

The effectiveness of silage additives applied to hay crop silage stored in concrete midi-silos

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Research Report 03-1

Introduction

Some farmers rely on silage additives to maintain consistent forage quality. A producer can benefit most from silage additives when good silo management is being practiced. Previous work has shown that “good” silages can be made “better” through the proper use of silage additives however, they will not make “poor” silage “good”. Silage additives can be classified into four broad categories: 1) bacterial inoculants, 2) enzymes, 3) acids and 4) nutritive additives. This study evaluated the use of a bacterial inoculant and an acid silage additive on ensiling characteristics of alfalfa/grass silage stored in concrete midi silos.

The objectives of this study were: 1) To determine if the use of either silage bacterial inoculant and/or acid silage additive results in a reduction in dry matter losses in alfalfa/grass silage; 2) To determine if the use of either silage bacterial inoculant and/or acid silage additive results in improved silage quality and/or a reduction in fermentation losses; 3) To determine if either silage bacterial inoculant and/or acid silage additive results in faster fermentation and/or reduced temperatures during fermentation; and 4) To determine if either silage inoculant and/or acid silage additive results in superior aerobic stability of silage at the time of “feed-out”.

Materials and Methods

On the afternoon of June 9th and the morning of June 10th, 2002, first cut alfalfa was harvested from four plots within a single field. The June 9th harvested material was chopped for ensiling at mid-day on June 10th and forage harvested June 10th was chopped in the evening of June 10th at a target DM of 26-28%. Forage was treated at the chopper with one of three treatments: 1) Control – no additive (Control); 2) Silage bacterial inoculant (Bacterial); or 3) Acid silage additive (Acid). The three treatments were replicated (4x) in midi silos for a total of 12 silos. Midi silos were made from 3’ X 4’ concrete culvert with 4” thick walls and a poured concrete bottom. These silos were buried 2-3 feet in the ground on a slope to simulate conditions found in standard bunker silos (see Figure 1). Effluent was collected through a center drain and measured via a collection system (see Figure 2).

The silage bacterial inoculant and acid additive were applied at a rate recommended by the manufacturer as the silage was chopped. Silage treatments were randomly assigned within four plots while the field was being chopped into a dump truck bed. Bacterial inoculant was applied as a dry granular at a rate of 1 lb./T of forage using a Gandy applicator. The acid (Cargill Silage-Mate II) was applied as a liquid spray at a rate of 2 lb./T of forage using an AFP applicator. Application rates were calibrated by the field crop manager prior to harvest. Between treatments, one load of forage was chopped as a “clean-out” to remove any residual products from the spray system. Between treatments, the dump truck bed was flushed with water to remove any inoculant or additive residue.

At the midi silo, forage was dumped in a pile and ~1000 lbs. of forage were added to each silo, three inches at a time and packed to obtain a theoretical packing density of 40 lbs./cubic foot wet silage. The silos were packed using a combination of manual packing and packing with a circular plunger attached to a skidsteer bucket. One plot of midi silos was packed mechanically with a gas-powered tamper.

As each midi-silo was being filled, grab samples of silage were taken for every 50 lbs. added, composited for each silo and divided into two samples. One sample from each midi-silo (approximately 1 lb.) was submitted for nutrient analysis immediately to Dairy One forage testing laboratory (Ithaca, NY). The second sample (approximately 2 lbs.) was frozen at -20°C. A Tiny Talk[®] temperature data logger was placed in the bottom third of the silo at approximately 13”, encased in a PVC tube (Figure 1). After packing to a theoretical density of 40 lbs./cubic foot, the silo was sealed using bunker black plastic, tire weight, plywood to prevent rain from pooling on plastic, and tire weights to secure the plywood.

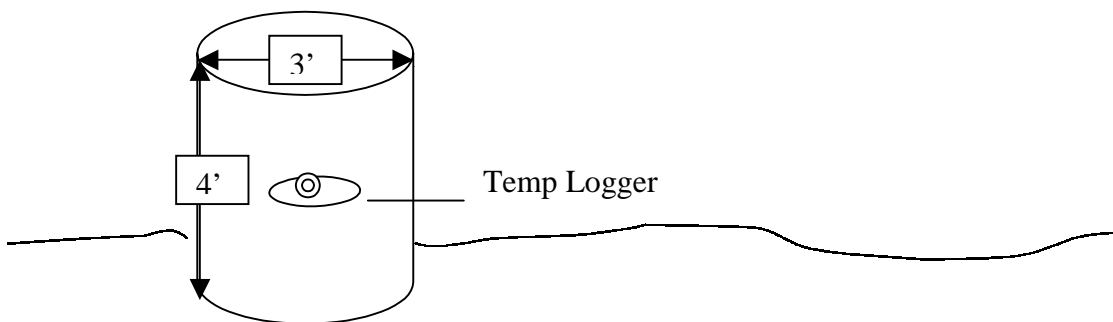
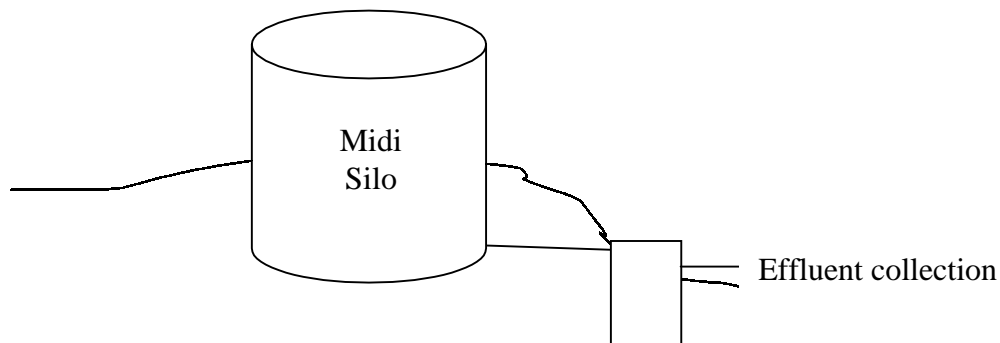


Figure 1. Buried concrete Midi-silo showing placement of Tiny Talk temperature data logger.

Silage temperatures were measured every 3 hours for the first 21 days of the trial by presetting the Tiny Talk[®] unit to record data at the desired interval. Silage effluent was to be collected and measured after 28 days by external collection (see Figure 2). Unfortunately there appeared to be leakage at the seam of the flooring and concrete sides which prevented uniform collection and evaluation of effluent. After 28 days of ensiling, the silos were opened. Moldy forage was removed, weighed and discarded.

Approximately three inches of silo face were removed daily, weighed and sampled until the silos were empty. Total dry matter loss was assessed. Samples were frozen and later composited and analyzed as the top third, middle third and bottom third for each silo.



These composites were analyzed for: DM, crude protein, soluble protein, ADF, NDF,

Figure 2. Schematic drawing of side view of midi silo positioned on sloping hill to allow for external collection of effluent.

NSC, ash, lignin, starch, and sugar at Dairy One forage testing laboratory (Ithaca, NY): pH, titratable acidity, lactic acid, acetic acid, propionic acid, isobutyric acid, butyric acid, total VFAs, lactic acid-VFA, ammonia, mold and yeast at Cumberland Valley Analytical Services. Ensiled samples were analyzed in the Miner Institute Forage Laboratory for *in vitro* analysis for the following information: organic matter, DM disappearance, DM disappearance-true, NDF disappearance, and organic matter disappearance. The temperature information recorded by the Tiny Talk[®] system was uploaded to a computer and temperature change during fermentation was determined. Silo face material was also placed into a Honig Box and stored in a temperature controlled room at 80°F where temperature of silage was measured at 6 and 24 hours with a digital long-stem thermometer to determine the stability of the silage. A Tiny Talk[®] set to record temperature every 30 minutes for 24 hours was placed into one block(plot) of Honig Boxes to characterize the heating pattern of the untreated and treated forages.

All response variables were analyzed using PROC GLM procedures of SAS to determine if differences exist between treatments. The chemical composition and forage quality data were analyzed using the following a split-plot design model:

$$Y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \gamma_k + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk}$$

Where τ = plot, β = silage treatments, and $(\tau\beta)$ represent the whole plot and whole plot error; and γ = silo section, $(\tau\gamma)$, $(\beta\gamma)$, and $(\tau\beta\gamma)$ represent the subplot and subplot error. Orthogonal contrasts were analyzed to determine effect of treated silage compared to untreated silage and comparing inoculated silage to silage treated with the acid additive. Mean separation was also performed to compare all treatments.

Fresh forage and midi silo temperature data were analyzed following a randomized block design. Orthogonal contrasts were analyzed to determine effect of treated silage compared to untreated silage and comparing inoculated silage to silage treated with the acid additive. Mean separation was also performed to compare all treatments.

Results and Discussion

Actual fresh forage DM, chemical composition and packing density of fresh forage are presented in Table 1. No significant treatment differences were found for any of the initial parameters evaluated, indicating similar forages were ensiled for all treatments tested. Crude protein (CP) and lignin were analyzed to determine if there were any treatment differences prior to ensiling. Although no significant differences were found, the forage treated with bacterial inoculant tended to have a slightly lower CP content prior to ensiling. The DM of forage at the time of ensiling was within the target range of 26-28% DM. These forages were wetter than would normally be considered ideal forage DM at the time of ensiling. It was hypothesized that the wetter forage would challenge the ensiling system and determine the efficacy of using silage treatments on wetter forages.

Table 1. DM, nutrient parameters and packing densities of fresh chopped forage prior to ensiling.

Item	Control	Bacterial	Acid	SE	P-value
DM	25.96	27.28	27.10	0.472	0.1879
CP (%DM)	18.43	17.80	18.30	0.156	0.0643
Lignin (%DM)	7.75	8.43	8.68	0.346	0.2279
Wet Density ¹	40.45	37.62	38.98	1.014	0.2215
DM Density ¹	10.48	10.24	10.51	0.242	0.7090

¹lbs/cubic foot

The effect of silage bacterial inoculant and acid additive treatments on amount of DM loss during ensiling is presented in Table 2. There were no significant differences between treatments. The amount of DM loss during the aerobic stability tests was also not significantly different between treatments (% DM loss in Honig), although the forage treated with acid tended to have a lower amount of DM loss indicating the silage tended to be more aerobically stable. The total amount of spoilage measured was also not significantly different, however the silage treated with the bacterial inoculant tended to have more spoilage than either the Control or Acid treatments.

Table 2. The %DM loss in midi-silos and Honig boxes and % silo spoilage by forage treatment.

Item	Control	Bacterial	Acid	SE	P-value
% DM loss in silo	3.98	6.05	7.625	1.553	0.3191
% DM loss in Honig	1.13	1.53	0.05	0.687	0.3559
% spoilage in silo	4.58	6.33	4.65	0.455	0.0578

The chemical composition and forage quality parameters of the treated forages following ensiling were evaluated to determine treatment effects (Tables 3 and 4). The treatment means were adjusted using the respective fresh forage chemical composition as a covariate in the analyses. There were no significant treatment differences in chemical composition of ensiled forages. However, forages treated with either bacterial inoculant or acid additive tended to have higher starch and sugar values when compared to untreated forage.

Table 3. Adjusted mean chemical composition of treated forages after ensiling. (lsmean +/-se)

Item	Control		Bacterial		Acid		P-value
DM (%)	25.31	0.29	25.86	0.29	25.93	0.29	0.6896
CP (%DM)	18.36	0.21	17.86	0.24	18.11	0.18	0.4193
SP (%CP)	61.94	0.88	59.32	0.89	59.49	0.78	0.0986
ADF (DM)	39.22	0.34	39.76	0.34	39.43	0.34	0.5428
Lignin (%DM)	8.80	0.21	9.07	0.18	9.42	0.20	0.1584
NDF (%DM)	48.91	0.42	48.76	0.46	49.10	0.42	0.8693
NSC (%DM)	5.60	0.18	6.25	0.18	5.99	0.17	0.0582
Starch (%DM)	1.86	0.12	2.12	0.13	1.94	0.13	0.3264
Sugar (%DM)	3.78	0.10	4.17	0.11	3.95	0.11	0.0591
Ash (%DM)	10.73	0.13	10.79	0.13	10.70	0.13	0.8686

The pH values for all treatments were similar and fell within the expected range of 4.0-4.5. The high protein content of the forage may have increased the buffering capacity of the forage, resulting in values toward the higher end of the normal range. The ammonia N values were not significantly different and indicate excellent fermentation for all silage treatments because values are all less than 8% (Pflaum, et al. 1998). The lactic acid and total VFA values for forages treated with bacterial inoculant were significantly lower and propionic acid values were significantly higher than either untreated or forage treated with acid additive. These findings conflict with other reports that the use of bacterial inoculants will increase lactic acid concentration of silage (Weis and Underwood, 2000). Additionally, propionic acid levels were significantly higher for forages treated with acid additive when compared to the untreated Control. There were no significant differences between treatments for either mold or yeast counts. While not significant, both true and apparent DM disappearance tended to be higher for the untreated forage after ensiling. However, NDF disappearance was significantly higher for the untreated forage when compared to either inoculant or additive treated forages.

Table 4. Fermentation profile and digestibility parameters of treated forages after ensiling.

Item	Control	Bacterial	Acid	SE	P-value
pH	4.41	4.51	4.39	0.05	0.2484
Ammonia (%)	1.20	1.25	1.20	0.09	0.8721
Ammonia N as % total N	6.45	7.02	6.59	0.50	0.6331
Titrateable acidity (meq/g)	5.49	4.62	5.28	0.23	0.1030
Lactic Acid (%)	5.68 ^a	4.76 ^b	5.41 ^a	0.19	0.0211
Acetic Acid (%)	1.37	1.08	1.17	0.10	0.2892
Lactic Acid/Acetic Acid	4.67	4.87	4.74	0.37	0.9257
Propionic Acid (%)	0.004 ^a	0.038 ^b	0.088 ^c	0.008	0.0011
Isobutyric Acid (%)	0	0.003	0.006	0.004	0.4219
Butyric Acid (%)	0.004	0.073	0.029	0.017	0.1244
Total VFAs (%)	7.06 ^a	5.96 ^b	6.70 ^a	0.18	0.0095
Lactic Acid/VFA	79.84	78.80	79.60	1.63	0.9351
Mold (colonies/g)	8.37x10 ⁵	1.74x10 ⁶	4.22x10 ⁶	2.28x10 ⁶	0.5967
Yeast (colonies/g)	2.76x10 ⁷	2.26x10 ⁷	1.76x10 ⁷	1.63x10 ⁷	0.9217
True DM disapp	70.06	66.89	68.38	0.50	0.1035
Apparent DM disapp.	75.77	73.77	74.46	0.414	0.1462
NDF disapp.	47.21 ^a	44.41 ^b	44.67 ^b	0.60	0.0384
OM disapp.	76.59	74.88	75.54	0.44	0.1941
Ash-free NDF	44.34	45.89	44.53	0.52	0.3139

Columns with differing superscripts are significantly different $P < 0.05$.

The average temperatures recorded by the data logger during the ensiling process are presented in Figure 3. Temperature patterns indicate two distinct fermentations for all treatments. The first fermentation appeared to occur within the first few days after forage was ensiled. This fermentation was characterized by a rapid heating to approximately 80°F followed by a rapid decline in forage temperature to approximately 64°F. The second fermentation appeared to occur with a gradual temperature increase from 10 to 25 days after ensiling, with temperatures once again topping approximately 80°F. There was no significant difference between treatments when evaluating the start and peak temperature of the first fermentation (Control = 6.65°F, Bacterial = 8.05°F, and Acid = 7.05°F; SE=0.48°; $P=0.1943$). There was also no treatment difference between the lowest and highest temperature recorded during the second fermentation (Control = 16.5°F, Bacterial = 16.0°F, and Acid = 15.7°F; SE = 0.30°; $P=0.220$).

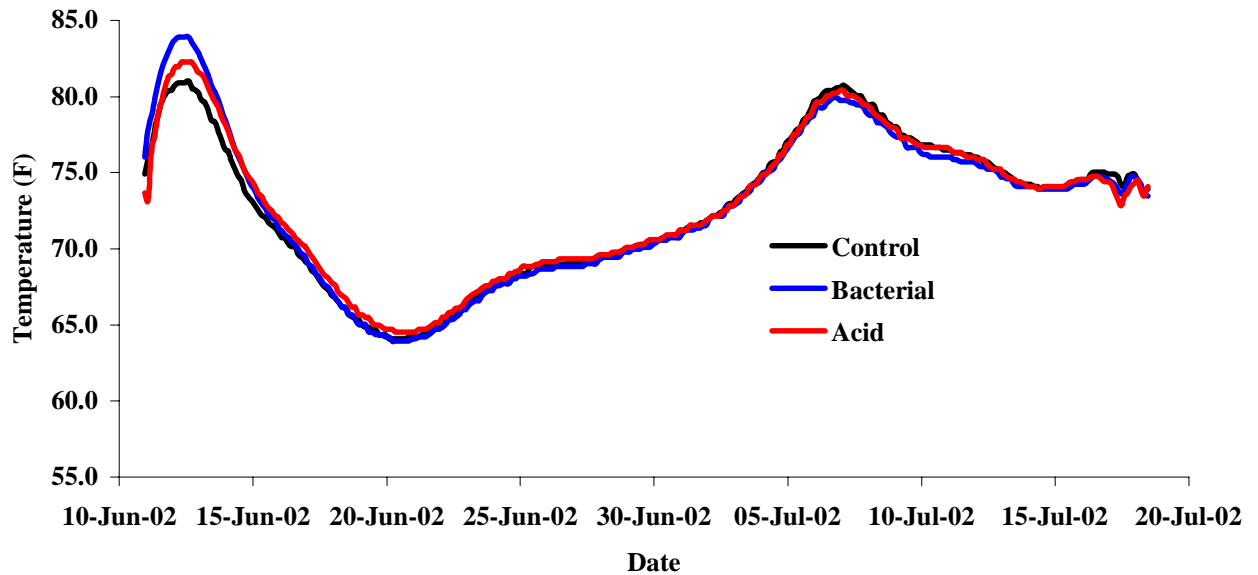


Figure 3. Midi silo temperature during ensiling process.

After 28 days of ensiling, the midi silos were opened and three inches of face material was removed daily until the silos were emptied. On a daily basis, a subsample of silage removed from the silos was placed into a Honig box and stored at 80°F to evaluate the stability of the forage. Temperature differences after 6 and 24 hours of storage are presented in Tables 5 and 6. Overall, no significant treatment differences in heating at 6 and 24 hours was realized, however the forage treated with the bacterial inoculant tended to have a slightly higher difference in temperature after 24 hours of storage at 80°F.

Table 5. Difference in temperature at 6 and 24 hrs. after removal of silage from midi silo and stored in Honig box at 80°F for 24 hrs. (°F)

Item	Control	Bacterial	Acid	SE	P-value
6 hr. temperature difference	4.72	5.94	4.30	0.887	0.3999
24 hr. temp. difference	8.78	12.44	9.19	1.405	0.1406

When temperature differences were evaluated by section of midi silo where silage was removed (top, middle or bottom third), the bacterial inoculant treatment tended to show more heating at both 6 and 24 hours for the top third of silage removed. No treatment differences were found for silage removed from the middle or bottom third of the silos with only slight changes in temperature noted for both the 6 and 24 hour readings. This indicates that all the silage treatments were aerobically stable after ensiling.

Table 6. Difference in temperature at 6 and 24 hrs. after removal of silage from top, middle and bottom third of midi silo and stored in Honig box at 80°F for 24 hrs. (°F)

Section	Hour	Control	Bacterial	Acid	SE	<i>P</i> -value
Top	6	5.75	7.71	5.30	0.874	0.0792
	24	13.10	22.24	13.23	2.653	0.0750
Middle	6	3.61	3.19	3.51	0.469	0.7612
	24	6.76	6.04	6.86	1.03	0.6908
Bottom	6	4.83	5.99	3.81	2.28	0.8196
	24	6.60	8.09	7.34	2.57	0.8654

The 24 hour heating pattern of the top, middle and bottom third of each silo after silage removal and storage in the Honig box system at 80°F is characterized in Figures 4-6. These figures were generated from silage taken from only one plot of silos from the study, therefore are only representative of possible heating patterns of silage treatments at different sections of the midi silo. The slight heating of untreated Control forage and forage treated with bacterial inoculant is observed for silage removed from the top third of the midi silo (Figure 4). No heating was observed for any forage treatment for silage removed from the middle third of the silo, indicating that the silage was aerobically stable (Figure 5). The silage removed from the bottom third of the midi silo exhibited heating for the untreated Control silage (Figure 6). This heating was not observed in the compost thermometer recordings of all reps presented in Table 6, however the heating appeared to be greatest between 10-18 hours and the greatest difference in temperature may not have been recorded by the 6 and 24 hour reading.

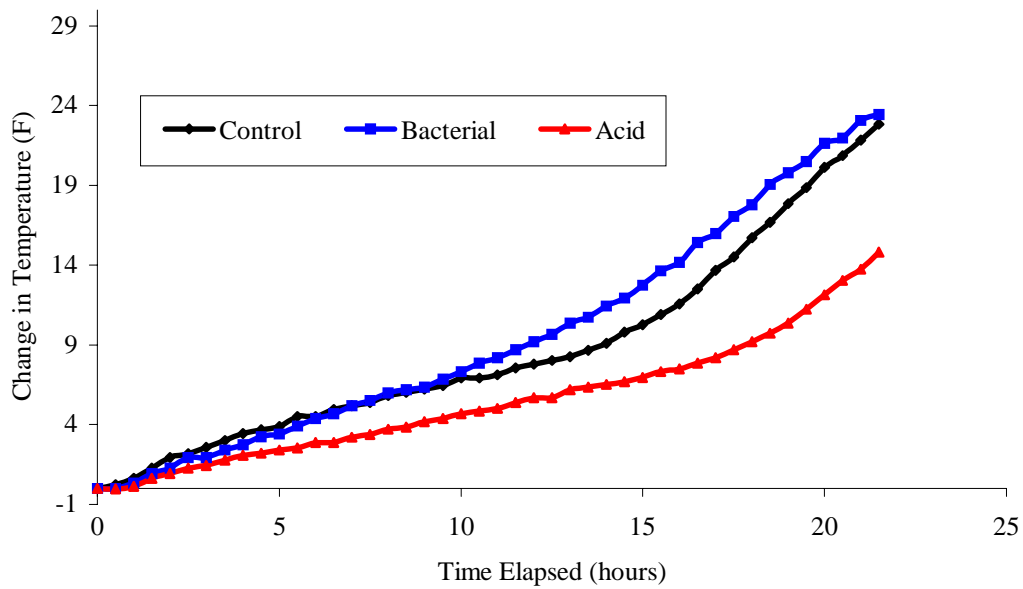


Figure 4. Temperature change of silage from top third of silo stored in Honig box for 24 hrs.

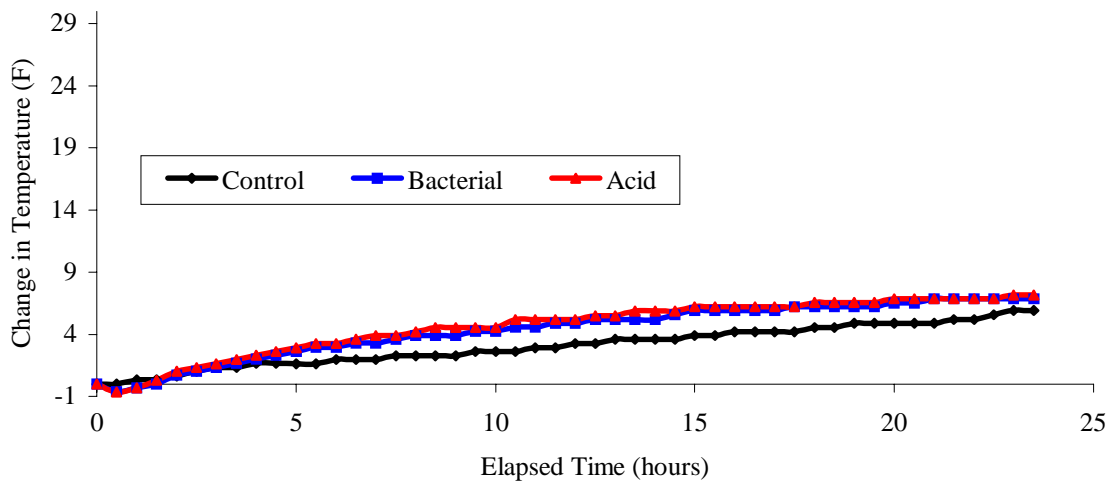


Figure 5. Temperature change of silage from middle third of silo stored in Honig box for 24 hrs.

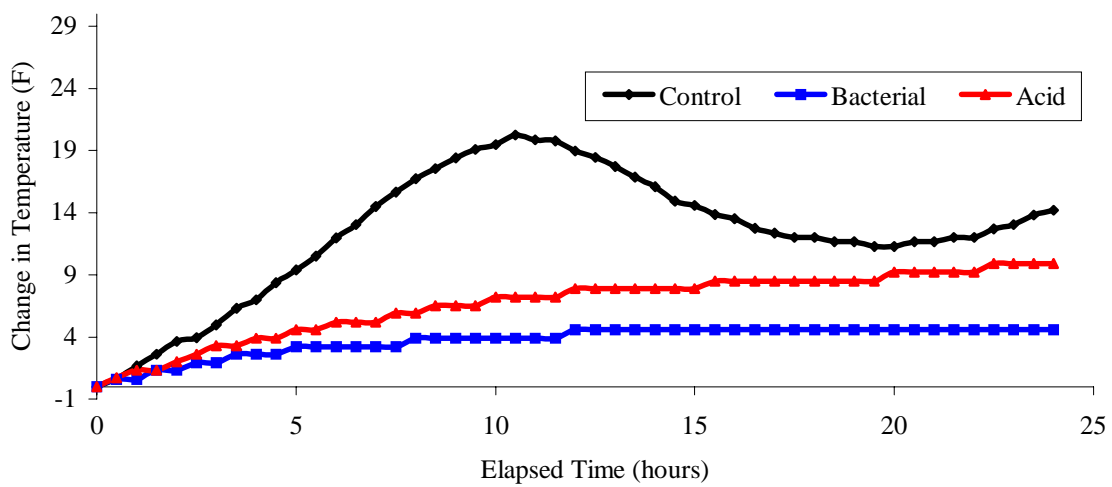


Figure 6. Temperature change of silage from bottom third of silo stored in Honig box for 24 hrs.

Summary

The effectiveness of a bacterial inoculant and a silage acid additive were evaluated in this study. The quality of silage and fermentation characteristics did not appear to be affected by treatment of forages prior to ensiling. Temperature during fermentation and aerobic stability of the forage after aerobic exposure as indicated by temperature increase over 24 hours did not appear to be affected by treatments.

References

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Appendix I. Mean chemical composition of treated silages by section of removal from midi silo. (lsmean +/-se)

Item	Section	Control	Bacterial	Acid	SE	P-value
DM (%)	Top	24.86	25.20	25.78	0.67	0.6494
	Middle	25.30	26.63	26.33	0.54	0.2687
	Bottom	25.75	25.75	25.70	0.89	0.9989
CP (%DM)	Top	18.80	18.23	18.35	0.25	0.3130
	Middle	18.45	17.88	18.08	0.37	0.5727
	Bottom	18.15 ^a	17.03 ^b	18.08 ^a	0.18	0.0073
SP (%CP)	Top	60.50 ^a	57.00 ^b	56.75 ^b	0.92	0.0484
	Middle	63.75	61.50	61.00	1.11	0.2526
	Bottom	62.25	58.75	60.75	1.28	0.2321
ADF (DM)	Top	39.93	40.95	40.40	0.27	0.0917
	Middle	38.78	38.70	38.73	0.48	0.9938
	Bottom	38.85	39.80	39.08	0.60	0.5382
Lignin (%DM)	Top	8.95	9.50	9.45	0.28	0.3695
	Middle	8.43	8.83	9.05	0.23	0.2391
	Bottom	9.08	8.88	9.73	0.37	0.3153
NDF (%DM)	Top	49.80	50.40	50.25	0.65	0.8027
	Middle	47.68	47.60	48.13	0.50	0.7374
	Bottom	48.75	49.20	48.50	0.52	0.6452
NSC (%DM)	Top	5.35	5.85	5.85	0.31	0.4567
	Middle	5.90	6.15	5.90	0.34	0.8414
	Bottom	5.65	6.63	6.25	0.31	0.1619
Starch (%DM)	Top	1.55	1.83	1.83	0.20	0.5555
	Middle	2.03	2.10	2.13	0.21	0.9431
	Bottom	1.98	2.25	2.13	0.20	0.6481
Sugar (%DM)	Top	3.78	4.05	4.00	0.20	0.6240
	Middle	3.90	4.05	3.78	0.16	0.5323
	Bottom	3.68	4.38	4.10	0.20	0.1143
Ash (%DM)	Top	10.97	11.15	10.86	0.42	0.8878
	Middle	10.68	10.76	10.31	0.41	0.7135
	Bottom	10.95	10.62	10.39	0.14	0.0851

Columns with differing superscripts are significantly different $P < 0.05$.

Appendix II. Mean fermentation profile of treated silages by section of removal from midi silo. (lsmean +/-se)

Item	Section	Control	Bacterial	Acid	SE	P-value
pH	Top	4.65	4.85	4.72	0.11	0.4883
	Middle	4.28	4.28	4.17	0.06	0.3750
	Bottom	4.31	4.39	4.30	0.08	0.7039
Ammonia (%)	Top	1.51	1.86	1.48	0.18	0.3220
	Middle	1.06	0.92	1.01	0.09	0.5814
	Bottom	1.01	0.97	1.11	0.14	0.8016
Ammonia N (% total N)	Top	7.99	10.21	8.06	0.90	0.2179
	Middle	5.75	5.16	5.60	0.43	0.6284
	Bottom	5.61	5.69	6.10	0.81	0.9045
Titratable acidity (meq/g)	Top	4.52	3.19	3.83	0.49	0.2338
	Middle	5.94	5.61	6.14	0.20	0.2477
	Bottom	6.02	5.08	5.89	0.36	0.2113
Lactic Acid (%)	Top	4.43	3.35	3.78	0.49	0.3630
	Middle	6.65 ^a	5.95 ^b	6.40 ^{ab}	0.15	0.0395
	Bottom	5.95	4.98	6.05	0.31	0.0870
Acetic Acid (%)	Top	1.60	1.23	1.20	0.22	0.4224
	Middle	1.10	0.93	1.05	0.08	0.3324
	Bottom	1.43	1.10	1.27	0.27	0.7142
Lactic Acid/Acetic Acid	Top	2.97	3.07	3.27	0.69	0.9551
	Middle	6.12	6.70	6.11	0.60	0.7464
	Bottom	4.92	4.85	4.85	0.94	0.9983
Propionic Acid (%)	Top	0.013 ^a	0.080 ^{ab}	0.118 ^b	0.022	0.0412
	Middle	0.00 ^a	0.00 ^a	0.07 ^b	0.001	0.0001
	Bottom	0.00 ^a	0.033 ^a	0.075 ^b	0.010	0.0058
Isobutyric Acid (%)	Top	0.00	0.01	0.02	0.01	0.4219
	Middle	0.00	0.00	0.00	-	-
	Bottom	0.00	0.00	0.00	-	-
Butyric Acid (%)	Top	0.01	0.16	0.53	0.04	0.1155
	Middle	0.00	0.00	0.013	0.004	0.1400
	Bottom	0.00	0.06	0.02	0.02	0.1862
Total VFAs (%)	Top	6.05	4.82	5.17	0.42	0.1825
	Middle	7.75 ^a	6.88 ^b	7.53 ^a	0.12	0.0057
	Bottom	7.38 ^a	6.17 ^b	7.42 ^a	0.31	0.0467
Lactic Acid/VFA	Top	72.40	69.60	72.53	4.98	0.8976
	Middle	85.69	86.66	84.91	1.12	0.5742
	Bottom	81.44	80.15	81.35	3.70	0.9629
Mold (colonies/g)	Top	2.5 x 10 ⁶	5.1 x 10 ⁶	2.6 x 10 ⁶	3.6 x 10 ⁶	0.8468
	Middle	3.75x10 ³	2.65x10 ⁴	4.00x10 ³	1.49x10 ⁴	0.5041
	Bottom	6.50x10 ³	1.02x10 ⁵	1.01x10 ⁷	5.76x10 ⁶	0.4189
Yeast (colonies/g)	Top	8.3 x 10 ⁷	5.8 x 10 ⁷	4.8 x 10 ⁷	5.0 x 10 ⁷	0.8810
	Middle	5.40x10 ⁴	2.01x10 ⁵	3.00x10 ³	5.51x1 ⁴	0.0999
	Bottom	8.50x10 ³	1.01x10 ⁷	5.13x10 ⁶	4.99x10 ⁶	

Columns with differing superscript letters are significantly different $P < 0.05$.

Appendix III. Mean forage digestibilities of treated silages by section of removal from midi silo. (lsmean +/-se)

Item	Section	Control	Bacterial	Acid	SE	<i>P</i> -value
True DM disapp	Top	74.81	72.39	72.79	0.85	0.1801
	Middle	76.29	75.69	75.44	0.60	0.6120
	Bottom	76.23	73.24	75.17	0.68	0.0534
Apparent DM disapp.	Top	68.55	64.81	66.20	1.07	0.1186
	Middle	70.88	69.36	69.93	0.79	0.4369
	Bottom	45.55	46.83	44.97	0.73	0.1059
NDF disapp.	Top	45.83	44.55	43.52	0.75	0.1762
	Middle	47.99	45.81	45.60	0.10	0.2507
	Bottom	47.82 ^a	42.88 ^b	44.89 ^{ab}	0.94	0.0274
OM disapp.	Top	75.34	72.70	74.71	0.84	0.1435
	Middle	77.34	76.41	75.97	0.69	0.4093
	Bottom	77.09	75.53	75.96	1.15	0.6344
Ash-free NDF	Top	45.39 ^a	49.35 ^b	45.82 ^a	0.94	0.0459
	Middle	43.47	43.69	44.26	0.64	0.6837
	Bottom	44.16	44.62	43.50	1.24	0.8200

Columns with differing superscripts are significantly different $P < 0.05$.