Changing The Way Silage Density is Measured For More Consistent Porosity

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For more than 10 years, researchers have been emphasizing getting a high dry matter (DM) density in bunker and pile silos by improving filling and packing practices. That has been a reasonable goal, but more recent work has shown that bulk density (or as-fed density) might be a better measure than DM density for two main reasons: 1) It is easier to measure bulk density when filling the silo and 2) bulk density is more closely related to porosity, which is more closely related to silage quality.

Why is silage density important when packing bunkers and piles? Attaining a high silage density is important for two primary reasons. Most importantly, density and DM content determine the porosity of the silage. Porosity, in turn, sets the rate at which air moves into the silo and subsequently the amount of spoilage which occurs during storage and feedout. Kurt Ruppel measured DM loss for alfalfa silage and developed an equation to relate the loss to DM density (Table 1). Secondly, the higher the density, the greater the capacity of the silo. Thus, higher densities generally reduce annual cost of storage per ton of crop by both increasing the amount of crop entering the silo and reducing crop losses during storage.

What is porosity and why is it important? Porosity is a measure of the voids between the solid particles of a material. In silage, these voids are filled with gas and water. The "gas-filled" porosity allows gases to move within the material. The preferred gas in stored silage is carbon dioxide, and in a well-sealed silo upwards of 90% of the gas will be carbon dioxide with the remainder being nitrogen (N_2). When the silo is opened, carbon dioxide will drain from the silo face because it is heavier than air, and oxygen will move into the silo. The rate at which this occurs is proportional to the gas-filled porosity; the greater the porosity, the more quickly the oxygen moves in.

Table 1. *DM loss as influenced by silage density.*

DM Density (lbs/DM/ft^3)	DM Loss, 180 Days (%)
10	20.2
14	16.8
15	15.9
16	15.1
18	13.4
22	10.0

Oxygen permits aerobic microbial activity. Aerobic microbial activity first decomposes available carbohydrates with resultant DM loss. Evidence of rapid aerobic microbial activity is heating silage. Evidence that aerobic activity has occurred for some time is increased fiber and CP contents, higher ammonia, bound protein, elevated pH and, in extreme cases, moldy gray to black colored silage. To help reduce these losses, one should strive to pack bunkers and piles to minimize gas-filled porosity.

If porosity is used as a measure of how well silage is packed, how is it measured? Porosity is difficult to measure on the farm. As it turns out, a good DM density does not guarantee a low porosity either. A minimum DM density of 15 lbs DM/ft^3 has been

Figure 1. *Gas-filled porosity vs. DM content for various DM densities.*

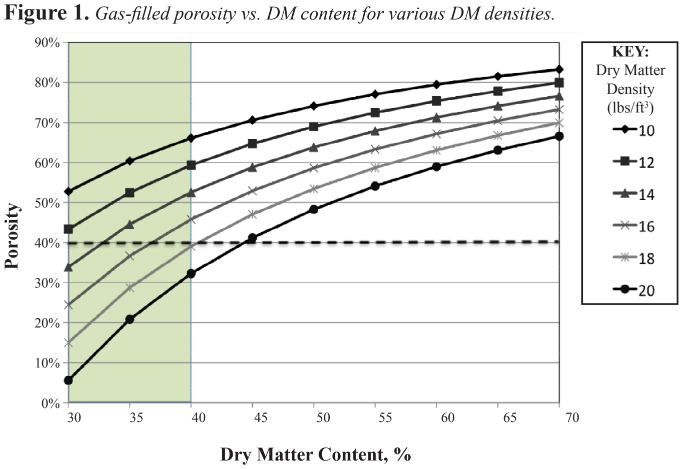
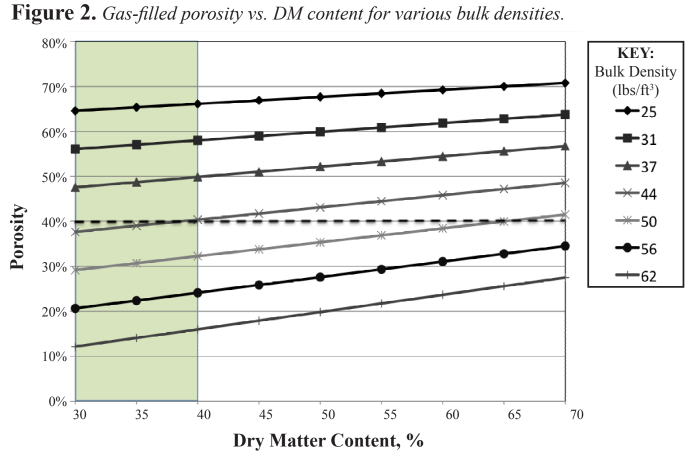


Figure 2. *Gas-filled porosity vs. DM content for various bulk densities.*



recommended as a reasonably attainable density for a bunker or pile silo. At a 30% DM content, silage packed to 15 lbs DM/ft^3 has 35 lbs of water/ft^3, leaving approximately 30% of the cubic foot as gas-filled porosity. At a 40% DM content, silage packed to 15 lbs DM/ft^3 has only 22.5 lbs of water/ft^3. Gas-filled porosity increases to almost 50%, and oxygen movement into the 40% DM silage is 67% faster than into the 30% DM silage in this example. Figure 1 shows how gas-filled porosity changes with DM content and DM density over a wide variety of conditions. Thus with drier silages, packing to only 15 lbs DM/ft^3 leads to a more porous silage that is more prone to spoilage and heating.

Working with an equation relating gas-filled porosity to the density of organic matter, ash, and water in packed silage, researchers found porosity is most influenced by bulk or as-fed density (Figure 2). Notice the porosity for a given bulk density does not change much over a wide range of DM contents. Thus, if packing to a target bulk density, porosity is fairly similar whether packing at an ideal DM content for a bunker (i.e., 35% DM) or packing an overly dry hay crop silage. A side benefit to packing to a target bulk density is the ease of estimating silage density on the fly during filling based on the wet weight put in the silo and the volume filled.

From Figure 2, a minimum bulk density of 44 lbs/ft^3 keeps gas-filled porosity below 40% at recommended DM contents for bunker and pile silos. This is a reasonably similar density to the minimum 15 lbs DM/ft^3 at recommended ensiling DM contents for bunkers and piles, but achieving 44 lbs as-fed/ft^3 calls for much greater packing measures when the crop is drier than recommended.

How to achieve a minimum recommended bulk density of 44 lbs/ft^3. Density is primarily a function of the packing practices used in filling bunker or pile silos. The main factors are the number and weight of packing tractors, packing time, layer thickness, crop DM content and height of the bunker or pile. Resources for estimating silage densities based on individual conditions and packing practices are the Bunker Silo Density Calculator and the Silage Pile Density Calculator. These are Excel spreadsheets available from the UW Team Forage Harvesting and Storage website (http://www.uwex.edu/ces/crops/uwforage/storage.htm).