing tractor #2	12000/100	12000/100	12000/100	16000/100	18000/80
Bulk density (kg AF/m^3	660	705	704	701	703
Porosity	.44	.40	.40	.40	.40

AF = as fed (weight of silage with moisture),

Calculations from Bunker Density Calculator at fyi.uwex.edu/forage as excel spreadsheet for bunkers or piles.

In summary, packing density is crucial to reducing silage spoilage, quality and dry matter loss, especially during feedout. A packing density of 705 kg/m3 will result in a porosity of 0.4 at 35% dry matter silage and reduce silage quality and dry matter loss compared to lesser silage densities. The main factors affecting silage density are the rate of silage delivery to the bunker/pile, packing layer thickness, the number and weight of tractors, packing time, crop dry matter content and height of the bunker or pile. A spreadsheet is available to calculate the best options for obtaining optimum silage density in your operation.