A Literature Review on Corn Silage Management

A Senior Project

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Bachelor of Science

by

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Abstract

There are many different ensiling methods, each having positive and negative aspects to them. The aim of ensiling corn is for the corn to go under a proper fermentation process, free of oxygen and other environmental stressors. The objective of this literature review is to determine the most ideal method of corn silage management from the time the corn is chopped, until the cow consumes it in the total mixed ration (TMR).

The literature review was conducted by analyzing more than thirty articles covering silage management and the effects it has on the corn silage quality and productivity of the cow. The higher density corn silage has (lbs. per cubic foot) when packed, increases the possibility of anaerobic fermentation throughout the pile. Packing silage densely and sealing it properly are key contributors to managing corn silage allowing for anaerobic fermentation. Aerobically unstable silage is detrimental to the corn reducing the amount of beneficial nutrients and increasing the amount of toxins that can potentially spread throughout the pile. Aerobically unstable silage has develops molds that have harmful effects on cows, which directly affects health of the cow and dry matter intake (DMI), and indirectly decreases milk production. Silage that is managed properly can decrease unnecessary losses from shrink and milk production, eliminating the risk of the cost of a ration increasing.
The greater the packing density and less exposure to oxygen has shown to decrease the amount of corn silage loss due to shrink. Ruppel et al. (1992) showed a corn silage with a greater density could cut the dry matter losses from shrink in half. Oelberg et al. (2006) showed a difference of the value of corn silage per acre up to $38.60 based on corn silage prices of $20 per ton. In a study conducted by Dickerson et al. (1992) dry matter recovery comparing covered and uncovered silage can have a difference of 70% recovery and noticeably higher quality silage. This literature review will analyze the proper techniques of silage management, determining how to create the most profitable silage possible.
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I. Introduction

Corn silage is a large component of rations fed to milk cows on dairy farms across the United States (Stone, 2010). Although corn silage is nutritionally beneficial, it can also be nutritionally detrimental if it is managed incorrectly.

Corn silage is produced from chopping and harvesting corn, putting the corn in a silo (enclosed area where forages are preserved for fermentation), ensiling the corn, and feeding the corn post fermentation. Ensiling corn is a method of preservation for moist corn, based on anaerobic fermentation, whereby water-soluble carbohydrates are converted into organic acids (mainly lactic acid), by epiphytic lactic acid bacteria (Chen and Weinberg, 2009). The purpose of ensiling corn is to create a stable environment so corn can properly undergo the fermentation process. Using proper methods to manage corn silage is key to a good fermentation and high-quality silage. High-quality silage must first start by using the correct hybrid of corn (which is determined by digestibility, yield, and other attributes), chopping it at the correct moisture level, and chopping it at the correct particle size. Once the corn is chopped is must be packed into a silo and covered to reduce oxygen exposure, enhancing the fermentation process. The greater pack the silage has in the silo increases the density and the better the corn is covered, decreases the exposure to oxygen due to its inability to penetrate into the corn and the silo.
Research on dairy farms has proven that silage that is exposed to oxygen can become aerobically unstable (Oelberg et al., 2006). Aerobically unstable silage can cause many different losses because of the molds and yeasts continue to grow and deplete the silage quality and availability due to the toxic substances they carry. Molds can cause many different problems to the silage because it ruins the quality, causing it to lose value, but it impacts cows the most due to lack of digestible nutrients and the toxicity the molds carry (Woolford 1990). Healthy cows that consume toxic molds will be affected, decreasing their health and profitability for the dairy farm (Driehuis and Oude Elferink, 2000).

Silage can be managed to reduce the bacteria growth, whereby saving the dairy producer money from silage shrink (loss of silage from aerobically unstable silage and environment reasons) as well as from the negative effects it has on the cow. It has been shown that high quality silage derives from proper management techniques and low quality silage derives from poor management techniques (Oelberg et al., 2006).

The objective of this literature review is to evaluate managing strategies of corn silage, by showing the difference of poor quality silage and high quality silage and why they are impacted.

II. Types of Forages and Ensiling

Across the United States there are many different forages that are ensiled for the feeding of dairy cows. Corn, wheat, sorghum, grass, milo, and hay (haylage) are among the main forages used for ensiling on dairy farms.
Central California has an advantage on other states across the nation, with the ability to grow more forage throughout the year. Due to weather restraints, other states (such as the northeast) can only grow one forage in a field per year, where as central California can double crop or even triple crop each field all year round. Corn is ensiled across the nation and is a large part of dairy rations in the western United States (Kezar, 2001).

There are many different types of silos and ways of ensiling. Over the past decades as dairy farms become larger, there have been immense changes in the style of ensiling (Harrison, 2001). The different styles of silage include: vertical silo, horizontal silo (which include drive-over, bunker, and conventional), and bag silage. There are pros and cons of every different type of silos as shown in Table 1.

*Table 1 (Modified from Kung.)*

<table>
<thead>
<tr>
<th>Silo Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Vertical Silo | • Utilizes minimum area  
               • Ability to fill and pack quickly with minimal labor  
               • Low feeding and storage losses if silage is harvested at optimum DM  
               • Low labor required for feeding | • Moderately high capital output for silo  
               • Fixed location for silage |
| Bunker     | • Large storage capacity  
               • Moderately low capital output | • High storage losses  
               • Moderately high labor requirement |
Vertical silos are becoming less and less popular as dairies have been becoming larger and drive-over piles are much more prevalent due to their ability to hold more silage. A drive-over pile is a type of bunker pile that has the ability to be packed and driven over in every direction. When building a dairy a decision must be made of which type of silo will maximize the opportunity for high quality silage in order to prepare a location for the silage to be placed. One should decide the most efficient way to store the silage, yet still reduce the shrink of silage and make it as nutritionally beneficial as possible.

### III. Corn Selection and Processing

#### a. Types of Corn

Deciding on a specific hybrid of corn in order to plant with the purpose of being made into silage, can often be overlooked, yet can be either beneficial or detrimental to the nutritional value of the future silage. Quality silage from the proper hybrid of corn has a large impact on dairies, with prominence of having the ability to greatly impact dry matter intake (DMI) and milk
production. There are many different options and character traits available in the process of selecting the proper hybrid. Corn silage hybrids vary in various attributes important for silage production including yield, digestibility, grain to stover ratio, pest resistance, etc. (Adesogan, 2009). All of these are very important, but when deciding on one specific hybrid one should attempt to use the hybrid that is most profitable. Prices for different hybrids have a large range of pricing. Corn hybrids can cost $15 per acre; where as others such as brown midrib (BMR) corn can be priced at over $90 per acre (Roth et al., 2001).

Typically, purchasers of corn hybrids are searching for hybrids that specifically produce high yields and have high-energy digestibility traits. Depending on different areas of the country yields can greatly differ. Specifically in the San Joaquin Valley in California, corn that yields 30 tons per acre is considered to be a good yield and corn that yields 40 tons per acre is considered phenomenal, assuming dry matter is between 32%-36%. Due to irrigation, the corn plants typically have a greater abundance of water availability because of the ability to irrigate; where as other parts of the country rely on rainfall and have lower yields.

Often, hybrids with traits of low fiber contents, high fiber digestibility, high starch content, high starch digestibility, and Neutral Detergent Fiber (NDF) digestibility are desirable (Adesogan, 2009). Neutral Detergent Fiber is an insoluble fiber in corn silage, and needs to be digested to promote microbial growth in the rumen, resulting in a healthier cow. A 1% increase in NDF digestibility has been associated with a 0.37 lb/day increase in dry matter intake (DMI) and a 0.55 lb/day increase in fat-corrected milk production by dairy cows (Oba and Allen, 1999). High starch content depends on
management, genetics, environment, grain to stover ratio, and proper maturity when the corn is chopped (Kezar, 2001; Ruppel et al. 1992). Both grain and stover digestibility have a huge role in the nutritional value of silage, but grain digestibility is much more important. On the average, grain is consistently 90 percent digestible while stover may differ in digestibility (Kezar, 2001). Hunt et al., (1993) tested two hybrids (Pioneer 3377 and Pioneer 3389) on steers with a five percent difference in digestibility (61.9% vs. 56.7%), showing that hybrids can make a difference on a ruminant. In all aspects of the nutritional components of corn silage, digestibility of each nutrient is the key to profitable corn silage.

**b. Stages of Corn**

When deciding on the correct time to harvest corn, the corn must be in the proper stage for optimum nutritional value. Once the corn ears begin to mature, the kernels start to develop milk sugars and then eventually convert those milk sugars to highly digestible starch (Kezar, 2001). As the kernels change into being comprised of more starch, the milk line (also known as the starch line) on the kernels becomes smaller (Kezar, 2001). The milk line refers to the obvious change of color between the milk stage of the kernel and the kernel developing a yellowish color. In order to check to see if the corn is ready, an ear of corn must be picked from at least ten rows into the field and broken in half in order to see the milk line. When the milk line is about 1/3 to 1/2 of the kernel it should be chopped and all chopping needs to be completed by the time the kernels have 2/3 milk line (Johnson et al., 2002). If the corn is chopped and processed at the proper time, it should be put into the silage about 30%-37% dry matter (Johnson et al., 2002).

If corn is harvested too early (milky), the corn will be too wet and could cause
effluent (run-off). If silage effluent should occur, a lot of nutrients could be lost. Research shows silage run-off typically contains 20% nitrogen compounds, 25% minerals, and 55% organic material, primarily in the form of organic acids (Kezar, 2001). This unnecessary loss in nutrient value is a lot of digestible material that needs to be consumed by the cow. When harvesting too early, the corn is still immature and the kernels are very milky, which can detrimental because poor fermentation in the silo can occur, increasing the risk of an aerobically unstable fermentation process (Seglar, 2003). If the corn is too mature when harvested, the kernels start to show a black layer. Kernels become black due to the starch becoming crystalline making it harder to be digested in the rumen (Kung). Also, if the silage is too mature then it is too dry making it harder to pack increasing the chance of silage becoming oxidized and mold growing on the pile.

c. Types of Chopping/Processing
The most important time for the silage is the day it gets processed. It is so valuable because so many different errors can occur as far as chopping, putting in the silo, packing, and covering. When chopping the corn silage, the correct tractor is necessary so the corn can be chopped correctly and to the right length (Hinen, 2006). The harvester must have sharp knives and it is recommended to have a chop length around 1/2” in order to break as many kernels as possible (Hinen, 2006). The ideal chop length is best when the cow is able to digest more, allowing for a healthy rumen, but still allows the silage to ferment by packing the pile better. If the chop length is too large, the kernels are not split, making them less digestible for the cow, instead passing through the cow’s rumen (Stone 2010).

A great procedure when deciding if the chop length is optimal is using the Penn
State Shaker Box. The Penn State Shaker Box is designed to separate corn by particle length in order to determine if the corn has been processed properly. The Penn State Shaker Box is a set of separating screens that assesses and provides information in order to decipher if the chop length is the desirable length. The screens help to determine particle length distribution of the corn silage. Table 2 represents how the silage should ideally be separated in the shaker box. Seglar (2003) modified the recommendations of the ideal lengths for corn to be processed.

<table>
<thead>
<tr>
<th>Screen</th>
<th>Pore size (mm)</th>
<th>Particle size (mm)</th>
<th>Corn Silage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper sieve</td>
<td>19.05</td>
<td>&gt; 19.05</td>
<td>3-8</td>
</tr>
<tr>
<td>Middle sieve</td>
<td>7.87</td>
<td>7.87-19.05</td>
<td>45-65</td>
</tr>
<tr>
<td>Lower sieve</td>
<td>1.27</td>
<td>1.52-7.87</td>
<td>30-40</td>
</tr>
<tr>
<td>Bottom pan</td>
<td></td>
<td>&lt; 1.52</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

Harvesting tractors now have rollers, which allows for a longer chop length, yet crack most of the kernels (Kezar, 2001). The corn goes through a kernel processor, making for the ideal chop length (Kezar, 2001). The optimal length for the rollers to be is at one millimeter. Processing silage has many advantages including: improved packing, improved digestibility, and a healthy rumen (Kezar, 2001). The disadvantage of processing the corn is that the harvesting costs are increased. Assuming all the kernels get cracked, 3/4" is the optimal length for the corn particles for the silage (Kezar, 2001). If the silage is too long there will be a loss of dry matter, but if it is too short it could potentially cause acidosis and a decrease in butterfat (McDonell and Kung, 2006). This
is caused because if there are a high percentage of finely chopped particles (50% or more smaller than 1/3”) then there will likely not be enough effective fiber (which stimulates rumination) in the feed ration, which can result in rumen health problems (Hinen, 2006). The Penn State Shaker Box measures the proper length of the corn silage and determines if the corn was processed correctly (Hinen, 2006).

**d. Silage Inoculants**

Silage inoculants are applied to the corn in the time period of when the corn is chopped and when it is put in silo and are intended to improve silage stability, as well as decreasing the amount of dry matter lost (Kezar, 2001). There are many inoculants that are backed by research and have been proven to improve silage quality, yet there are many other inoculants that are less expensive but have not been thoroughly tested and do not do anything to improve the silage. When purchasing a silage inoculant, the dairy producer must analyze the research data in order to see if the data is adequate.

An inoculant is a silage additive that is used to impact fermentation in order to produce the highest quality silage. There are many different types of inoculants such as, Lactobacillus plantarum, Enterococcus faecium, and Pediococcus acidilactici, that all act on the silage differently (McAllister and Hristov, 2000). One example is that Enterococcus species and Pediococcus species can tolerate higher dry matter conditions and can grow more rapidly than Lactobacillus species can (McAllister and Hristov, 2000). Rapid growth of Pediococcus species and Enterococcus species increases the rate of acid production in recently ensiled forage, and the rapid decline in pH facilitates the establishment of lactobacilli as predominant microorganisms in the fermentation process (McAllister and Hristov, 2000).
Although there could be bacterial species that could be the exact same, they can have a different strain (Lactobacillus plantarum and Lactobacillus acidophilus) making the same bacteria completely different (McAllister and Hristov, 2000). In this case, different results will occur and the fermentation process will be different having a much greater impact on the silage quality as well as the performance of the animal. This makes it very difficult to know which is the most optimal inoculant, especially in years past silages with the same bacteria look the same on paper. Different companies and organizations have made tests that sample and target for specific characteristics of inoculants such as controlling pathogens or improving aerobic stability.

Silage inoculants need to be chosen based on the future profitability it has to offer. If a dairy always has a problem with silage (whether temperature, pH levels, or quality), and silage management is not an issue, they should either begin purchasing inoculants or change the inoculants they are already using. The purchaser of the silage inoculant must realize that each company wants to sell their product and will give research for how each inoculant works to improve silage quality and increase animal performance. If a company did not put enough money into having enough research, most likely they have not put enough money into the best strain for your silage. Research that shows the response of the animal is generally the most reliable research, because in the end producers want a higher performance from their animals (McAllister and Hristov, 2000).

IV. Packing/Covering

In general packing the silage is the most important phase of silage management when trying to reach optimal silage quality and is becoming much more prominent among producers (Kezar, 2001). The entire purpose of packing silage is to reduce the
availability of oxygen before, during, and after the fermentation process (Muck and Holmes, 2000). Silage with more work and management put in during pack time will reduce expenses (by increases animal performance and decreasing shrink) for the rest of the year saving the dairy a lot of money (Oelberg et al., 2006). Although there are many factors that can affect well-packed silage, there are a few that impact the silage the greatest. These factors include: initial layer thickness, packing weight of the tractor, dry matter content, and packing time (Muck and Homes, 2000).

**a. Initial Layer**

The first important area of silage management when packing silage is putting in the initial layer of silage. It must be spread evenly on the ground (in the pile) with the intention of making the layer as thin as possible (Ruppel et al., 1995). Research has found that the ideal minimum depth of the initial layer should be around four inches (Muck and Homes, 2000). After the initial layer of silage is put in the pile, every layer after that is put on needs to be pushed and spread throughout the pile. The thinner that each layer is when it is pushed onto the pile, the better pack the silage potentially has (Muck and Holmes, 2000). An ideal goal to aim for is to have no greater than six inches thick put on the silage for each layer, so the silage is spread on a greater surface area (Muck and Holmes, 2000).

**b. Packing Density**

Packing Density is measured by pounds of silage per cubic foot. The greater the density the silage is, the less likely that it will have the ability to be oxidized (worsening silage quality and increasing silage molds), allowing for less dry matter loss. Table 3 shows dry matter loss after silage has been ensiled in bunker silos for 180 days based on
silage density. A greater silage density can be achieved by a better pack using heavy tractors that “push” the oxygen out of the pile, so the silage can become more compressed (Muck and Holmes, 2000).

Table 3. Modified from Ruppel et al. (1992)

<table>
<thead>
<tr>
<th>Density (lbs DM/ft³)</th>
<th>DM Loss, 180 days (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>20.2</td>
</tr>
<tr>
<td>14</td>
<td>16.8</td>
</tr>
<tr>
<td>15</td>
<td>15.9</td>
</tr>
<tr>
<td>16</td>
<td>15.1</td>
</tr>
<tr>
<td>18</td>
<td>13.4</td>
</tr>
<tr>
<td>22</td>
<td>10.0</td>
</tr>
</tbody>
</table>

c. Packing with tractors

When packing silage in a pile, it is best to put as many tractors as possible (assuming it does not become too dangerous), and as heavy of tractors as possible, on the silage. The steeper the sides are on a pile of silage, the fewer tractors a pile can fit, and less valuable silage will be the outcome. An optimal pile of silage (drive-over) should have a 3:1 ratio of the length of the width of slope compared to the length of the height of the pile (Ruppel et al., 1995). If there is less of a slope, such as a 1:1 ratio the pile will not get as good of a pack and is prone to becoming oxidized on the slopes of the pile (Ruppel et al., 1995). Heavy tractors need to drive onto the pile as it is being filled, with the sole purpose of using its weight to apply pressure in order for a greater packing density (Muck and Holmes, 2000). Ruppel et al. (1995) created a formula (after researching packing densities on 12 farms in New York) to determine the ideal amount of
tractor weight for how many tons per hour, which is listed below:

Packing Vehicle(s) Weight = Filling Rate (tons per Hour) x 800

This was determined by how heavy the tractor is on the pile along with the amount of silage that is put onto the pile in an hour. This may be difficult to attain due to silage facilities on a typical U.S. dairy farm are not built as exceptional as a research facility, but this formula shows how much weight it takes to attempt to improve and perfect silage packing. A better pack that is done on silage typically has less shrink, and a larger amount of retention in the pile (Ruppel et al., 1995).

Typically the faster the silage gets from the field to the pile, the greater amount of tractors are needed, but the faster it gets to the pile packing time decreases making it more difficult for the proper pack (Muck and Holmes, 2000). The greater amount of tractor weight on the pile is the highest correlation with dry matter density (Muck and Holmes, 2000). The drawback of this is that the longer it takes to get to the pile, the longer the pile goes uncovered. Every pile, bunker, or silo needs to be packed and covered as soon as possible so more tractors (tractor weight) are ideal in order to speed up the process (Muck and Holmes, 2000). It is critical because reducing exposure of oxygen is the whole purpose of silage going through fermentation, so the longer it is uncovered, the more oxygen it is exposed to (McDonell and King, 2006).

**d. Covering the Silage**

Covering silage quickly and properly is key to minimizing oxygen and reducing shrink in a pile (Oelberg et al., 2006). Silage needs to be covered once packing is complete and there are several different ways to do it. On a typical horizontal pile (including a drive-over pile) two tarps (recommended 4-6mm) are placed over the entire
stack with tires tied together on top of the tarp (McDonell and Kung, 2006). The tires need to all be touching one another in order to hold the tarp down so it becomes oxygen resistant (Chen and Weinberg, 2009). Another management concern is if oxygen can enter through the bottom of the tarp and seep all around the base of the silage causing top spoilage. This has made many dairy produces cover the base of the tarp as well with anything from dirt to bags of sand around the entire silage stack (McDonell and Kung, 2006). If the silage is poorly covered, oxygen may be present under the tarp allowing for molds to grow around the outsides of the entire pile (McDonell and Kung, 2006). If that moldy silage gets fed to the cows, it could be detrimental to the cows’ rumen causing sicknesses due to inconsistent feeding and the poisons existing in the mold (McDonell and Kung, 2006).

**V. Fermentation Process**

Aerobically unstable silage is the most common difficulty that dairy producers have when having silage troubles. Aerobically unstable silage is caused by the lack of silage management during the fermentation period. Good silage management reduces the pH of the silage during fermentation, which increases the difficulty for spoilage organisms to live and grow in the silage (Stone 2010). A good measurement of silage fermentation is pH, lower pH typically proves a better fermentation occurred, yet is not a sure sign of good fermentation (Chen and Weinberg, 2009). During fermentation (if done properly) aerobic activity will be diminished and dry matter losses will be decreased as well (Seglar et al., 2003). When silage has access to oxygen, aerobic activity increases, the corn sugars increase the temperature of the silage and the quality of the silage worsens (Chen and Weinberg, 2009). In order for the silage to be anaerobic, it must have the ability to
go through heterofermentation as well as homofermentation (Seglar et al., 2003). Heterofermentative anaerobes convert water-soluble carbohydrate into various fermentation end products at the expense of energy (because dry matter is decreased) (Seglar et al., 2003). Homofermentative bacteria (lactic acid bacteria) convert water-soluble carbohydrate to lactic acid; little energy is consumed and dry-matter loss is diminished (Seglar et al., 2003). Although both types of fermentation are crucial for silage fermentation, increasing homofermentation and decreasing heterofermentation makes for the most efficient fermentation (Seglar et al., 2003). The fermentation process of silage consists of six phases from the time of harvest to the time of feeding (Seglar et al., 2003).

The first phase is during the time of harvest. Once the corn is chopped, the epiphytic (original) aerobic organisms use water-soluble carbohydrates and convert them into carbon dioxide, heat, and water (Seglar et al., 2003). Shortly after the corn is ensiled, the water-soluble carbohydrate content is decreased, which causes the NDF content to be increased (Seglar et al., 2003). Although nutrients are lost during the aerobic phase, this phase is unavoidable, but it encourages the anaerobic conditions for the silage as well as producing compounds that increase the aerobic stability of the silage during feedout (Driehuis and Oude Elferink, 2000). Silage needs to be as unexposed to oxygen as possible so reducing the amount of silage exposed is the best option for preserving silage in an anaerobic state.

The second phase is caused by the reduction of oxygen after being ensiled, starting anaerobic heterofermentation (Seglar et al., 2003). Enterobacteria can stand the heat that is produced during phase one, become established within the silage, and produce volatile
fatty acids (VFAs), ethanol, and carbon dioxide (Seglar et al., 2003). They are able to make these by using the water-soluble carbohydrates post-fermentation (Seglar et al., 2003). Heterofermentation is not ideal because of its lack of efficiency during fermentation, producing a minimal amount of acid but still have nutrient losses, which is not optimal. Enterobacteria can tolerate a pH range from 5-7, and are only useful during that time, but the VFAs they produce drop the pH below six (Seglar et al., 2003). Once the pH starts to lessen, it becomes a positive environment (below a pH of 5) for homofermentation. Once homofermentation begins (24-72 hours after being ensiled), this phase is completed (Seglar et al., 2003).

The third phase lasts a shorter period of time than even the second phase, lasting around 24 hours (Stone, 2010). This phase occurs once the pH has been reduced and the population of homofermentative lactic-acid bacteria is increased (Seglar et al., 2003). By producing lactic acid, the pH drops at a much faster rate. The anaerobes present during this phase cannot tolerate heat as well as the heterofermenters in phase two, so heat starts to dwindle causing the lactic acid to become inhibited (Seglar et al., 2003). Once the heat is dissipated and the environment’s pH phase four begins.

When phase four begins, phase three is not necessarily completed, but rather continued in a different manner because of the change of environment. The temperature of the silage becomes constant once the water-soluble carbohydrates are converted into lactic acid (Stone, 2010). Over 60% of the VFAs are lactic acid because it is the strongest and promotes the best quality silage (Seglar et al., 2003). The main strain of lactic acid is *Lactobacillus plantarum* and is very influential of the rate of fermentation because it promotes such rapid fermentation, which leads to a greater conservation of
nutrients (Seglar et al., 2003). Later on, the cows can be in favor and use that lactic acid in their diet, assuming the ration is properly balanced and adjusted based on the nutrient value.

During the fermentation process of phases 2-4, potential spoilage organisms are not destroyed but rather their growth is inhibited (Woolford, 1990). These phases can last (in total) from ten days to three weeks depending on moisture, maturity, and buffering capacity of the corn, but can be reduced with certain inoculants. Buffering capacity is the crop’s resistance to drops in pH (Seglar et al., 2003). Corn is a low-buffered crop (has a constant pH), so does not require as much water-soluble carbohydrates as forage such as alfalfa for bacterial fermentation in order to decrease pH (Seglar et al., 2003). When silage has completed fermentation, it goes to a preserved state which is usually has pH about 4 or below for corn. The rate at which the silage reaches completion depends on the moisture level when the corn is ensiled as well as the hybrid of corn (Seglar et al., 2003). Although silage is considered to be finished with the fermentation process around three weeks, most dairy producers do not like the risk of opening silage too early, so leaving silage in a closed pile for as long as possible typically is a better course of action than taking the risk of opening the silage before the completion of fermentation.

Once fermentation is complete, the fifth stage (stable phase) begins and lasts through the duration of storage (Stone, 2010). Although it is known as the stable phase, it is plausible for many changes to still occur depending on various other factors such as oxygen entering the pile and different organisms that were already on the crop during harvest (Seglar et al., 2003). It is optimal, yet nearly impossible to have no changes after fermentation, but it is a goal that is reliant on every different factor up to completion of
fermentation.

The final phase occurs when the pile is opened and ready to be fed. This phase is just as important than all of the other phases, yet can be highly over looked (Hinen, 2006). On a silage pile, the tarp should be taken off (or pulled back) only as far as necessary for the amount of silage that is going to be used one day to prevent secondary spoilage due to the exposure of oxygen (Seglar et al., 2003). The longer the silage is exposed to the air, the more nutritionally unavailable it becomes, diminishing all the work that has been completed in the previous phases. Once the oxygen is available for the silage, aerobic microbial activity is once again increased. The aerobic activity increases temperature while also making the silage not as nutritionally beneficial (Seglar et al., 2003). This causes the silage to become instable because aerobic bacteria is now able to thrive once again, making a balanced ration much more difficult to achieve.

When more environmental stresses that are put on the silage, there is greater chance of decreasing the value of the silage (Stone, 2010). The value of silage decreases due to dry matter losses and nutrient losses. Once the silage is fed to the cows, and the longer it stays in the bunk, it is still getting the opportunity to lose nutritional value, which is the reason that bunks should be cleaned out every day, especially in hotter temperatures (McAllister and Hristov, 2000).

VI. Aerobically Unstable Silage

a. Oxidized Silage

i. Temperature

Aerobically unstable silage can have many detrimental effects to cows, including loss in milk production, poor reproduction, abortions, and many more effects (Driehuis
and Oude Elferink, 2000). These occur because of the toxins that unstable silage carries from the molds they produce. Silage can become aerobically unstable very quickly and once it has started, it is only possible to slow down the growth rate of molds, yet impossible to completely inhibit the molds from growing (Ashbell et al., 2002). When oxygen becomes accessible for the silage, it is a silage management issue that could have been prevented. As it has been stated early, covering the silage properly is key to silage management, but that does not mean it is finished.

Buying plastic and tires in order to cover the silage could look relatively expensive on paper, but a one-time purchase of plastic and tires saves much more money long term. The value of spoiled silage was estimated to be four times the cost of buying plastic and tires, in addition to paying for labor to install and remove them both due to the deterioration of silage and lack of production from cows (Berger et al., 2005). Although it is a large preventative and return on investment for putting plastic and tires on silage, it does not mean silage will be perfected. With covered or uncovered silage on a horizontal pile, the deterioration of silage is still typically found on the top, sides, and the perimeter of piles (Dickerson et al., 1992). The difference between the two is that an uncovered pile has dramatically more deterioration than a covered pile. The reason for this is that the outsides have a much higher risk of being aerobically unstable due to a less dense pack and an easier accessibility to oxygen (Green et al., 2009). Table 4 compares the uncovered and covered silage with the depth of their surface being analyzed for many different negative affects of oxidized silage in a horizontal silo 12 weeks post ensiling.

**Table 4. Modified from Dickerson et al. (1992)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Depth from surface (in)</th>
<th>DM recovery</th>
<th>pH</th>
<th>Lactic Acid</th>
<th>Temp. (F)</th>
</tr>
</thead>
</table>

19
In all aspects of the silage and its negative effects that were tested and shown in Table 4, covering silage is key to quality silage as well as reducing losses of dry matter. This shows that allowing oxygen to be accessed by the silage causes a snowball effect. If oxygen is allowed into the pile, temperature raises causing lactic acid to decrease. Lactic acid (along with the VFAs) keeps the pH down, but the less lactic acid (shown in Table 4) the higher the pH (Dickerson et al., 1992). Mold activity typically begins when the pH has risen above 4.5. The seemingly largest variable, dry matter recovery, goes down as pH goes up, making for a less quality silage, less valuable silage, and less availability of silage (Seglar et al., 2003). This shows that uncovered silage increases the risk of having poor quality silage, causing for very inconsistent silage (Dickerson et al., 1992).

Inconsistent feed quality makes formulating a ration very difficult because the components of the silage vary greatly everyday. This causes cows to have trouble because their ration never has consistent feed quality, which is immediately noticed in the milk tank (Stone, 2010).

When oxygen is available to a silage pile, the temperature of the silage immediately starts to rise because of an increase of aerobic deteriorating microorganism activity.
(Seglar et al., 2003). Initially, silage temperature is increased due to fermentation, but once fermentation is complete the temperature should decrease and become more stable (Ashbell et al., 2002). The quickest way to detect if silage has aerobic activity (other than visually seeing mold) once the pile has been opened is to feel if the silage is hot, if it is, there is microbial growth in the silage pile (Chen and Weinberg, 2009). The majority of this heat that is given off is from microbial respiration, which causes a browning to occur in the beginning stages of silages heating up (Ashbell et al., 2002). The browning of the silage is a chemical reaction when plant sugars and hemi cellulose bind with proteins and amino acids (Seglar et al., 2003). In order for molds and yeasts to thrive, they need an elevated temperature, so with oxygen they are able to produce a proper temperature so they can live and thrive (Driehuis and Oude Elferink, 2000). Lactate assimilating yeasts are the main cause of a rapid increase in temperature in a silage pile. Once aerobic activity has began, the lactate assimilating yeasts can allow peak temperature of the silage within the first 24 hours of the silage being exposed to oxygen (Borreani and Tabacco, 2010).

Figure 1 is an infrared picture taken on a dairy in Visalia, CA and shows silage with mold on the side of a silage pile. Where the silage has the highest temperature, mold appears on the surface, which shows this portion of the silage pile is aerobically unstable. The coolest part of the silage shows 59.3° Fahrenheit (15.6° C) and shows no mold, but the moldy area shows a distinct difference of 98.5° Fahrenheit (36.9° C), showing that mold thrives in hot temperatures.

**Figure 1**
Weather can have a negative effect on the face of silage when the pile is opened and becomes exposed to outside conditions. Once the pile is open, the corn silage is being fed from the face, which is the silage that is completely open to the outside environment. This is unavoidable due to the fact that it is the only way for silage to be attained in order to be fed. Research has shown that once silage is exposed to the air, it is typically stable when ambient temperatures are below 10°C and over 40°C [10°<unstable<40°] (Ashbell et al., 2002). When the face is exposed and the ambient temperature exceeds 40°C the face of the silage is stable because it absorbs the heat from the outside exposure. Although silage is stable at these temperatures, it is recommended to prepare for ambient temperatures to vary greatly. When the ambient temperatures are at 20°C and 30°C, the silage is not stable and yeast
activities increase (Ashbell et al., 2002). The most optimal time for microbial growth for the yeast within the silage is at 30°C and it is most susceptible to the outside exposure. This is the reason that minimal silage should be left on the ground after it has been faced off (Borreani and Tabacco, 2010). The longer it is exposed to the ambient temperature the more likely that it will be aerobically deteriorated. Silage that had been exposed for three days at 30°C had the highest yeast counts and the highest pH (Ashbell et al., 2002). These studies show that silage feed out should be managed even more rigorously during warm climates before it experiences high aerobic and quality losses.

Silage that has the slightest bit of aerobic activity, characteristically has spots that have been affected the greatest and are higher in temperature than the rest of the pile (Ashbell et al., 2002). These hot spots are usually found on the outsides of the pile and the exposed face of the pile (the more time it is exposed, the higher temperature it tends to be). The hot spots are all around the outside (surfaces) of the silage pile because it is the hardest part to pack after harvest due to the slope of the walls and the outside’s inability to have a high density because a lack of packed corn on top of it (Borreani and Tabacco, 2010). Drive-over piles are more ideal than conventional horizontal piles for this exact reason. A slope that is less steep, such as drive-over piles have, increases packing density on the sides, which decreases hot spots and aerobic activity on the outsides of the pile (Borreani and Tabacco, 2010). It is unavoidable for the face to not have exposure to oxygen, so when attempting to discover hot spots on silage, looking for hot spots should be done beneath
the surface (between 12” and 24”) (Borreani and Tabacco, 2010). Exposing less surface area of the face by using proper face management should minimize the infiltration of oxygen.

Figure 2 shows a corn silage pile in northwest Visalia, California. The entire face of the pile is shown to show the condition of this pile of silage. Two 18-inch temperature probes were put into the face of the silage, in order to find the temperature of the silage behind the face. Figure 3 and Figure 4 show the locations of the two thermometers on the silage pile. The first probe (Figure 3) was inserted in the middle of the face of the silage pile about four feet off the ground and showed a temperature of 83°F (28.3°C). The second probe (Figure 4) was inserted in the face of the pile, but about two feet from the slope (edge) of the pile and showed a temperature of 97°F (36.1°C).

Although no mold is shown in either Figure 3 or Figure 4, the temperature of the silage in Figure 4 shows that aerobic microbial activity has occurred near the edge of the pile. This silage was harvested in late August 2011, so the ambient temperature during harvesting was about 33°C. A general goal for stable silage is for the temperature of silage to not change more than -6°C from the ambient temperature at the time of harvest (Borreani and Tabacco, 2010). The core of the pile has a temperature of 28.3°C, which proves that this silage can be relatively cool in temperature. In these circumstances, below 33°C silage has very little to no aerobic exposure and has potential to be unaffected, 32°C-34°C silage has been affected by oxygen, and silage with a temperature over 34°C has a lot of aerobic microbial activity and has
potential to be low quality silage. This is consistent with silage on most dairies, due to the difficulty of packing and covering silage appropriately.

Figure 2

![Figure 2 Image]

Figure 3

![Figure 3 Image]

Figure 4

![Figure 4 Image]

**ii. Types of Microorganisms and Growth**

Silage that goes through a second fermentation process is called
Clostridial (butyric) silage (Seglar et al., 2003). This is typified by the production of butyric acid from lactic acid and sugars and the breakdown of proteins and amino acids to amines, amides, and ammonia, an excess of which products can result in a silage being described as of low quality (Woolford, 1990). This produces a strong, pungent, butyric acid smelling odor that is typically associated with poor silage. Clostridial silage begins when silage has aerobic exposure and begins second fermentation-producing microorganisms such as yeasts, molds, and listeria (Driehuis and Oude Elferink, 2000).

Molds are formed and grow in areas that are infiltrated by air because of poor sealing and compaction as well as in areas that have mycotoxins (Driehuis and Oude Elferink, 2000). Air, plant, stress, the stage of development of the crop at harvest, soil type and antagonistic activities between species of fungi all have been implicated in mycotoxin production (Woolford, 1990). Molds are eukaryotic microorganisms and occur in highly developed aerobic deteriorated silage. When molds are fed to cows, they frequently cause many disorders to cows such as health problems, a weakened immune system, respiratory infections, reproduction problems (increase of abortions and inability to impregnate cows), and hazardous vital organ problems (Driehuis and Oude Elferink, 2000). Not only do they affect the cow, but also the feed loses feed value and palatability due to a high pH for the cows, reducing dry matter intake leading to a reduction in milk production Seglar et al., 2003).
Yeasts are facultative eukaryotic microorganisms present within both anaerobic and aerobic conditions (Driehuis and Oude Elferink, 2000). Yeasts decrease the quality of silage in both conditions and are generally detrimental to the silage. In aerobic conditions, lactic acids are oxidized by yeast, which allow growth for many different spoilage organisms (Driehuis and Oude Elferink, 2000). High temperatures of silage (especially on the surface) are caused by yeasts and their production of heat (Driehuis and Oude Elferink, 2000). In silage anaerobic conditions, yeasts ferment sugars to ethanol and CO2 (Driehuis and Oude Elferink, 2000). Ethanol production in silage not only decreases the amount of sugar available for acid production, but it also increases dry matter loss during ensilage and may have a negative effect on the taste of milk (Driehuis and Oude Elferink, 2000). Aerobic spoilage is primarily started by yeasts, which commonly depend on the pH levels and organic acids during anaerobiosis (Dickerson et al., 1992). Methyl acetate and ethyl acetate are produced by yeasts and are the strong odors (resembling a similar smell of nail polish remover) that are found in Clostridial silage (Driehuis and Oude Elferink, 2000).

Listeria is similar to yeasts because it can be aerobic or a strain of facultative anaerobic bacteria and lives and grows depending on anaerobiosis and the level of pH (usually a pH > 4.4 but has been found to grow at a pH of 4.2; Driehuis and Oude Elferink, 2000). Listeria is initiated in spoiled silage and exponentially grows once it gets into the silage (Driehuis and Oude Elferink, 2000). Listeria is typically found in silage bags and ensiled bales but
is much more uncommon to bunkers and horizontal silos (Driehuis and Oude Elferink, 2000). Listeria affects both humans and animals negatively because the pathogens it carries are extremely harmful. Cows are able to get listeria from silage but it is much more prominent in sheep and goats because of their susceptibility to disease (Driehuis and Oude Elferink, 2000). Humans have the ability to receive listeriosis from cows, although it is very difficult and nearly impossible. In order for humans to get listeriosis, they must consume raw (unpasteurized) milk from cows that got listeria from silages (Driehuis and Oude Elferink, 2000). Because of the unpopularity of raw milk, the difficulty it is for cows to get listeriosis, as well as having listeria-containing silage makes listeriosis a disease that humans do not have to worry about.

iii. Testing for oxidized silage

Poor quality silages can be detrimental to cows as well as detrimental to the dairy producer’s financial statement, because of losses in milk production, poor reproduction, and silage that must been thrown away (Woolford, 1990). It is always more profitable to get rid of moldy silage rather than feeding it to cows, but silage should be tested before it is rid of, so high quality silage does not get mistakenly wasted (Kezar, 2001). Visually observing silage, feeling heated silage, and smelling the silage for a butyric acid odor can usually assess poor quality silage before it needs to be analyzed. Different ways and equipment that can be used when analyzing silage include: pH paper, temperature probes, and Penn State Shaker Box, but the most accurate means of testing silage is to get it tested at a laboratory (Seglar et al., 2003). These
are all different methods that assist in testing for poor silage quality, but do not determine if the silage is of high quality (except for laboratory testing). Laboratory testing is important and necessary for silage and should be done as often as possible due to silage constantly changing characteristics throughout the pile (Seglar, 2003).

**b. Effects on Cows**

Feeding aerobically unstable silages can cause many negative effects to cows. Aerobically unstable silage has harmful effects to cows because of the mycotoxins that are in the silage when it is fed to the cows. Effects that can occur to cows include: milk production losses, decrease in dry matter intake, decline in rumen function, increase of abortions, and reproduction losses, amongst many more health problems (McDonell and Kung, 2006).

Dry matter intake and milk production negatively cooperate with one another when unstable silages are fed to milk cows. When aerobically unstable silages or clostridial silages are fed to dairy cows, it does not contain palatability and could contain mycotoxins, so the cow will not consume the feed that is fed to them, decreasing dry matter intake (Seglar, 2003). Cows that do end up consuming the spoiled feed are not able to digest the beneficial nutrients and end up digesting harmful molds, causing a decline in the cow’s overall health (Woolford, 1990). The decline of dry matter intake and the health of the cow directly affect the milk production of the cow in a negative manner. Hoffman and Ocker (1997) performed a research study on feeding spoiled silage to 18 mid-lactation Holstein cows in order to see if spoiled
silage effects a cow’s milk yield. They concluded the study by every cow dramatically decreasing milk production after aerobically unstable corn silage entered the total mixed ration (TMR).

Spoiled silage especially takes a toll on the rumen. The mycotoxins and molds that are consumed by cows, not only affect the rumen because of digestibility difficulties, but they also destroy the rumen mat (McDonell and Kung, 2006). The rumen has to attempt to process and digest the spoiled silage that is consumed because of its naturally function. Through the process of digesting the toxic silage, it causes the rumen mat to become either partially or fully destroyed, making the cow’s ability to function in natural manner exceedingly difficult (McDonell and Kung, 2006). In the same experiment that Hoffman and Ocker (1997) performed, all 18 cows’ rumen mat was destroyed making the cows increasingly ineffective as dairy cows. The rumen mat is destroyed because the cows attempted to digest the toxic material. Cows that consumed silage that had been more spoiled than others, had a completely destroyed rumen mat.

Reproduction in cows is also affected by feeding poor quality silage (McDonell and Kung, 2006). A cow’s natural instinct is to fight any toxic material that enters its body and when spoiled silage (especially mycotoxins) enters the body, the cow tries to attack the problem and keep homeostasis. This, intern, doubly keeps the cow from getting pregnant because it is against any type of change to its body as well as the toxins destroying anything within the body (Driehuis and Oude Elferink, 2000). With dairy farms that
are feeding any amount of spoiled silage, typically they have a lower pregnancy rate and a higher abortion rate (McDonell and Kung, 2006). Far off dry cows can often be forgot on a dairy farm and are fed old (not fresh) milk cow feed clean out and the greater amount of spoiled silage (McDonell and Kung, 2006). This can cause both abortions and poor transition for cows in the future.

c. Facing Silage

Once the silo has been opened and exposed to air, it is important for the silage to be faced properly, limiting the amount of silage exposed to the air. There are different ways to face silage, some limiting oxygen exposure and other promoting a larger amount of oxygen exposure than necessary. The key to facing silage is keeping the face firm and smooth and to face off only the silage that needs to be fed for that day, leaving a minimal amount of loose silage that could heat up and become spoiled (Kezar, 2001). The silage face needs to be smooth across the entire face to reduce surface area that could be exposed to oxygen (McAllister and Hristov, 2000). The silage also needs to remain firm and dense, because the more loose that the silage becomes, the greater the risk of oxygen infiltrating the silage pile, therefore it is ideal to take the plastic off only the silage that is needed for the day rather than leaving more silage to be uncovered (Borreani and Tabacco, 2010). Facing only enough silage for each day is necessary because silage that is faced off and left on the ground until the next day will become heated up and oxidized because it is fully exposed. Once the loose silage is exposed to oxygen, there
can be loss in beneficial nutrients in the silage as well as and animal performance (McAllister and Hristov, 2000). Properly facing silage allows for silage quality to remain in the state it is, but improperly facing silage can cause major negative quality effects as well as shrink due to continued aerobic deterioration throughout the pile (Borreani and Tabacco, 2010).

Theses different styles of facing silage include: using a silage rake (facer) which allows for minimal silage to be faced, while leaving a flat silage face, using a loader and facing sideways (while taking small amounts of silage off the face at a time), and ramming the silage’s face in with a loader in order to scoop the silage off the face (leaving large portions of the face uneven). Using the smash and scoop method of facing silage is in no way advantageous to the silage. A greater amount of surface area is shown, making for an extremely inconsistent silage pile (McAllister and Hristov, 2000). Every time the loader drives into the face of the silage, the rest of the silage is forced back and pushed up every time. By using the smash and scoop method, the farther into the pile that has been faced off, the greater chance of poor quality silage, until the end of the pile, which could all need to be disposed of (Tabacco et al., 2011). Table 5 shows the differences between the three ways silage is usually faced. Figures 5-7 show the faces of silage from three different piles in Visalia, Ca using each facing technique.

Table 5. Difference styles of facing silage.

<table>
<thead>
<tr>
<th>Type of Facing</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rake Facer</td>
<td>• Smoothest face</td>
<td>• Initial Investment</td>
</tr>
<tr>
<td></td>
<td>• Keeps the firmness of the silage pile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easy to use</td>
<td></td>
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<tr>
<td>------------------</td>
<td>-------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Sideways Facing</td>
<td>Cheap</td>
<td>Hard to reach high</td>
</tr>
<tr>
<td>with Loader</td>
<td>Smooth and</td>
<td>areas of silage</td>
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<td>firm (but</td>
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<td>is variable</td>
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<td>for different</td>
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</tr>
<tr>
<td></td>
<td>people)</td>
<td></td>
</tr>
<tr>
<td>Smash and Scoop</td>
<td>Fast</td>
<td>Increase of aerobic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>deterioration</td>
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Figure 5. Silage faced with a rake facer.

Figure 6. Silage faced sideways with a loader.
Figure 7. Silage faced using the Smash and Scoop method.
**d. Oxidized Silage in the TMR**

Once silage is put into the TMR, it is exposed to oxygen and promotes an environment for bacterial growth. Depending on the weather (ambient temperature and precipitation), bacterial growth can increase or remain stable for a longer period of time (Ashbell et al., 2002). When the ambient temperature increases, the amount of spoilage increases, therefore fresh feed should be available to the cow as often as possible (Kezar, 2001). Due to the high moisture levels of corn silage, it has a much faster rate of deterioration than many other feeds (Bolsen et al., 1999). When the ambient temperature is high, the silage and TMR temperature is also elevated because of both the direct exposure of the weather in addition to the TMR being oxidized and increasing microbial growth. Due to the necessity of fresh TMR available for cows, nutritionist recommend feeding cows multiple times a day (Bolsen et al., 1999). Bolsen et al. (1999) also suggest to feed about 2/3 of the daily amount of feed later in the day (afternoon/night) when the weather is cooler in order for the feed to remain fresh for a longer period of time. Rain can also have an effect on silage quality because of the inconsistency of moisture levels. When rain has the ability to enter into silage and the TMR, the dry matter levels change making for a completely different ration (Bolsen et al., 1999).

In order to keep consistency throughout the ration on a daily basis, proper feed bunk management should be applied. Bunks should be cleaned as often as possible (recommended once per day) to reduce spoilage in the TMR
(Bolsen et al., 1999). When the TMR is left at the bunk for a long period of time spoilage continues and quality deteriorates (McAllister and Hristov, 2000). Cows sorting feed can cause silage to be left at the bunk, and because of the rapid deterioration of silage, molds can form quickly especially in the heat. The more time the silage is in the bunk, the more mold has the opportunity to grow. If feed bunks are not managed properly and mold grows on silage in the bunk, eliminating the purpose in silage management before feedout. Bunks should be managed everyday, by only feeding the proper amount of feed daily, limiting extra feed in the feed bunk (Bolsen et al., 1999). It is optimal for bunks need to be cleaned everyday in order to limit the exposure to the environment, decreasing the risk of molds and yeasts (Bolsen et al., 1999).

**e. Disposing of Spoiled Silage**

Once mold has begun to grow on the surface of a silage pile, it should not be fed to milk cows, dry cows, or heifers (Woolford, 1990). Spoiled silage has no beneficial effects to the animal, only negative effects, so instead of keeping the silage in order to save money, the spoiled silage should disposed. Feeding young stock spoiled silage does make a big difference in the animal’s ability to grow, future productivity, reproduction, and general health (Fluharty).

Heifers that consume spoiled silage are immediately impacted by an initial decrease in dry matter intake (Driehuis and Oude Elferink, 2000). The lack of palatability that the silage has makes the TMR less desirable so heifers will only eat when they need to. The main objective that dairy producers
typically have in regards to heifers is to give them the opportunity to grow as large and as fast as possible. When spoiled silage is fed to heifers, they are eating a poor quality ration the does not offer the beneficial nutrients they need for growth. They also refuse to eat, resulting in an undesirable average daily gain (ADG). Similar to cows, feeding spoiled silage can also result in an inability to become pregnant and the destruction of their rumen mat (McDonell and Kung, 2006).

Instead of feeding spoiled silage to any animals, mold on the outsides of the pile need to be eliminated from the pile once the plastic has been taken off and the mold is suddenly visible (McDonell and Kung, 2006). The simplest method of getting mold of a silage pile is using a pitchfork to flake it off. Mold should be flaked off the pile onto the ground away from any high quality silage. Once it has been removed off of the pile it should be put in a designated area that should be away from all other feeds on the dairy.

VII. Silage Quality

a. Silage Consistency

Silage consistency throughout an entire pile makes for a more consistent ration, which is favorable to cows. Inconsistency throughout a silage pile makes it difficult to formulate a ration as well as knowing what the true dynamics of the ration are (Seglar et al., 2003). The dry matter of corn when it is ensiled, as well as the pH of the silage, are key contributors that encourage a consistent pile (Ashbell et al., 2002). If corn does not have a consistent dry matter when it is chopped (due to getting silage from different
fields and leaving it exposed too long before it is ensiled), there is a much higher chance of silage having different nutrient values on a daily basis (Kezar, 2001). Having similar and correct dry matter levels in silage promotes sufficient lactic acid fermentation, and diminishes the risk of excessive protein breakdown and energy loss from prolonged fermentation (Seglar et al., 2003). Levels of dry matter should be tested the day corn is chopped and as often as possible once the silage pile is opened (Seglar et al., 2003). The pH of silage also needs to be tested as often as possible once the silage is opened, for the reason that it shows the stability of the silage. The pH can be tested by using pH litmus paper or a pH meter and should be tested about 2-3 feet beyond the face of the silage (Seglar et al., 2003). The lower pH that silage has (less than 4.0 is ideal, 4.0-4.3 is adequate, greater than 4.4 is potentially harmful) is an indicator of the silage fermentation process (Seglar et al., 2003). The more consistent pH (preferably a low pH) throughout a silage pile, indicates a proper fermentation and a smaller risk of inconsistent silage being fed (Tabacco et al., 2011).

**b. Testing Silage**

In order to determine the consistency of a silage pile once it has been opened, silage should be sent to a laboratory for testing every 2-4 weeks. The silage should be tested in the laboratory for a thorough evaluation of the silage’s nutritional and microbial values such as starch, pH, dry matter, crude protein, bound protein, ash, NDF, ADF, volatile fatty acids, lactic acid, nitrogen, yeasts, molds, bacillus, mycotoxins, and many others.
Silage acids are necessary to the fermentation process in silage but only at certain levels. Lactic Acid is a key nutritional factor in silage because it is a major fermentation acid in silage and ideally is three times more available than volatile fatty acids (Seglar et al., 2003). Lactic acid is a result of homofermentation and lowers the pH of silage at a greater rate than any other VFA. Lactic acid does not volatilize upon exposure to air and provides for a more efficient fermentation because it is stronger than volatile fatty acids (Seglar et al., 2003).

The volatile fatty acids that are in silage, assist in the stability of the silage and include: acetic acid, proprionic acid, and butyric acid (Seglar et al., 2003). Acetic acid is has a vinegar-like odor is produced during the fermentation process in order to maintain the aerobic stability of silage. Acetic acid is usually found in silages as less than 3% and anything greater than 3% shows inefficient heterofermentative fermentation (Seglar et al., 2003). Proprionic acid is not as available as acetic acid and is also produced during the fermentation process. The amount of proprionic acid is typically ideal under 1% (Seglar et al., 2003). Butyric acid is the acid that is a result of a second fermentation process in silage ensuing in Clostridial silage. Butyric acid should be found at a level of less than 0.1% in silage and offers a rancid smell the greater amount in the silage (Seglar et al., 2003). When levels of butyric acid increase, amines and amides (nitrogenous end products) often decrease the energy levels in forage and deteriorate the silage (Seglar et al., 2003).
When taking silage samples in order to be tested in the laboratory, the samples need to serve as an example of what is going to be fed to the cows and should be a representative of the rest of the silage pile. Assuming a well-managed pile would have minimal loose silage, silage samples would not be taken from the loose material on the ground. Rather, all samples should be taken from about 2 feet behind the face, from different locations all over the face because it has not yet been affected by exposure to oxygen and is a good representative of what the cows are being fed. A sample of silage that is taken from one area of the pile typically does not represent an entire pile, so it is difficult to use that sample as a true measuring tool when putting together a balanced ration.

Simple ways to test for potentially spoiled silage and aerobically deteriorated silage, due to an increase of temperature, can be tested by using temperature probes, an infrared camera, or a hand test. Temperature probes are quick, easy, and cheap to use but can get the temperature of one direct spot of the silage and may not represent the silage temperature too well or find the hot spots on the silage. A temperature probe is inserted into the face of the silage pile and measures the temperature of the silage 18 inches deep. Using an infrared camera to find the temperature of silage is quick and easy but relatively expensive due to the cost of camera costing around $7,000. An infrared camera is used just as a normal camera and takes a picture of a designated spot. The advantage of an infrared camera is that it can take temperature and find hot spots around the entire face quickly, so it is easy to
see where aerobic microorganism activity can be seen due to the increase of temperature of certain spots on the silage. The least expensive way to test the temperature of silage is a hand test, yet it is not accurate. This is done by physically touching the silage for a hot, high temperature to see if it has been affected is not accurate but does allow the producer to see if their silage has been affected. Taking temperatures of silage does not test the silage for certain components, but rather can show if the silage has been packed, covered, and sealed properly.

**VIII. Silage Shrink**

*a. Less Shrink Equals More Silage*

Since forages are usually the majority of a ration (compared to other feeds), especially corn silage, a lot of money can be lost by poor management techniques (Oelberg et al., 2006). Silage shrink (the loss of silage) is unavoidable but can be minimized under proper silage management practices. Shrink can begin right when the corn is ensiled and continue until the silage is fed to cows. Shrink can occur in the pile when the corn is ensiled, during the fermentation process, once the pile is opened, and during the feedout phase. Minimizing shrink in a silage pile will allow for more stored silage therefore allowing the dairy producer to add more silage to the ration or buying less silage the following year.

Silage lost during ensiling can represent a poor pack and a poor cover (McDonell and Kung, 2006). The greatest amount of shrink is usually the day it is packed as a result of a poor packing density and the inability to cover the
silage to reduce oxygen exposure. Air pockets can be found in the silage, increasing the amount of aerobically deteriorated silage (Muck and Holmes, 2000). Silage shrink will continue and increase if the silage goes through a second fermentation process allowing for Clostridial silage. Once the pile is opened and is being fed to cows, face management is a big reducer of silage shrink (Borreani and Tabacco, 2010). Keeping a firm flat face reduces the exposure of oxygen, which decreases silage deterioration. A large impact of silage shrink that underestimated yet often occurs is leaving loose material on the ground increasing the oxygen availability. Loose silage is constantly heating up, making for the silage to be nutritionally inadequate and increasing the deterioration rate greatly (Hinen, 2006). Lastly, an employee can increase silage shrink after scooping the silage and putting it in the mixer wagon. Silage can spill out of the bucket of the loader, falling on the ground, as well as by overfilling a mixer wagon. Once silage has been spilled, it is rarely retrieved and is wasted. Decreasing silage shrink can save a dairy producer unnecessary losses, while increasing the expected amount of silage available.

**b. Economic Losses**

Poorly managed corn silage can cause extreme losses in profitability various different ways. Different ways the corn silage can negatively affect profitability include loss due to shrink and an increase of processed corn in the ration. Table 6 shows the amount of money that can be lost to shrink on 40 dairies surveyed in the Midwest (Oelberg et al., 2006). Table 6 shows that
there is a great amount of loss

*Table 6. Redrawn from Oelberg et al. (2006)*

<table>
<thead>
<tr>
<th>Location of DM Loss</th>
<th>Current Practice</th>
<th>Best Case from Survey</th>
<th>Difference</th>
<th>$ Value Lost per ton (@ $20/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunker Shrink</td>
<td>18.5%</td>
<td>12.3%</td>
<td>6.2%</td>
<td>$1.24</td>
</tr>
<tr>
<td>Feedout Shrink</td>
<td>6.5%</td>
<td>5%</td>
<td>1.5%</td>
<td>$0.30</td>
</tr>
<tr>
<td>Total Shrink</td>
<td>25%</td>
<td>17.3%</td>
<td>7.7%</td>
<td>$1.54</td>
</tr>
<tr>
<td>Lbs. lost in 25 tons of silage per acre</td>
<td>12,500 lbs.</td>
<td>8,650 lbs.</td>
<td>3,850 lbs.</td>
<td></td>
</tr>
<tr>
<td>Value of DM lost per acre @ $20/ton</td>
<td>$125.00</td>
<td>$86.60</td>
<td>$38.60</td>
<td></td>
</tr>
</tbody>
</table>

due to shrink using $20/ton silage. Corn prices have risen greatly since the experiment was done in 2006 to double or triple the price per ton ($40-$60). This shows that managing silage affects profitability greatly.

Other than losing money from shrink, poor quality silage is not as nutritionally beneficial as high quality silage. This causes an increase in processed corn or silage to be fed in order to meet the needs of the cow from a nutritional standpoint. Increasing the amount of processed corn (or other commodities) in a ration increases the price of the ration altogether (Bolsen et al., 1993). If the dairy producer decides to feed more silage instead of processed corn, the availability of silage diminishes and more corn silage must be bought. Managing corn silage properly will reduce these unnecessary losses that can occur, increasing the chance of profitability and success for the dairy.
IX. Conclusion

Corn silage can be managed many different ways, but managing the silage properly is the key to producing high quality silage. Managing corn silage can assist in avoiding losses due from the silage being exposed to oxygen. Proper management can also increase profitability from healthy, high producing cows. Many different management techniques prove to be beneficial and detrimental to the silage, allowing the dairy producer the opportunity to make or lose money.

Drive-over piles seem to be the most efficient ways of ensiling corn on an average California dairy (assuming the dairy has enough area). Drive over piles use a lot of area, but can achieve the greatest pack, minimizing the amount of oxygen exposure due to the packing density of the silage. Since the exposure of oxygen tends to be the greatest difficulty when producing a high quality silage, using a drive-over pile proves to be the cost efficient, because the least amount of silage is lost and the cows chance of digesting toxic materials is minimized.

Whichever method of ensiling is done to corn, management is the basis of producing high quality silage. Corn should be processed to the ideal length to optimize dry matter density in the bunker yet still be beneficial to the cow allowing for rumination. Once corn is processed, it needs to be packed into the pile as dense as possible by applying as much tractor weight as possible. Silage should be covered with plastic and tires as soon as it is fully packed, and sealed around the edges with sand bags. Once the corn silage is no longer
exposed to the outside environment, it should remain enclosed for a minimum of three months to allow proper fermentation. Lastly, once the pile is opened, the face of the pile should be kept flat and firm, reducing the amount of surface area exposed, leaving no loose silage on the ground. Silage management techniques give corn silage the greatest opportunity to be optimal and should be applied to every corn silage pile. Since corn silage is such a substantial ingredient in a dairy ration, it should be managed properly, allowing for the cows to have a consistent, nutritionally beneficial feed to digest, allowing for a healthy, milk producing cow.
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