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Advances in Silage Sealing

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Abstract

Spoiled silage at the top and shoulders of a horizontal silo is common because of their lower density and higher aeration. Thus, avoiding or reducing aerobic deterioration in the peripheral areas of the silages becomes a key factor for commercial farms. There are two factors that affect the top spoilage: the quality of the plastic film and how well it is held to the forage. The quality of the plastic film is related to oxygen permeability, thickness, and ultraviolet blocking. To hold the sheet to the crop, sidewall plastic associated to gravel bags and used tires have been good alternatives to be used as weights to secure the sheet on the top surface, but many other means can be applied like sidewall disks. Preventing silage losses due to an inappropriate sealing is important, both from nutritional and economic contexts. Proper air sealing produces well-fermented silage and mitigates losses in the upper layer of the silo.

Keywords: plastic cover, aerobic deterioration, dry matter losses, oxygen barrier film, silage storage

1. Introduction

Limiting losses in the upper silage layer is crucial for ensiling process. When no seal is applied, or when the seal is inadequate, air and moisture enter into the silo, affecting the quality of silage; therefore, silage is covered for two primary reasons. The first is to exclude rainfall because precipitation washes organic acids and other soluble feed components from the forage, and the second is to reduce exposure to air.

Oxygen enables various aerobic spoilage microorganisms to become active and to multiply themselves, resulting in aerobic deterioration [1] and substantial economic losses. The deterioration of the silage is indicated by temperature and pH increase, dry matter (DM) and nutrient losses, surface mold growth, and feed refusal by the animals.

Livestock farms can store silage in various ways such as horizontal silos (bunker and stacks), tower silos, bagged silos, or wrapped bales. Several farms prefer horizontal silos due to relatively low construction costs, greater safety compared to tower silos and high work rates for filling and unloading [2]. Nevertheless, their design allows large areas of the ensiled material to be exposed to the environment and prone to spoilage, especially in the upper layer and near the walls [3].

In horizontal silos, during the storage period, a spoiled layer is formed below the sealing sheet, known as “surface waste.” Although there is also some evidence that invisible oxidation losses occur throughout the whole mass of silage during the storage period. A large percentage of the silage mass (about 25%) can be within the top 1 m depending on silo size and depth.

The most common material used to seal horizontal silos is the plastic film. The principal function of the film is to seal the forage and allow anaerobic conditions to establish [4]. Plastic films of 150–200 μm thickness have been used for this purpose. Although polyethylene (PE) sheeting has been the most common method used to protect silage near the surface, the protection provided is highly variable and often changes during storage [5]. Thus, the effectiveness of covering methods is very important to limit aerobic deterioration and losses in the large mass being protected.

This chapter presents the main factors related to sealing methods that affect the extent of aerobic deterioration in horizontal silos. Furthermore, the chapter review aims to identify proper management strategies to improve silage quality on commercial farms.

2. Unsealed silos

Along with proper harvesting and filling techniques, it is also equally important to properly cover a bunker silo. Previous studies have demonstrated that the quality and recovery of silage are compromised if horizontal silos are not covered with plastic film.

A study summarized the DM and nutrient losses when bunker and stack silos are not sealed [6]. From 1990 to 1993, the top 0.90 m of silage from 127 horizontal silos was sampled at three sites throughout the silo face. Sampling depths from the surface were 0–0.45 m (depth 1) and 0.45–0.90 m (depth 2). The silos were sealed with a single PE film of black or white-on-black (from 100 to 150 μm thick) secured with tires, sidewall disks or soil.

Losses were higher in bunkers and stacks that were not sealed. Silage located in the peripheral area of the unsealed silos showed pH values ranging from 4.75 to 8.55, which were typical of spoiled silage. When a plastic film was applied, the organic matter losses in the upper layer (top 0.45 m) were reduced. Silage sealing also reduced spoilage losses in the second 0.45 m.

The aerobic deterioration is initially limited to the top 15–30 cm in an uncovered silo. The reason for this is that aerobic microbial activity is great enough in the upper layer to remove all of the oxygen entering into the crop either by diffusion or by convection. As the readily degradable components of the crop in the top layer are exhausted, the rate of microbial activity declines allowing oxygen to move deeper in the silo and cause deterioration at that level [7].

Economic evaluations indicate that the reduced losses from using a cover return more than \$8.00 for each \$1.00 invested in plastic and labor to cover a bunker silo [8]. In a 200-t bunker silo (6 m wide by 20 m long by 2.5 m deep), an effective seal to protect the top 1 m of silage can prevent the loss of 100–400 dollars worth silage, depending on the value of the crop. Proper sealing with a plastic cover is therefore essential to reduce losses and prevent microbial deterioration, which may result in the presence of toxins.

3. Lining bunker walls with plastic

A large part of the silage stored in horizontal silos is exposed to air and is prone to spoilage, especially in the upper part near the walls (at the shoulders of the silo), which are difficult to seal properly. A research reported silage DM losses near the surface of bunker silos to be the highest (76%) near the silo wall and the lowest (16%) in the core [9]. Thus, a problem still not fully solved is the connection of the cover to the bunker silos.

The best results are achieved by putting an additional film 1–2 m deep (depending of the silo size) between wall and forage, and then over the forage, before the main sheet is attached (**Figure 1**). The result of this additional effort is that silage quality along the wall is similar as that throughout the silo [10, 16].

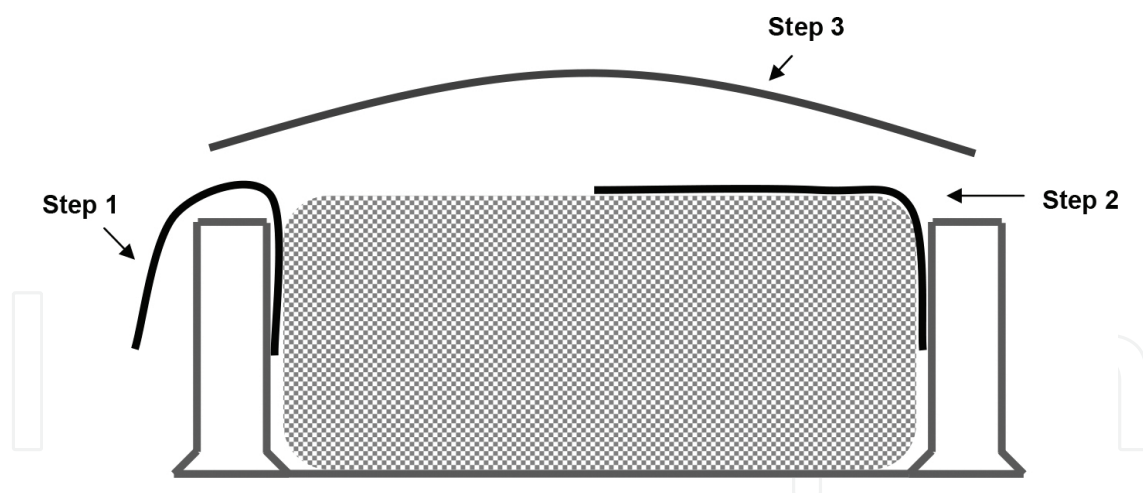


Figure 1. Bunker lining diagram. Step 1 = before silo filling, place a plastic sheet along the length of the sidewall with approximately 2 m of excess draped over the wall; Step 2 = sidewall plastic should lap onto the forage top at the end of filling; and Step 3 = cover the bunker with additional plastic film.

There are limited studies showing the effects of bunker silo sidewall plastic on silage characteristics. A survey in 20 dairy farm bunker silos, 10 without and 10 with sidewall PE plastic, demonstrated that lining bunker wall improves fermentation and produces silage with greater digestibility [11]. Sidewall plastics have more effects on forage preservation; however, it will be addressed in Section 4.2 of this chapter.

4. Plastic film to cover silage

A plastic film to cover silage has to fulfill three essential functions. First, the film should prevent precipitation and damage caused by meteorological effects and animal attack. Second, the film should be UV resistant to resist prolonged exposure to sunlight. Finally, the third function of the silo film is guarantee anaerobic conditions in the silage.

4.1. Color and thickness of plastic film

The color of sheet should affect the amount of air infiltration and subsequent aerobic losses because oxygen permeability into the silage is highly dependent on the temperature of the plastic. Only few data have been published about the thermal effects of covers on the upper silage layers. It is important to emphasize that these surface layers are highly susceptible to poor fermentation because of unsatisfactory packing density and the proximity to the plastic film. Moreover, a microclimate in the upper layer created by the high temperature influences strongly the growth of undesirable microorganisms (yeasts, molds, and aerobic bacteria).

This is consistent with the observations by Bernardes et al. [12], who found highest DM losses and yeast counts when corn silages were sealing with black PE. Black sheet also shows higher temperature in relation to white-on-black film during storage period (**Figure 2**).

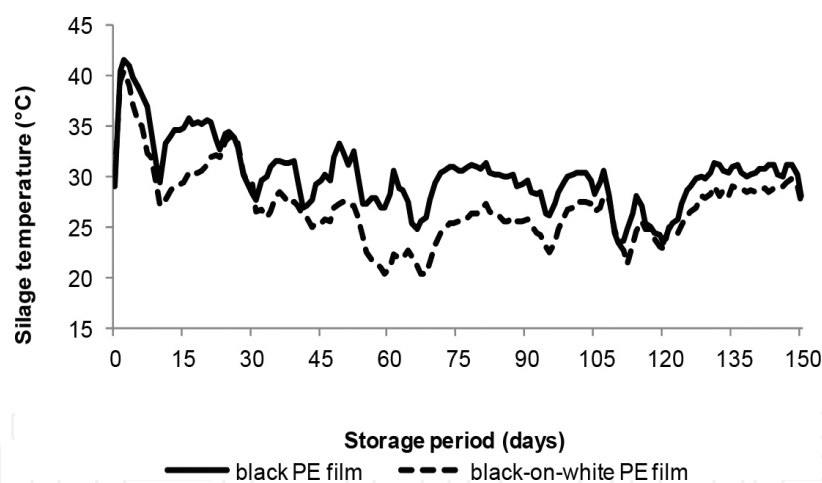


Figure 2. Effects of the color of plastic film on temperature of corn silages during 150 d of storage.

A study reported the effects of the color on the temperature of the film surfaces [13]. The authors found that in the morning hours, temperature peaks were up to 16°C higher for the black film in comparison with the white film. As expected, the highest values were reached at midday, with the black and green colored films showing a very similar thermal behavior. The same applied for the evening hours.

A model to establish the costs of plastic and respiration losses because of air penetration through the film was developed by Savoie [5]. To calculate the optimal thickness, the following parameters were considered: storage period, silage density and DM content, film permeability,

and the relative value of plastic and silage. Polyethylene silage bags of different thickness (100, 150, and 200 μm) did not produce significant differences in losses in 130 d, averaging 0.2% loss/month when perfectly sealed [5]. However, modeling of different film thickness indicated that 100 μm was economically optimum on a stack silo for 3 months storage, 150 μm for 7 months, and 200 μm for 12 months. It is important to emphasize that films with thicker thickness have more puncture and tear resistance than the thin ones.

4.2. Oxygen permeability of plastic films

Air is the major cause of spoilage in silage. Polyethylene is not totally impermeable to oxygen diffusion and thus will not completely prevent oxygen ingress. There is a general agreement, therefore, that low oxygen permeability of the sheets has to be sought.

The first generation of barrier films emerged in the early 2000s when a co-extruded PE-polyamide film was developed for covering horizontal silos [14]. It had 125 μm in thickness and comprised two outer layers of PE with a central layer of polyamide. However, this film showed some problems such as rigidity and fragility what led to less use in farm conditions.

More recently, oxygen barrier (OB) films made with PE and ethylene-vinyl alcohol (EVOH) have been available. Ethylene-vinyl alcohol combines the highest barrier properties with good mechanical characteristics such as puncture resistance, tear resistance, and stretch properties [15].

There are two types of OB films, which are available on European and American market, respectively. The first one is a white-on-black sheet, which is composed by a layer of EVOH between layers of PE during the manufacturing process. The second is a thin film (45- μm -thick PE + EVOH), which needs to be covered by tarp or a second layer of PE during its application in practical conditions. This procedure is necessary because it is not UV stabilized. Originally, the thin OB film was associated with a tarp to protect from UV light as well as from physical damage. However, this type of UV cover is expensive for producers with modest resource availability. Thus, to overcome this problem, a method that combines the thin film with a conventional PE sheet has been created. An experiment was carried out to evaluate the effectiveness of this method for covering corn silage in bunker silos [16]. Two systems were assessed, as follows: the first method comprised a sheet of 45- μm -thick OB film placed along the length of the sidewall before filling, with approximately 2 m of excess draped over the wall. After filling, the excess film was pulled over the wall, and a sheet of PE was placed on top. The second system involved using a standard sheet of 180- μm -thick PE film. Over 2 years, eight commercial bunker silos were divided into two parts lengthwise so that half of the silo was covered with OB and the other with standard system. Oxygen barrier method produced well-fermented silages, which were similar to the central part of the silo (core), whereas PE system showed less lactic acid and greater pH and mold counts compared with core. The estimated milk yield for PE system was 116 kg/ton less than core, as OB system and core were similar (1258 and 1294 kg/ton, respectively), as shown in **Figure 3**. These results and those obtained by Borreani and Tabacco [17] showed a net economic gain when the OB films are used due to both reduced nutrient losses and labor time required to clean the upper layer, even though these films cost more than the PE layer.

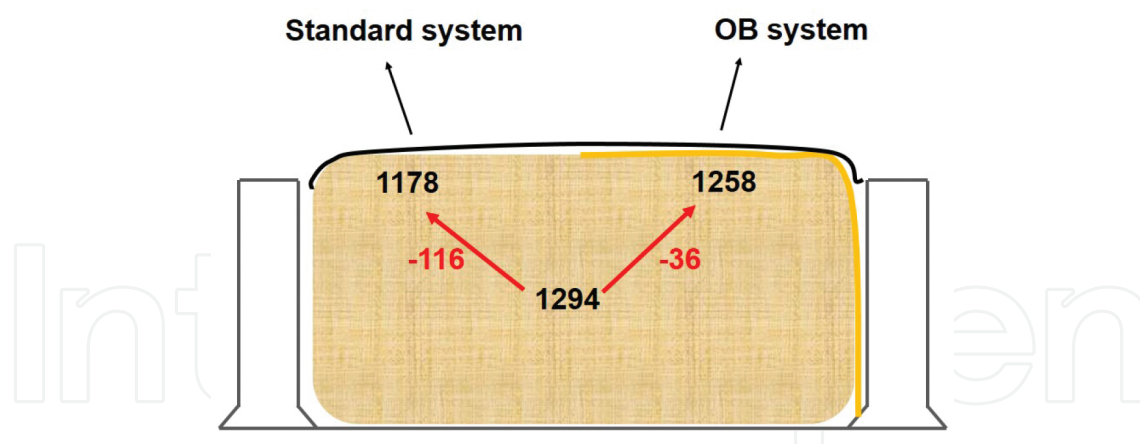


Figure 3. Effects of two covering system on estimated milk yield (kg/ton) of corn silages. Standard system = a single sheet of polyethylene (PE) film; OB system = oxygen barrier film between the silo wall and forage and covered by a second layer of PE film. *Source:* Lima et al. [16].

4.3. Biofilms

An environmental objective is to reduce the quantity of plastic used in agriculture, and there may be opportunity for achieving this by reducing the use of the plastic film for sealing silos. However, horizontal silos produce less plastic wastes than most other systems that use PE film for air tightness. Round bale silage requires at least 5.5 kg of plastic/ton DM. Stack silos use about 1.3 kg of plastic/ton DM, four times less than the round bale silage system [5].

A study was conducted to determine whether the PE film could be replaced with bio-based biodegradable films [18]. A standard 120- μm -thick white-on-black PE film and two different 120- μm -thick biodegradable plastic films were used to produce the silage bags for that experiment. The results of this research showed that the development of new degradable materials to cover silage could be possible. In addition, the authors recommended that further research should be undertaken to improve the blend for enhancing film stability over time and its resistance under outdoor conditions.

5. Weighting the plastic cover

To prevent deterioration in horizontal silos, the common practice is to use plastic film held in place with used car tires. Tires have been widely used because of their low cost and ready availability. In a study reported by Ruppel [19], there was a reduction in the temperature and improved protein availability of hay crop silage when the number of tires per square meter increased. The effects of several covering methods on reduction in the silage losses in the top layer concluded that higher tire density (30 tires per 10 m²) and sand bags along the shoulders resulted in lower losses [19].

The results of a study on different silage sealing systems were presented by Borreani and Tabacco [20]. A farm bunker silo was covered with a single white-on-black sheet. Half of the

width of the sheet was covered with tires (25 kg/m²), and the other half was covered with gravel (200 kg/m²). The silo was opened for summer consumption and had a low feed-out rate (12 cm/d). The results showed that the difference in sealing system affected the temperature in the peripheral areas of the corn silage. The silage covered with tires reached a maximum temperature exceeding 40°C, whereas that covered with gravel did not.

The amount of soil placed on top of the PE plastic cover also has an effect on silage quality. The effectiveness of several sealing strategies that are used in Brazil on reduction in losses in the top layer was tested by Griswold et al. [11]. Covering a black plastic sheet with soil (100 kg/m²) reduced losses, and this was associated with decreased pH and ash content and lower counts of yeasts. However, most farmers are very reluctant to cover horizontal silos with soil, particularly if the silo is large because they do not believe that the labor and costs involved in covering with soil are reasonable and economical. Moreover, the soil used as a cover can contaminate the silage during unloading. Thus, alternative covering strategies to reduce aerobic deterioration in the peripheral areas of the corn silage in a warm climate were investigated. Three treatments were evaluated: (1) black PE film (control); (2) black PE film plus sugarcane bagasse (10 kg/m²) over the sheet; and (3) black PE film plus soil (30 kg/m²) over the sheet [21]. Treatments did not affect the temperatures during the early part of the storage period, but after about 80 d of fermentation, the temperature started to rise in the control silage but not in the others. This can be attributed to the effect of oxygen permeability of the film during a long storage period because the gas transmission rate is reduced by the presence of soil or sugarcane bagasse over the sheet. These results also suggest that the material over the film reduces billowing caused by the wind what affects the amount of air drawn into the silo.

It is important to emphasize that keeping the plastic cover weighed down is critical during the storage and feed-out periods. During the unloading, air can penetrate the peripheral areas of a silo up to 1 m or more beyond the feed-out face [10], especially when the sealing cover is not weighed down or is weighed only with tires, suggesting that, in these situations, daily removal rates should be higher than 30 cm/d to avoid extended aerobic spoilage.

6. Chemical additives on the top of the silos

Especially in warm climates, whole-crop cereal silages such as corn, sorghum, and wheat are susceptible to aerobic deterioration. This is because aerobic yeasts are most active at 20–30°C [22]. Therefore, efforts need to be made to protect the silage near the surface when PE films are used. A research evaluated the application of additives (sodium benzoate and *Lactobacillus buchneri*) directly to the top of the silage and concluded that sodium benzoate applied at a 2 g/kg rate was the most suitable additive to improve the fermentation, reduce the aerobic deterioration, and preserve the nutrients of corn silage at the top of bunker silos [23]. Results from this study showed that the *in vitro* digestibility of the silage at the core and those treated with sodium benzoate were above 640 g/kg, whereas silages untreated and treated with two strains of *L. buchneri* had values close to 600 g/kg (**Figure 4**). According to the authors, under field conditions, the strains may have had their growth affected by high temperatures, and

thus, chemical additives present more robust effects than biological ones when applied at the top.

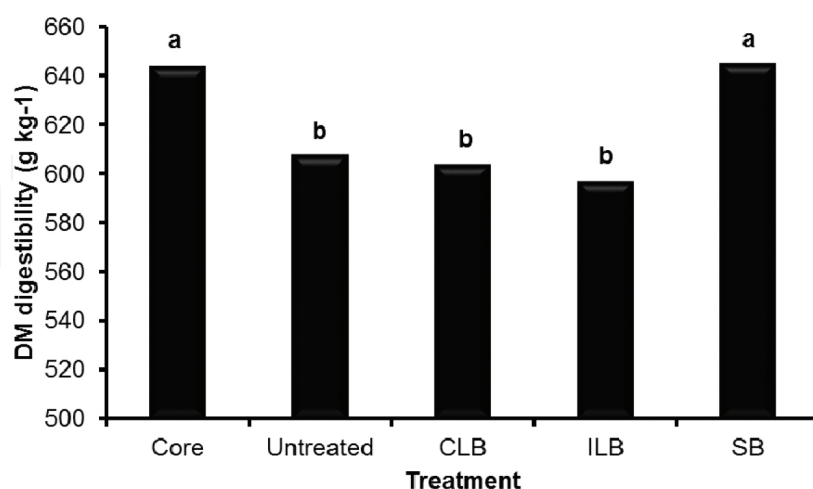


Figure 4. Effects of additives on *in vitro* DM digestibility in different zones of the bunker corn silage. Core = silage in the core of the silo; CLB = silage treated with commercial *Lactobacillus buchneri*; ILB = silage treated with indigenous *L. buchneri*; SB = silage treated with sodium benzoate. Source: Da Silva et al. [24].

7. Conclusions

The detrimental effect of air at silage near the surface is a key point to avoid losses of dry matter and quality. To date, no alternative to the use of plastic in covering bunkers or stacks has proven commercially viable for silage producers. Given the widespread use of horizontal silos worldwide, it is vitally important that the film used possesses good oxygen barrier properties as well as good mechanical properties.

In horizontal silos, the plastic needs to be held tightly to the crop. This is usually accomplished with used tires, but many other means can be applied. Besides that, lining bunker walls with plastic improve silage quality along the walls.

The silos' sealing will continue evolving to meet future needs in a conservation of fresh forage, minimize loss and cost, reduce environment contamination, and provide a safe and efficient on-farm feeding system.

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