Effects of Silage pH on Voluntary Intake of Corn Silage

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ABSTRACT
We evaluated effects of silage pH on corn silage intake. Sixteen Holstein heifers (292 kg) were fed control corn silage during a 2-wk preliminary period. This was followed by an 8-wk experimental period in which animals were fed silage neutralized with 0, 2, 4, or 6% sodium bicarbonate (dry matter) added prior to feeding with corresponding pH's 3.72, 4.46, 5.62, and 8.05. Organic matter intake was increased 1.0 and 1.2 kg/day by addition of 2 and 4% sodium bicarbonate versus controls whereas 6% sodium bicarbonate reduced intake .7 kg/day. An equation developed to predict organic matter intake from silage pH was: 

\[ Y = -3.20 + 3.92 \text{(pH)} - .35 \text{(pH)}^2 \]

with coefficient of determination .66. This equation predicted maximum organic matter intake at pH 5.6. It appears that silage pH is a factor that affects voluntary consumption of corn silage and that pH 5 to 6 is optimum, whereas silage pH above and below may reduce intake.

INTRODUCTION
Voluntary intake of dry matter (DM) from silage by ruminants is less than that of the same crop fed fresh (5, 15, 22) or as hay (3, 9, 20). Depression of consumption from ensiling ranges from 4 to 50%, establishing a negative relationship between ensiling and forage intake.

Silage pH or free acid content has been suggested as a possible inhibitor of silage intake (21). A relationship between silage pH and intake has been demonstrated in studies involving partial neutralization of silage acidity with sodium bicarbonate in both grass silage (12, 13) and corn silage (19). Increasing silage pH 1 to 1.5 units in grass silages (12, 13) resulted in 10 to 20% increases of organic matter intake by sheep and growing cattle. Responses were similar for growing steers fed neutralized corn silage (19). Increasing silage pH above 5 resulted in an average intake response of 12.9% for growing cattle and 14.9% for sheep (6, 11, 12, 13, 19). Neutralization of acid in silage improved silage intake of lactating cows (10, 16). However, other studies showed no benefit to acid neutralization of silages (6, 7, 11).

Objectives were to evaluate effects of silage pH on corn silage intake by growing heifers and to determine optimal silage pH for maximum intake.

MATERIALS AND METHODS
Sodium bicarbonate 4 (NaHCO3) was added to corn silage at three percents to obtain a range of pH's for determining maximum intake. Whole corn plant was harvested and stored in a concrete upright silo for use in the feeding trial. Sixteen Holstein heifers weighing between 250 and 300 kg at the start of the trial were fed in a Calan door feeding system to allow for individual feed intakes and refusals. Animals were fed untreated corn silage for ad libitum intake during a 2-wk preliminary period used as a covariate. After the preliminary period animals were assigned randomly to one of four experimental treatments (four animals per treatment) for an 8-wk experimental period. Experimental treatments consisted of: 1) control corn silage, 2) control plus 2.0% NaHCO3 (DM), 3) control plus 4.0% NaHCO3, 4) control plus 6.0% NaHCO3. Additions of NaHCO3 resulted in pH ranging from 3.72 to

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4 Church & Dwight, Inc., Piscataway, NJ; Feed-grade Sodium Bicarbonate.
8.05 across the four treatments. The NaHCO₃ was mixed with the corn silage in a weigh-mix feeding cart immediately prior to feeding. Animals were fed forage twice daily for ad libitum intake. All animals received .68 kg/day of a protein-vitamin-mineral supplement containing 85.0% soybean meal (49%), 5.0% trace mineralized salt, 5.0% dicalcium phosphate, and 5.0% vitamin A, D, and E premix. Supplement was fed separately from forage immediately prior to the a.m. forage feeding and was consumed readily.

Feed refusals were measured once daily throughout preliminary and experimental periods. Amounts fed were recorded twice daily. Weekly body weights were recorded along with body weights from 3 consecutive days at the end of both preliminary and experimental periods. Forage samples taken after mixing were collected weekly and analyzed for DM content by toluene distillation. Buffering capacity (17) and pH were measured on 20 g of silage (as is) blended in 200 ml distilled water for 5 min. Weekly samples from each treatment composited over wk 1 to 4 and 5 to 8 of the experimental period were used for chemical analysis. Dried forage samples were analyzed for neutral detergent fiber (NDF) by the modified procedure of Robertson and Van Soest (18), acid detergent fiber (ADF) by methods of Goering and Van Soest (8), and organic matter (OM) determined as weight loss by ashing at 600°C overnight. Total nitrogen and ammoniacal nitrogen were determined on wet samples of the forage by the Kjeldahl procedure. Forage extracts for volatile fatty acid (VFA) and lactic acid (LA) determinations were prepared by soaking 15 g forage (as is) in 45 ml .6 N HCl for 2 days at 4°C. The extract was filtered through two layers of cheesecloth and centrifuged. Four milliliters of the supernatant was acidified with 1 ml 25% metaphosphoric acid and frozen in polyethylene bottles until analyzed. Lactic acid was determined by the method of Barker and Summerson (1). Volatile fatty acids were measured by gas chromatography with a column with 10% Carbowax 20M-TPA on 80/100 Chromosorb W-AW packing. Column temperature was 120°C, injector temperature 180°C, and detector temperature 180°C with helium as a carrier gas. Concentrate samples were analyzed for dry matter content by drying in a forced air oven at 100°C and total nitrogen by the Kjeldahl procedure. Concentrate and control silage samples were sent to the New York Dairy Improvement Forage Laboratory for mineral analysis.

Intake data from the last week of the preliminary period were covariates in a least squares analysis of covariance (4). Silage pH data were analyzed by analysis of variance for a completely randomized design. Body weight change (BWC) was measured as the difference between mean body weights taken on 3 consecutive days from the last week of the experimental and preliminary periods. Average daily gain (ADG) was analyzed with DM intake from the last week of the preliminary period as a covariate. Orthogonal polynomial contrasts (4) were used to test for linear, quadratic, and cubic relationships between treatment and response. An equation to predict OM intake (OMI) from silage pH was developed from OMI weekly least squares means. Statistical analysis and equation development were by the general linear model procedure of the Statistical Analysis System (2). Intake and gain data were analyzed by the statistical model:

$$Y_{ijk} = \mu + T_i + b(X_{ij} - \bar{X}) + C_{j(i)} + W_k + (TW)_{ik} + E_{ijk}$$

where:

- $Y_{ijk}$ is the dependent variable for the $i^{th}$ treatment, on the $j^{th}$ animal, for the $k^{th}$ week,
- $\mu$ is common mean,
- $T_i$ is effect of $i^{th}$ treatment, $i = 1$ to 4,
- $b$ is partial regression of $Y_{ij}$ on $(X_{ij} - \bar{X})$,
- $(X_{ij} - \bar{X})$ is covariate for the $i^{th}$ treatment on the $j^{th}$ animal minus the average $(\bar{X})$ of all observations in the control period,
- $C_{j(i)}$ is replicate effect of the $j^{th}$ animal nested in the $i^{th}$ treatment,
- $W_k$ is effect of the $k^{th}$ week, $k = 1$ to 8,
- $(TW)_{ik}$ is interaction of the $i^{th}$ treatment and the $k^{th}$ week,
- $E_{ijk}$ is random residual.

Treatment effects were tested by the replicate effect of the $j^{th}$ animal nested in the $i^{th}$ treatment as the error term.
TABLE 1. Chemical composition of control corn silage.

<table>
<thead>
<tr>
<th>Chemical analysis (dry matter)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>33.6</td>
</tr>
<tr>
<td>Organic matter, %</td>
<td>95.9</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>6.8</td>
</tr>
<tr>
<td>Neutral detergent fiber, %</td>
<td>46.6</td>
</tr>
<tr>
<td>Acid detergent fiber, %</td>
<td>27.1</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>.26</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>.24</td>
</tr>
<tr>
<td>Magnesium, %</td>
<td>.12</td>
</tr>
<tr>
<td>Total organic acids, %</td>
<td>5.68</td>
</tr>
<tr>
<td>Lactic acid, %</td>
<td>4.46</td>
</tr>
<tr>
<td>Total volatile fatty acids,a %</td>
<td>1.22</td>
</tr>
<tr>
<td>Ammonia nitrogen, % total nitrogen</td>
<td>10.78</td>
</tr>
<tr>
<td>Buffering capacity, meq/100 g dry matter</td>
<td>44.2</td>
</tr>
<tr>
<td>pH</td>
<td>3.72</td>
</tr>
</tbody>
</table>

*a Acetic, propionic, and butyric acids.

Figure 1. Weekly buffering capacities.

TABLE 2. Treatment effects on silage pH and least squares means for intake and gain.

<table>
<thead>
<tr>
<th>Item</th>
<th>0%</th>
<th>2%</th>
<th>4%</th>
<th>6%</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silage pH</td>
<td>3.72</td>
<td>4.46</td>
<td>5.62</td>
<td>8.05</td>
<td>.17L</td>
</tr>
<tr>
<td>Silage dry matter intake kg/day</td>
<td>6.7</td>
<td>7.8</td>
<td>8.1</td>
<td>6.2</td>
<td>.3QQ</td>
</tr>
<tr>
<td>% Body weight</td>
<td>1.95</td>
<td>2.37</td>
<td>2.41</td>
<td>1.93</td>
<td>.06Q</td>
</tr>
<tr>
<td>Silage organic matter intake kg/day</td>
<td>6.4</td>
<td>7.4</td>
<td>7.6</td>
<td>5.7</td>
<td>.3QQ</td>
</tr>
<tr>
<td>Average daily gain, kg/day</td>
<td>.93</td>
<td>.97</td>
<td>1.04</td>
<td>.88</td>
<td>.08</td>
</tr>
</tbody>
</table>

L Significant linear treatment effect (P<.001).
QQ Significant quadratic treatment effect (P<.001).
QQQ Significant cubic treatment effect (P<.001).

RESULTS AND DISCUSSION

Composition of control silage is in Table 1. Extent of fermentation is indicated by low silage pH and content of total organic acids. Organic matter content of silages fed declined with increasing amounts of added NaHCO₃ to a low of 92.3% at the highest addition of NaHCO₃. Silage buffering capacity varied weekly (mean equals 44.2 meq/100 g DM), tended to increase as the study progressed (Figure 1), and was possibly due to increased silage fermentation near the bottom of the silo. This resulted in weekly variations of the pH of neutralized silages. Neutralized silage pH showed a slight decline across treatments during the experiment.

Least squares means for average daily intakes of silage are in Table 2. Sodium bicarbonate addition increased (P<.001) silage pH at an increasing rate. Increasing silage pH with NaHCO₃ had a quadratic effect (P<.001) on average daily intake of DM and OM. There was also a quadratic effect (P<.005) on DM intake expressed as a percent of body weight. When silage pH was increased to 4.46, intakes of DM and OM were increased 1.1 and 1.0 kg/day. Intake was maximum when silage pH was increased to 5.62 with intakes of DM and OM increased 1.4 and 1.2 kg/day. Similar increases of intake associated with increases of silage pH have been reported (12, 13, 19). Increasing silage pH to 8.05 decreased intakes of DM and OM .5 and .7 kg/day compared to control animals. This depression of intake could be due to effects of palatability from either high silage pH or high concentrations of NaHCO₃. There
were no significant differences in silage intake for sheep when silage pH was increased to 6.1 and 7.7 with the addition of 12.5% NaHCO₃ in two studies from (11). A quadratic regression equation was developed by regressing least squares means for weekly OM intake on silage pH (Figure 2). The equation developed to predict OM intake from silage pH was: 

\[ Y = -3.20 + 3.92 \times \text{pH} - 0.35 \times (\text{pH})^2 \]

with \( R^2 = 0.66 \). This equation predicted maximum OM intake (7.78 kg) at pH 5.6. No statement can be made about the response surface between pH 6 and 7 because there were no observations in this area.

There were no significant differences in average daily gain (Table 2), although differences did correspond to differences in intake. It is probable that the experimental period (8 wk) was not of sufficient length to measure gain differences. Also, changes of ruminal fill from addition of NaHCO₃ could have affected weight measurements and confounded differences of gain.

These data indicate silage pH is a factor that affects voluntary consumption of corn silage. Addition of sodium bicarbonate prior to feeding to neutralize partially silage acidity may be effective in improving silage intake. It appears pH 5 to 6 is optimal, whereas silage pH above and below may reduce intake.

**ACKNOWLEDGMENTS**

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**REFERENCES**


