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The effect of a chemical additive on the fermentation and aerobic stability of high-moisture corn

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ABSTRACT

The objective of this experiment was to evaluate the effect of a chemical additive on the fermentation and aerobic stability of high-moisture corn (HMC). Ground HMC (~63% dry matter) was untreated, or treated with an additive containing sodium benzoate, potassium sorbate, and sodium nitrite as active ingredients, at 0, 2, 3, or 4 L/t of fresh matter. Laboratory silos (7.5 L) were prepared and ensiled for 21 and 90 d (4 silos/treatment per d of ensiling). Small bag silos were prepared for untreated HMC and HMC treated with 4 L/t of the additive and analyzed for nitrate-N and nitrite-N after 0, 3, and 7 d of ensiling. The concentration of nitrate-N was similar between these 2 treatments and was below levels considered problematic for ruminants. Nitrite-N was greater in HMC treated with the high level of additive but was also very low for both treatments. Numbers of yeasts were similar among treatments in fresh HMC and decreased substantially after ensiling. Numbers of yeasts were similar among treatments after 21 d of ensiling but after 90 d they were lower in treated versus untreated HMC. Concentrations of organic acids (lactic, acetic, and propionic) and pH were not different among treatments at any time of ensiling. In contrast, treatment with the additive markedly decreased the concentration of ethanol in HMC after 21 and 90 d when compared with untreated HMC. Treatment with all levels of the additive markedly improved the aerobic stability and improved the recovery of dry matter compared with untreated HMC. Overall, our findings suggest that the chemical additive used in this study has the potential to improve the fermentation and aerobic stability of HMC after a relatively short period (21 d) and after a moderate length (90 d) of ensiling.

Key words: silage, potassium sorbate, sodium benzoate, yeast

INTRODUCTION

High-moisture corn (**HMC**) is commonly fed to animals throughout the world (Buchanan-Smith et al., 2003; Szasz et al., 2007; Canizares et al., 2011). However, this ensiled feedstuff often has a high number of epiphytic yeasts (3–5 log cfu/g, Pahlow et al., 2003) and its aerobic stability can be very poor, especially when ambient temperatures are warm (Taylor and Kung, 2002; Kung et al., 2004). The reasons why HMC is high in yeasts is not clearly understood, but may be related to the fact that the plant is shuttling sugars to the ear and any potential physical damage to the ear results in potential substrate for these organisms (Teller et al., 2012). The aerobic deterioration of ensiled feeds results in a loss of DM and an increase in the numbers of undesirable microorganisms (Lindgren et al., 2002; Borreani et al., 2013), which may produce toxic substances harmful to animals and humans (Ivanek et al., 2006; Alonso et al., 2013). In addition, feeding aerobically spoiled silages can result in depressions in nutrient intake (Whitlock et al., 2000; Gerlach et al., 2013) and production (Hoffman and Ocker, 1997) in ruminants.

Because lactate-assimilating yeasts are usually thought to initiate aerobic spoilage in ensiled feeds, additives containing or generating antifungal components have been used to decrease their numbers to improve aerobic stability. For example, microbial-based additives such as *Lactobacillus buchneri* can convert lactic acid to acetic acid, which has good antifungal attributes (Taylor and Kung, 2002). However, one drawback of using this microbe is that it has a slow growth rate (Schmidt et al., 2009) and its effects often requires about 50 to 60 d (or longer) of ensiling to be detected in corn silage (Kleinschmit et al., 2005) and HMC (Taylor and Kung, 2002). Chemical-based additives with antifungal properties such as various organic acids (Yasin et al., 1992; Sebastian et al., 1996) or ammonia (Diaz et al., 2013) have also been successful in improving the aerobic stability of HMC. These additives are not dependent on the growth of added microorganisms for their antifungal effects. An additive based on sodium benzoate, potassium sorbate, and sodium nitrite has

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recently been evaluated in forage-based ensiled crops (Knický and Spörndly, 2011) and HMC (Loučka, 2010), but to our best knowledge no peer-reviewed publications were available on this formulation in North America when the current research was undertaken. Thus, the objective of this study was to evaluate several doses of this additive on the fermentation characteristics and aerobic stability of ensiled HMC after different lengths of storage.

MATERIALS AND METHODS

Ensiling of HMC and Treatments

Shelled corn (unknown hybrid), from a commercial dairy farm, was harvested with a John Deere 9400 combine (Moline, IL) at about 63% DM and ground through a Gehl hammer mill (model #170, Manitou Americas Inc., West Bend, WI). Freshly ground HMC was transported to the University of Delaware where it was treated within 2 h of harvest with (1) control, no additive; (2) 2.0 L of Safesil (Ab Hanson and Möhring, Halmstad, Sweden)/t of fresh matter, **S2**; (3) 3.0 L of Safesil/t, **S3**; or (4) 4.0 L of Safesil/t, **S4**. The active ingredients in the additive were sodium benzoate (200 g/kg), potassium sorbate (100 g/kg), and sodium nitrite (50 g/kg). Four replicated piles (each pile treated individually) containing 20 ± 0.03 kg of ground HMC were prepared for each treatment (total of 16 piles). Each pile was treated with a volume of 200 mL of liquid to ensure uniform treatment distribution (water alone for the no additive treatment or water mixed with appropriate amounts of the additive to obtain the targeted application rate). Treatments were applied with a hand sprayer while manually mixing the HMC.

High-moisture corn from each pile was packed in 7.5-L bucket silos and sealed with plastic lids with O-ring seals. Targeted packing density was approximately 672 ± 5 kg of DM/m^3. Buckets were stored for 21 and 90 d at 22°C before opening. Weights of full and empty bucket silos were recorded at the start and at each opening. Dry matter recovery was determined based on the differences between weights at ensiling and at the openings according to Jobim et al. (2007).

Three bag silos containing approximately 600 g of HMC were also prepared from each of the replicate piles 1 to 3 for each of the no additive and S4 treatments. The bag silos were made of nylon-polyethylene (3.5-mil embossed pouches, 15.2 × 30.5 cm; Doug Care Equipment Inc., Springville, CA). Air was evacuated from the bags before they were heat-sealed using a Best Vac vacuum machine (distributed by Doug Care Equipment Inc.). Bag silos were opened after 3 and 7 d of ensiling. All silos (buckets and bags) were stored at 22°C.

The aerobic stability of HMC was determined at each silo opening for samples from the bucket silos. At each opening, approximately 2 ± 0.01 kg of representative HMC from each bucket silo was returned to the same cleaned silo without compaction. A thermocouple wire was placed in the geometric center of each sample mass and temperatures were recorded every 15 min using a data logger DataTaker DT85 (Thermo Fisher Scientific Australia Pty, Scoresby, VIC, Australia). Ambient temperature was recorded from a thermocouple wire in an empty bucket. Buckets were covered with 2 layers of cheesecloth and exposed to air in the laboratory (22 ± 1°C). Aerobic stability was calculated as the number of hours before the temperature of the silage mass rose 2°C above baseline temperature.

Laboratory Analyses

Fresh HMC before ensiling from each pile was sampled and analyzed for DM, NDF, ADF, CP, soluble protein (**SP**), starch, pH, lactic acid bacteria (**LAB**), yeasts and molds, NH_3-N, water-soluble carbohydrates (**WSC**), and buffering capacity. The DM content of the samples (approximately 150 g) was determined in a 60°C forced-air oven for 48 h. A portion of each dried sample was ground using an Udy Cyclone Sample Mill (Udy Corp., Fort Collins, CO) to pass through a 1-mm screen and analyzed for NDF via the procedures of Van Soest et al. (1991). Acid detergent fiber was quantified on dried ground samples according to procedures described by Goering and Van Soest (1970), with the modification that the fiber residue from the ADF was recovered on a 1.5-μm particle retention 7-cm Whatman filter in a California Buchner Funnel (934-AH, Whatman Inc., Clifton, NJ) instead of a Gooch crucible, to allow for better filtration. Total N was determined by combustion of the sample (Leco CNS 2000 Analyzer, Leco Corporation, St. Joseph, MI), and CP was calculated by multiplying the resulting total N by 6.25. Soluble protein (% of CP) was determined by the method of Krishnamoorthy et al. (1982). A separate portion of the dried samples was ground to pass through a 3-mm screen and analyzed for starch (Hall, 2009). Dried samples from the bag silos were analyzed for concentrations of nitrate-N and nitrite-N at the Swedish University of Agricultural Sciences, Uppsala, Sweden as described by Knický and Spörndly (2009) using the ASN 110–01/92 method (Tecator, 1992) with a FIA system from FOSS-Tecator (Höganäs, Sweden).

Representative samples of fresh and ensiled HMC were mixed with sterile quarter strength Ringer's solution (Oxoid BR0052G, Oxoid, Unipath Ltd., Basingstoke, UK) and homogenized for 1 min in a Proctor-Silex 57171 blender (Hamilton Beach/Proctor-Silex