‘Shrink’ in Corn Silage Piles. What are the Real Losses?

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Abstract

Silage shrink, or losses of weight between ensiling and feedout, represent a loss of nutrients to the dairy producer, as well as the potential to degrade air quality if that loss is volatile carbon compounds, or to degrade water quality due to weepage to surface water – or seepage to subsurface aquifers. Thus numerous Federal and State agencies are concerned about defining and minimizing silage shrink, even though virtually no research has documented the extent of silage shrink in large commercial silos or documented impacts of the mitigations designed (in some cases required) to minimize it, especially in the silage piles commonly used in the Southwest USA. Indeed the term ‘shrink’ is generally undefined, and can be expressed as loses of wet weight (WW), oven dry weight (oDM), and oDM corrected for volatiles lost in the oven (vcoDM) weight, which can all be expressed with or without wastage (i.e., silage recovered but not fed). Using 8 corn silage piles (2 rollover, 1 bunker, 5 wedge) ranging in size from 1052 to 13470 tons (as built), on concrete (5), dirt (2) and a combination base (1), on 4 dairy farms, in 2 areas of the San Joaquin Valley, all covered within 48 h by professional crews with an oxygen barrier inner film and black/white outer plastic weighted with tire chains, fed out by professional crews using a silage tracking system, and from the 2013 crop year; total shrink losses as well as the phase of the process where those losses occurred were measured. Total WW, oDM and vcoDM losses (not including wastage) were 8.4 +/- 1.59, 6.8 +/- 1.82 and 2.8 +/- 2.08 %, suggesting that much of what is measured as WW shrink is water and what is measured as oDM shrink contains a lot of volatiles driven off during oven drying. The largest part of shrink occurred in the silage mass prior to face exposure, with losses from the exposed face, as well as between face removal and the mixer, being small. Other (undefined) losses were quantitatively similar to losses in the mass. These losses could be evaporation of water during pile building, plant respiration of CO_2 prior to pile covering, small losses of fresh chop and silage during transit to and from the pile, as well as weepage and seepage. While the number of piles were insufficient to examine many mitigations, pile bulk density, face management, rate of face use and face orientation did not have obvious impacts on shrink. The only factor which seemed to impact shrink was the average temperature during pile feedout (higher temperatures related to higher shrink losses), but mainly for WW shrink. Real shrink losses (i.e., vcoDM) of well managed corn silages piles are much lower than has been generally assumed, the exposed face is a small portion of those losses, and many of the proposed mitigations may not be effective in

reducing shrink, possibly because it is quantitatively so small in large well manged silage structures.

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Introduction

Corn silage has been an important silage crop for a very long time in America. And in today's America, of over 350 million people and a resulting high requirement for dairy products leading to large commercial dairy enterprises, corn silage is far and away the most important ensiled crop in virtually all US dairy areas. As in most aspects of life, where we want to receive all of whatever it is that we pay for, losses of corn silage post-harvest during the ensiling period represent an economic loss to the dairy industry. Generally referred to as 'shrink', although seldom clearly defined, it is the proportion of the fresh crop weight that is not recovered from the pile as feedable, or sometimes expressed as total, silage. Shrink can refer to wet weight (WW) recovery of silage or as oven dry weight (oDW) recovery. But, however you express it, shrink could be costly. For example, 10% WW shrink on a 15,000 ton corn silage pile represents a loss of $90,000 if WW corn silage is valued at $60/ton WW. In addition to an economic loss to a dairy farmer, shrink can represent a loss of carbon compounds to waterways as weepage from the pile, or to aquifers as seepage, or to the atmosphere as gases. As such, these silage loses have attracted the attention of various US regulatory agencies, especially water and air districts in California which are tasked with reducing environmental impacts of farming as a way to create cleaner water and air. These regulatory efforts have, in some cases, resulted in semi-mandatory mitigations to dairy farmers to reduce silage shrink; mitigations (based upon limited data of questionable relevance to large commercial silage piles), which may or may not actually reduce silage shrink which itself may or may not be a problem of a magnitude equal to that assumed by the regulatory agencies. As with many governmentally regulated areas in our society, nothing is simple.

Nevertheless reducing shrink is important. So what is an achievable corn silage shrink loss and what factors impact it? Shrink numbers in the commercial literature are commonly in the 5 to 20% range, and numerous management strategies have been suggested to reduce it. These include practices such as use of an inoculant at chopping, building piles on a concrete base, creating high pack density at silage pile building, use of a plastic cover, rapid covering of the mass with that plastic cover, use of an inner plastic film, use of an inner film with enhanced oxygen barrier characteristics, use of weights on the plastic, sealing the periphery of the pile with dirt or weights, minimizing exposed face at feedout, removing the maximum possible depth of silage at feedout, maintaining a 'smooth' silage face, using moveable weight lines along the cut surface of the plastic, only removing as much silage as is immediately needed, use of mechanical defacers, use of block cutter defacers, and leaving no overnight piles of loose silage. Quite an extensive list – some simple and some not so simple. The common feature of all of these potential mitigations is that they will increase dairy costs, while the telling feature of the combined list is that it would take a team of 20 scientists about 10 years to investigate the efficacy of each individually. Let's not consider the time and cost of investigating their efficacy if used concurrently. And that is the pickle – lots of costly suggested mitigations of silage shrink with no guarantee that any of them are cost effective – in fact there is little evidence for many that they are efficacious in reducing shrink at all. Thus, in general, common silage-sense and experience are the bulk of what dairy farmers have to go on. Not a great situation, especially when it is recognized that the actual extent of the base 'problem' that the mitigations are designed to address - that silage shrink is substantive economically and environmentally – has little or no supporting data in real world corn silage piles.

Defining 'Shrink'

Shrink losses of corn silage can be defined in many ways. However the most common definition is the proportion of the WW fresh crop which is packed into a silo structure (including a pile) and is later placed into a TMR mixer. Under this definition, spoilage which is removed by hand (in most cases) and disposed of by land application or feeding to heifers counts as shrink. However shrink as defined by air and water boards typically includes wastage since this material is actually recovered (and not 'lost'). The interpretive limitation of WW shrink is that much of it will be water, which has no substantive economic or environmental impact. Thus some dairy producers and regulatory boards also measure shrink on an oDM basis.

To convert WW shrink to oDW shrink it is necessary to collect many samples of fresh cut crop at ensiling, as well as collect many samples of the silage that is put into the TMR mixer. This is a time consuming chore which involves collecting and pooling many samples over the period of silo structure building, as well as many samples over the often long feedout period, in order to create pooled samples representative of the crop ensiled and of the silage fed out. Both of these tasks are prone to poor practices and creation of samples which are not representative of the fresh cut crop ensiled and/or the silage placed into the TMR mixer. While these issues can be dealt with by using defined sample collection protocols, a serious structural issue is that this oDW shrink estimation procedure will <u>always</u> overestimate real DW shrink by adding volatile carbon compounds lost during oven drying to the shrink estimate.

The base problem with oDW shrink is that drying fresh chopped corn crop in an oven will almost exclusively drive off water, since very few volatile carbon compounds are in a fresh chop corn crop, but drying corn silage in an oven will drive off volatile carbon compounds, most of which will actually be fed to the cows, as well as water. Examples of volatile carbon compounds commonly found in corn silage include the volatile fatty acids (VFA) acetic, propionic and butyric, the alcohols ethanol, 1,2 propanediol and 2,3 propanediol, as well as a host of minor volatile carbon compounds. Even lactic acid, always found in corn silage, will be lost to some extent during oven drying – and the 'oven volatility' of all of these compounds differs, and also differs within compound in the range of normal oven drying temperatures. As a group, potentially volatile compounds in corn silage typically make up 2 to 5% of the fresh weight and, depending upon their proportions in the silage, up to 60% of them could be lost during oven drying. Thus 'oDW shrink', where the DW is determined by oven drying, could overestimate actual DW shrink (i.e., volatile corrected DM shrink; vcoDM Shrink) by up to 5 % units. In other words, an oDW shrink of 10% might only be ~5% when corrected for the volatiles lost during oven drying.

Silage Sources (Areas) of 'Srink'

Shrink losses of corn silage originate from many facets of the ensiling process such as during pile building after the fresh chop material is weighed but prior to plastic covering, from the mass while it is ensiled, from the silo 'face' at (or near) its exposure to air, during the defacing operation, after silage has been defaced but before it is moved to the TMR mixer and, finally, during transport to the TMR mixer – which is typically where the amount of fed out silage is measured.

Losses During Pile Building. Once the fresh chop corn crop is weighed in the trucks, small quantities of it could be lost on the way to the pile due to wind, or simply by falling off the trucks. However this is unlikely to be substantial during the life of a pile building operation. A more likely loss of weight is evaporation of moisture (water) from the fresh chop material once it is placed on the pile since, typically, piles are built on pleasant sunny days when solar radiation levels are high. Of course such losses will impact WW shrink to a much greater extent than oDW shrink since there is little opportunity for non-water compounds to evaporate because their levels in a freshly chopped corn crop are very low. Another likely source of oDM shrink is from plant respiration because the plants are not really dead when they are delivered to the pile. Until the plants are fully dead, due to creation of an acidic environment and/or heat and/or they run out of sugars in their biomass, the plants will continue to be metabolically active and, once they are no longer in the sun and photosynthesizing, they will utilize stored sugars to meet their energy requirements which will result in creation of CO_2 which will largely be released to the atmosphere. Such CO_2 losses would be measured as WW, oDW and vcoDW shrink since the carbon atoms are coming from metabolized sugars. Unlike water losses, carbon losses as CO_2 impact the total nutritional value of the silage pile, but would have no air quality impact in most regulated air districts at this time (i.e., CO_2 is a greenhouse gas (GHG), but not a volatile carbon compound which impacts air quality).

Losses From the Silage Mass. Once the fresh chop corn crop is packed and covered it will go through a fermentation cycle which starts with aerobic bacteria (which create heat) and finishes with anaerobic bacteria, which create the alcohols and acids, primarily lactic, acetic and propionic, which drives down the pH to create a 'stable' silage mass. This silage mass, if protected from oxygen penetration, should be unchanging for prolonged periods of time. However it is possible that due to the long period of ensiling, >12 months in some cases, and low level penetration of oxygen through and around the plastic cover (as well as into the face once it is exposed) that some losses of gases, and vaporized water, could occur. Indeed as most silage piles have the plastic peeled back up to 8 feet from the exposed face, evaporative losses of water and volatilization of carbon based compounds (i.e., the surface dries out) could occur from the exposed silage area. Of course if this exposed material is rained on, the losses could turn into weight gains, but only as WW. A silage weight loss which could be negligible or substantive is weepage and seepage of low DM fluid from the silage mass. The extent of this loss will be impacted by the moisture content of the fresh cut crop as well as its pack density which, logically, will be positively correlated (i.e., it is hard to obtain high pack density of a low moisture crop no matter how much packing pressure is applied).

Losses from the Silage 'Face' at (or near) its Exposure to Air. This is an area of high interest from regulatory agencies as it seems intuitive that losses of silage weight occur from silo face areas once they are exposed to air. Such losses could be water, but there must be losses of some alcohols and volatile acids since such compounds are easily detected by simply smelling a freshly exposed corn silage face. Such losses would likely be impacted by factors such as the orientation of the exposed face (south faces in the northern hemisphere having higher losses than north faces due to their being sun exposed), temperature and relative humidity during face exposure (higher temperatures being associated with higher losses), smoothness of the exposed face (rough surfaces creating more real surface area to emit volatiles than smooth surfaces), wind (the higher the wind speed over the face the higher the losses) and perhaps time of exposure of the face (emissions/unit area declining with time of exposure).

Losses from Silage During Defacing. In all silage face removal systems there are likely to be losses of water and volatiles as the silage collapses into a pile after defacing. Such losses would likely be impacted by the violence of the defacing process. For example mechanical rotating defacers are relatively violent, front end loader buckets intermediate and block cutters relatively benignly violent silage removal methods. A greater extent of silage disturbance during defacing could increase immediate losses of volatiles and water, as well as create the potential for higher losses of volatiles and water while it is in the 'drop down pile' awaiting transport to the TMR mixer.

Losses from Silage After Defacing. In all systems where silage is left on the ground for a period of time between defacing and being placed in a TMR mixer (i.e., in the drop down pile), there are likely to be losses of water and volatiles as the silage waits for removal and loading into a

TMR mixer. Such losses would likely be impacted by the length of the delay between defacing and placement in the TMR mixer (for example overnight delays might be expected to maximize losses), the size of the drop down pile (larger piles emitting less per unit weight) as well as the environmental conditions during that wait, as were discussed earlier for losses from the face. Weight 'losses' during this period could even be small weight gains for silage structures on dirt bases if some dirt is picked up by the loader operator with the silage.

Losses of Silage During Transport to the TMR Mixer. Such losses include silage which is never picked up from the ground or falls off the load while it is being transported to the TMR mixer. However it could also result in a weight gain for silage piles on dirt bases if some of that dirt is picked up with the silage. In total, these losses are unlikely to be substantial.

Overall, there are a number or areas of the ensiling process where silage weight, as fresh or dry material, can be lost (or gained in a few cases) between the time that the fresh material is weighed into the pile until the silage is weighed into a TMR mixer. But we had questions. The first questions addressed the issue of the extent of corn silage shrink as WW, oDW and vcoDW, because that focuses on the extent of the silage shrink 'problem' from the perspectives of dairy farm economics as well as potential impacts on air and water quality. The second questions addressed the issue of where in the entire process (as outlined above) shrink is occurring because that suggests where mitigations should be focused to reduce it. Finally, the third questions addressed the issue of which ensiling practices and characteristics exacerbate or mitigate shrink, and where that mitigation occurs in the entire ensiling process, because that suggests where mitigations would likely be more or less efficacious in terms of reducing shrink.

First Questions: Measuring Total Silage 'Shrink' Losses

Silage piles can be very large – 15,000 ton piles are not uncommon – and can be fed out over periods in excess of 12 months. This makes measuring shrink a challenging task, and identification of where that shrink occurs even more challenging. While it is not difficult to measure shrink in mini- or model silos of a few pounds to a few hundred pounds, it is unlikely that such models can be expected to fully represent a 10,000 ton silage pile. However total shrink losses in commercial silage piles can be measured by recording the total WW of fresh cut corn crop delivered to a silage pile at building relative to the amount of WW corn silage measured as being placed into the TMR mixer at feed out. We used 8 corn silage piles (2 rollover, 1 bunker, 5 wedge) ranging in size from 1052 to 13470 tons (as built), on concrete (5), dirt (2) and a combination base (1), on 4 dairy farms, in 2 areas of the San Joaquin Valley, all covered within 48 h by professional crews with an oxygen barrier inner film and black/white outer plastic weighted with tire chains and fed out by professional crews using a silage tracking system, and all from the 2013 crop year. On these 8 piles, average WW shrink losses (i.e., where silage recovered, but not fed, is not classified as shrink) were 8.4 +/- 1.59 %, a number within the range suggested by many persons working on silage issues.

Conversion of WW loss calculations to oDW losses occurs by creating pooled samples of the incoming fresh cut corn crop and fed out corn silage which are both oven dried at 105^{o}C. These pooled samples are then assayed in both their 'as sampled' and 'oven dried' forms, and then arithmetically adding them back to recovered oDM the amount of volatile compounds lost during oven drying. Using this approach, oDW losses were 6.8 +/- 1.82 % (*n*=7) and vcoDM losses were 2.8 +/- 2.08 % (*n*=7), confirming that a lot of measured WW shrink is really water, and some of what is measured as oDM shrink is actually volatile compounds driven off in the drying oven.

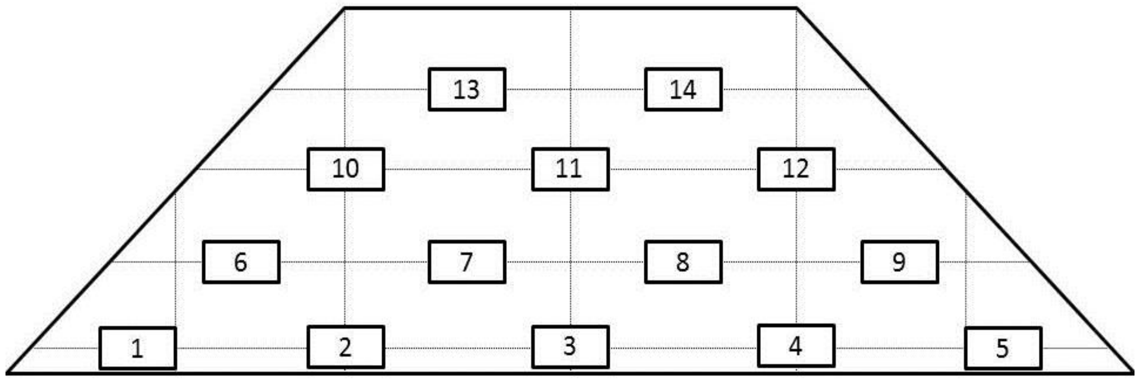
Second Question: Measuring Where Silage 'Shrink' Losses Occur

While it is critical to know total shrink losses for silage piles, as this effects environmental impacts and farm economics, it is as interesting to know where, in the entire silage creation and feedout process, which those losses occur since this suggests where mitigation efforts should be directed.

Losses From the Silage Mass. Once the fresh chop corn crop is packed and plastic covered it goes through a fermentation process that starts with aerobic bacteria (which create heat) and finishes with anaerobic bacteria. The anaerobes are the bacteria which create the alcohols and acids, mainly lactic, acetic and propionic, which drive down the pH to create a 'stable' silage mass. If protected from oxygen penetration, this mass should be relatively unchanging for prolonged periods of time. The extent of this loss was measured by burying Dacron mesh bags of fresh crop in the pile at filling and recovering them from the face at silage removal (Figure 1). We utilized a grid of 14 bags (Figure 2) in each of 4 corn silage piles. Data from these bags suggests that the WW, oDW and vcoDW losses from the mass were 3.9 +/- 2.40, 7.2 +/- 1.12 and 3.5 +/- 1.27 %, respectively. As with total pile shrink losses, as noted above, a lot of what is measured as oDM shrink actually contains a lot of volatile compounds driven off in the drying oven, and not actually lost from the pile.

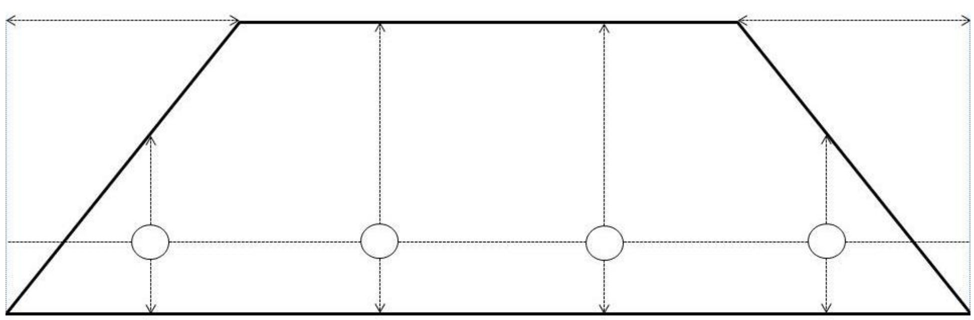
Figure 1. Buried bags prior to burying and after recovery.

Figure 2. The 14 Buried Bag Grid



Losses from the Silage 'Face' at (or near) its Exposure to Air. This is an area of interest to regulatory agencies as it seems intuitive that losses of silage weight will occur as volatile compounds and water are lost from silo faces once they are exposed to air. The extent of this loss was measured by coring each silage pile on two occasions in a 4 core grid (Figure 3), to 20 inches of depth from a freshly exposed face (new face) and from a face exposed for ~20 h (old face) at ~5 ft above grade. WW, oDW and vcoDW losses from the face were 1.3 +/- 1.16, -0.6 +/- 1.55 and 0.1 +/- 1.40 % respectively. Although these values are very low overall, they confirm suggestions that most of the weight loss from the face is water.

Figure 3. The 4 Location Face Coring Grid (samples cored to 20 in depth 5 feet above grade).



Losses from Silage During and After Defacing. In all silage face removal systems there are likely to be losses of water and volatiles as the silage collapses into a pile after defacing, and while it awaits transport to the TMR mixer. The extent of this loss can be estimated by comparing the composition of the silage in the 'new face' with the composition of the silage in the drop down pile that is loaded into the TMR mixer. These WW, oDW and vcoDW losses from the drop down piles were 0.9 +/- 0.54, -0.6 +/- 2.27 and -1.5 +/- 2.17 respectively.

Other Losses. Such losses include fresh chop crop which is weighed but never makes it to the pile, evaporative losses from the pile surface during building, continued plant respiration in the pile as

CO_2, weepage and seepage, and silage which is never picked up from the ground or falls off the loader in transport to the TMR mixer. Unaccounted losses (i.e., those calculated by difference) for WW, oDW and vcoDW were 4.6 +/- 2.50, 2.7 +/- 1.57 and 2.6 +/- 1.66.

In general, shrink losses are highest when measured as WW, intermediate as oDM losses and lowest as vcoDM losses, are measureable from most phases of the ensiling process, and occur at relatively low levels. However percentage losses from the face are, quantitatively, far from the most important shrink losses, which are summarized in Figure 4 below.

Total losses are not the sum of individual losses since the bars represent different numbers of piles (i.e., n= 4-8/bar)

Third Question: Factors Impacting Silage 'Shrink' Losses

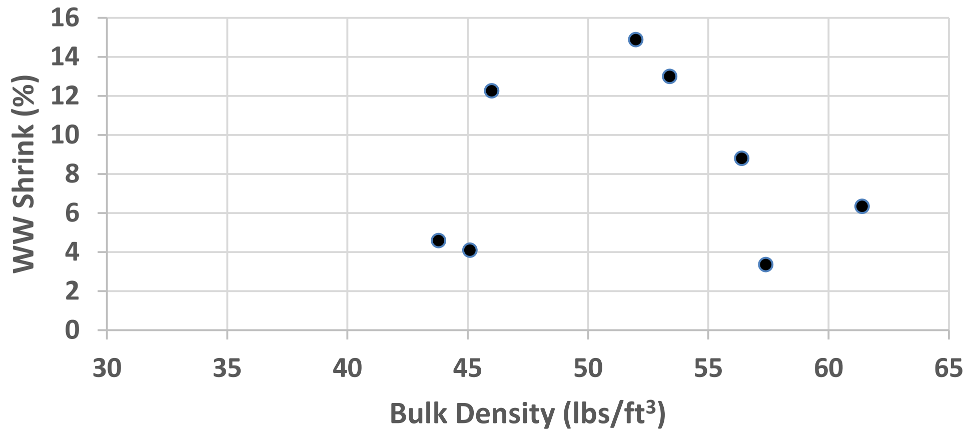
As already discussed, there are numerous factors which could impact total shrink losses from corn silage piles. In fact many of these factors can be controlled (i.e., they are chosen) by the operator, at least to some degree. For example, pile orientation (S, N, E, W) and its base (dirt or concrete), use of a thin underlay film with or without enhanced oxygen barrier characteristics, chop length of the crop, use rate (i.e., inches/day) of the pile and face management can be virtually fully controlled. However factors such as the moisture level of the crop, pack density and environmental conditions during feedout can only be partially controlled (or anticipated) by the operator.

With only 8 silage piles, where each pile differed from all other piles in many ways, while being the same in many ways, it is difficult to assess the efficacy of individual mitigations. For example as all piles had an oxygen barrier underlay, were harvested and packed by professional crews, were rapidly covered (within 48 h) with an inner oxygen barrier film and black/white outer plastic, were weighted with tire chains, and were opened and fed out by professional crews, none of these ensiling practices can be evaluated. However some practices can, although the data requires care in interpretation.

The relationships (below) are shown as WW shrink since they are quantitatively higher than oDW and vcoDW shrink and thus more likely to show impacts of practices/mitigations.

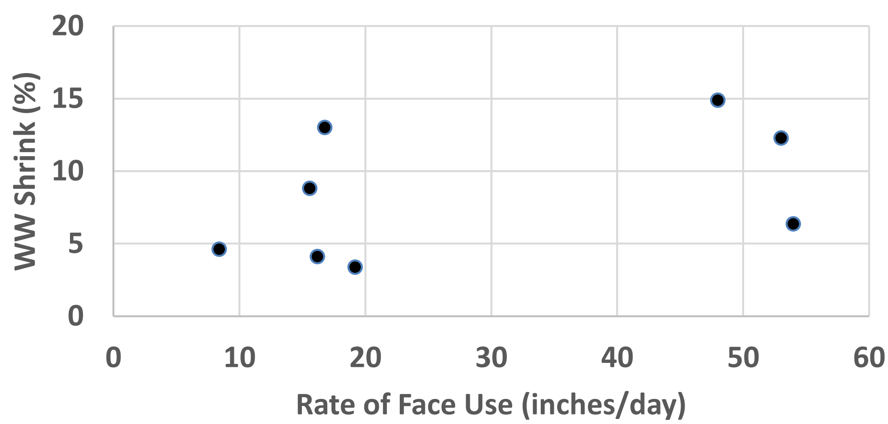
Shrink Losses and Silage Density. This is an area of interest to regulatory agencies as it seems intuitive that losses of silage weight would be reduced if the silage was packed more densely. However in our corn silage piles there was no apparent relationship of bulk density and WW shrink (Figure 5).

Figure 5.

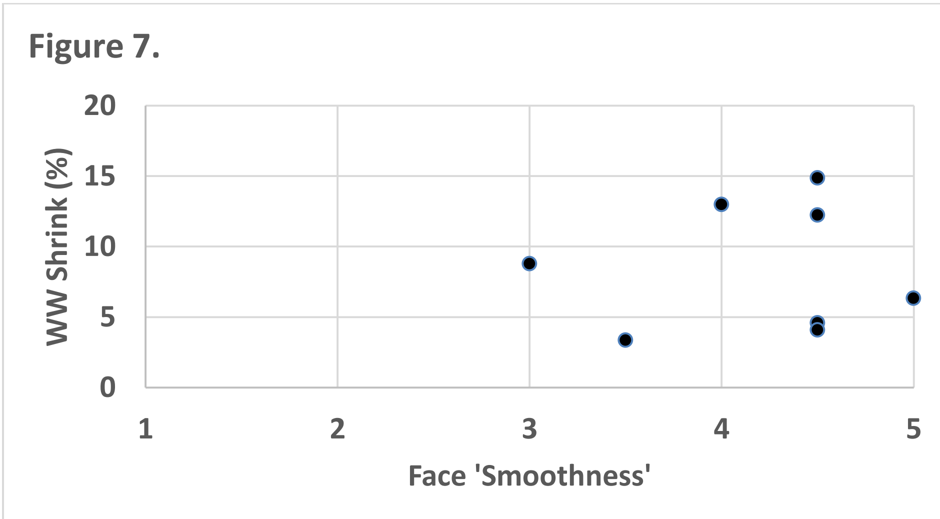


Shrink Losses and Speed of Face Use. This is also an area of interest from regulatory agencies as it also seems intuitive that losses of silage weight would be reduced if the silage was fed out more quickly. However in our piles there was no apparent relationship between the speed of feedout and WW shrink (Figure 6), possibly because face losses were very low overall.

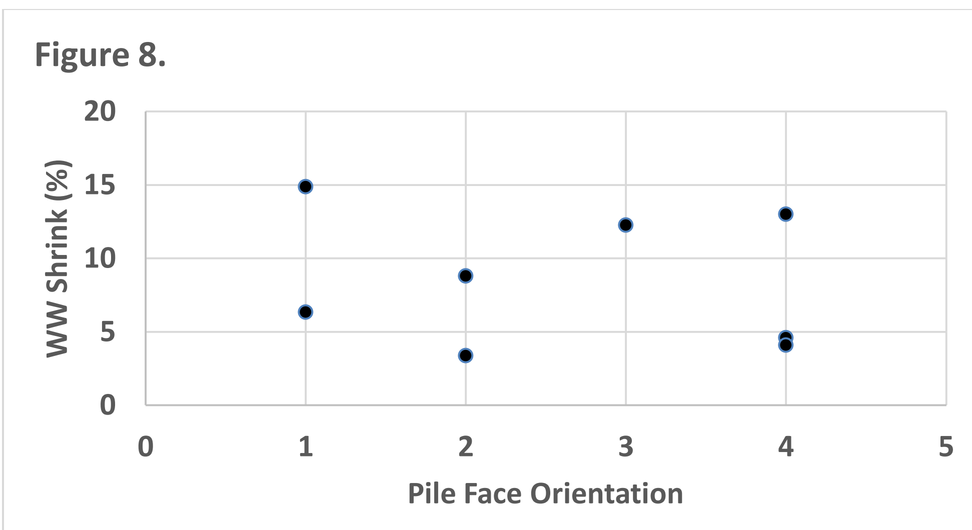
Figure 6.



Shrink Losses and 'Smoothness' of the Face. This is also an area of interest to regulatory agencies as it seems sensible that losses of silage would be reduced if the silage face was left 'smooth' at the end of the day. To assess this possibility, faces were scored subjectively on a scale of 1 (really rough) to 5 (really smooth). In our piles, there was no relationship of face 'smoothness' and WW shrink (Figure 7).

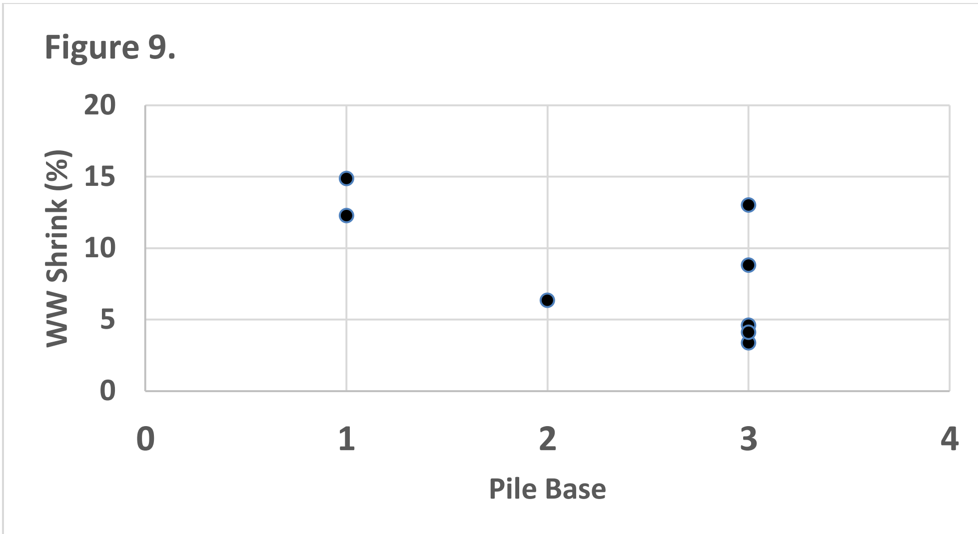


Shrink Losses and Face Orientation. This is a practice which could, at least theoretically, be changed on-farm – certainly on the long term. However in our piles there was no relationship of pile face orientation and WW shrink (Figure 8; *1=W, 2=E, 3=S, 4=N*).

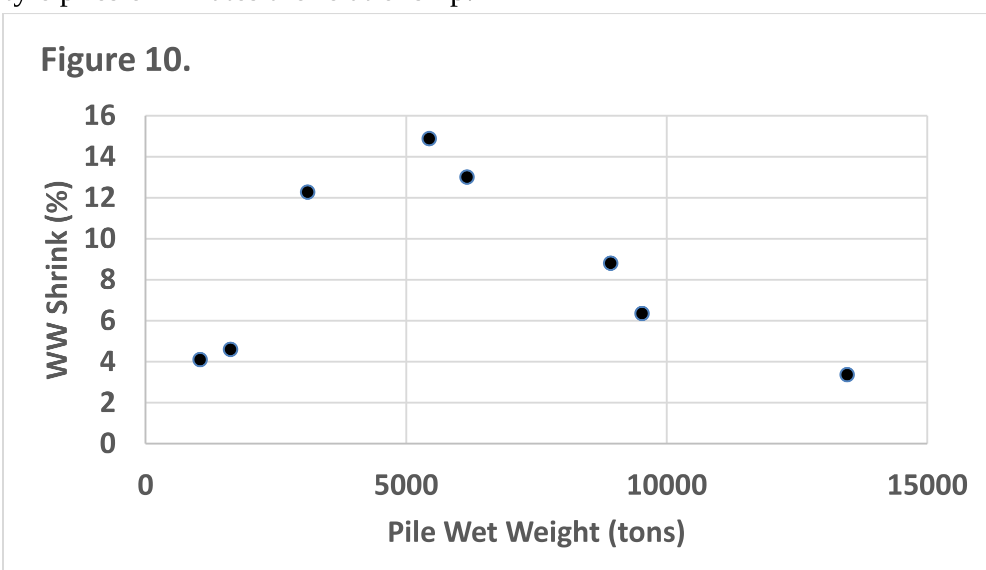


Shrink Losses and Pile base, and Style of Pile. Pile base (i.e., concrete *vs.* dirt) is a practice which could, also theoretically, be changed on-farm, and it seems sensible that a concrete base would reduce leaching losses. In our piles there seemed to be a relationship of pile base and WW shrink

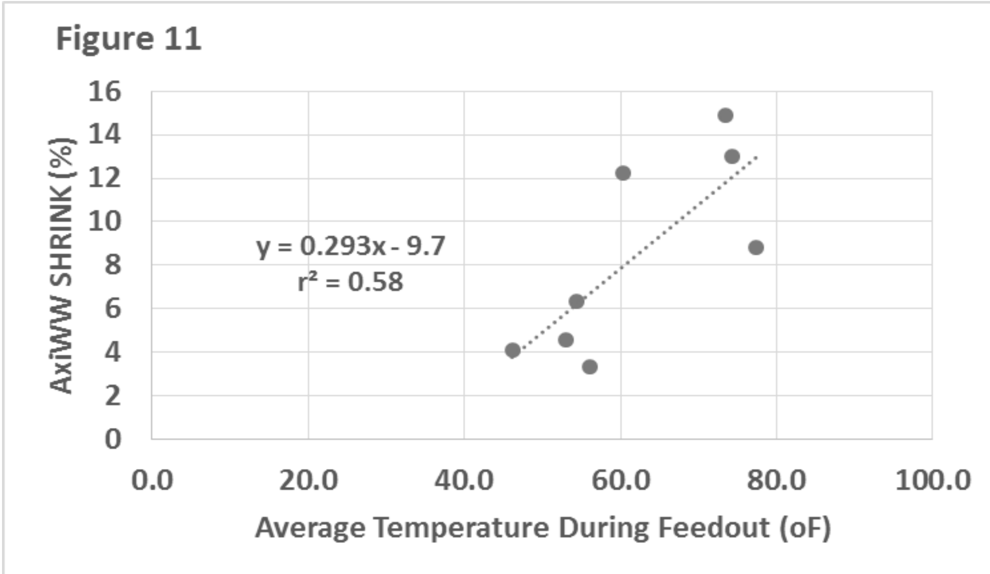
(Figure 9; 1=Dirt, 2=50/50, 3=Concrete). However this interpretation is muddled since both of the dirt base piles were rollover piles and the 50/50 base was a pit with a concrete bottom and dirt sides.



Shrink Losses and Pile Size. Pile size is also a practice which could be changed on-farm. In our piles there was a clear curvilinear relationship of pile size and WW shrink (Figure 10). However this interpretation is also muddled since both of the rollover piles were of intermediate size. Using only the wedge style piles eliminates the relationship.



Shrink Losses and Ambient Temperature at Feedout. Environmental conditions during feedout are certainly not conditions within the control of producers, but it is clear that higher temperatures during feedout did increase shrink losses (Figure 11). Finally something which seems sensible which actually occurred!



Shrink Losses and Chemical Composition of the Fresh Chop Corn Crop. The fresh chop was analyzed for its moisture content (i.e., oDM) as well as the level of neutral and acid detergent fiber, ash, fat and crude protein in the oDM. There were no meaningful relationships (i.e., r^2 <0.15) of these components to WW shrink.

The failure to identify mitigations or practices associated with reduced silage shrink is discouraging as it could be interpreted to suggest that silage shrink is random. This is unlikely to be the case. The more likely explanation is that with only 8 piles, albeit representing an amount of effort that the senior author does not ever wish to expend again on a single project, it is still a very very small data set to examine practices associated with reduced shrink, especially when the number of defined practices that differed among piles, and might be expected to impact shrink losses, is more than the number of piles examined. Obviously the possibility of inter-correlations is high, which could lead to concluding that a mitigation is efficacious when it is not, but is related to a mitigation that is effective.

However another reason for the failure to identify practices that reduce silage shrink may simply be a combination of the variability in the methods which were deployed to examine shrink in large commercial silage piles combined with the relatively small values for shrink, especially vcoDM shrink, compared to expectations at the start of the study. With total shrink in the 3 to 8% range it would likely have required at least 30 piles to create meaningful relationships of silage shrink and practices/mitigations that may have impacted it. There are clearly limits to what can be done in a study such as this one where the piles, albeit carefully selected to be representative and well managed, exhibit a host of differences in factors that may impact silage shrink and, perhaps critically, very low levels of shrink no matter how shrink is expressed.

Conclusions

The extent of silage shrink has been greatly overestimated in large well managed commercial corn silage piles, likely due to incorrect assumptions and inappropriate research models to measure it. However the most important reason may have been due to the failure to measure real shrink (i.e., vcoDM) in favor of WW shrink which is exaggerated due to losses of water, or oDM shrink which classes volatile compounds which are actually in the silage, but lost during oven drying, as being a part of shrink. When the correct measure of silage shrink is used (i.e., vcoDM), total shrink averaged less than 3% in our commercial corn silage piles. Within the context of these low vcoDM losses overall, losses from the face and after defacing were trivial contributors to shrink in contrast to losses while the silage was in the mass prior to face exposure and from unmeasured losses such as weepage, seepage and material which fell off trucks and loaders. While the number of silage piles that we used were too small (relative to the number of definable differences between them) to allow examination of many practices commonly used to minimize shrink (and because many piles had similar characteristics by design), the commonly suggested mitigations of increasing bulk density, increasing face feedout rate and maintaining a 'smooth' face had no discernable impact on total shrink losses, probably because these mitigations are all designed to reduce losses from the exposed face which was a trivial contributor to overall shrink. Only the average ambient temperature during feedout impacted shrink, with warmer temperatures during feedout being associated with higher shrink, but mainly for WW.

While corn silage shrink exists, and can be costly to dairy producers and impactful to air and water quality, the extent of shrink in large well managed corn silage piles is low and the ability to mitigate shrink seems, unfortunately, to be very low due to our inability to find support for several commonly accepted mitigations. However dairy producers should continue to use good silage practices (i.e., common sense) in creating corn silage piles, but recognize that silage shrink is likely only to become excessive under extreme conditions.

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