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An evaluation of the effectiveness of a chemical additive based on sodium benzoate, potassium sorbate, and sodium nitrite on the fermentation and aerobic stability of corn silage

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ABSTRACT

We evaluated the effectiveness of an additive comprising sodium benzoate, potassium sorbate, and sodium nitrite (SSL) as active ingredients for its ability to improve the aerobic stability of corn silages made in North America. In experiment 1, treatment with SSL (1.5 and 2.0 L/t) on whole-plant corn (WPC) was compared with treatment with an additive containing buffered propionic acid and citric acid (BPA; 2 L/t) on corn harvested at 32 and 38% DM and ensiled for 120 d. Silage treated with BPA was higher in ammonia-N and propionic acid relative to other treatments. Treatments with all of the additives had numerically, but not statistically, fewer yeasts compared with untreated silage. Both application rates of SSL resulted in lower concentrations of ethanol compared with untreated and BPA silages. Treatment with BPA improved the aerobic stability of silages compared with untreated silage, but the effect from SSL was markedly greater. In experiment 2, WPC was untreated or treated with 2 or 3 L of SSL/t or a microbial inoculant containing *Enterococcus faecium* M74, *Lactobacillus plantarum* CH6072, and *Lactobacillus buchneri* LN1819 (final total lactic acid bacteria application rate of 150,000 cfu/g of fresh forage). Silages were air stressed for 24 h at 28 and 42 d of storage and ensiled for 49 d before opening. Inoculation had no effect on acid end products, ethanol, number of yeasts, or aerobic stability compared with other treatments. Treatment with SSL decreased the amount of ethanol, had no effect on number of yeasts, and improved aerobic stability in a dose-dependent manner compared with other treatments. In experiment 3, WPC was untreated or treated with 2 L of SSL/t and ensiled for 5, 15, and 30 d. Treatment with SSL resulted in silage with fewer yeasts and lower concentrations of ethanol after all times of ensiling compared with untreated silage. In addition, SSL improved aerobic stability after each period of ensiling, but the effect was more at 15 and 30 d compared with 5 d of storage. Treating WPC with SSL can improve the aerobic stability of corn silage made in North America, and the effect can be observed as soon as 5 d after ensiling.
Key words: aerobic stability, antifungal, silage

INTRODUCTION

Corn silage is the most common type of silage fed to dairy cows in North America, but it can spoil rapidly when exposed to air during storage or feedout, especially in warm weather. Yeasts that metabolize lactic acid under aerobic conditions are usually the initiators of this process (Woolford, 1990), resulting in an oxidation of nutrients characterized by heating of the silage mass. Feeding spoiled silage is undesirable because it is lower in nutritive value than fresh silage and it can depress DMI (Hoffman and Ocker, 1997; Windle and Kung, 2013). Spoiled silage that is not fed and is discarded results in a loss of valuable feed inventory.

Many factors affect the aerobic stability of silages. For example, air can penetrate into a silage mass during prolonged storage, especially if the packing density is low because air penetrates deeply into porous material (Pitt and Muck, 1993). Air can penetrate into the face of a silo as much as 1 m (Muck and Huhnke, 1995) even in adequately packed silos. If 20 cm of silage is removed per day due to feedout, the average silage being fed would have been exposed to air for about 4 to 5 d. Silages that are high in DM (>40%) have lower concentrations of natural antifungal compounds (e.g., acetic acid) than wetter silages (<30% DM), and thus they are often more prone to aerobic spoilage. Silages that are exposed to air in warm weather will also spoil

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more quickly because most yeasts are mesophilic and grow best between 20 and 30°C (Deak, 2008).

Microbial-based additives have been applied to forages at the time of harvest to specifically improve the aerobic stability of silages (Kung et al., 2003). The added microbes must compete with other microorganisms in the silo and produce sufficient amounts of antifungal end products to improve aerobic stability, but this process can take weeks or months. For example, the improvement in aerobic stability obtained via the production of acetic acid by *Lactobacillus buchneri* requires at least 45 to 60 d of ensiling (Kleinschmit and Kung, 2006; Schmidt et al., 2009). In many instances, dairy farmers are forced to feed silage from freshly filled silos after very short periods of time of ensiling. In these situations, *L. buchneri* would not have sufficient time to increase acetic acid and improve aerobic stability. An alternative solution for improving the aerobic stability of silages is through the use of chemical additives whose primary active antifungal ingredients are short-chain organic acids. Although the cost of using chemical additives is relatively more than that of using microbial-based additives, in their favor, the former is not dependent on the growth of microorganisms to produce active end products. Buffered propionic acid is one of the most common antifungal ingredients in many chemical-based silage additives sold in North America. This acid has improved the aerobic stability of corn-based crops (Britt et al., 1975; Kung et al., 2000). More recently, potassium sorbate and sodium benzoate have also been effective in improving the aerobic stability of silages (Knicky and Spörndly, 2011; Nadeau et al., 2012; Seppala et al., 2016), but research with these compounds on corn silage in North America is limited (Kleinschmit et al., 2005; Queiroz et al., 2013; Hafner et al., 2015) and data supporting their efficacy after short periods of ensiling are lacking.

The objective of this study was to evaluate the effects of a chemical additive, developed in Europe, comprising the active ingredients sodium benzoate, potassium sorbate, and sodium nitrite (**SSL**), on the fermentation and aerobic stability of corn silage. In experiment 1, we compared the effects of SSL with those of an additive containing buffered propionic acid and citric acid on corn silage harvested at 2 concentrations of DM (32 and 38%). In experiment 2, SSL was compared with a microbial containing *L. buchneri* LN1819 on the ability to improve the aerobic stability of corn silage that was subjected to air stress during storage. In experiment 3, we determined whether SSL could improve the aerobic stability of corn silage after relatively short periods of ensiling (5, 15, and 30 d). Collectively, these were the first group of experiments to evaluate SSL on corn silage in North America.

MATERIALS AND METHODS

General Information

The experiments were conducted between 2012 and 2015 at the University of Delaware Farm, Newark. Corn was planted in fields of silt loam soil. Fields had been managed with a corn–alfalfa rotation or continuous corn. Fields were fertilized with manure (sheep, cow, and horse). At planting, a pop-up liquid fertilizer (3-5-4) was applied at 9.35 L/ha. Side dressing with 421 L/ha of 30% urea-ammonium nitrate occurred between the V5 and V6 stages of maturity. A pre-emergence herbicide, Lumax (Syngenta US, Greensboro, NC), was applied within 3 d of planting. Corn was planted at a stand population between 73,482 and 77,805 seeds/ha.

Experiment 1

Whole-plant corn (P1376XR, DuPont Pioneer, Johnston, IA) was harvested at 32% DM and chopped to a theoretical length of 19 mm using a pull-type chopper (3975, John Deere, Moline, IL) equipped with a kernel processor with a roller gap set to 1.4 mm. Several days later, using the same field and variety, additional corn was harvested at 38% DM with the same equipment. Plants at each harvest were obtained from 5 random locations within the field to correspond with 5 replicates per treatment. Five replicated piles of forage were prepared for each of the following treatments at each concentration of DM: (1) untreated (**CON**), (2) 1.5 L of SSL/t of fresh forage weight (**S1.5**; Safesil Ab Hanson & Mohring, Halmstad, Sweden; contained 200 g/kg of sodium benzoate, 100 g/kg of potassium sorbate, and 50 g/kg of sodium nitrite), (3) 2 L of SSL/t (**S2.0**), or (4) 2 L/t of CropSaver (**BPA**; CNH Industrial America LLC, Racine, WI; contained 64.5% propionic acid and 5% citric acid as active ingredients). Treatments were applied with a hand sprayer while mixing into the forage mass. Forage from each pile was packed into 7.5-L buckets that served as laboratory silos and sealed with plastic lids with O-ring seals. A single port with rubber tubing leading from the top of each silo was placed into a beaker of water for release of silo gas and permanently sealed after about 2 wk of storage when production of gas ceased. Targeted packing density was approximately 224 ± 5 kg of DM/m^3. After filling and sealing, silos were stored at 21 ± 0.5°C for 120 d. Weights of empty and full silos were recorded at filling and at silo openings and used, with the determination of DM content, to calculate DM recovery (**DMR**) at silo openings.

Fresh, treated forage from each pile from d 0 was sampled and analyzed for DM, NDF, ADF, CP, soluble