Effects of Covering System, Sealing Time, Packing on Fermentation, Nutritional Quality, and Organic Matter Loss of Corn Silage in a Drive-over Pile

A Senior Project

presented to

the Faculty of the Dairy Science Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements of the Degree

Bachelor of Dairy Science

by

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March 2014

Acknowledgements

I would like to thank everyone who helped me on this project for their continued support and encouragement. To Dr. Henderson for being my faculty advisor, helping me analyze the data, and for editing my paper. To Dr. Keith Bolsen for all that he did in planning, gathering, analyzing, and computing the data and for taking the time to help me understand the material, edit, and write this project. To Ron and Connie Kuber from Connor Marketing for providing the materials (Silostop, gravel bags and Std. plastic) for this trial and for providing the means to have all of the samples analyzed. Also, for coming out to the Cal Poly Dairy plan this project, to cover the silage pile, take samples, and pictures. To Rich Silacci for allowing this trial to take place the Cal Poly dairy and for his work with covering the pit and taking samples. Without each one of you this project wouldn't have been possible; I appreciate all that you have done!

Abstract

This project involved an experiment conducted using a 550-ton capacity drive-over pile of whole-plant corn silage. The main effects compared were: packing the final forage surface with a loader or crawler (**Figure 1.**), delay or immediate sealing, and covering with standard plastic or an oxygen barrier film.

Figure 1. Loader and crawler packing the pit.

Numerous studies have shown that the absence of oxygen in silage stored in a bunker silo or pile is

crucial for proper fermentation and to ensure the highest quality silage at feed out. When oxygen is allowed to permeate through the covering material, it leads to visible spoilage. This trial showed that the oxygen barrier film reduced organic matter loss in the outer 18 inches of the pile and there was less visible spoilage compared to the silage covered with the standard plastic (8.3 percent difference in OM loss). When the crawler was used to pack the final surface compared to the loader, there was less organic matter loss in the outer layer of the pile (5.3 percent difference). By delaying 24 hours to seal the pile, the data showed that organic matter loss increased compared to sealing immediately (3.3 percent difference) as more oxygen was allowed to permeate the outer layer of forage, which prolonged the aerobic phase and slowed the fermentation process.

Silage packed with the crawler, sealed immediately, and covered with oxygen barrier film had higher nutritional quality in the outer 0 to 18 inches of the pile than silage packed with the loader, delay sealed, and covered with standard plastic.

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Introduction

With feed prices at an all time high, crop producers and dairymen want to get the most out of their corn acres. Corn silage is one of the main ingredients in dairy rations. From 2009 to 2013 an average of 111.2 million tons of whole-plant corn was harvested annually for silage in the USA (United States Department of Agriculture, 2014). It is very important to have the best nutritional quality with minimum dry matter loss and visible spoilage to insure adequate nutrition and health for dairy cows. Research has shown that adding corn silage that contains surface spoilage may have negative affects on dry matter intake (DMI) and nutritive value of a corn silage-based ration (Berger and Bolsen, 2006).

High quality corn silage starts in the field by harvesting at the right stage of maturity, inoculating at the forage chopper, packing to an optimum density, and covering the bunker silo or drive-over pile as soon as possible. These management practices allow the ensiled forage to undergo a rapid and efficient fermentation process.

This project looked at the effect the type of of covering system, sealing time post-filling, and final pack vehicle of fermentation, nutritional quality, and organic matter loss of corn silage stored in a drive-over pile.

Literature Review

Phases of Silage Fermentation

There are four main phases of the ensiling process according to Dr. Keith Bolsen, Ben Brent, and Ron Pope in the paper “The Ensiling Process: Basic Principles.” These four phases are as follows: the aerobic, fermentation, stable, and feed out phases. Advanced Forage Management in Chapter 7: Forage Quality, found online at farmwest.com, the first phase is where there are aerobic microorganisms on forage at harvest that consume oxygen as the forage continues to respire. This process could last a few hours to several weeks depending on how well oxygen is kept out of the pit, which will determine the quality of the corn silage (Pacific Field Corn Association 1999).

The fermentation phase starts when anaerobic conditions are reached. Anaerobic bacteria ferment the soluble carbohydrates into acetic acid, which can be used by rumen microbes. This phase usually lasts between 24 and 72 hours and comes to an end when the pH drops below 5.0. As the pH drops below 5.0 the acetic acid producing bacteria cannot survive in this more acidic environment and the lactic acid producing bacteria replace them (Pacific Field Corn Association 1999).

Here, lactic acid producing bacteria are dominant, these are the most desirable bacteria for the fermentation process because they are more acidic and bring the pH down faster (Pacific Field Corn Association 1999). However, if the pH doesn’t drop, clostridial spores become dominant, they can cause a second fermentation, which converts sugars to butyric acid causing DM loss (Bolsen et. al, The Ensiling Process: Basic Principles 2014). This is why it is so important for the pH to drop quickly because clostridial spores cannot survive in low pH environments (Bolsen et. al, The Ensiling Process: Basic Principles 2014). J.W. Shroeder, an Extension Dairy Specialist from North Dakota State University stated that, “the faster the fermentation is completed, the more nutrients will be retained in the silage” (2004).

According to Advanced Forage Management, “In well-preserved silage, lactic acid should comprise more than 60% of the total silage organic acids and the silage should contain up to 6% lactic acid on a dry matter basis. This continues until the pH of the forage is low enough to inhibit the growth of all bacteria. When this pH is reached, the forage is in a stable state so long as oxygen is excluded.” (1999).

This next phase of the silage being in a stable state is where the silage has a low pH and there is little biological activity unless oxygen gets in. In that case, aerobic microorganisms will use the oxygen and increase yeast, mold, DM loss, and heat which all reduce the quality of the silage (Bolsen et. al, The Ensiling Process: Basic Principles 2014).

The final phase occurs when the silage is being fed out and is exposed to oxygen. According to Advanced Forage Management, up to 50% of silage dry matter losses occur from secondary aerobic decomposition (1999). In “The Ensiling Process: Basic Principles,” yeasts and molds grow rapidly and once yeasts reach a 106 – 107 colony forming units (cfu) per gram, the silage will begin to heat causing sugars and fermentation products to be lost quickly (Bolsen et. al, The Ensiling Process: Basic Principles 2014). “DM losses are about 1.5 – 3.0 percent per day for each 8 – 12 degrees Celsius rise in silage temperature above ambient” (Bolsen et. al, The

Ensiling Process: Basic Principles 2014). This can be prevented with proper packing, sealing, and pit management.

Corn Harvesting

In order to ensure high quality silage at feed out, one must start with good quality forage to begin with. As stated above, the moisture content has to be right in order to achieve this so it is important to harvest at the right maturity. J.W. Schroeder stated that, “proper maturity assures adequate fermentable sugars for silage bacteria and maximum nutrition value for livestock. Maturity also has a tremendous impact on moisture with unwilted forage crops such as corn silage. Adequate moisture for bacterial fermentation is essential for bacterial fermentation and aids in packing to help exclude oxygen from the silage.” (2004).

J.W. Schroeder said in “Silage Fermentation and Preservation” that for corn the milk line on the kernels to make sure that the it is 1/2 to 2/3 down the kernel (2004). Considering maturity at harvest, one also needs to consider the length of the cut when chopping. According to DuPont Pioneer experts, assessing the milkline of the kernels about four weeks after silking, when the corn kernels start to dent, can be a helpful tool when determining when to harvest (News Release 2013). One-third milkline would indicate 68 to 72 percent moisture, while two-thirds milk line indicates 63 to 68 percent moisture (News Release 2013). DuPont Pioneer experts suggest letting the crops reach 63 percent moisture in the field in order to get the most out of the starch levels and tonnage (2013).

Dr. Donna Amaral-Phillips stated, “Unprocessed corn silage should be chopped at 3/8 to ½ inch length and processed corn silage (with kernel processor) at ¾ inch (Reminders for Corn Silage Chopping Time). In order to optimize starch digestion and provide adequate effective fiber, corn should be cut to 3/4 theoretical length while having the roller clearance set to 0.12 inches (Amaral-Phillips 2014). The goal would be to have 55 to 64 percent of the kernels damaged so that the dairy animals are able to digest them and get the energy from them (Amaral-Phillips 2014).

According to Schroeder, this will allow for the best compaction when packing the pit and nutritive value since cutting it any finer could reduce milk fat production and increase incidences in displaced abomasums for milk cows due to the lack of scratch factor for the rumen in the diet. On the other hand, chopping forages too long will make compacting the pile much more difficult causing more oxygen to stay in the pile which will result in heating and spoilage during phase one of fermentation (Schroeder 2004).

Packing Forage in Bunker Silos and Drive-over Piles

When filling the silage pit, it is important that the forage be filled rapidly so as not to have excessive respiration which causes spoilage (Schroeder 2004). Schroeder states that a wheeled tractor is preferred to pack the silage pit because it supplies more weight per surface area unit than tracks (2004). According to Dr. Amaral-Phillips, "To achieve adequate silage density, the packing vehicle's weight and thickness of a layer of silage being packed must be taken into consideration. Filling rate or weight of tractors used to pack silage can be calculated using these equations:

Optimum filling rate(tons/hr.)=Vehicle weight (lbs.)/ 800

Optimum packing weight(lbs.)= filling rate (tns/hr.)X 800

(Calculations to achieve minimum packing density of 14 lbs/ft^3)." (2014).

Dr. R. Charley stated in “Silage Packing Density – A Critical Management Control Point for Producing High Quality Silages,” “Optimally packing time should be one to three minutes per ton of forage (fresh weight). It may take more than one packing tractor to achieve this without impacting the forage delivery rate. Thinner is better and the old rule-of-thumb of six inches as a maximum should really be applied.” (2014).

In the paper, Silage Packing Density: A Critical Management Control Point for Producing High Quality Silages, Dr. Charley said, “Lynch and Kung (2000) showed that decreasing silage packing density resulted in slower ensiling fermentation” (2014) This is shown in Table 1. The effect of packing density on the DM loss of corn silage as the silage packing density goes up there is less dry matter loss.

Table 1. The effect of packing density on the DM loss of corn silage

Silage Density (lbs. DM/cubic ft.)	Dry Matter Loss (%)
10	20.2
14	16.8
15	15.9
16	15.1
18	13.4
20	10.0

Table 1. The effect of packing density on the DM loss of corn silage

Source: Charley

Plastics and Films Used to Cover Bunker Silos and Drive-over Piles

Silostop Orange™ is a 45-micron plastic that has been shown to have at least 100 times more of a barrier to oxygen than conventional 125-micron silage covers as the oxygen transfer rate (OTR) is 400 in Std. plastic but only 3 in Silostop Orange™ (Silostop.com)

Plastics are rated on how well they are able to keep oxygen out by laboratories testing for OTR. Laboratory test results that use the American Standard Test Method (ASTM) have shown that silage plastics vary from 30 to 6,000 cubic centimeters of oxygen per square meter in 24 hours of being exposed to a 100 percent oxygen environment (Bolsen Progressive Forage Grower 2013). Dr. Keith Bolsen stated that, “Traditional white-on-black silage plastic with a five-mil thickness has an OTR of 1,811, while oxygen barrier film with a 1.8-mil thickness has an OTR of 29. For comparison's sake, it takes 60 sheets of regular plastic to equal the protection provided by one sheet of oxygen barrier film." (Progressive Forage Grower 2013).

In research done by Paola Dolci, Ernesto Tabacco, Luca Cocolin and Giorgio Borreani in Italy, it was found that silages sealed with the standard polyethylene film led to silages with higher pH ($P < 0.002$), and lower concentrations of lactic acid ($P < 0.033$) in comparison with the OB silages (Dolci et. al 2011).

Dr. Keith Bolsen and Dr. Larry Berger in "Sealing strategies for bunker silos and drive-over piles," compared silage that was 1) unsealed, 2) sealed immediately after filling, and 3) sealed 7 days post-filling. Both of the treatments that were sealed, were sealed with 4-mil polyethylene. It was found that the silages had similar fermentation characteristics from 12-36 inches but there were major differences in the 0-12 inch depth. They said that at both opening times (90 and 180 days), the delay-sealed silos had higher DM losses (14.7% at 90 days and 15.7% at 180 days) compared to the DM losses in silos sealed immediately after filling (8.0% at 90 days and 6.8% at 180 days) (Berger and Bolsen 2006). The delay-sealed silage having almost 10% more DM loss than the immediate seal shows that delaying sealing 7 days would cost a farmer about 6-10 tons of silage in a 1000 ton bunker silo (Berger and Bolsen 2006).

In the research paper titled, “Preservation Efficiency and Nutritional Quality of Whole-Plant Corn Sealed in a Large Pile Silo with an Oxygen Barrier Film (Silostop™) or Standard Polyethylene Film”, when comparing the oxygen barrier film to the standard film in the corn silage pit after 300 days of filling the pile, it was observed that the section of silage under the oxygen barrier had very little spoilage whereas the standard polyethylene plastic sealed section had visible mold and spoilage especially in the top 0-12 inches (Kuber et. al 2008). Under Silostop there was 19% OM loss between 0 and 18 inches compared to 41.1% under the standard polyethylene plastic cover (Kuber et. al 2008). These results show us that the oxygen barrier film allows for a better fermentation process and results in less spoilage and OM loss than the standard polyethylene film.

Materials and Methods

This project was conducted using a 550-ton capacity drive-over pile of whole-plant corn silage. The main effects compared were: packing the final forage surface with a pay loader or crawler, delay or immediate sealing, and covering with standard plastic (Std. plastic) or a total oxygen barrier film (OB film).

The first section of the drive-over pile, which had the final pack with a crawler, was left unsealed for approximately 24 hours (delay), before being covered with: 1) Std. plastic or 2) OB film. The second section of the pile, which had the final pack with a pay loader, was covered immediately with: 3) Std. plastic or 4) OB film. The third section of the pile, which had the final pack with a crawler, was covered immediately with: 5) Std. plastic or 6) OB film.

On August 21 and 22, 2013 approximately 550 tons of whole-plant corn was chopped at the Maddox Dairy near Riverdale, California (www.maddoxdairy.com). The corn was in the two-thirds milk line stage of maturity, contained approximately 32% dry matter, and was inoculated at the forage harvester with Biotal Buchneri 500 (Lallemand Animal Nutrition 2011). The chopped forage was transported to the California Polytechnic State University dairy farm in San Luis Obispo (**Figure 2**).

Figure 2. Chopped whole-plant corn unloaded at the Cal Poly Dairy.

The forage from each load was spread in thin layers and packed to form a drive-over pile, which was approximately 55 feet wide at the base, 200 feet long at the base, and 5 feet height at the apex (**Figure 3**).

Figure 3. The dimensions of the silage pile were 200 feet long, 50 feet wide and 5 feet tall (apex).

About one-half of the forage was delivered to the dairy farm on August 21st, and it was packed with a loader. After the last load of forage for the day had been packed, the entire surface of the pile was packed with a crawler. This forage was left unsealed at a daytime high temperature of 80 degrees Fahrenheit and a nighttime low temperature of 56 degrees Fahrenheit.

On August 22nd, the remainder of the whole-plant corn was chopped, inoculated, and transported to the dairy farm. As on day 1, all of the forage was spread in thin layers and packed with the loader. After the last load of the day was packed, one-half of the surfaces received a final pack with the pay loader and the other one-half of the surfaces received a final pack with the crawler (**Figure 4**).

Figure 4. Packing the forage surface with the loader or crawler.

The entire surface of the pile was seal with either Std. plastic or OB film as soon as the final pack was completed on the second day (**Figures 5 and 6**).

Figure 5. The silage pile was covered with OB film/Std. plastic.

Figure 6. The final covered silage pile.

A sheet of Std. plastic was placed on the OB film to protect it from ultraviolet light. The covering materials were secured with tire sidewalls, and soil was placed around the edges of the pile. The adjoining seams that separated the six treatments were weighted with pea gravel bags placed end-to-end.

Figure 7. The corn silage pile before opening, making visual observations of the silage surface, and taking samples.

The corn silage in the pile was undisturbed until November 20, 2013. The covering materials were removed from the south half of the drive-over pile (**Figures 7 and 8**).

Figure 8. The OB film and Std plastic covers being removed from the pile.

Samples were taken at 0 to 6, 6 to 12, and 12 to 18 inches from the surface at three north-south locations, which were equal distance from the east and west sides of each of the six treatments (**Figures 9, 10, and 11**).

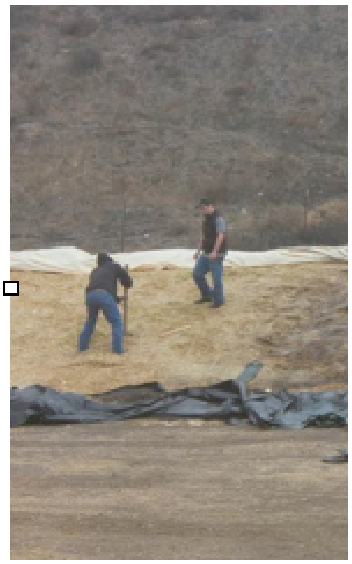

Figure 9. Digging holes to get samples at each depth.

Figure 10. Obtaining samples from 0 to 6, 6 to 12, and 12 to 18 inches from the surface.

Each of the 54 samples was weighed, frozen, and sent to Rock River Laboratories West, Inc., Visalia, California. Analysis included standard nutritional value and silage fermentation profiles (**Appendix Table 1**).

Figure 11. Samples being weighed.

Results and Discussion

The results of the trial will be presented for the means of the three sampling depths. The main effects of covering system, sealing time post-filling, and pack vehicle on fermentation, nutritional quality, and estimated OM loss in corn silage are shown in **Table 2.** The oxygen barrier film, immediate sealing, and crawler silages had numerically lower pH and OM losses than the Std plastic, delay sealing, and loader silages. Lactic acid, acetic acid, total volatile fatty acids (VFA), and lactic acid as a percent of total VFAs were similar for the six treatments. The oxygen barrier film, immediate sealing, and crawler silages had numerically lower ash, acid detergent insoluble crude protein (ADICP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and lignin values and had numerically higher NDF digestibility (NDFd) and starch values than the Std plastic, delay sealing, and loader silages. Dry matter (DM) and crude protein (CP) were numerically similar for the six treatments.

The covering system (Std plastic vs, OB film) had a greater effect on OM loss than either sealing time or pack vehicle. The OB film reduced OM loss by 8.3 percentage points vs, Std plastic; the crawler, by 5.8 percentage points vs. the loader; and immediate sealing, by 3.3 percentage points vs. delay sealing.

Table 2. Effects of covering system, sealing time post-filling, and pack vehicle on fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface after 60 days of storage.

Item	**Std**	**OB film**	**Delay**	**Immediate**	**Loader**
DM, %	30.6	30.4	29.9	30.1	31.4
OM loss[1] %	19.5	11.2	15.6	12.3	18.1
pH	4.15	4.02	4.06	3.95	4.23
	------------------ % of the silage DM ------------				
Ash	5.03	4.61	4.83	4.63	5
CP	7.28	7.13	7.09	7.17	7.34
ADICP	9.03	8.8	9.2	9	8.5
ADF	28.1	26.9	27.7	26.8	28.1
NDF	47.7	45.2	46.8	45.1	47.5
DNFd	60.9	63.5	63	63.2	60.3
Lignin	2.88	2.66	2.89	2.54	2.88
Starch	26.9	29.5	28	28.7	27.9
Lactic acid	2.61	3	3	3	2.4
Acetic acid	3.00	3	2.7	3.1	3.2
Total VFAs	6.00	6.4	6.1	6.2	6.1
LA in VFAs	0.455	0.481	0.502	0.488	0.415

The results comparing Std. plastic and OB film when sealed immediately and packed with a crawler are shown in **Table 3.** The OM Loss was higher under the Std. plastic than the OB film by 6.48 percentage points indicating that the OB film allowed for a faster fermentation and allowed less oxygen to permeate into the silage pit. This correlates as the ash, ADF, NDF, lignin, and pH were also higher in the silage under the Std. plastic whereas the NDFd, starch, and lactic acid were lower in the silage under the OB film.

Table 3. Fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface of the pile for Std plastic vs. OB film when sealed immediately and packed with a crawler.

Item	Std plastic	OB film
DM %	30.13	30.11
--------------- percent of the silage DM --------------		
Ash	4.77	4.49
CP	7.28	7.05
ADF	27.12	26.39
NDF	46.01	44.19
NDFd	62.86	63.55
Lignin	2.59	2.50
Starch	27.9	29.57
pH	3.99	3.92
Lactic acid	2.62	3.33
Acetic acid	3.23	3.01
Total VFAs	6.05	6.42
LA in VFAs	0.459	0.517
OM loss[1]	15.54	9.06

[1] As a percent of the OM ensiled.

Table 4. Fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface of the pile for Std plastic vs. OB film when sealed immediately and packed with a loader.

Item	Std plastic	OB film
DM %	31.26	31.5
--------------- percent of the silage DM ----------------		
Ash	5.32	4.68
CP	7.46	7.23
ADF	29.28	26.82
NDF	49.82	45.28
NDFd	58.03	65.52
Lignin	3.07	2.69
Starch	25.14	30.73
pH	4.37	4.09
Lactic Acid	2.37	2.45
Acetic Acid	3.04	3.42
Total VFAs	5.83	6.46
LA in VFAs	0.432	0.397
OM Loss[1]	23.91	12.19

[1] As a percent of the OM ensiled.

The results comparing Std plastic and OB film when sealed immediately and packed with a loader are shown in **Table 4**. The silage under the Std. plastic had a much higher OM loss than the silage under the OB film, by 11.72 percentage points. The silage under the Std. plastic was also higher in ash content, ADF, NDF, and lignin; it is lower in NDF digestibility and starch.

This shows that the corn silage under the Std. plastic is less nutritious for the cow because lignin cannot be digested by the rumen and has less starch which is what is readily available for energy. The Std. plastic allowed more air to permeate into the silage causing higher ash content as well as more OM loss.

Table 5. Fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface of the pile for Std plastic vs. OB film when delay sealed and packed with a crawler.

Item	Std plastic	OB film
DM %	30.27	29.51
----------------- percent of the silage DM ----------------		
Ash	5.01	4.65
CP	7.09	7.09
ADF	27.91	27.45
NDF	47.4	46.25
NDFd	61.69	64.34
Lignin	3	2.78
Starch	27.77	28.13
pH	4.07	4.05
Lactic Acid	2.86	3.2
Acetic Acid	2.75	2.63
Total VFAs	6.11	6.17
LA in VFAs	0.473	0.53
OM Loss[1]	17.74	12.26

[1] As a percent of the OM ensiled.

The results comparing Std plastic and OB film when delay sealed and packed with a crawler are shown in **Table 5**. The corn silage under the Std. plastic is slightly higher in ash as well as the NDF. The starch and NDF were slightly lower. However, this numerical data was not as drastically different as the data comparing the difference between the Std. plastic and OB film covers on the silage packed immediately with the loader. These numbers show that the silage that was delayed in covering had more OM loss than the silage that was immediately covered, as they had a difference of 5.48 percentage points in OM loss.

Table 6. Fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface of the pile for loader vs. crawler as the pack vehicle.

Item	Loader	Crawler
DM %	31.38	30.12
---------------- percent of the silage DM -----------------		
Ash	5	4.63
CP	7.34	7.17
ADF	28.05	26.75
NDF	47.55	45.1
NDFd	60.28	63.21
Lignin	2.88	2.55
Starch	27.94	28.74
pH	4.23	3.95
Lactic Acid	2.41	2.97
Acetic Acid	3.23	3.12
Total VFAs	6.14	6.24
LA in VFAs	0.414	0.488
OM Loss[1]	18.05	12.3

[1] As a percent of the OM ensiled.

The results comparing a loader and a crawler as the pack vehicle are shown in **Table 6**. The silage that was packed with the loader had higher ash content, ADF, NDF, pH and lactic acid content than the crawler tractor. The NDFd and starch were lower in the silage packed with the loader compared to the crawler tractor. The overall OM loss was 18.05 percent in the silage packed with the loader compared to 12.30 percent OM loss in the silage packed with the crawler which is a difference of 5.75 percentage points. All of these things indicate that packing with a lighter tractor (the loader) will lead to lower nutritional quality feed and more spoilage in the top 0-18 inches.

To calculate the cost of OM loss between the corn silage packed with the loader compared to the crawler, based on a 1,000-ton drive-over pile (with a 10-foot apex height and 1 to 3 side slopes) and 65-dollar price per ton, the loader having 18.05 percent OM loss in the 0 to 18 inch depth would end up being 3,139 dollars lost. For the crawler with 12.30 percent OM loss in the 0 to 18 inch depth it would be 2,139 dollars lost. This is a difference of 1,000 dollars less silage lost by packing with the crawler.

The results comparing delay and immediate sealing are shown in **Table 7**. The silage that was immediately covered had a lower ash content, ADF, NDF, and lignin compared to the silage that was delayed 24 hours before covering. The starch content, NDFd and OM loss, which had a difference of 3.34 percentage points, was higher in the silage that was covered immediately compared to the silage that was delayed 24 hours before covering. This shows that there was an advantage to covering the pit immediately instead of delaying 24 hours as it kept more oxygen out to speed up the fermentation process.

Table 7. Fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface of the pile for delay vs. immediate sealing.

Item	Delay	Immediate
DM %	29.89	30.12
----------------- percent of the silage DM ----------------		
Ash	4.83	4.63
CP	7.09	7.17
ADF	27.68	26.75
NDF	46.83	45.1
NDFd	63.02	63.21
Lignin	2.89	2.55
Starch	27.95	28.74
pH	4.06	3.95
Lactic Acid	3.03	2.97
Acetic Acid	2.69	3.12
Total VFAs	6.14	6.24
LA in VFAs	0.502	0.488
OM Loss[1]	15.64	12.3

[1] As a percent of the OM ensiled.

Based on 65 dollars per ton of corn silage, in a 1,000-ton drive-over pile (with a 10-foot apex height and 1 to 3 side slopes), the delayed covering having 15.64 percent OM loss, would be 41.84 tons of silage lost. That would be 2,720 dollars of corn silage. For the immediately covered silage with 12.30 percent OM loss that would be 32.90 tons of silage lost. At 65 dollars per ton, that would be 2,138 dollars. Therefore, in a 1000-ton drive-over pile the results of this trial show that 582 dollars would be saved by covering immediately instead of delaying 24 hours.

Table 8. Fermentation, nutritional quality, and estimated OM loss in corn silage at 0 to 18 inches from the surface of the pile for std plastic vs. OB film covering system.

Item	Std plastic	OB film
DM %	30.6	30.4
---------------- percent of the silage DM --------------		
Ash	5.03	4.61
CP	7.28	7.12
ADF	28.1	26.89
NDF	47.74	45.24
NDFd	60.86	63.47
Lignin	2.89	2.66
Starch	26.94	29.48
pH	4.14	4.02
Lactic Acid	2.61	2.99
Acetic Acid	3.01	3.02
Total VFAs	6	6.35
LA in VFAs	0.455	0.481
OM Loss[1]	19.46	11.19

[1] As a percent of the OM ensiled.

The results comparing Std plastic and OB film are shown in **Table 8.** it shows that the ash, ADF, NDF, and the pH were higher in the corn silage covered with Std. plastic compared to the OB film. And the starch, NDFd, and lactic acid were lower in the silage covered by the Std. plastic compared to the silage under the OB film. The OM loss for the ST silage treatments was 19.46 percent whereas the OM Loss for the OB film was 11.19 percent. This is a difference of 8.27 percent.

The OB film has better nutritional quality and better fermentation compared to the ST film because it blocked more oxygen out compared to the Std. plastic allowing the silage to ferment quicker. Based on the data there was a numerical difference. When the pile was opened up, there was a visual difference between the OB and ST treatment areas- the silage covered with OB had very little visible spoilage whereas the silage covered with the ST plastic had visible spoilage and mold (**Figure 12**). This shows that the OB film appears to have sealed better and likely had less oxygen permeate the silage than the ST plastic allowing it to ferment sooner.

Figure 12. The silage that was covered with Std plastic showed excessive visible mold and surface spoilage.

For calculating the cost of the OM loss in the outer 0 to 18 inch depth for the Std plastic, it would be 3,384 dollars, which is based on a 1000-ton drive-over pile (with a 10-foot apex height and a 1 to 3 side slopes) at 65 dollars per ton with an OM loss of 19.46 percent. Based on the same pile of corn silage for the OB film it would be 1,946 dollars lost with 11.19 percent OM loss in the outer 0 to 18 inch depth. This is a difference of 1,438 dollars. The sealing cost for OB film would be approximately 831 dollars higher than for Std plastic, so the net silage lost would be about 607 dollars less for OB film.

Conclusion

This project evaluated the effects on the quality of corn silage based on: 1.) whether it was packed with a loader or crawler, 2.) sealed immediately or delayed 24 hours, and 3.) if it was covered with standard plastic or an oxygen barrier film.

The data showed that the OM loss was higher in the silage that was delay sealed 24 hours than the silage that was sealed immediately (by 3.34 percent). Although this was only one day it still allowed oxygen to permeate the silage causing the fermentation process to be slowed and therefore surface spoilage to increase.

When the silage was packed with the loader, which was a lighter tractor, the silage had more OM loss (5.75 percent more) than the silage that was packed with the crawler, which was a heavier tractor. By having a lower packing density, more oxygen was able to permeate the outer layer of forage, which prolonged the aerobic phase, slowing the fermentation process.

Silage that was covered with the OB film had higher nutritional quality in the outer 0 to 18 inches of the pile than the silage that was covered with the Std. plastic. When the pile was uncovered at 60 days, visible spoilage was seen in the silage under the Std. plastic but ver little was seen on the silage under the OB film. The OB film was more effective in keeping oxygen out and had lower OM loss than the Std. plastic.

References

Amaral-Philips, D. Reminders for Corn Silage Chopping. 2014. University of Kentucky: College of Agriculture, Food and Environment.

Arriola, K., O. Queiroz, E. Muniz, J. Romero, M. Zarate, J. Hamie, A.T. Adesogan. 2014. Reducing Dry Matter and Nutrient Loss in High Moisture Forage. Department of Animal Sciences. IFAS.

Berger, L.L. and K.K. Bolsen. 2006. Sealing strategies for bunker silos and drive-over piles. In: Proc. Silage for Dairy Farms: Growing, Harvesting, Storing, and Feeding. NRAES Publ.181. Ithaca. NY.

Bolsn, K. K., B. E. Brent, R. V. Pope. 2014. The Ensiling Process: Basic Principles. Department of Animal Sciences and Industry, Kansas State University.

Bolsen, K.K., J.T. Dickerson, B.E. Brent, R.N. Sonon Jr., B.S. Dalke, C. Lin, J.E. Boyer Jr. 1993. Rate and Extent of Top Spoilage Losses in Horizontal Silos. Department of Animal Sciences and Industry, Kansas State University. J Dairy Sci. 76:2940-2962.

Bolsen, Keith. Managing Forage for Single Digit Shrink Loss in Bunker Silos and Drive Over Piles. 2012 Corn Silage and Forage Field Day. May 24, 2012. Citra, FL.

Bolsen, Keith. 2013. Silage Plastic: Looks can be Deceiving. Progressive Forage Grower. Issue 3. Page 21. March 2013.

Borreani, G., E. Tabacco. 2008. Low Permeability to Oxygen of a New barrier Film Prevents Butyric Acid Bacteria Spore Formation in Farm Corn Silage. J. Dairy Sci., 91:4272-4281.

Charley, R. 2014. Silage Packing Density: A Critical Management Control Point for Producing High Quality Silages. ADM Alliance Nutrition Inc.

Dolci, P., E. Tabacco, L. Cocolin, G. Borreani. 2011. Microbial Dynamics During Aerobic Exposure of Corn Silage Stored Under Oxygen Barrier or Polythylene Films. Appl. Environ. Microbiol. 77:7499-7507.

Henning, Jimmy C., Gary D. Lacefield, and Donna Amaral-Phillips. 2014. Interpreting Forage Quality Reports.

Hoffman, Patrick C., Combs David K. Managing Aerobic Stability. 2014. Department of Dairy Science. University of Wisconsin-Madison.

Kuber, R., K. K. Bolsen, S. Wigley, J. M. Wilkinson, and R. E. Bolsen. 2008. "Preservation efficiency and nutritional quality of whole-plant corn sealed in large pile silos with an oxygen barrier film (Silostop) or standard polyethylene film." In Proceedings XIII International Conference on Forage Conservation, Nitra, Slovak Republic, pp. 178-179.

Kung, Limin Jr. 2014. Practical Management Aspects of Corn Silage for Dairy Cattle. Ruminant Nutrition & Microbiology Laboratory.

Lallemand Animal Nutrition. 2011. Biotal Buchneri 500. Oct. 11, 2011. http://www.lallemandanimalnutrition.com/products/biotal-buchneri-500/

Making Silage: The Fermentation Process. 1999. Forage Management. Pacific Field Corn Association. Agassiz, BC. Farmwest.

Muck, R.E. 2014. Butyric Acid in Silage: Why it Happens. U.S. Diary Forage Research Center.

News Release. 2013. Corn Silage Harvest Timing. DuPont Pioneer. July 1, 2013. Agweb.

Schroeder, J.W. 2004. Silage Fermentation and Preservation. North Dakota State University. June 2004.

Silostop: How it Works. Available: http://us.silostop.com/howitworks. Accessed: Jan. 12, 2014.

Undersander, Dan. 2007. Ash in Forage. Agronomy. University of Wisconsin Extension.

Table 1. Effects of covering system, packing vehicle, and covering time on corn silage nutritional and fermentation quality.

Sample	Crawler/ Loader	Delay/ Immediate	ST/OB	DM%	Ash	CP	ADICP	ADF	NDF	NDFD	Lignin	Starch	pH	Lactic	Acetic	Propionic	Butyric	Total VFAs	LA in VFAs	OM Loss
A1	Crawler	Delay	ST	29.18	5.56	7.4	10.24	28.82	49.92	59.76	3.09	26.73	4.18	2.35	2.5	0.3	0.08	5.48	0.451	18.94
A2	Crawler	Delay	ST	30.98	4.64	7.25	9.05	27.39	45.61	61.93	3.16	28.18	4.01	3.29	3.15	0.4	0.01	6.85	0.477	18.94
A3	Crawler	Delay	ST	30.65	4.83	6.63	9.67	27.53	46.66	63.38	2.75	28.4	4.03	2.93	2.59	0.47	0.01	5.99	0.491	18.94
B1	Crawler	Delay	OB	29.81	4.65	6.89	8.62	27.58	47.3	64.56	2.85	27.4	4.08	2.8	2.88	0.26	0.01	5.93	0.472	12.33
B2	Crawler	Delay	OB	28.88	4.69	7.01	9.11	27.81	47.3	64.46	2.73	26.08	4.03	3.14	3.01	0.52	0.01	6.67	0.499	12.33
B3	Crawler	Delay	OB	29.82	4.61	7.38	8.68	26.97	44.15	64.01	2.76	30.93	4.03	3.64	2	0.4	0.01	5.91	0.619	12.33
C1	Loader	Immediate	OB	31.59	4.82	7.34	8.67	26.45	44.34	61.27	2.65	31.9	4.2	1.74	3.56	0.47	0.01	6.1	0.291	12.91
C2	Loader	Immediate	OB	32.14	4.65	7.27	7.98	26.27	44.45	62.32	2.84	31.06	4.13	2.27	3.48	0.52	0.01	6.28	0.416	12.91
C3	Loader	Immediate	OB	30.78	4.57	7.08	8.7	27.75	47.04	63.52	2.59	29.22	3.93	3.35	3.22	0.4	0.03	6.99	0.484	12.91
D1	Loader	Immediate	ST	30.46	6.25	8.54	9.35	32.11	52.97	48.88	3.49	21.07	4.95	1.53	2.96	0.34	0.05	4.87	0.379	23.91
D2	Loader	Immediate	ST	32.97	5.1	7.02	7.4	28.04	48.37	62.64	3.11	27.91	4.14	2.74	3.09	0.34	0.01	6.17	0.476	23.91
D3	Loader	Immediate	ST	30.35	4.6	6.81	8.73	27.68	48.12	62.58	2.6	26.45	4.04	2.85	3.07	0.4	0.07	6.46	0.441	23.91
E1	Crawler	Immediate	ST	30.28	5.06	7.61	8.1	27.8	48.08	62.76	2.9	27.63	4.08	2.05	3.78	0.28	0.01	6.12	0.333	15.54
E2	Crawler	Immediate	ST	29.47	4.75	7.45	9.14	27.2	45.44	62.56	2.67	27.98	4.01	2.16	3.96	0.3	0.01	6.43	0.394	15.54
E3	Crawler	Immediate	ST	30.63	4.5	6.79	9.57	26.35	44.52	63.16	2.22	28.1	3.87	3.63	1.94	0.01	0.01	5.59	0.65	15.54
F1	Crawler	Immediate	OB	29.93	4.58	7.06	8.82	26.21	44.39	63.56	2.65	30.29	3.99	2.21	3.98	0.13	0.01	6.33	0.351	9.06
F2	Crawler	Immediate	OB	30.02	4.46	6.85	9.11	26.9	45.01	63.73	2.59	28.66	3.89	3.46	2.82	0.01	0.01	6.3	0.548	9.06
F3	Crawler	Immediate	OB	30.39	4.43	7.25	9.3	26.06	43.17	63.36	2.25	29.77	3.87	3.87	4.32	2.22	0.08	6.64	0.651	9.06