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Case Study: NaCl Addition to the Top Layer of Corn Ensiled in Bunker Silos[1]

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Abstract

The objective of this study was to examine fermentation characteristics and the quality of corn silage in response to top-dressing with NaCl after ensiling. Two bunker silos were divided into six sections each. Three alternate sections per silo had salt applied at a rate of 22.5 kg/121-m² section. The other three sections were not treated. The silos were covered with black plastic sheeting and secured with tire sidewalls. Four weeks after covering, seven silage samples were taken from the top layer of each of the sections, composited, and analyzed for DM, pH, NDF, ADF, acetic acid, lactic acid, mold, yeast, total aerobic bacteria, clostridia, deoxynivalenol, and zearalenone. The silage samples from the salt-treated sections exhibited several properties that indicated improved fermentation and reduced spoilage, including trends for reduced pH, NDF content, zearalenone concentrations, and total aerobic bacteria counts, when compared with the unsalted silage. Adding salt to the top layer of corn silage is an economically feasible way of reducing top layer spoilage and may reduce silage waste.

(Key Words: Corn Silage, Salt, Fermentation.)

Introduction

Because of the large costs and slow filling speed incurred with vertical silos and because of the equipment required for rapid filling, horizontal silos are economically attractive. However, their design can allow large amounts of the ensiled material to be exposed to the environment (5). Indeed, Bolsen (5) reported that over 25% of the initial silage mass is located in the top 1 m of most bunker silos. In addition, Bolsen (5) observed that 75.1 % of the initial corn silage DM was lost in the top 25 cm of an unsealed bunker silo. Sealing with plastic, which is a routine practice, reduced DM loss to 10% (5). Any method to further reduce top layer losses would be a benefit to the silage user. Reducing top layer loss requires improving the fermentation that occurs when lactic acid-producing bacteria convert carbohydrates into lactic and other organic acids. Lactic acid rapidly lowers the pH of the silage. Common salt has been used in preservation of foods by inhibiting the growth of harmful bacteria. Some strains of lactic acid bacteria are tolerant to salt, enabling them to survive additional salt while the growth of salt-sensitive aerobes is inhibited. Sodium chloride has been used to decrease aerobic activity and silage spoilage (6, 11). Using small silo models, Cai et al. (6) observed that adding 40 g NaCl/kg wet sorghum silage at ensiling reduced DM losses from 14 to 7 %. Shockey and Borger (11) observed a reduction in the number of clostridium bacteria when 4 g NaCl/100 g were added to alfalfa silage in test tubes. Salt was distributed throughout the silage in these experiments.

The present study focused on the effects of applying salt directly to the top layer of corn silage in the bunker silo. The surface of the silo is exposed to air prior to covering, which promotes undesirable aerobic bacterial growth. Concentrating the additive in this location may be beneficial. Therefore, the purpose of this study was to evaluate the addition of salt to corn silage and its effects on fermentation characteristics of the top 15 cm of silage.

Materials and Methods

Corn silage was cut at 1/3 to1/2 kernal milk line, chopped, and

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packed with a tractor in a bunker silo. The average chemical analysis of the chopped forage at the time of ensiling was 30.8% DM, 48.2% NDF, 28.1% ADF, and 7.6% CP. Pioneer® Brand Corn Silage Inoculant 1132 (Pioneer Hi-Bred International, Des Moines, IA) containing 90 billion cfu/g from *Lactobacillus plantarium* and *Enterococcus faecium* was manually applied as a liquid providing 1.1 g inoculant/1,000 kg. Two silos (40.7 × 7.4 × 3.7 m; capacity: 600,000 kg each) were each divided across the top into six equal 121-m^2 sections. Plain white salt was applied to alternating sections of the silo with a manual drop spreader at a rate of 22.5 kg/121 m^2. The salted silos were covered with black plastic (0.6 mm) and secured with tire sidewalls to minimize exposure to air and sunlight. Four weeks after covering, the top 15 cm of silage were sampled by hand at each corner, at the center edges, and in the center of each section. Samples from the same section were composited for a total of six samples (three control and three NaCl) per silo. Samples were frozen and stored at –20ºC for later analysis. The samples were analyzed for DM (100ºC for 12 h) and ground through a 1-mm screen using a Wiley mill (Wiley, Philadelphia, PA). Ground, dried samples were analyzed for CP (4), ADF, NDF (8), lactic and acetic acid (7), total aerobes, yeasts, clostridia, and molds (2), and pH (3). The pH was transformed to hydrogen ion concentration before statistical analysis (9). Mean (±SEM) of hydrogen ion concentration was determined by antilogarithmic transformation of pH data, and variance was determined by ANOVA (9). These values were then converted to pH. Zearalenone was analyzed using the Romer® Labs Method (Romer® Labs, Inc., Union, MO) (Version 95.5) with a Waters 470 Fluorescence Detector (Waters Corp., Milford, MA). Deoxynivalenol was determined using Romer® Labs Method (Version 95.2) DON HPLC Method with a Beckman 166 Detector (Beckman, Schaumburg, IL). Silage samples were placed in a pre-heated 600ºC furnace for 2 h for ash determination (1). Calcium, P, Mg, and Na were estimated using atomic absorption (1). Potassium, S, and Cl were estimated using official methods (1).

The data were analyzed using the general linear model procedure (10). The model included silo, treatment, and silo × treatment interaction. Because there were no interactions, the final model included silo and treatment, thereby providing nine degrees of freedom in the error term. Outliers were values that were three standard deviations from the mean, which were removed from the data set; included were one clostridia count and one yeast count from a control sample and one total aerobe and one clostridia count from a sample of a treated silage.

Results and Discussion

Well-fermented silage attains a low pH quickly via lactic acid bacteria that inhibit the growth of aerobic bacteria that cause spoilage. Several variables in this experiment approached significance, including pH, NDF content, and zearlenone content. The pH of the salted corn silage tended to be less (P<0.11) than the control corn silage. This result was similar to that of Cai et al. (6), who found that the pH declined more slowly in the first few days of fermentation, but reached lower levels by d 8 of fermentation when salt was added to sorghum silage.

Crude protein and ADF concentrations were not different between treatments (Table 1). However, ADF was numerically less in the salted sample. Lactic acid and acetic acid concentrations were similar between treatments.

The NDF content of the salted silage tended to be less than the NDF content of the unsalted silage (P=0.11; Table 1). This result might have been due to breakdown of cell walls by certain lactic acid bacteria or to a reduction in aerobic loss of DM. Increased bulk density and potentially less DMI are characteristics of increased NDF content. Therefore,

TABLE 1. Chemical comparison of unsalted and salted top layer of corn silage.

	Treatment			
Variable	**Unsalted**	**Salted**	**SEM**	***P*<**
DM, %	25.2	28.9	1.86	NS
pH[a,x]	4.87 (+0.30, –0.17)	4.51 (+0.11, –0.08)		NS
CP, %	11.1	10.8	1.08	NS
NDF, %[x]	50.7	47.6	1.08	NS
ADF, %	30.5	28.8	0.98	NS
Ash, %[x]	5.55	6.47	0.33	NS
Ca, %	0.22	0.16	0.02	0.03
P, %[b]	0.35	0.26	0.02	0.03
Mg, %	0.21	0.17	0.02	0.01
K, %	1.83	1.00	0.07	0.0001
S, %	0.16	0.14	0.01	0.03
Na, %	0.10	2.87	0.24	0.0001
Cl, %	0.52	4.99	0.33	0.0001
Lactate, %	1.70	1.96	0.42	NS
Acetate, %	1.11	1.20	0.23	NS

[a]Values in parentheses are the SEM for the pH after converting from hydrogen ion concentration to pH.

[x]A difference between treatments was detected (P=0.11).

TABLE 2. Mold, yeast, total aerobes, and mycotoxins of the unsalted and salted top layer of bunker silo corn silage (DM basis).

	Treatment			
Item	Unsalted	Salted	SEM	*P*<
Mold, cfu/g	1.93×10^8	1.34×10^8	1.04×10^8	NS
Yeast, cfu/g	2.26×10^8	1.47×10^8	1.08×10^8	NS
Clostridia, cfu/g	457	53.0	199	NS
Total aerobes, cfu/g[x]	4.59×10^9	6.84×10^8	1.62×10^9	NS
Deoxynivalenol, mg/kg	1.54	1.26	0.31	NS
Zearlenone, mg/kg	315	155	73.4	NS

[x]A difference between treatments was detected (*P*<0.11).

the salt-treated silage would likely be more digestible than the untreated silage.

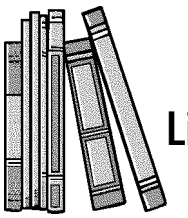
Ash percentage tended to be greater (*P*=0.11; Table 1) for the NaCl-treated silos, likely because of the additional mineral (NaCl) added to the top layer. Similarly, Ca, P, S, and Mg concentrations were less in the treated silage. However, Na was 28.7 times greater, and Cl was almost 10 times greater, for the salt-treated silage. Bolsen (5) reported that, as spoilage occurs, OM disappears, resulting in an increased content of minerals in the silage. Therefore, results from our experiment indicate that less top layer OM spoilage occurred in the salt-treated corn silage.

The mycotoxin zearlenone content was twice as high (*P*=0.15) in unsalted silage than in salted silage (Table 2). Mycotoxins are produced from molds and can alter DMI and milk production and can affect overall health and productivity. Thus, lower levels of mycotoxins in salted silage indicate less mold growth and better fermentation. Clostridia counts were numerically greater in the non-treated sections but, because of large variability, were not different (*P*=0.17) from treated sections. Shockey and Borger (11) observed lower clostridia counts in salted alfalfa silage compared with controls.

Although not significant, mold, yeast, and deoxynivalenol were numerically less in the salted samples (Table 2). Total aerobic counts tended to be less in the salted samples, similar to the results of Cai et al. (6). These results indicate that salting the top layer of bunker silos containing corn silage reduced spoilage.

Implications

Using the economic model of Bolsen (5) and assuming a 20% loss in the first 1 m, economic loss from the corn silage bunkers used in this study cause by silage spoiling would be $1,085 per silo. The cost of purchasing the salt would be approximately $100 per silo. The overall net return by adding salt to each silo if spoilage is reduced by 50% would be $492.50. In addition, further benefit might result from reduced OM loss and the improved performance of cattle fed silage of higher quality. Adding salt to the top layer of corn silage appears to be a cost-effective method of reducing spoilage. More research is needed to determine the aerobic stability and bunk life of salt-treated silage as well as the optimal rate of salt application.



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