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Anhydrous Ammonia Injection Into Polyethylene Silage Bags to Enhance Forage Quality Attributes

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ABSTRACT

The injection of anhydrous ammonia (A-NH_3) into bagged silage would allow variable applications of N to improve crude protein content of feeds. Trials evaluated the effectiveness of A-NH_3 injection into silage for changes in nutrient characteristics and to evaluate animal preference. In Trial 1, A-NH_3 was injected into a 30 t polyethylene bag of sorghum silage at 1% DM. Injection was easily accomplished; the A-NH_3 moved some vertically and horizontally, but movement was limited, likely due to excessive moisture in the silage. In Trial II, polyethylene bags with 10 lb of forage were injected with 0, 1 or 2% A-NH_3 on a DM basis and injected either pre-ensiling with or without corn or post-ensiling. Silage quality was improved with higher levels of A-NH_3. Injection of A-NH_3 during pre-ensiling stage of fermentation improved ($P<.05$) crude protein (CP) and NDF characteristics. Injection of A-NH_3 during post-ensiling phase had no effect ($P>.05$) on characteristics, but A-NH_3 volatilization losses occurred during injection. Holstein heifers fed various treated silage combinations showed no refusals, indicating acceptable silages. Treating silages with A-NH_3 shows potential as a method of increasing CP of silages and improving diet digestibility, but issues of optimum moisture content in silages and timing should be addressed.

KEY WORDS: silage, anhydrous ammonia, quality characteristics

INTRODUCTION

Profitable livestock operations are dependent on providing inputs that efficiently generate outputs, usually with high levels of animal performance. Feed costs represent from 45 -75% of the total cost of livestock production, depending on the species, and average 50 -60% and 70% for dairy and finishing beef cattle operations, respectively (Damron, 2003). Protein supplements in livestock diets are usually one of the most costly feed ingredients. Because of their ability to utilize dietary N to fulfill their nutrient requirements for protein, ruminants can be fed NPN sources (Jewell et al., 1986). Anhydrous ammonia (A-NH_3) is generally the cheapest source of N, but it is a hazardous material and caution must be taken with this pressurized liquid that has a boiling point of -28^{0}F (Shutske, 2005). Pressurized liquid A-NH_3 becomes a gas when exposed to the atmosphere and quickly binds with water, so typically it has been used as a fertilizer for agronomic crops and injected into the soil where it turns into a gas, but quickly binds with soil moisture.

"Bagging silage" began in Germany in the 1970's and came to the U.S. later that decade. Bagged silage continues to gain popularity as an inexpensive way to store silage and bags can be placed almost anywhere. The silage polyethylene bags (portable silos) could potentially allow an easy method of applying A-NH_3 to silages, since a small hole can be made in the bag at specified intervals to inject the A-NH_3 to effectively deliver the desired amount of N to the silage. While adding A-NH_3 to conventional silos has been attempted, most methods occur in the field at the end of the chopper or at the end of a blower, exposing the A-NH_3 to air. Volatilization losses of A-NH_3 are typically between 10 and 30% when utilizing these conventional methods of applying A-NH_3 (Kung et al., 1989). The silage bag would seem to be a better alternative because of its airtight environment and the small holes made in the bag to inject A-NH_3 can be closed post-injection with tape. However, there is no available research regarding injecting A-NH_3 into silage and any potential problems.

The objectives of this study were to evaluate A-NH_3 injection into a large silage bag to determine the potential, and if successful, utilize small experimental silos to evaluate level (0, 1 or 2%) of A-NH_3 injection at either pre-ensiling with and without added corn or post-ensiling, and to offer treated silages to heifers to determine silage refusals.

MATERIALS AND METHODS

This project had three phases: 1) pilot study to determine feasibility of injecting A-NH_3 and "small" bag experimental silos, 2) rates and timing of A-NH_3 application and its effects on silage quality characteristics, and 3) animal preference trial. The pilot project was to determine feasibility of adding A-NH_3 to the silage mass since only references regarding adding A-NH_3 to dry hay were available (Woolford et.al., 1984 and Wyatt et.al., 1989).

Phase 1. The pilot project was performed beginning in the summer of 2004 by injecting 1% A-NH_3 (DM basis) into a small (30 t) polyethylene bag of sorghum silage. The purpose of the pilot project was threefold: 1) test the effectiveness of the application device, b) test movement of the A-NH_3 and c) determine the effectiveness of mini silos.
Approximately 30 t of high moisture sorghum silage was bagged using a 10 ft diameter bagging machine manufactured by Ag Bag International. Injection of A-NH_3 was accomplished using a 1 in pipe 6 ft long and injected into the silage every 15 ft. The 1 in pipe was welded closed on one end and sharpened to a point and then re-opened by drilling a .5 in hole immediately behind the point. The other end of the pipe was attached to a flow meter, which was attached to a hose and fed directly from an A-NH_3 transport

trailer. After 4 wk post-injection, the silage bag was opened and visually inspected along with samples taken from four areas around the injection site (Figure 1).
The mini-silo feasibility project was performed using the sorghum silage to visually observe various A-NH_3 treatments. This study placed 10 lb of silage in 12 different 20 qt containers lined with heavy duty 120 qt trash bags. Each of the mini silos were labeled, twisted closed and rolled, and then duct-taped to properly seal the bags. Each mini-silo was injected with various amounts of A-NH_3, based on the number of seconds the valve on the regulator was opened.

Phase 2. In spring, 2005, 36 mini-silos were filled with approx. 10 lb each of mixed small grain (oat/ryegrass, *Avena sativa/Lolium multiflorum*) forage that was between 65% and 75% moisture. These mini-silos were created using a 3 ft diameter plastic tube filled with 10 lb of chopped forage and vacuum sealed. Bags were injected with A-NH_3 in three sites along each tube with a 60 ml syringe and 2 ½ in needle. The 36 mini-silos were divided into 4 replicates, each replicate having sub sets; 1): control silage, 2): A-NH_3 applied at the time of ensiling at 1% of DM , 3): A-NH_3 applied at the time of ensiling at 2% of DM, 4): control silage, 5): A-NH_3 applied post-ensiling, 1% A-NH_3, 6): A-NH_3 applied post-ensiling, 2% A-NH_3, 7): control + corn grain , 8): control +corn grain and 1% A-NH_3 at ensiling, and 9): control + corn grain and 2% A-NH_3 at ensiling. All mini-silos were allowed to ferment at least 4 wk to ensure ample fermentation time, with silos opened and sampled for nutrient characteristics, including % CP, NDF, ADF and IVDMD.

Phase 3. After completion of the ensiling period and collection of samples for chemical analysis, remaining silage was utilized in a silage preference trial using 340 kg Holstein heifers. Trials consisted of heifers in individual pens with access to three different treated silages in individual containers to determine if heifers refused to consume any of the silage treatments. The first set of studies evaluated preference of silages differing by timing of the application of the A-NH_3 (pre-ensiling with or without corn or post-ensiling). The second set of preference trials evaluated the effects of the level of A-NH_3 injected into the forage (0, 1% or 2% of DM). In preference trials, 4 heifers in individual pens were given choices in a cafeteria-style preference study with 5 lb of different types of silage: Day 1: 0% A-NH_3, control silage or silage + corn. Day 2: 1% DM of A-NH_3 injected pre-ensiling, post-ensiling, or pre-ensiling + corn. Day 3: 2% DM of A-NH_3 injected pre-ensiling, post-ensiling and pre-ensiling + corn. In the second portion of the trial where level of injection A-NH_3 was compared; Day 4: silages injected pre-ensiling plus corn with A-NH_3 at 0, 1%, and 2% DM basis. Day 5: silages injected post-ensiling with A-NH_3 at 0, 1%, and 2% DM basis. Day 6: silages injected pre-ensiling with A-NH_3 at 0, 1%, and 2% DM basis. The preference measurement period was 2 hr, with an intermediate weight of any remaining silage at 30 minutes. After each measurement period, heifers were allowed feed and water until 18:00 h, then only water until the following preference measurement period at 8:00 h.

Statistical Analysis.

The experimental design for the silage quality characteristics (CP %, NDF %, ADF %, hemicellulose %, IVDMD % and DM%) was a 3 x 3 factorial in a completely randomized design with 4 replications per treatment. Statistical analysis of each experiment was conducted using SAS PROC=GLM (SAS Institute, 2004, Cary, NC). Two separate analyses were used, one that recognized structure within the experiment and one that considered each treatment separately and therefore did not take the structure into account. The analysis that accounted for structure used the following sources of variation: A-NH_3 level, timing, timing × A-NH_3 level, carbohydrate (timing), and A-NH_3 level × carbohydrate (timing) which totaled 8 d.f. Sources of variation are considered significant at $P < .05$. For the second (unstructured) analysis, each treatment was allotted a unique dummy variable. These dummy variables were then used to facilitate construction of specific comparison (contrasts) that were not available from the structured analysis as well as for calculating a global LSD value applicable across treatments. The experimental design for the feeding preference portion of this project was a 3 x 3 factorial in a randomized block design (b = 4) and each heifer considered a block.

RESULTS AND DISCUSSION

Injecting A-NH_3 into the 30 t bag of silage (phase 1) increased CP content of the silage, but individual samples taken from four areas within the silage bag showed the increase in CP was inconsistent, indicating poor distribution of the A-NH_3 (Figure 1). However, this increase in CP % showed that it was feasible to use a probe to inject A-NH_3 into silage. The manufactured probe worked without problem, with no visual signs of volatilizing A-NH_3 during the injection process. The sorghum silage used in this study was over 80% moisture, which is higher than recommended, particularly when using A-NH_3 which is known to be highly attracted to water. The excessive moisture in the silage caused the formation of a Maillard reaction which allowed us to observe the pattern of diffusion of the A-NH_3 in the silage, seen as a dark area in the silage (Figure 1). Initially, the fresh silage was 9.5% CP, but increased to 10.2 to 20.5% in the four sampled areas approximately as shown below (Figure 1). The expected increase in CP was 4 % (Kung et al., 1989), with this study reporting increases of less than 1% to 10%.

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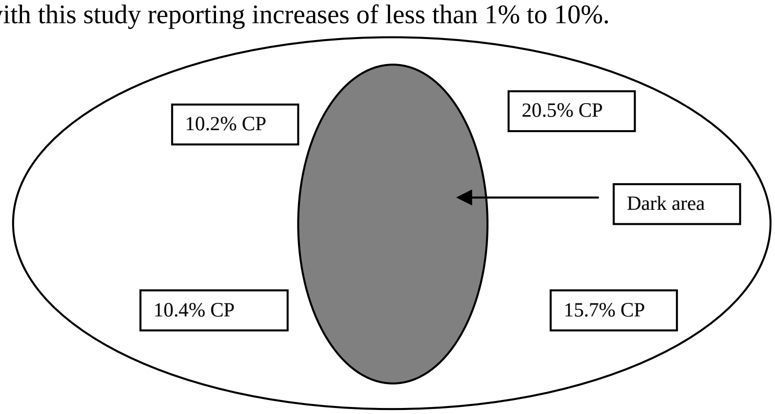

Figure 1. The 10 ft silage bag and the approximate areas sampled for CP content, and the visualappraisal of the area affected by the Maillard reaction

In the pilot study evaluating the "mini-silos," inspection of the treated silage revealed no NH_3 odor in any of the treatment bags. In treatments with 2% A-NH_3, spots of mold within the packed portion of the silage were observed, revealing complications with the fermentation process, possibly due to the effects of the NH_3 slowing the necessary drop in pH. All samples with 2% A-NH_3 injection felt "gooey" to the touch, possibly indicating the cell structure of the silage was broken down, similar to Grotheer et.al. (1986). This breakdown of the fiber would increase digestibility, but may negatively impact feed intake. One of the 1% A-NH_3 samples from the post-ensiled treatment had this same poor texture. Color of the silages was somewhat inconsistent. All control samples (0% A-NH_3) had a normal green color, while there was a yellowing of the forage in some of the 1% A-NH_3 –treated samples. The 2% A-NH_3 samples had a slightly darker appearance.

Forage analysis from silage in the mini silos (phase 2; Table 1) showed increases ($P<.05$) for CP for the silage injected with A-NH_3

Table 1. Effects of injecting different levels of A- NH_3 either post- or pre-ensiling with or without corn on the nutrient characteristics of oat-ryegrass silage

-----------NH_3-----------			CP	NDF	ADF	Hemi-cellulos	IVDMD
Timing[1]	Level[2] (%)	Carb[3]	------------------------------%-------------------------------				
Pre	0	No	15.9 ^{h}	59.9 ^{d}	38.5 ^{d}	21.3 ^{d}	70.3 ^{g}
Pre	0	Yes	16.2 ^{gh}	58.4 ^{de}	37.7 ^{d}	20.7 ^{d}	72.4 ^{efg}
Post	0	No	16.3 ^{gh}	59.9 ^{d}	38.3 ^{d}	21.6 ^{d}	71.1 ^{fg}
Pre	1	No	18.9 ^{de}	54.4 ^{fg}	35.5 ^{de}	18.9 ^{de}	74.8 ^{de}
Pre	1	Yes	17.9 ^{ef}	55.6 ^{efg}	38.6 ^{d}	17.0 ^{ef}	71.7 ^{fg}
Pre	2	No	18.9 ^{de}	53.6 ^{g}	38.3 ^{d}	15.3 ^{f}	73.2 ^{def}
Pre	2	Yes	19.8 ^{d}	53.9 ^{fg}	37.2 ^{de}	16.6 ^{ef}	75.8 ^{d}
Post	1	No	16.9 ^{fgh}	57.4 ^{def}	38.6 ^{d}	18.8 ^{de}	72.3 ^{efg}
Post	2	No	17.3 ^{fg}	57.5 ^{def}	38.1 ^{d}	19.4 ^{de}	73.1 ^{ef}
LSD(0.05)			1.1	3.7	1.9	3.1	2.7

[1] Timing of A-NH_3 injection
[2] Percent of A-NH_3 injected per Mg of silage
[3] Corn added to silage prior to ensiling (5 lb/100 lb)
[4] Hemicellulose is a calculated value (NDF-ADF=Hemicellulose)
[a,b,c,d,e] Means in the same column with different superscript letters differ ($P<.05$).

pre-ensiled compared to controls, but silages injected with A-NH_3 post-ensiled showed no or only slight increases in CP. Adding A-NH_3 should increase N in the silages, unless volatilization losses occurred. Ambient temperatures were about 12 to 14^0F higher when A-NH_3 injection was attempted into mini silos post-ensiling, and the volatilization losses were quite obvious using the needle and syringe. Similar to the CP responses, IVDMD generally improved (P<.05) with A-NH_3 injection pre- but not post-ensiling, again indicating that volatilization losses occurred post-ensiling. Additionally, NDF levels were generally lower (P<.05) for A-NH_3 injected pre-ensiling as compared to either post-ensiling or control silages.

Table 2. *P* values for statistical analysis with structure for selected quality characteristics as influenced by anhydrous ammonia level and timing (pre-ensiled or post-ensiling) and the addition of a carbohydrate source.

		Quality characteristic					
Source	DF	CP	NDF	ADF	Hemi	IVDMD	DM
		-------------------------------- Pr>F -------------------------------					
NH_3[a]	2	0.0001	0.0007	0.0221	0.0002	0.0006	0.1074
Timing[b]	1	0.0005	0.0160	0.1557	0.0430	0.2457	0.6224
Timing x NH_3	2	0.0056	0.4844	0.3026	0.5522	0.2813	0.6748
Carb(timing)[c]	1	0.7229	0.9911	0.4492	0.6447	0.4913	0.8614
NH_3 x Carb(timing)	2	0.0566	0.3895	0.2087	0.2062	0.1398	0.1806

[1] Level of NH[a] injected (0, 1, and 2 %)
[b] Pre-ensiled or post-ensiled
[c] Pre-ensiled + corn

Injection of A-NH_3 (0, 1 or 2%) affected (P<.05) all quality attributes analyzed except DM (Table 2). There was a timing of the injection effect (P < .05) on CP, NDF, and hemicellulose likely due to the A-NH_3 volatilization losses that occurred post-ensiling due to instrumentation. There was also a timing x A-NH_3 level interaction for CP (P < .05). In the heifer preference trial, all silages were acceptable and there were no refusals. While there appeared to be some textural problems with silages injected with 2% A-NH_3 on visual inspection, heifers readily consumed all silages.

CONCLUSION

In conclusion, with the ability to add A-NH_3 to silage already in polyethylene bags, timing and amount of A-NH_3 application become options. Due to the volatilization losses at post-ensiling in the present study with mini silos, further work with improved A-NH_3 injection equipment needs to be conducted to better evaluate the effects of time of application (pre- or post-ensiling) along with rate of application. Also, initial moisture content of the silage and the subsequent lack of movement of injected A-NH_3 through the silage mass should be conducted to determine optimum silage moisture content. Feeding trials need to be conducted to evaluate animal performance using various levels and timing of A-NH_3 injection into silages.

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