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Impacts of a polyethylene silage pile underlay plastic with or without enhanced oxygen barrier (EOB) characteristics on preservation of whole crop maize silage, as well as a short investigation of peripheral deterioration on exposed silage faces

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ABSTRACT

Large silage piles, up to 15,000 t, common in some dairy areas, present challenges since their large surface area creates an enhanced potential for oxygen to penetrate the mass. Use of thin inner (*i.e.*, between the silage and main plastic cover) plastic films with enhanced oxygen barrier (EOB) properties are recognized by some governmental agencies as a mitigation of silage deterioration even though underlay films are generally accepted to only potentially impact the outer 30–50 cm of the silage in a pile. In four large maize silage piles, underlay film with or without EOB properties had no impact on silage fermentation parameters indicative of spoilage in the outer 25.4 cm of the silage pile, or in the 25.4–50.8 cm depth below the surface of closed silage piles at ∼3 and at ∼6 months post pile building. In contrast, in a 5th pile, there was evidence of deterioration in the surface silage to a 25.4 cm depth immediately behind the exposed silage face, which was not impacted by type of underlay film. A final experiment in a 6th pile showed that surface spoilage occurred well behind the exposed silage face, and that it moved into the pile at a similar rate as silage was removed from the face. Results do not support use of a thin plastic underlay film with EOB properties, *versus* one without, since air ingress to the silage mass through the silage pile cover appeared minimally causative of silage deterioration, which was associated with the exposed face. Maize silage deterioration of exposed face silage would likely be minimized by increasing speed of exposed face movement, and/or use of weight lines directly behind the exposed face, as has been recommended by others.

1. Introduction

Maize silage is the most important ensiled crop in most developed dairy areas. However spoilage of silage while it is ensiled are an economic loss to dairy farmers. One of the critical points to control spoilage in silage is to limit, as much as possible, oxygen ingress to the silage mass since it supports growth of aerobic microorganisms and the resulting heat production can lead to silage with degraded nutritional quality (Woolford, 1984). Indeed Bolsen et al. (1993) demonstrated the beneficial

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impacts of 'sealing' the surface of an ensiling mass with a plastic cover weighted with tires on several measures of silage spoilage. Since that time, many management practices have been suggested to reduce maize silage spoilage by reducing oxygen availability in the ensiled mass (*e.g.*, Bolsen, 2006; Wilkinson and Davies, 2012), and many are now very commonly used commercially. These include creating a high pack density at silage pile building, rapid covering of the ensiled mass with a plastic cover, sealing the periphery of the pile with soil or weights and using 'weight lines' along the area of plastic overlap on the pile surface. However a relatively simple practice, recommended by Bernardes et al. (2012) and Wilkinson and Davies (2012), as well as others in the commercial literature, which has gained wide use on commercial maize silage piles, is use of a thin inner plastic film (*i.e.*, between the silage mass and the main plastic cover), generally containing enhanced oxygen barrier (EOB) properties.

The meta-analysis of Wilkinson and Fenlon (2013) seems very convincing that use of inner plastic cover films with EOB characteristics on silage, *versus* non-EOB plastics, reduced dry matter (DM) losses and increased aerobic stability, amongst many other beneficial impacts. However 9 of 21 studies in Wilkinson and Fenlon (2013) did not specify the covering of the plastic silage covers on the piles (*i.e.*, on top of the outer plastic cover), and 6 of 21 studies confounded the plastic silage covers with its protective covering (*i.e.*, lines of ½ car tires or protective nets—which is important since nets transmit less solar radiation to the silage surface—and protect the plastic from bird and rodent damage—than ½ tire chains which are associated with dark 'ring shadows'). Thus it appears that at least some of the benefits attributed by Wilkinson and Fenlon (2013) to EOB characteristics in plastic films and covers may have been due to the protective cover, or in reality the 'silage covering system', which was the case in 6 of the 21 Wilkinson and Fenlon (2013) studies.

While the Wilkinson and Fenlon (2013) dataset included many studies with maize silage (13 of 21), most were laboratory scale or small bunkers, and there were only two studies (*i.e.*, Kuber et al., 2008; Basso et al., 2009) with large surface area maize silage piles which create an enhanced potential for oxygen to penetrate the ensiled mass. While these 2 studies reported strong treatment effects, what the studies actually compared was a single layer of 125 micron polyethylene *versus* a layer of the same polyethylene over an inner 45 μm EOB film, which confounds use of an inner film with the EOB characteristics of the film. Thus there are no studies comparing a thin underlay film with EOB properties to a polyethylene film with a similar thickness without EOB properties in large maize silage piles (or any silage structures).

The objectives of our study were to measure fermentation characteristics of maize silage indicative of silage spoilage, as impacted by use of thin plastic underlay films with or without EOB characteristics. In Experiment 1, two separate silage pile geographic orientation experiments, each with 2 maize piles, were completed to examine impacts of these films on silage fermentation characteristics in the outer 50.8 cm of the surface (as the 0 to 25.4 and 25.4 to 50.8 cm depths) at 2 times after pile building, but before silage feedout. In Experiment 2, underlay film impacts were measured on silage at a 60 cm depth below the surface and in the outer 25.4 cm of the surface, as well as on silage from deep in the pile, all during silage pile feedout. Due to unanticipated results of these two experiments relative to the underlay folms, Experiment 3 was completed in which impacts on silage deterioration of the distance of the silage surface core point from the exposed silage face at different times relative to silage pile feedout was assessed, in order to identify the reasons for peripheral deterioration on exposed silage faces.

2. Materials and methods

2.1. Experiment 1

Four large 'wedge type' maize silage piles were constructed between September 17 and October 13 (2013) in the Northern San Joaquin Valley of California (USA) to examine surface spoilage of silage under the cover plastic at ~3 and at ~6 months post pile building (*i.e.*, indicative of relatively short and long times of silage fermentation prior to feedout) as impacted by plastic underlay film. Based upon long-term pre-experiment visual experiences which suggested there were different impacts of the side face orientation of North/South *versus* East/West silage piles, two of the piles had a North/South orientation and two had a East/West orientation.

2.1.1. Experiment 1a

The two piles with a North/South orientation (average 6,900 t as built) were Experiment 1a. After pile construction was complete, all piles were covered within 48 h near one end with alternate coverage (Fig. 1) of a clear, pliable polyethylene film (POLY) of 40.6 μm (ARI Co., Belmont, CA, USA; trade name 'HiTec Underlay') or an enhanced oxygen barrier plastic film (EOB) of 45.7 μm (Industria Plastica, Mongralese, Italy; trade name 'Silostop'). Experimental sections on the pile surfaces were created with 15 m wide plastic sheets with ~0.8 m overlaps at each side and the top of the piles. All piles were covered with 127 micron white/black plastic, white side out, and covered with side-by-side rings of ½ tires—with treatment overlaps covered with 2 rings of ½ tires.

At 3.2 months after covering, and again at 5.7 months, the pile surfaces were core sampled. On each core sampling occasion in each of the four sections of each pile (Fig. 1), sampling was by coring through the silage cover plastic four times at two levels, being $^1/_3$ of the way up each side (Low level; 2 cores/section) and $^2/_3$ of the way up the side (High level; 2 cores/section), where side heights were ~13 m. Cores were separated by a minimum of 1 m. The coring device was a 4.76 cm (inside diameter) by 61 cm length stainless steel tube driven by an 18 V cordless Ridgid drill (Model R86008; Ridgid Tool Co., Elyria, OH, USA) and with 2 marked segments of 25.4 and 50.8 cm from the tip. Each coring event consisted of first