# Effects of Sodium Bicarbonate, Magnesium Oxide, and a Commercial Buffer Mixture in Early Lactation Cows Fed Hay Crop Silage[1]

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## ABSTRACT

Sixteen early lactation Holstein cows fed 70% concentrate: 30% hay crop silage were used to determine effects of .7% sodium bicarbonate, .7% sodium bicarbonate plus .28% magnesium oxide, or 1.8% commercial buffer mixture (total ration dry basis). This mixture contained a variety of buffers, alkalis, and other compounds known to affect milk production or composition in some circumstances. Buffers did not affect dry matter intake, milk yield, or milk composition but decreased efficiency of milk production. Ruminal fluid pH was not affected, but fecal pH and digestibilities of dry matter, organic matter, energy, acid detergent fiber, and cellulose were increased by the mixed buffers compared with sodium bicarbonate alone. Total ruminal volatile fatty acid concentration was reduced by buffers. Compared with sodium bicarbonate alone, mixed buffers increased ruminal ammonia concentration, acetate proportion, and acetate:propionate ratio and decreased proportions of propionate and butyrate. Valerate was reduced by all three buffers. Ruminal volume and liquid dilution rate were unaffected, but buffers increased total fluid outflow from the rumen. Higher amounts of buffers or alkalis may be necessary to offset low rumen pH and affect production with hay crop silage-based diets.

## INTRODUCTION

Early lactation cows, abruptly switched from a high forage dry cow diet at parturition, adapt only slowly to a high concentrate lactation diet. Inclusion of buffers and alkalis such as sodium bicarbonate ($NaHCO_3$) and magnesium oxide (MgO) alone or in combination have in various studies increased dry matter (DM) intake, milk yield, milk fat percentage, fat yield or fat-corrected milk (FCM) yield, when corn silage was the sole or major source of forage in the diet (8, 9, 14, 15, 21, 28, 29). Improvements in performance have been associated with increased ruminal fluid pH, increased acetate:propionate ratio in ruminal fluid, and improved digestibility of DM or fiber (9, 15, 21, 24).

However, with high concentrate diets containing forages other than corn silage as the sole or major forage source, production responses have not been observed (5, 7, 11, 13, 19, 25) despite changes in ruminal pH, volatile fatty acid (VFA) proportions, or nutrient digestion (3, 22, 25) in some experiments.

Inclusion in diets of $NaHCO_3$, with or without supplemental MgO, has become commonplace in the dairy industry, and complex mixtures of buffers, alkalis, and other compounds known to affect milk production or composition are available commercially. Our objective was to evaluate the effects of $NaHCO_3$ alone and with additional MgO and of a complex commercial buffer mixture on performance and metabolism of early lactation cows fed a high concentrate diet containing hay crop silage as the sole source of forage. Preliminary results of these experiments have been reported in abstracts (27, 31).

## MATERIALS AND METHODS

Sixteen Holstein cows that had completed at least one lactation were in four independently randomized 4 × 4 Latin square arrangements. Cows were assigned to square based on previous lactation 305-d, mature equivalent (ME) milk

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TABLE 1. Ingredient composition of the diets (dry basis).

| Ingredients | Buffer treatment | | | |
|---|---|---|---|---|
| | Control | .7% $NaHCO_3$ | .7% $NaHCO_3$ plus .28% MgO | Commercial[1] mixture |
| Silage | 30.0 | 30.0 | 30.0 | 30.0 |
| Corn | 18.2 | 18.2 | 18.2 | 18.2 |
| Soybean oil meal | 17.8 | 17.8 | 17.8 | 17.9 |
| Ground oats | 9.4 | 9.4 | 9.4 | 9.4 |
| Legumin[2] | 1.4 | 1.4 | 1.4 | 1.4 |
| Limestone | 1.1 | 1.1 | 1.1 | 1.1 |
| Salt | .7 | .7 | .7 | .7 |
| Vitamin D premix[3] | .2 | .2 | .2 | .2 |
| Potato meal | 21.0 | 20.3 | 20.0 | 19.1 |
| Magnesium oxide | .2 | .2 | .5 | .2 |
| Sodium bicarbonate | ... | .7 | .7 | ... |
| Commercial buffer | ... | ... | ... | 1.8 |

[1] Internation Stock Food Corp., Waverly, NY.

[2] A dairy mineral mixture with vitamins, Agway Inc., Syracuse, NY.

[3] Provided 660 IU vitamin $D_3$/kg diet.

production and calving date and were assigned randomly to treatment within square. Two squares of cows were classified as high producers (>9000 kg 305-d ME milk production) and two as low producers (>8200 kg 305-d ME milk production) to determine if production affected response. One square of four animals was prepared with ruminal cannulae during their dry period and was used for determination of ruminal fluid composition and liquid kinetics.

All cows were fed hay crop silage to meet energy recommendations (17) during the last 2 wk of gestation and were switched abruptly to their experimental diets at 2 d postpartum. Diets consisted of 30% first cut hay crop silage and 70% concentrate on a DM basis fed as total mixed diets once daily. Buffer treatments, as a percentage of total ration DM, were control (no buffer), .7% $NaHCO_3$, .7% $NaHCO_3$ plus .28% MgO, and 1.8% of a mixed commercial buffer,[3] which contained $NaHCO_3$, sodium sulfate, sodium bentonite, MgO, magnesium carbonate, calcium oxide, malt flour, sodium acetate, methionine hydroxy analog, yeast culture, processed grain by-products, cane molasses, mineral oil, and artificial flavor. Buffers were substituted for potato meal in the concentrate (Table 1).

Each experimental period consisted of 14 d challenge feeding to 5% feed refusal for adaptation to treatment, 7 d controlled feeding at the maximum intake attained by d 14, and 7 d for total collection of excreta. For fistulated cows, adaptation was reduced to 12 d to allow 2 d for rumen sampling after completion of the digestibility trial. Each animal began the 112 d trial at d 2 postpartum. Cows were milked twice daily and, except during digestibility measurements, were weighed weekly immediately after milking and prior to feeding.

Samples of silage and grain were taken weekly for DM content, and ratios of silage to grain were adjusted to maintain the desired forage:concentrate DM ratio. Samples of silage grain and orts were taken daily between d 19 and 26 of each period to determine nutrient intakes. Nutrient composition of the total mixed diets is in Table 2. During digestibility measurements, milk samples were obtained at each milking, preserved with potassium dichromate, and composited according to production prior to analysis. Seven-day composite samples of feeds, orts, and excreta were stored at −20°C until analysis. Fresh samples of feces

[3] Cattle Special Buffer, International Stock Food Corp., Waverly, NY.

and urine were obtained daily for determination of pH during the digestibility trial.

Ruminal liquid dilution rate was determined in fistulated cows with cobalt-ethylenediaminetetraacetate (Co-EDTA) as a liquid phase marker (30). Twenty-one g Co-EDTA in 200 ml distilled water were injected into several sites in the rumen 3 h prior to feeding. Ruminal fluid samples were removed from several sites by suction every 2 h for 22 h, beginning 1 h postdosing. Rumen fluid pH was measured immediately, and samples were strained through two layers of cheesecloth. Samples for cobalt analysis were not acidified but samples for compositional analysis were acidified with 2% of 50% (vol/vol) sulfuric acid and stored at −20°C until analysis. Total ruminal volume was determined by manual removal of ruminal ingesta 24 h postdosing. Samples were taken for DM determination, and digesta were returned to the rumen.

Dry matter of silage and orts samples was determined by toluene distillation (4) and of concentrate, feces, and ruminal digesta by drying in a forced draft oven at 40°C. Crude protein content was determined on undried samples of silage, orts, feces, urine, and milk but on dried, ground samples of concentrates by macro-Kjeldahl method (1). Dried samples of silage, orts, and feces were analyzed for ash, ether extract (1), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (12). Gross energy was measured by an adiabatic bomb calorimeter, milk fat by the Babcock procedure, and milk solids-not-fat by the Golding Bead Test. Rumen fluid centrifuged at 17,000 × *g* was analyzed for ammonia by steam distillation (2), VFA by gas chromatography (10), and cobalt by atomic absorption spectrophotometry (Perkin Elmer Model 703). Slope of $\log_n$ cobalt concentration versus time was taken as dilution rate (%/h). Rumen volume was determined both by back extrapolation of the dilution curve to obtain zero time marker concentration and from the DM percentage of the rumen contents. Fluid outflow rate was calculated as the product of volume and dilution rate.

Production, digestibility, and nitrogen partition data were analyzed by analysis of variance for repeated Latin squares (6) using the general linear model procedure of the Statistical Analysis System (23). The model was:

$$Y_{ijkl} = \mu + S_i + P_j + (S \times P)_{ij} + B_k + (S \times B)_{ik} + S_i(C)_l + E_{ijkl}$$

TABLE 2. Nutrient composition of silage and total mixed diets.[1]

| Composition | Silage | Buffer treatment | | | |
|---|---|---|---|---|---|
| | | Control | .7% $NaHCO_3$ | .7% $NaHCO_3$ plus .28% MgO | Commercial mixture |
| Dry matter, % | 27.3 | 53.5 | 53.4 | 53.5 | 53.4 |
| | | Dry matter | | | |
| Crude protein, % | 13.9 | 19.9 | 19.9 | 19.4 | 19.4 |
| ADF,[2] % | 37.7 | 15.9 | 16.2 | 15.5 | 16.1 |
| $NE_l$,[3] Mcal/kg | 1.21 | 1.62 | 1.62 | 1.62 | 1.62 |
| Calcium,[4] % | .60 | .99 | 1.03 | 1.11 | 1.20 |
| Phosphorus,[4] % | .28 | .60 | .61 | .60 | .62 |
| Potassium,[4] % | 2.68 | 1.60 | 1.65 | 1.60 | 1.60 |
| Magnesium,[4] % | .18 | .31 | .31 | .43 | .42 |
| Sodium,[4] % | .01 | .31 | .45 | .54 | .64 |

[1] Based on four analyses of weekly samples composited by square.

[2] Acid detergent fiber.

[3] Net energy for lactation, estimated from ADF.[4]

[4] New York Dairy Herd Improvement Cooperative Forage Testing Laboratory, Ithaca, NY.

where $\mu$ represents a mean, S square, P period, S × P interaction of square with period, B buffer treatment, S × B interaction of square with buffer, S (C) cow effect nested within square, and E residual error. Treatment sums of squares were separated by *a priori orthogonal* contrasts. Squares classified as "high producers" and "low producers" were contrasted directly, and buffer treatments were contrasted as control versus buffered diets, $NaHCO_3$ versus the two mixed buffers, and $NaHCO_3$ plus MgO versus the commercial buffer mixture. Ruminal metabolism data were analyzed as a single Latin square including main effects of cow, period, and buffer in the model. Production data are for the digestion trial days of each period.

## RESULTS AND DISCUSSION

### Production

Buffer supplementation did not affect DM intake, yields of milk and milk components, or milk composition (Table 3), and responses to treatments were not affected by previous production of the animals. A tendency for greater milk fat percentages as each increment of buffer was included in the diet failed to reach statistical significance and was largely due to small reductions in milk yield. Changes in DM intake, milk yield, and fat percentage resulted in lower efficiencies ($P<.09$) of conversion of DM intake to FCM with the buffered diets. Despite the apparently uniform energy content of the diets based on ADF, efficiency values paralleled the declining energy content of the concentrates as greater amounts of minerals were substituted for potato meal in each case. Improvements in milk fat content have been demonstrated with addition of $NaHCO_3$ and MgO to low fiber, high concentrate diets (9, 21, 28, 29), but in the present experiment, fiber was only marginally below recommendations [16 vs. 21%; (17)], and milk fat percentages were not depressed. In cows producing milk of normal fat content, con-

TABLE 3. Dry matter intake, yields of milk and milk components, and milk composition as affected by buffer treatments.

| | Buffer treatment | | | | |
|---|---|---|---|---|---|
| | Control | .7% $NaHCO_3$ | .7 $NaHCO_3$ plus .28% MgO | Commercial mixture | SE[1] |
| Dry matter (DM) intake | | | | | |
| kg/d | 19.80 | 19.79 | 20.06 | 20.37 | .29 |
| kg/% body weight | 3.30 | 3.31 | 3.38 | 3.41 | .06 |
| Yields of milk components, kg/d | | | | | |
| Total | 39.12 | 38.26 | 38.04 | 38.16 | .69 |
| 3.5% Fat-corrected milk (FCM) | 39.53 | 39.15 | 39.31 | 39.93 | .85 |
| Solids-corrected milk | 36.84 | 36.63 | 36.74 | 37.02 | .76 |
| Fat | 1.40 | 1.39 | 1.41 | 1.45 | .04 |
| Protein | 1.17 | 1.15 | 1.14 | 1.15 | .02 |
| Solids-not-fat | 3.45 | 3.41 | 3.39 | 3.37 | .06 |
| Efficiency of milk production | | | | | |
| FCM/kg DM intake | 2.00 | 1.97 | 1.92 | 1.90 | .03[a] |
| Milk composition, % | | | | | |
| Fat | 3.58 | 3.66 | 3.73 | 3.81 | .10 |
| Protein | 2.99 | 3.03 | 3.00 | 3.02 | .03 |
| Solids-not-fat | 8.82 | 8.92 | 8.94 | 8.84 | .07 |

[a]Control > buffered ($P<.09$).

[1]Standard error.

suming corn silage-based diets, $NaHCO_3$, or $NaHCO_3$ plus MgO increased DM intake and milk yield (8, 14). Greatest responses in milk fat percentage and FCM yield have been observed with combinations of $NaHCO_3$ and MgO (8, 9, 28). Lack of responses in the present experiment agree with studies where forages other than corn silage were fed in high concentrate diets (5, 7, 11, 13, 19, 22, 25). Lack of response may also have been related to the Latin square design because greatest responses to buffer supplements have been shown to occur in the first few weeks of lactation before animals have fully adapted to high concentrate feeding (8, 14).

#### Digestion and Metabolism

Fecal pH was greater with buffered diets than the control, and the effect was greatest with the diets containing additional MgO (Table 4). Urine pH was not affected by treatment. Fecal pH has been increased by supplemental MgO, although the precise relationships between fecal pH and diet digestibility is not well-defined (8, 9, 28, 29). Digestibilities of DM, organic matter (OM), gross energy, ADF, and cellulose were greater in diets containing mixed buffers compared with supplementation with $NaHCO_3$ alone (Table 4). With corn silage-based diets, supplementation with $NaHCO_3$, MgO, or with both has increased digestibilities of DM, OM, ADF, and NDF (9, 21, 24), but similar effects have not been shown with diets based on alfalfa hay (13, 22) or hay crop silage (25).

Buffer supplementation did not affect partition of dietary nitrogen (Table 5), although urinary nitrogen losses tended to be higher with buffered diets, as with buffer supplementation of corn silage-based diets (9, 24). Ruminal ammonia concentration was increased by feeding diets supplemented with mixed buffers and was greatest with the diet containing .7% $NaHCO_3$ and .28% MgO. Ruminal ammonia, however, was not closely related to urinary nitrogen losses. Published effects of buffers on ruminal ammonia concentration include increases (15), decreases (25), or no effect (14, 28).

#### Ruminal Fluid pH and Volatile Fatty Acids

Mean pH and minimum ruminal fluid pH (Table 6) were not affected by buffer treatment and were lower than previously reported

TABLE 4. Fecal and urine pH and nutrient digestibilities as affected by buffer treatments.

| | Buffer treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | Control | .7% $NaHCO_3$ | .7% $NaHCO_3$ plus .28% MgO | Commercial mixture | SE[1] | Significant effects | $P<$ |
| Fecal pH | 6.23 | 6.30 | 6.56 | 6.50 | .02 | 1 < 2 + 3 + 4<br>2 < 3 + 4 | .0001 |
| Urine pH | 8.11 | 8.11 | 8.19 | 8.12 | .04 | ... | ... |
| Digestibility | | | | | | | |
| Dry matter | 74.6 | 74.2 | 75.6 | 74.7 | .38 | 2 < 3 + 4 | .05 |
| Organic matter | 76.5 | 76.2 | 77.6 | 76.8 | .35 | 2 < 3 + 4 | .03 |
| Gross energy | 74.7 | 73.9 | 75.8 | 75.3 | .39 | 2 < 3 + 4 | .01 |
| Cell solubles | 80.7 | 80.9 | 81.8 | 81.5 | .38 | ... | ... |
| Crude protein | 71.8 | 72.5 | 72.7 | 72.3 | .52 | ... | ... |
| Ether extract | 67.8 | 71.2 | 73.4 | 69.9 | 3.16 | ... | ... |
| Neutral detergent fiber | 60.9 | 58.8 | 61.6 | 59.7 | 1.05 | ... | ... |
| Acid detergent fiber | 53.0 | 52.2 | 55.3 | 54.6 | .92 | 2 < 3 + 4 | .03 |
| Hemicellulose | 68.0 | 64.7 | 67.5 | 65.0 | 1.59 | ... | ... |
| Cellulose | 60.0 | 59.3 | 63.1 | 61.6 | .98 | 2 < 3 + 4 | .02 |

[1] Standard error.

for 30% concentrate diets with hay crop silage (25). Lack of change in ruminal fluid pH agrees with some reports (8, 22) but is contrary to others (3, 9, 15, 25). Neither forage source nor control ruminal pH are clearly related to these responses. Lack of change in ruminal pH is surprising in view of the increased digestibilities of DM, OM, energy, ADF, and cellulose. As pointed out by Rogers et al. (22), such an effect may reflect an increased rate of digestion and increased rate of production of VFA (20). Total ruminal VFA concentration was reduced in animals consuming the buffered diets, possibly related to dilution of the diets by the

TABLE 5. Partition of dietary nitrogen and rumen ammonia concentration as affected by buffer treatments.

| Measurement | Buffer treatment | | | | SE[1] |
|---|---|---|---|---|---|
| | Control | .7% $NaHCO_3$ | .7% $NaHCO_3$ plus .28% MgO | Commercial mixture | |
| Total nitrogen[2] balance, g/d | 198.0 | 195.0 | 199.6 | 194.2 | 7.53 |
| Tissue nitrogen balance, g/d | 14.6 | 14.2 | 22.8 | 13.8 | 7.12 |
| As % of nitrogen intake | | | | | |
| Urine nitrogen loss | 37.6 | 39.8 | 38.2 | 38.5 | .99 |
| Total nitrogen[2] balance | 34.2 | 32.7 | 34.6 | 33.8 | 1.15 |
| Tissue nitrogen balance | 2.2 | 1.6 | 3.8 | 2.2 | 1.23 |
| Rumen ammonia, mg/100 ml | 7.9 | 7.1 | 10.1 | 8.1 | .61[a] |

[a] $2 < 3 + 4$ ($P<.03$); $3 > 4$ ($P<.07$).

[1] Standard error.

[2] Total nitrogen balance = tissue nitrogen balance + milk nitrogen.

TABLE 6. Rumen fluid composition as affected by buffer treatments.

| Measurement | Buffer treatment | | | | SE[1] | Significant effects | $P<$ |
|---|---|---|---|---|---|---|---|
| | Control | .7% $NaHCO_3$ | .7% $NaHCO_3$ plus .28% MgO | Commercial mixture | | | |
| Mean pH | 5.77 | 5.81 | 5.71 | 5.76 | .08 | ... | ... |
| Minimum pH | 5.23 | 5.35 | 5.19 | 5.28 | .08 | ... | ... |
| Volatile fatty acids | | | | | | | |
| Total concentration, mm/L | 97.9 | 92.9 | 91.0 | 87.8 | 3.00 | $1 > 2 + 3 + 4$ | .04 |
| Acetate, % | 52.2 | 49.0 | 56.0 | 57.8 | 1.13 | $2 < 3 + 4$ | .0001 |
| Propionate, % | 33.8 | 36.0 | 32.0 | 30.6 | .92 | $2 > 3 + 4$ | .0001 |
| Butyrate, % | 9.4 | 10.6 | 8.6 | 9.0 | .45 | $2 > 3 + 4$ | .002 |
| Valerate, % | 2.50 | 2.03 | 1.07 | .91 | .15 | $1 > 2 + 3 + 4$ | .0001 |
| Acetate:propionate ratio | 1.68 | 1.50 | 1.87 | 2.08 | .08 | $2 < 3 + 4$ | .0001 |

[1] Standard error.

additional minerals and in agreement with Stokes and Bull (25). Molar proportion of acetate and acetate:propionate ratio were lowest with .7% $NaHCO_3$ and were increased by the other buffers. Proportions of propionate and butyrate were greatest with .7% $NaHCO_3$ and were reduced by the other buffers. Although not significantly different, .7% $NaHCO_3$ increased propionate and reduced acetate and acetate:propionate ratio compared with controls in a trend similar to a previous report with a 70% concentrate: 30% hay crop silage diet supplemented with .7% $NaHCO_3$ (25). Molar proportion of valerate was reduced by the buffer treatments compared with control. Fermentation shifts away from propionate and valerate and toward acetate and butyrate have been associated with the provision of more nonglucogenic precursors for milk fat synthesis (18) and have been observed with buffer supplementation of diets containing 25 to 40% corn silage (9, 21, 24) but not with diets containing 40 to 50% alfalfa hay (3, 22). Reduction of acetate:propionate ratio with hay crop silage-based diets supplemented with .7% $NaHCO_3$ suggests changes in ruminal microbial population or ruminal kinetics different from those that occur with corn silage-based diets.

**Ruminal Liquid Measurements**

Ruminal liquid volume and liquid dilution rate (LDR) were not affected by treatment, but estimates of volume from Co-EDTA dilution were 12 to 26% higher than volumes measured by manual removal (Table 7). These differences are smaller than those observed previously (26) with hay crop silage-based diets. There was no evidence of nonlinearity in the marker dilution curves in the present experiments, and correlation coefficients averaged .98 for all 16 measurements. Liquid dilution rates averaged 17.6%/h, which is intermediate between values reported for early lactation cows fed 60 and 70% concentrate with hay crop silage (16, 26). Total ruminal outflow estimated from marker volume was not affected by treatment, but outflow estimated from the manually determined ruminal volume was increased about 11% with the buffered diets. Supplemental $NaHCO_3$ up to 2% of DM intake has not increased LDR in early lactation cows (21, 26), but 1.4% $NaHCO_3$ increased LDR in cows receiving a 54% alfalfa hay diet (22). However, LDR in that experiment was much lower (10.4%/h) and was raised only to 12.1%/h. In steers fed a diet with a high percentage of alfalfa hay, $NaHCO_3$ in excess of 2% of DM intake increased

TABLE 7. Ruminal liquid volume, dilution rate, and outflow as affected by buffer treatments.

| Measurement | Buffer treatment | | | | |
|---|---|---|---|---|---|
| | Control | .7% $NaHCO_3$ | .7% $NaHCO_3$ plus .28% MgO | Commercial mixture | SE[1] |
| Ruminal liquid volume, L | | | | | |
| Manual removal | 56.0 | 60.4 | 57.4 | 61.0 | 2.69 |
| Marker estimate[2] | 70.7 | 69.6 | 66.8 | 68.3 | 7.86 |
| Volume excess, %[3] | 126.2 | 116.7 | 117.1 | 111.8 | 10.04 |
| Liquid dilution rate, %/h | 17.1 | 18.3 | 17.3 | 17.8 | .59 |
| Ruminal liquid outflow, L/h | | | | | |
| Manual estimate[4] | 9.5 | 10.9 | 9.9 | 10.8 | .38[a] |
| Marker estimate[5] | 11.6 | 12.8 | 11.0 | 11.8 | 1.27 |

[a]Control < buffered, ($P<.05$).

[1]Standard error.

[2]Estimated from dilution of cobalt-ethylenediaminetetraacetate.

[3]Marker estimate as percent of manual estimate.

[4]Manual volume estimate X liquid dilution rate.

[5]Marker volume estimate X liquid dilution rate.

LDR and total liquid outflow (20). Given the difficulties associated with dosing, mixing, and sampling for markers in the nonsteady state conditions caused by large intermittent intakes of feed and water in lactating cows (26), it may not be possible to detect effects on liquid kinetics in producing animals.

## CONCLUSIONS

Inclusion of buffers in a 70% concentrate: 30% hay crop silage diet for early lactation dairy cows had little effect on milk production or composition but decreased efficiency of production. Although ruminal pH was unaffected, mixed buffers increased fecal pH, rumen ammonia concentration, and digestibilities of DM, OM, energy, ADF, and cellulose compared with $NaHCO_3$ alone. Mixed buffers increased ruminal proportion of acetate and decreased those of propionate, butyrate, and valerate. Ruminal liquid volume and LDR were unaffected by buffers, but total liquid outflow was increased. These amounts of buffers and alkalizers were insufficient to modify the very low observed ruminal fluid pH in early lactation cows and suggests that higher amounts of such minerals may be necessary to elicit a production response in animals fed hay crop silage-based diets.

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## REFERENCES

1 Association of Official Agricultural Chemists. 1965. Official methods of analysis. 10th ed. Assoc. Offic. Agric. Chem., Washington, DC.
2 Bremner, J. M., and D. R. Keeney. 1965. Steam distillation methods for determination of ammonia, nitrate and nitrite. Anal. Chem. Acta 32:485.
3 DePeters, E. J., A. H. Fredeen, D. L. Bath, and N. E. Smith. 1984. Effect of sodium bicarbonate addition to alfalfa hay-based diets on digestibility of dietary fractions and rumen characteristics. J. Dairy Sci. 67:2344.
4 Dewar, W. A., and P. McDonald. 1961. Determination of dry matter in silage by distillation with toluene. J. Sci. Food Agric. 12:790.
5 Donker, J. D., and G. D. Marx. 1985. Dietary sodium bicarbonate for high-producing Holstein cows over complete lactations. J. Dairy Sci. 68:140.
6 Edwards, A. L. 1968. Experimental design in psychological research. Holt, Reinhart, and Winston, New York, NY.
7 English, J. E., T. J. Fronk, D. G. Braund, and J. E. Nocek. 1983. Influence of buffering early lactation rations with sodium bicarbonate and magnesium oxide and subsequent withdrawal or addition effects. J. Dairy Sci. 66:505.
8 Erdman, R. A., R. L. Botts, R. W. Hemken, and L. S. Bull. 1980. Effect of sodium bicarbonate and magnesium oxide on production and physiology in early lactation. J. Dairy Sci. 63:923.
9 Erdman, R. A., R. W. Hemken, and L. S. Bull. 1982. Dietary sodium bicarbonate and magnesium oxide for early postpartum lactating dairy cows: effects on production, acid base metabolism, and digestion. J. Dairy Sci. 65:712.
10 Erwin, E. S., G. T. Marco, and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.
11 Fisher, L. J., and V. G. MacKay. 1983. The investigation of sodium bicarbonate or bentonite as supplements in silages fed to lactating cows. Can. J. Anim. Sci. 63:939.
12 Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analysis. Agric. Handbook No. 379. US Dep. Agric., Agric. Res. Serv.
13 Grieve, C. M. 1977. Effects of protected fat and sodium bicarbonate on milk production and composition. Page 52 *in* 56th Annu. Feeders' Day Rep. Univ. Alberta.
14 Kilmer, L. H., L. D. Muller, and P. J. Wangsness. 1980. Addition of sodium bicarbonate to rations of pre- and postpartum dairy cows. J. Dairy Sci. 63:2026.
15 Kilmer, L. H., L. D. Muller, and T. J. Snyder. 1981. Addition of sodium bicarbonate to rations of postpartum dairy cows: physiological and metabolic effects. J. Dairy Sci. 64:2357.
16 MacGregor, C. A., M. R. Stokes, W. H. Hoover, H. A. Leonard, L. L. Junkins, Jr., C. J. Sniffen, and R. W. Mailman. 1983. Effect of dietary concentration of total nonstructural carbohydrate on energy and nitrogen metabolism and milk production of dairy cows. J. Dairy Sci. 66:39.
17 National Research Council. 1978. Nutrient requirements of dairy cattle. 5th ed. Natl. Acad. Sci., Washington, DC.
18 Orskov, E. R. 1975. Manipulation of rumen fermentation for maximum food utilization. World Rev. Nutr. Diet. 22:152.
19 Rearte, D. H., E. M. Kesler, and W. C. Stringer. 1984. Forage growth and performance of grazing dairy cows fed concentrates with or without sodium bicarbonate. J. Dairy Sci. 67:2914.
20 Rogers, J. A., and C. L. Davis. 1982. Rumen volatile fatty acid production and nutrient utilization in steers fed a diet supplemented with sodium bicarbonate and monensin. J. Dairy Sci. 65:944.
21 Rogers, J. A., C. L. Davis, and J. H. Clark. 1982. Alteration of rumen fermentation, milk fat synthesis and nutrient utlization with mineral salts in dairy cows. J. Dairy Sci. 65:577.
22 Rogers, J. A., L. D. Muller, T. J. Snyder, and T. L. Maddox. 1985. Milk production, nutrient digestion,

and rate of digesta passage in dairy cows fed long or chopped alfalfa hay supplemented with sodium bicarbonate. J. Dairy Sci. 68:868.

23 SAS Institute, Inc. 1982. SAS User's guide. Raleigh, NC.

24 Snyder, T. J., J. A. Rogers, and L. D. Muller. 1983. Effects of 1.2% sodium bicarbonate with two ratios of corn silage: grain on milk production, rumen fermentation, and nutrient digestion by lactating cows. J. Dairy Sci. 66:1290.

25 Stokes, M. R., and L. S. Bull. 1986. Effects of sodium bicarbonate with three ratios of hay crop silage to concentrate for dairy cows. J. Dairy Sci. 69: (in press).

26 Stokes, M. R., L. S. Bull, and W. A. Halteman. 1985. Rumen liquid dilution rate in dairy cows fed once daily: effects of diet and sodium bicarbonate supplementation. J. Dairy Sci. 68:1171.

27 Stokes, M. R., L. L. Vandemark, and P. H. Knowlton. 1983. Buffers with hay crop silage diets for early lactation cows. J. Dairy Sci. 66(Suppl. 1):271. (Abstr.)

28 Teh, T. H., R. W. Hemken, and R. J. Harmon. 1985. Dietary magnesium oxide interactions with sodium bicarbonate on cows in early lactation. J. Dairy Sci. 68:881.

29 Thomas, J. W., R. S. Emery, J. K. Breux, and J. S. Liesman. 1984. Response of milking cows fed a high concentrate, low roughage diet plus sodium bicarbonate, magnesium oxide, or magnesium hydroxide. J. Dairy Sci. 67:2532.

30 Uden, P., P. E. Colucci, and P. J. Van Soest. 1980. Investigation of chromium, cerium and cobalt as markers in digestion. Rate of passage studies. J. Sci. Food Agric. 31:625.

31 Vandemark, L. L., M. R. Stokes, L. S. Bull, and C. K. Walker. 1981. Effect of buffers on performance by early postpartum cows fed diets based on hay crop silage. J. Dairy Sci. 64(Suppl. 1): 135. (Abstr.)