LACTATIONAL AND METABOLIC RESPONSES TO RUMEN-MATE^{R} AND SODIUM BICARBONATE IN DIETS OF EARLY LACTATION HOLSTEIN COWS

BY

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INTRODUCTION

In early lactation, the dairy cow may be characterized as being in negative energy balance, subclinically ketotic and in an increasing dry matter intake phase. This state results from the fact that milk production (nutrient output) increases at a faster rate than dry matter intake (nutrient input). Thus, the cow is forced to utilize her body nutrient stores in order to meet this demand. If nutrient intake lags behind nutrient needs and body nutrient stores are exhausted, then total milk production will be reduced. Conversely, maximizing nutrient intake before body nutrient stores are exhausted increases summit milk yield.

High energy diets (restricted roughage-high grain) are often fed to early lactation cows in an attempt to maximize nutrient intake and reduce negative energy balance. This approach is not without problems. When cows are suddenly transferred from high forage diets to high concentrate diets there is a reduction in saliva production and increased ruminal volatile fatty acid production which results in low rumen pH. This results in negative effects such as off feed, low acetate:propionate ratio, decreased milk production and low milk fat percent.

A diet high in forage helps to alleviate the negative effects caused by high energy diet because rumination of forages increases saliva production. Saliva is a major source of sodium bicarbonate ($NaHCO_3$). Sodium bicarbonate buffers against a decrease in rumen pH. Forages are relatively high in and the major source of dietary potassium thus, reduced forage intake restricts the intake of potassium. This could affect general health and milk production because there is a constant lactational demand for potassium (West 1986). A reduction in potassium intake due to reduced forage intake, increased potassium loss through sweating during hot weather and lactational demand for potassium may result in potassium requirement above the current recommendation of the National Research Council (NRC) for dairy cows.

Extensive work on buffers has shown that buffering agents can be used in dairy cattle feeding systems to alleviate a decrease in rumen pH with a subsequent increase in milk fat percent and reduced incidence of off-feed (Kilmer et al. 1986; Erdman et al. 1980; West and Coppock 1986).

The use of $NaHCO_3$, potassium bicarbonate ($KHCO_3$) and magnesium oxide (MgO) to alter rumen fermentation and reduce milk fat depression due to high concentrate diets have been tried with varying results (Donker and Marx 1980;

Kilmer et al. 1981; Emery et al. 1964; Erdman et al. 1980). Because of the variable effects of these buffers, ($NaHCO_3$, $KHCO_3$ and MgO), additional work is required to define the effects of buffers on metabolic activities under various feeding regimes and lactational states.

The objectives of this study were 1)to evaluate the relative effectiveness of Rumen-Mate^R and $NaHCO_3$ on feed intake, feed efficiency, milk yield and milk composition in dairy cows during early lactation and 2)to define certain ruminal and metabolic effects of these buffers.

LITERATURE REVIEW

One of the major challenges to the dairy herdsman is meeting the nutrient requirements of the high producing dairy cow in early lactation. The challenge arises from the fact that her nutrient output via milk greatly exceeds her ability to consume feedstuffs. The immediate requirements for milk production are met by shifting nutrients from body stores to the mammary gland to supplement nutrients consumed. Hopefully, appetite will increase rapidly enough to maintain high production before her body stores enter the repletion phase. The practice most commonly used to enhance nutrient intake during early lactation employs two elements; 1) challenge feeding with a mixed concentrate up to one percent of body weight prepartum and 2) feeding a postpartum diet of high energy density.

Challenge feeding enhances rumen microbial adjustments to grain feeding prepartum and reduces the time required to attain peak appetite postpartum. A high concentrate-low forage diet during early lactation increases nutrient density in an effort to meet the cows nutritional requirements in a restricted intake situation.

High energy density diets have the observable adverse side effects of reducing milk fat percent and increasing the incidence of cows going off-feed with a subsequent reduction in milk production. Both of these side effects have a measurable negative economic impact on the dairy producer's income.

The sequence of ruminal events that predisposes the cow to become anorexic or to produce milk with reduced fat has been extensively investigated. High concentrate, low fiber diets fed to ruminants decreases salivary production (Oltjen et al. 1965; Davis 1979), decreases rumen pH (Coppock et al. 1982; West et al. 1987; Russell et al. 1981), depresses ruminal acetate (West et al. 1987) and increases ruminal propionate (Armstrong 1968). A shift in the acetate:propionate ratio in favor of propionate tends to depress milk fat percent (West et al. 1987; Edwards and Poole 1983; Donker and Marx 1985; Schaefer et al. 1982; Coppock et al. 1986). Buffers have been used in the early postpartum period to offset the anorexic and milk fat depressing effects of low roughage-high grain diets. This review will concentrate on sodium bicarbonate, magnesium oxide, potassium carbonate and some mixed buffers.

General Actions of Buffers

Problems which occur due to a sudden change from high roughage to high concentrate diets in dairy cows (Stakes et al. 1986) and in feedlot cattle (Erdman et al. 1986) have been previously noted. The use of buffers in diets of dairy and beef cattle to counteract these problems have been studied extensively and reviewed (Muller and Kilmer 1979; Trenkle 1979), but results have been inconsistent. The improved performance of dairy cows or feedlot beef cattle fed buffered rations may be limited to the early weeks of adaptation and may not extend throughout the finishing or lactation period (Pierce et al 1983; Muller and Harpster 1983).

Buffers seem to be beneficial in adapting feedlot cattle and sheep (Ralston and Patton 1979; Huntington et al. 1980; Kilmer et al. 1980) to high concentrate diets when the dietary change is characterized by the abrupt removal of roughage. However, responses to buffers have been variable and unpredictable. This variability has been attributed to different feeding systems (particularly concentrate to forage ratio, type of forage and level of intake) and different types and levels of mineral buffers (James and Wahlt 1985). Boerner et al. (1987) observed that ruminal pH averaged across buffers was higher ($p<.01$) for cattle fed a 50% concentrate diet (5.92) than a 90% concentrate diet (5.59). Both Trona (a naturally occuring mineral ore) plus sodium bicarbonate increased ($p<.05$) ruminal pH relative to control in the 90% concentrate diet and trona increased ruminal pH over control ($p<.15$) and $NaHCO_3$ ($p<.16$) in the 50% concentrate diet. Thomas and Hall (1984) also included $NaHCO_3$ in a similar 50% concentrate diet and reported that it had no effect on ruminal pH. This ineffectiveness in increasing ruminal pH in cattle fed mixed roughage/grain diets is partly due to the natural buffering capacity of roughage (Van Soest et al. 1984). Buffers can be beneficial when diets produce unfavorable digestive tract conditions (Emerick 1976; Mertens 1979). Diets that do not produce unfavorable digestive tract conditions would not be expected to be improved by buffers (Haal and Tyrrell 1982).

Buffers should improve fiber digestibility when fermentable carbohydrates are included in the diet and should increase the stability of ruminal pH (Mertens 1979). Research with dairy cattle (Coppock et al. 1986) indicates that Trona is as effective as $NaHCO_3$ in stabilizing pH and improving digestibility. Boerner et al. (1987) observed that sodium sesquicarbonate, in the form of Trona ore, more effectively normalizes digestive tract pH and function than $NaHCO_3$ thus, reflecting additional buffering capacity and extended buffering response.

Sodium bicarbonate is used in ruminant diets to buffer ruminal conditions under situations of dietary or ruminal acid stress. It has been added at various concentrations to diets of sheep and cattle entering feedlots and to diets of dairy cattle at parturition (DePeters et al. 1984). Addition of $NaHCO_3$ may be useful in assisting cows to adapt from a low energy ration during the dry period to a high energy ration postpartum in a group feeding situation (Kilmer et al. 1980).

For a buffer to neutralize fermentation acids, it must be distributed or circulated to come in contact with the acids. The more soluble the buffer, the greater the immediate action within the rumen. Sodium bicarbonate is very soluble in ruminal fluid compared to some other buffering materials (Owens et al. 1983). With sodium bicarbonate, greater increases in ruminal pH have been observed with higher concentrate than higher roughage diets (Rodgers and Davis 1982), partly due to the fact that pH will change less per unit of buffer the closer the pH is to the pK of the buffer (Owens et al. 1983).

Potassium (K) has been recognized as a nutritionally important mineral for many years. It plays a major roll in cellular osmotic balance. When dehydration or body water loss occurs, water is lost from extracellular compartments and replaced by intracellular water. When this occurs, potassium concentration increases in the extracellular space and aldosterone is activated to cause excretion of K.

Potassium (K) content of milk is about 0.15% which may represent 15 to 40% of total dietary K intake of lactating cows depending on production and feed intake. Only small amounts of K are stored in the body so the quantity of K in the diet can influence milk production (Schneider et al. 1986). Potassium and sodium may be important, especially during heat stress as major regulators of body water balance. Sodium is required by the kidney for K conservation and to balance bicarbonate excretion electrically.

During heat stress, lactating dairy cows benefit from dietary K higher than current recommendations (Schneider et al. 1984; West et al. 1987). Thus, it is desirable to evaluate compounds that provide both buffering capability and potassium supplementation. Schneider et al. (1984) reported that cows offered feed containing potassium bicarbonate ($KHCO_3$) had reduced intake and milk production. Herod et al. (1978) compared numerous buffers in vitro and found potassium carbonate (K_2CO_3) was a stronger buffer (neutralizer)than potassium bicarbonate or sodium bicarbonate.

In work with dairy cows at various stages of lactation, Schneidier et al. (1986) observed no effect of 1.3 or 1.8% total dietary potassium on serum sodium or potassium levels.

This was consistent with results of Pearson et al. (1948) and Fontenot et al. (1960) when 5% $KHCO_3$ was added to diets of ewes. Kunkel et al. (1953) reported a decrease in serum potassium when ewes were fed a diet containing 5% $KHCO_3$.

In addition to other functions, buffer systems play important roles in maintaining the bicarbonate/carbonic acid (HCO_3/H_2CO_3) system in a buffer relationship. The body controls this system by altering the partial pressure of carbon dioxide (P-CO_2) by respiratory means or varying HCO_3 concentration of the blood metabolically (Escobosa et al. 1984).

<u>Effects on Appetite</u>

Effects of a sudden change from a high fiber diet prepartum to a high grain diet early postpartum has been noted. Impaired feed intake has been associated with high grain diets (Doughesty 1976; Mackey 1979) and hot weather (Newton 1980). Total feed intake declines and cattle may restrict forage intake more than concentrate when heat stressed, thus, reducing total K intake (Newton 1980). Potassium loss through skin may be substantial during heat stress because major inorganic constituents of bovine sweat are potassium carbonate and potassium bicarbonate. Increased sweating has been observed during elevated ambient temperatures (35-45^{o} C.) resulting in sharp increases in K loss through skin secretions (Johnson 1967).

Mallonee et al (1985) found that shaded versus unshaded cows secreted 9.6 and 46.7 mgK/m^2 of body area per hour respectively during peak heat load in the early afternoon. The K loss in unshaded cows was similar to that observed by Jenkinson and Mahon (1973) in seven month old Aryshire heifers. In the later study, total K loss through skin was estimated at 11.5% of K intake at 40° C.

Reduction in plasma aldosterone observed during heat stress indicates the cow may be in marginal K status (Beede et al. 1982; El-Nough et al. 1980). El Nough et al (1980) reported that Holstein cows subjected to 35° C. had reduced plasma aldosterone, which was associated with a significant reduction in serum sodium (Na), increased Na excretion, and decreased K in serum and urine. Reduced plasma aldosterone aids in conservation of K at the expense of Na.

West et al. (1987) reported that the concentration of serum sodium was unaffected by dietary potassium, but urine sodium concentration was greatest in cows fed 1.29% potassium compared to .93 and 1.53% potassium. Although not significant, there was a trend toward greater fractional excretion of sodium with increasing dietary potassium, which is indicative of greater absorption and urinary excretion of sodium. Green et al. (1983) reported a positive effect of dietary potassium on other minerals. West (1987) noted that high dietary potassium effects on other minerals, especially magnesium could present a problem. Potassium is considered to be antagonistic to magnesium absorption in cattle.

High producing dairy cows are challenged nutritionally to achieve their genetic potential for milk production by feeding diets high in grain. Feeding such diets to heat stressed cows may be advantageous. Heat increment is lower in high concentrate diets than with high forage diets, but such diets tend to increase acid conditions in the rumen. Furthermore, thermally induced hyperventilation may alter acid-base homeostases by reducing buffering capacity of the rumen (Schneider et al. 1986).

Mechanisms by which buffers improve animal performance are not clear. Increased feed intake is the most common attribute of $NaHCO_3$ supplementation, although increases in digestion efficiency have been reported (Erdman 1980). The main mechanism by which buffers can improve digestion appears to be related to gastro intestinal pH. Compounds that stabilize the pH of the small intestines may promote digestion of starch that escaped fermentation (Rodgers et al. 1982).

Buffers such as sodium bicarbonate, magnesium oxide

(Erdman et al. 1980) and potassium carbonate (K_2CO_3) (West et al. 1987) are promising tools for dairymen to stimulate both appetite and digestibility early in lactation. In a comparison of potassium carbonate, potassium bicarbonate and sodium bicarbonate, West et al. (1986) found that cows offered a diet containing potassium carbonate consumed more forage and complete feed than when other buffers were used indicating its possible effectiveness as a dietary buffer. Diets low in fiber are often supplemented with buffers to prevent fat test depressions and rumen disorder (West et al. 1987). Cows offered diets containing 1.85% K_2CO_3 had higher milk fat percentage than controls and similar to those offered $NaHCO_3$. Therefore, potassium carbonate is a buffer similar to sodium bicarbonate and it serves as a K supplement. West et al. (1987) also reported that cows responded favorably to 1.53% K supplementation which is well above current N.R.C. recommendations. Cows on 1.53% K had a tendency toward greater milk and 3.5% fat corrected milk yield compared with .93% or 1.29% K. Based on these results and others (Mallonee et al. 1985; Schneider et al. 1984 and Benjamin, 1981), future recommendations for K in diets of lactating dairy cows should consider the effects of heat stress. Potassium carbonate can serve as an acceptable K supplement and buffer during hot weather (West et al. 1987).

In experiments conducted during cooler fall weather to ascertain the acceptability of buffered diets by milking Holsteins, West et al. (1986) observed that cows fed potassium carbonate ate more feed. It was also observed that rations buffered with either potassium carbonate or sodium bicarbonate were more digestible than the control ration.

Kilmer et al. (1980) reported that cows fed 60% corn silage, 40% concentrate rations containing 0.72% $NaHCO_3$ consumed more dry matter and produced more milk during the first four weeks postpartum than did control cows. They related improved intake responses and ration adjustments in early lactation with added $NaHCO_3$ to changes in acid-base status. They noted that the response of lactating cows to $NaHCO_3$ in the diet is limited to the first few weeks postpartum. $NaHCO_3$ exerts its effect early in lactation following a change to high energy, high concentrate rations as observed by Erdman et al. (1982).

Studies done by Boerner et al. (1987) indicate that buffers may shift the site of digestion thus, increasing intestinal digestion and reducing ruminal digestion. Trona increased ($p<.05$) dry matter (DM) digestion over $NaHCO_3$ in a 50% concentrate diet while $NaHCO_3$ and control diets were similar. Additionally, Trona increased ($p<.10$) starch digestion in the 50% concentrate diet over both control and $NaHCO_3$.

Nutritional stress of changing from high forage to high grain rations at calving has been reduced by incorporating of 0.8 to 1.5% $NaHCO_3$ into complete rations consisting of 40 to 60% concentrate and 60 to 40% corn silage (DM basis) (Erdman et al. 1980; Erdman et al. 1982; Kilmer et al. 1980; Muller and Kilmer 1979) These studies also indicated that DM intake and milk production were enhanced by dietary $NaHCO_3$. Erdman et al. (1980), when feeding cows $NaHCO_3$ and MgO, observed that cows receiving $NaHCO_3$ peaked two to three weeks earlier in intake and averaged 2.1 kg per day greater intake than those fed the control diet. DePeters et al. (1984) observed that at 0.72 to 1.5% of the diet DM, $NaHCO_3$ improved DM intake and milk yield during early lactation in cows fed corn silage based diets.

Rodgers et al. (1985) observed increased voluntary water intake when cows were fed forage of variable length with dietary sodium supplementation. Animals increased water intake in response to a need to maintain water and electrolyte balance.

Studies with beef cattle and sheep suggest benefits in improved intake from addition of $NaHCO_3$ to starter feed lot rations (Dunn et al. 1979; Emerick 1976). Since dietary changes are similar at parturition to those on entry to the feedlot, it seems possible that buffers might stimulate intake and production in early lactation.

Kellaway et al. (1977) reported increased gains and intake in young dairy calves from addition of up to 6% $NaHCO_3$ in diets. After weaning, feed intake increased about 29% and 52% for 3 and 6% $NaHCO_3$ in the diet respectively, but decreased (42%) with inclusion of 9% $NaHCO_3$. The diminished response at 9% $NaHCO_3$ inclusion suggests it was excessive.

In a study where $NaHCO_3$ and MgO were fed to cows, it was observed that cows fed $NaHCO_3$ consumed more ($p<.05$) or decreased consumption less than did those fed MgO (Thomas et al. 1984). It was however, observed that cows fed control diets consumed more feed than cows fed mineral supplemented diets. Cows fed larger particle size magnesium sources (.425 to 1.70 mm.) consumed more DM than those fed the smaller particle size Mg sources (<.425 mm. MgO).

Erdman et al. (1982) reported that $NaHCO_3$ reduced feed consumption when abruptly added to rations. However, this decreased consumption was only temporary. West et al. (1987) observed that DM intake increased significantly on 1.53% dietary potassium as compared to 0.93% and 1.29% potassium. There was no difference in feed intake between

0.93% and 1.29% potassium. This data suggests that lactating dairy cows respond to dietary potassium concentration up to 1.53%.

Donker and Marx (1980) reported that when 1.5% $NaHCO_3$ was included in the concentrate, cows ate more forage throughout lactation ($p<.02$) thus, the crude fiber content of the DM consumed was higher. The cows tended to use more total digestible nutrients (TDN) per unit of milk produced probably as a result of higher weight gain ($p<.05$). Weight gain was greater for cows fed $NaHCO_3$ than controls ($p<.05$). On the contrary Kilmer et al. (1980) noted that cows fed the buffered rations had not regained body weight between week one and nine while control cows had a positive net gain. Cows fed buffers consumed more DM during the first week as compared to cows fed no buffers.

West et al. (1987) observed that cows fed $NaHCO_3$ and K_2CO_3 ate more feed than the controls, although DM intake for those fed 1.25% K_2CO_3 (as opposed to 1.85% K_2CO_3) was not significantly different from controls. Buffers have increased feed intake in some studies (Escobosa et al. 1984; Kilmer et al. 1980) but not in others (Erdman et al 1982; Rodgers et al. 1982). The lack of significant response can be attributed to high intakes in all animals. Apparently, intake must be depressed by a ration for animals to respond positively to addition of buffers. Observed responses are due to buffers correcting factors causing off feed. Like high concentrate-low fiber rations, pelleted rations also may cause an acid condition because grinding and partial gelatinizing of starch enhances rate of fermentation and acid production which may depress intake and this depression may be responsive to buffers (Hart and Polan 1982).

Effect on Milk Yield and Composition

Depression of milk fat test by dietary factors was described by Powell in 1939. He showed that finely ground forage severely depressed fat test. Since then other dietary factors such as unground forage, type of fiber, type of concentrate, physical form of concentrates and heat processing of concentrates have been shown to alter milk fat percentage with slight or no effect on milk protein percent (Coppock et al. 1982).

Dairy cows, conditioned to a high forage diets during the dry period, adapt slowly to high concentrate lactation diets (Stokes et al. 1986). High concentrate diets result in increased ruminal acid production relative to high forage diets, reduced saliva production, often depressed milk fat percentage (Coppock et al. 1982) and reduced starch digestibility (Schaefer et al. 1982). High grain diets also result in ruminal acetate:propionate ratios favorable to propionate which have been associated with decreased milk fat percent (Erdman et al. 1980).

Dairy cows subjected to high temperatures are severely stressed with subsequent changes in their nutritional needs. Hot weather and high humidity reduces the cow's ability to radiate heat thus, her body temperature rises leading to heat stress. The cow eats less and may preferably eat less forage compared to grain if given the choice, because forages produce more heat during digestion than concentrate (West 1986). In addition to suppressing appetite, hot weather often depresses milk production and percentages of both fat and protein (Coppock et al. 1982).

Dietary buffers such as sodium bicarbonate, potassium carbonate and magnesium oxide have been used to reduce the effects of both the high grain-low forage diets and high temperatures. Dietary buffers in high concentrate diets result in increased dry matter intake, milk yield and milk fat percentage (Coppock et al. 1986).

Many researchers have shown that milk fat can be maintained at normal concentrations or elevated when sodium bicarbonate, magnesium oxide or both are added to high concentrate-low fiber diets (Thomas et al. 1984; West et al. 1986). The use of sodium bicarbonate and potassium bicarbonate to alter rumen fermentation and to inhibit milk fat depression due to high grain diets have been tried on a number of occasions with varied results. Some studies did not find an increase in milk fat percent when sodium bicarbonate was added to diets with nearly adequate fiber (Donker and Marx 1980; Kilmer et al. 1981), others found no effect (Emery et al. 1964; Erdman et al. 1982) or decreased milk fat percent (Gesse et al. 1981). Four percent fat corrected milk (FCM) was increased (Erdman et al. 1980; Kilmer et al. 1980) while protein yield was unaffected by addition of sodium bicarbonate, magnesium oxide or both (Emery et al. 1964).

Some studies have shown that ruminal molar proportions of acetic acid and acetate:propionate ratio were increased (Davis et al. 1964; Rodges et al. 1982; Huber et al. 1969; Emery et al. 1986; West et al. 1987) while some showed no change (Emery et al. 1964; Kilmer et al. 1980; Stout et al. 1972) when sodium bicarbonate or magnesium oxide was added to the concentrate. Fecal pH was increased proportionally to the amount of magnesium oxide fed to dairy heifers (Schaefer et al. 1982) and lactating cows (Erdman et al. 1980), but sodium bicarbonate had no effect (Erdman et al 1980; Kilmer et al. 1980).

Use of buffers may have greater benefits during hot weather. With forage intake reduced there is less inherent buffering capacity due to decreased rumination with a subsequent reduction in saliva production, a major source of $NaHCO_3$ (West and Coppock 1986).

Experiments conducted during cool weather to determine the acceptability of buffered rations by milking Holsteins indicate that potassium carbonate is more acceptable than sodium bicarbonate. In fact, cows fed potassium carbonate ate more feed. In another experiment, (West and Coppock 1986) rations buffered with either potassium carbonate or sodium bicarbonate were more digestible and produced milk with higher fat tests than control cows. Sodium bicarbonate may increase milk production and milk fat test counteracting depressions due to heat stress, but a compound that provides potassium and buffering capacity would be beneficial both during hot weather and cool weather (West et al. 1986).

Edwards and Poole (1983) noted that with a feeding system involving diets high in concentrate that resulted in depressed milk fat levels, addition of sodium bicarbonate resulted in a significant improvement in milk fat production. Donker and Marx (1985) also observed that sodium bicarbonate was effective in increasing the low fat content of milk from cows consuming low forage-high grain diets. They observed that production of milk over the entire lactation tended to increase when $NaHCO_3$ represented

1.5% of the concentrate or 1.0% of the total ration dry matter.

Erdman et al. (1980) observed that $NaHCO_3$ plus MgO did not affect milk fat test significantly although cows receiving MgO alone had slightly lower fat test than all other treatment groups. Differences in milk fat and milk yield contributed to a significant increase in fat corrected milk and total fat production for cows receiving $NaHCO_3$ ($p<.01$). Differences, however, were largest for cows receiving both MgO and $NaHCO_3$. These differences were greater during the first three to four weeks postpartum where cows receiving both $NaHCO_3$ alone or in combination with MgO had significantly higher FCM production ($p<.01$). However, a significant MgO and $NaHCO_3$ interaction ($p<.01$) was noted as total milk yield decreased in the $NaHCO_3$ group during the final week of the study. This was due to higher FCM production for cows fed both buffers. Donker and Marx (1980) also observed an increase in FCM from cows fed $NaHCO_3$. Milk production was 4.32 kg FCM/100 kg body weight for the bicarbonate group and 4.23 kg FCM/100 kg body weight for the control ($p<.05$). This difference amounted to .5 kg FCM daily per cow per lactation. The unadjusted fat content of milk from cows fed sodium bicarbonate was higher than from control cows (3.78% versus 3.71%; $p<.01$). However, 18 of the cows included in the $NaHCO_3$ group had produced milk with 3.85% fat in the previous lactation and seventeen cows on the control group had produced milk with 3.77% fat. This increase in FCM can be attributed to lower dietary fiber and the difference in FCM production would disappear for higher fiber diets. Benefits in higher peak milk production from high concentrate diets may be obtained while maintaining normal milk fat percentage if $NaHCO_3$ and MgO are used. If normal milk fat percentage can be maintained on high concentrate diets, then higher peak milk production from use of high concentrate diets may justify use of $NaHCO_3$ and MgO even without responses in intake (Erdman et al. 1982). DePeters et al. (1984) observed no change in feed intake, milk yield and composition when 0%, .25%, .5% and .75% sodium bicarbonate was added to the diet of Jersey cows. Apparent digestibility of dietary components was not affected by addition of $NaHCO_3$ and fatty acid composition of milk fat did not change. The most consistent benefit from the addition of $NaHCO_3$ to diets of lactating dairy cows has been the prevention of milk fat depression when diets contained a high proportion of concentrate (Kilmer et al. 1980). Normally, increased milk fat test could be expected from including $NaHCO_3$ in diets causing depressed milk fat. However, Kilmer et al. (1980) did not observe any depression in milk fat test of control cows (3.88%) suggesting that diets were adequate to maintain a normal milk fat test.

In an experiment where different levels of potassium (K) were fed to cows, West et al. (1987) observed that cows fed 1.53% K had a tendency toward greater milk and 3.5% FCM yield compared with cows fed 0.93 or 1.29% K. However, during comparison period two, potassium carbonate at 0, 0.5 or 1.0% had no effect on feed consumption or milk yield, but increased milk fat percentage and depressed milk protein percentage. Because K supplementation and buffering are needed during heat stress, it is logical to use a compound meeting both needs. West et al. (1986) compared potassium carbonate to potassium and sodium bicarbonates and found that potassium carbonate increased feed intake, milk yield and milk fat production.

A linear relationship between acetate:propionate ratio and milk fat percentage has been reported (Thomas and Emery 1984). Other studies indicate increased milk fat percentage with increased acetate:propionate ratio (Erdman et al. 1982; Snyder et al. 1983). West et al. (1986) observed similar results with milk fat percentage in cows fed 1.80% potassium carbonate versus control. All buffered diets resulted in a numerically greater milk fat percentage similar to trends noted for rumen acetate:propionate ratio. Higher pH in buffered diets and increased fiber digestibility were associated with the increased milk fat percent. Total solids tended to be greater in cows fed buffered diets.

Block and Muller (1985) reported decreased milk production but increased milk fat test when 0.23kg $NaHCO_3$ and 0.07kg MgO/cow/day were added to diets fed to lactating cows. The response in milk fat test was immediate with added buffers. The percentage of milk fat for the week preceding buffer addition was 3.01%, increased to 3.27% on the third day and to 3.37% a week after buffer addition.

Kilmer et al. (1981) related the increase in milk yield in their study to alterations in nitrogen metabolism as well as increased intake. Sodium bicarbonate apparently increased solubility of proteins as evidenced by the increased concentration of ammonia (NH_3) in the rumen. Others have also reported increased protein solubility with increased rumen pH (Trenkle 1979; Wohlt et al. 1973). The improvement in milk yield may be from a combination of more nitrogen and other nutrients consumed together with improved efficiency of nutrient utilization (Kilmer et al. 1981).

Thomas et al. (1984) reported the greatest increase in milk fat percent from MgO passing a 0.425 mm. sieve and most milk production from $NaHCO_3$ diet treatment. Cows fed diets supplemented with MgO and $NaHCO_3$ produced less protein than did control cows. Cows supplemented with $NaHCO_3$ produced more milk than those fed MgO. Some studies obtained similar results (Emery and Brown 1961; Erdman et al. 1980) while others contradicted (Miller et al. 1965; Nilsson et al. 1972). Feeding MgO tended to increase lipoprotein lipase activity of mammary gland and decrease linoleic acid content of milk fat. Both of these changes were correlated with increased production of milk fat (Thomas et al. 1984). Feeding Mg supplements did increase milk fat percent more than control or $NaHCO_3$, however, cows fed $NaHCO_3$ consumed more feed and produced more milk.

Michigan researchers (Emery and Brown 1961) proposed the use of $NaHCO_3$ and MgO to increase milk fat percentage depressed by high concentrate-low fiber diets. Field observations suggest that these mineral buffers are at least partially effective in alleviating milk fat depression during hot weather, but in many cases, effects of weather, diet and stage of lactation appear to be confounded (Coppock et al. 1982).

<u>Effectiveness of Buffers in Various Forage Based Diets</u>

Dairy cows are fed rations high in forage (often hay) with little or no concentrate during the dry period. Following parturition, cows are switched to high energy diets to provide nutrients necessary for high milk production. These diets often contain corn silage as the forage base with little or no stem hay. When cows are group fed according to production, the change from a low to a high energy diet immediately postpartum is often too abrupt for ruminal adaptation to occur. Uhart and Carroll (1967) reported marked decreases in urine pH from 8.2 to 5.9 in steers abruptly switched from alfalfa hay rations to high grain rations. High intakes of readily fermentable carbohydrates often are associated with reduced feed intake, increased infectious and metabolic diseases, more animals off feed and decreased fertility (Kilmer et al. 1980).

Erdman et al. (1980) fed 40% corn silage, 60% concentrate rations containing 1.5% sodium bicarbonate and .8% magnesium oxide either alone or in combination and reported that $NaHCO_3$ increases intake and milk production faster following parturition than either the control ration or the ration with MgO alone. Kilmer et al. (1981) fed 0.8% $NaHCO_3$ to cows eating 50/50 corn silage/concentrate and observed that differences in blood acid-base balance and urine alkalinity favor cows fed $NaHCO_3$. Feeding $NaHCO_3$ appears to create a more alkaline status, or at least reduces the acid condition developed due to an abrupt change from a low to a high energy ration. Stroud et al. (1985) observed that mean dry matter and neutral detergent fiber digestibilities were greater ($p<.05$) for dehydrated alfalfa and dehydrated alfalfa plus $NaHCO_3$ treatments in two trials compared with control group and may be responsible for the improved average daily gain (ADG) observed.

DePeters et al. (1984) observed the addition of $NaHCO_3$ to complete mixed diets high in concentrate and chopped alfalfa hay did not affect digestibility of dietary components despite a slightly depressed ruminal pH when cows were fed control diets. Ruminal characteristics were unaffected by $NaHCO_3$ addition to the diet except volatile fatty acid (VFA) concentration at six hours post feeding in one of their experiments. Alfalfa hay differs from corn silage in at least three aspects that may reduce the need for supplemental buffers. First, fiber is greater per unit of alfalfa such that in comparison to diets with equal forage to concentrate, alfalfa based diets offer more total fiber. Second, alfalfa has higher buffering capacity than corn silage, and finally alfalfa offered as hay is not acidic. Erdman et al. (1982) also noted that $NaHCO_3$ added to diets doesn't appear to raise ruminal pH unless it is below the normal 6.2 to 6.3 range. No improvement in fiber digestion would be expected in high forage diets as rumen pH would be well above the range in which $NaHCO_3$ (and possibly MgO) would be effective. Only in high concentrate diets, where fiber is normally a smaller portion of the total ration, would an increase in fiber digestion due to addition of $NaHCO_3$ or MgO be expected.

Responses of dairy cows to $NaHCO_3$ have been variable when cows were fed hay crop silage or alfalfa hay diets, but generally have been positive for cows fed a corn silage based diet in early lactation (Rodgers et al. 1985). Rodgers et al. (1985) observed that the length of alfalfa hay had no significant effect on milk production and composition. Milk fat percent was similar with added $NaHCO_3$. Digestibilities of dry matter, organic matter, crude protein and neutral detergent fiber were reduced significantly in cows fed chopped alfalfa hay. Decreased nutrient digestibility has been reported with reduction of feed particle size and reflects ruminal and post ruminal retention time of smaller feed particles (Rodgers and Davis 1982). Reducing particle size and addition of $NaHCO_3$ had minor effects on productive performance of lactating dairy cows.

Stokes et al. (1986) concluded that inclusion of MgO and $NaHCO_3$ 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. Mixed buffers ($NaHCO_3$, sodium sulfate, sodium bentonite, MgO, magnesium carbonate, calcium oxide, malt flour, sodium acetate, methionine hydroxy analog, yeast flour, sodium acetate, methionine hydroxy analog, yeast culture, processed grain by products, cane molasses, mineral oil and artificial flavor) increased fecal pH, digestibilities of dry matter, organic matter, energy, acid detergent fiber and cellulose compared to $NaHCO_3$ alone. They also increased ruminal proportion of acetate and decreased those of propionate. They did not affect ruminal pH. Eickelberger et al. (1985) observed a higher urine pH with alfalfa hay based diets than that with corn silage based diets.

DePeters et al. (1984) observed that at .72 to 1.5% of the diet dry matter, $NaHCO_3$ improve dry matter intake and milk yield during early lactation in cows fed corn silage based diets. Several studies have shown that sodium bicarbonate increased dry matter intake and milk yield when cows were switched abruptly at parturition from high fiber to high energy corn silage based diets (Chase et al. 1981; Rodgers et al. 1982). Reasons given for the improved performance include increased ruminal pH, improved digestibility and more rapid restoration of acid-base balance. Magnesium oxide either alone or with sodium bicarbonate increased milk yield and milk fat percentage in early lactation cows fed corn silage based diets (Muller and Kilmer 1979; Erdman et al. 1980). However, responses have been variable when buffers were added to diets containing forages other than corn silage (Edwards and Poole 1983; Rodgers et al. 1985; Stokes et al. 1983). In general addition of $NaHCO_3$ to alfalfa hay based diets has not increased milk yield and feed intake of cows in early to mid lactation. Alfalfa and coastal bermuda grass supplemented with $NaHCO_3$ resulted in increased production of solids corrected milk by cows in mid-lactation (Kilmer et al. 1980). Addition of $NaHCO_3$ to diets based on long stem hay increased milk fat percentage and intake of hay from early to mid-lactation (Edwards and Poole 1983). However, Rodgers et al. (1985) did not observe any change in milk production, milk composition or dry matter intake of cows in mid-lactation when $NaHCO_3$ was added to concentrate diets with long stem or chopped alfalfa hay as the forage. High quality alfalfa stimulates adequate rumination and saliva production which provides adequate natural buffering capacity, thus reducing the need for dietary buffers.

Responses of cows fed different forages supplemented with buffers have varied. While silage based diets are generally improved, cows fed alfalfa hay with buffers do not necessarily respond. Partial neutralization of silage acidity with buffers provides the basis for improved performance (McLeod et al. 1970).

MATERIALS AND METHODS

Experimental Procedure

Sixty-eight Holstein cows were used to evaluate a manufactured mineral supplement with buffering capacity (Rumen-Mate^{R}), a mineral mix formulated to simulate Rumen-Mate^{R} (Iso-Nutrient Product) and sodium bicarbonate ($NaHCO_3$) as dietary supplements during early lactation. Eleven multiparous and six primiparous cows were assigned to each of four treatments. Cows were blocked by milk production (day 1-16 postpartum), date of calving and age. Cows within blocks were randomly assigned to one of four experimental diets beginning on d 17 postpartum and continuing through d 86 postpartum. Days 1-16 postpartum were used as a standardization period to obtain data for use as a covariate in the analysis and to provide data for blocking cows. All cows received the basal diet during this period.

The basal diet consisted of approximately 40% forage (40% corn silage, 60% chopped alfalfa hay on DM basis) and 60% concentrate. Diets were formulated to meet or exceed NRC (1978) requirements. Dietary treatments were: 1) basal diet (control), 2) basal diet with 2.5% Rumen-Mate^{R}, 3) basal diet with 0.8% $NaHCO_3$ and 4) basal diet with 0.55%

MgO, 0.8% Trona, 0.56% Dyna-K[R] and 0.4% Dynamate[R]. Dietary treatments were added on a DM basis and substituted for corn grain.

Cows within experimental groups were housed together and bunk fed as a group. All experimental groups received a bunk mix of chopped alfalfa hay, corn silage and 6.8 kg of basal concentrate. The remaining concentrate plus dietary treatments were individually fed via a computer controlled concentrate feeder. The bunk mix was measured daily and group average intake calculated. Concentrate allocated and consumed through the computer controlled feeder was recorded daily. All cows were offered 10% more concentrate than was required for maintenance and milk during the increasing phase of their lactation cycle and according to production thereafter. The percent of each experimental compound was held constant regardless of concentrate intake by blending varying portions of basal mix with varying portions of experimental mixes while individual cows were eating from the three-bin computer controlled concentrate feeder. Thus, a cow consuming bunk mix plus 10 lbs of concentrate from the feeder and a cow consuming bunk mix plus 20 lbs of concentrate both received 2.5% of the DM allotted as Rumen-Mate[R] or the stated percent of the other experimental supplements.

Sampling Procedure

Samples of individual dietary treatment concentrates were taken from each batch mixed. Individual sample analyses were similar among treatment batches. Samples of alfalfa hay and corn silage used were taken weekly. Individual analyses were similar, thus a combined average analysis was used to calculate nutrient intake. Feedstuffs were analyzed for moisture, crude protein, crude fat, acid detergent fiber, ash, calcium, phosphorus, potassium, magnesium and sodium. Estimated net energy of lactation was calculated from ADF fraction. Feedstuffs analysis was conducted by a commercial laboratory (LSB Products, Manhattan, KS).[1]

Milk weights were recorded daily and composite AM-PM samples taken bi-monthly for butterfat, protein, solids-not-fat, lactose, and somatic cell count determinations. Milk component analyses were conducted by the Kansas State DHI Laboratory, Manhattan, KS.

Bodyweights were taken on day 1 and 2 of the experimental period, two consecutive days bi-monthly, and on day 85 and 86 of the experimental period. Consecutive day weights were taken at 2:30 PM and the average used in data analysis. Ruminal fluid, blood, urine, and fecal grab

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[1] LSB Products, 731 McCall Road, Manhattan, KS. 66502

samples were collected three to four hours post-feeding at 1, 5, and 10 weeks postpartum.

Samples of ruminal fluid were taken via stomach tube and strained through four layers of cheese cloth. Two ml. of 25% Metaphosphoric acid were added to 8 ml. of ruminal fluid and the sample stored at -20° C. Blood samples were drawn from the caudal vein into heparinized vacuum tubes and the plasma separated and frozen at -20° C. Urine was collected by manual stimulation, pH determined immediately, and a 20 ml. aliquot frozen at -20° C. Frozen ruminal fluid, urine and plasma were later shipped to Pitman-Moore Inc., Terre Haute, IN for mineral analysis. pH was determined on fecal grab samples and urine samples with a digital IONALIZER model 701 A pH meter.[2]

Analytical Procedure:

Ruminal fluid and urine were wet ashed in concentrated nitric acid followed by 30% hydrogen peroxide on a temperature controlled hot plate. The white ash of all samples was dissolved in 3 N HCL and made to appropriate volume (Schricker et al., 1982). Blood plasma, urine, and ruminal fluid were analyzed for Ca, Mg, Na, K and P by ICP-emission spectrophotometry (Mianghi and Barnes, 1985). Samples were analyzed for Cl using dionex ion chromatograph

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[2] ORION Research Incorporated, Cambridge, Massachusetts

2/20. Creatinine in urine and plasma was determined using an autoanalyzer (Roche Diagnostic Systems, Nutley, NJ). The procedure is based on the Jaffe reaction (Physio. Chem. 10, 391; 1986) where creatinine reacts with picric acid under alkaline pH to form a measurable red complex.

The acidified ruminal fluid was thawed, centrifuged at 2000 rpm and the supernatant analyzed for VFA's by gas liquid chromatography in a Hewlett-Packard 5890 gas chromatograph with 7672 A automatic sampler (Hewlett-Packard, Kansas City, MO).[3]

Data Analysis:

Data were analyzed according to the General Linear Models Procedures (Statistical Analysis System, 1982) for determining least squares means with unequal sample size.

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[3] Hewlett-Packard, 1001 E. 101st Street, Terrace Suite 120, Kansas City, MO, 64131

RESULTS

Production Response:

Cows were assigned to the study on day 16 postpartum if they exhibited a normal appetite, showed no signs of illness and had a normal parturition. Cows that were injured or became ill from causes unrelated to treatments were dropped from the experiment and replaced by healthy cows. Six cows were dropped during the preliminary period (day 1-16 postpartum). Four cows were dropped during the experimental period due to either hardware disease, metritis, chronic mastitis from udder injury or an injured rear leg from a fall.

Table 1 shows ingredient composition of concentrate mixtures per ton. Dietary treatments were substituted for corn grain. Chemical composition of concentrate mixtures is shown in Table 2. Both RM and INP supplemented diets had higher K and Mg levels compared to control and SB diets. Total ash was also higher in RM and INP diets. Proximate analysis were similar across treatments. Table 3 shows chemical composition of corn silage and hay on DM basis.

Cows used in the experiment calved between January 16, 1987 and June 22, 1987. Date of calving was equalized across treatment in so far as possible. The widest variation was 11 days in one group and 10 days in another while the remaining groups ranged from one to eight days. There were six heifers and 11 cows per treatment. Fifteen cows and heifers freshened in January, 5, 10, 16, 9 and 12 in February, March, April, May and June respectively. Significant ($p<.05$) month of freshening by treatment interactions were observed with respect to fat corrected milk (Table 10 & Figure 4), milk production (Table 12 & Figure 3), milk fat percent (Table 14 & Figure 6), milk protein percent (Table 16 & Figure 9), DM intake (Table 8 & Figure 2), feed efficiency (Table 9 & Figure 5) and somatic cell count (Table 18). Cows calving in January, February, March and April tended to produce more milk (33.9 kg versus 30.6 kg/day), with a slightly higher fat content (3.53% v 3.24%) while consuming about the same amount of dry matter (21 kg v 20.5 kg), but with improved feed efficiency (.69 kg DM per kg milk v. .78 kg DM per kg milk) relative to cows calving in May and June. Milk protein % was similar (2.95, 2.88, 2.98) for cows calving in January, February and March, then declined linearly thereafter (2.80, April; 2.78, May; 2.72, June). Somatic cell count was more variable than the other components, but tended to be lower in cows calving in January, February and March (205,000) than those calving in April, May and June (264,000).

Significant age by treatment interactions (p<.05) were observed with respect to DMI, milk yield, fat %, FCM, and protein % (tables 7, 11, 13, 15 & 17 respectively). Four and five year old cows were grouped for comparison as were cows older than five years to increase numbers per group. Three, four and five year old cows tended to consume more kg of DM per day (21.4 and 21.0) than two (20.6) or older (20.4) cows. Milk production was approximately 19% greater from four, five and older cows than from two year olds, while three year olds produced 9% more milk than two year olds, but 11% less than the four, five and older cows. Milk from the two year old cows averaged 3.45% fat compared to 3.29, 3.27 and 3.32% for three, four and five and older cows. However, FCM followed the same trend as uncorrected milk production. Milk protein concentration (%) was less for four and five year old cows (2.75) than for two (2.89), three (2.92) and older (2.85) cows.

RM did not affect dry matter intake relative to control, whereas SB and INP significantly increased DMI (p<.05) over control and RM treatments (Table 4). This effect of SB and INP was observed across all ages except three year old cows where DMI was similar across treatments. Older cows fed RM produced slightly more FCM (36.6 kg) compared to 2, 3, 4 and five year old (27.3, 27.5, and 30.7

kg, respectively).

Production responses (DMI, feed efficiency, milk yield, FCM, Fat %, Protein %, SNF and SCC) were observed bi-monthly (periods). There were five periods of 14 days each inclusive, i.e. period 1 = day 17 - 30, period 2 = day 31-44, period 3 = day 45 - 58, period 4 = day 59 - 72, period 5 = day 73 - 86 postpartum. These periods were used to determine the effects of length of time after parturition on production responses.

Table 6, shows effect of periods on production parameters irrespective of treatments and age of cows. Dry matter intake increased from day 1 through 58 and remained constant thereafter. All cows irrespective of treatment were more efficient (.69 kg DM per kg milk yield) in feed utilization ($p<.05$) during the first two periods (d 17 through 44 postpartum) than during the latter periods (d 45 through 86 postpartum). Cows supplemented with RM were more efficient ($p<.05$) in feed utilization (.68) compared to other groups (Table 4).

Milk production peaked in period two (d 31 to 44 postpartum) (Table 6). Fat corrected milk was relatively constant from d 17 through 58 postpartum and then decreased ($p<.05$). Percent milk fat tended to be higher during d 17 to 58 postpartum and then decreased gradually. Protein %

was higher (p<.05) during period one compared to other periods. There were no significant period effects on milk solids-not-fat and somatic cell count.

Least square means for DM intake, feed efficiency, milk yield and composition are shown in Table 4. Dry matter intake (kg) was significantly higher for cows fed SB and INP compared to control and RM. There was no difference between means for cows fed RM and control cows.

Uncorrected milk yield was significantly higher (p<.05) for cows fed SB compared to other cows (Table 4). Cows receiving RM produced significantly more FCM (p<.05) compared to control cows and slightly more than cows fed SB and INP (30.5 kg vs 29.4 & 29.5 kg respectively). The RM group had higher fat % (p<.01) than the SB group while the control and INP group had higher fat % (p<.05) than the SB group. However, the RM group had slightly higher milk fat % than the control and INP group. Protein % and solids-not-fat % were not different. Control cows had higher somatic cell count (SCC) than RM and SB (p<.05) while SCC in cows fed INP were slightly lower than control (287 versus 400), slightly higher than SB (287 versus 150) and significantly higher (p<.05) than RM.

Figure 1 shows the relationship between days in milk and feed provided, actual feed consumed and milk produced.

Irrespective of treatment, age of cow and month of freshening, cows peaked in DM intake and milk production at day 33 while consuming 22.3 kg DM and producing 34.1 kg of milk. During the dry period, cows received 1% body weight in grain and 4.5 kg of a chopped alfalfa and corn silage mix similar to that fed postpartum. They also received free choice prairie hay prepartum.

Metabolic Parameters

At the beginning of the trial six cows would not respond to manual stimulation making it difficult to get urine samples. Seventeen plasma and urine samples were lost during shipment. Plasma creatinine values are available on 38 of the 68 cows.

Data for urine and fecal pH and ruminal VFA production are in Table 5. Fecal pH was higher ($p<.05$) for cows fed RM compared to other groups while urine pH was similar for all treatments. Cows fed RM had higher ruminal acetate (M%) ($p<.05$) than the control group whereas, ruminal acetate was intermediate for the SB and INP groups. Ruminal propionate (M%) was lower ($p<.07$) in cows fed RM (19.8) compared to control and INP (22.1, 22.4). Ruminal propionate percentage for SB group was similar to the RM group. Butyrate (M%) was higher for the control group compared to SB and INP group. Ruminal valerate (M%) was higher for control group than for

RM and SB group. Isobutyrate and Isovalerate were similar for all treatments.

Acetate:Propionate ratio was higher (3.4) for RM group compared to control group (3.0) ($p<.05$). Cows on buffered diets tended to have similar acetate:propionate ratio with RM cows being higher. Fecal pH for RM and INP groups tended to increase from week one to ten postpartum (Figure 7 & Table 20). Fecal pH for SB group was higher during week five postpartum and then decreased while fecal pH of the control group tended to remain relatively constant during the ten week study. Fecal pH was similar for all treatment groups during week one postpartum (preliminary period). At week five ($p<.05$) and week ten ($p<.03$) postpartum RM group had higher fecal pH compared to control (Table 20 and Figure 7). Urine pH was similar for all treatments during the ten week study period (Table 21 and Figure 8).

Ruminal acetate (M%) was similar for all treatments at week one postpartum (preliminary period) (Table 22 & Figure 10) while cows fed RM had higher acetate (M%) at week five and ten postpartum compared to control ($p<.05$). Propionate (M%) was lower for RM ($p<.05$) compared to control at week five postpartum (Table 23 & Figure 11). Thus, as acetate increased, propionate tended to decrease for RM group. Mean acetate:propionate ratio (Table 24 & Figure 12) was similar for all treatments at week one, five and ten postpartum. Mean Isobutyrate, Butyrate, Isovalerate and Valerate (Appendix XXIV, XXV, XXVI and XXVII respectively) were relatively constant across treatments and weeks postpartum.

<u>Mineral Profile</u>

The estimated mineral intake (Table 26) of cows in this study show calcium and phosphorus relatively constant across treatments while cows fed RM and INP diets consumed more magnesium (191 and 119 grams) than cows fed control and SB diets (49 and 44 grams). Sodium intake was lower (110 grams) in control cows relative to cows receiving RM (161 grams), SB (162 grams) or INP (146 grams). Potassium intake was similar for cows fed control and SB diets (237 and 225 grams) compared to RM (355 grams) and INP (384 grams).

Ruminal calcium, phosphorus, sodium, magnesium and potassium were not significantly different across treatments (Table 25 and 27). This is unexplainable since estimated intakes of sodium, magnesium and potassium were quite different between treatments, cows receiving RM consumed approximately 3.8 times more magnesium and 1.5 times more potassium than cows fed control or SB diets. Ruminal fluid samples were taken by stomach tube and may not accurately reflect the mineral concentration of the total rumen contents since stratification of ingesta occurs in the rumen. RM supplemented cows had significantly less ($p<.05$) ruminal chlorine than INP supplemented cows and slightly less (508 ppm) than control (550 ppm) and SB supplemented cows (578 ppm).

The plasma mineral concentrations followed similar trends as ruminal fluid (Table 25 and 27) with the exception of sodium. Cows receiving SB had elevated ($p<.05$) plasma sodium relative to RM and slightly higher than control and INP cows.

Urine concentration of sodium was not significantly different across treatments, however, cows receiving RM had highest sodium value for urine. Cows fed RM had higher urinal K, Ca and Cl than control cows, while urinal P was lower for cows fed RM compared to other treatments. Urine concentration of Mg was not significantly different across treatments, although cows fed SB had the highest Mg level.

Kidney Filtration Ratio (KFR) for Ca ($p<.05$), K, Cl ($p<.09$) and Mg ($p<.07$) respectively was higher for cows fed RM compared to other treatments (Table 25 and 27). KFR values for Na and P respectively were similar across treatments.

DISCUSSION

Mineral buffers have been recommended to alleviate problems associated with high concentrate feeding. More research work has been done on sodium bicarbonate than any other buffers. Buffers like magnesium oxide, potassium carbonate, potassium bicarbonate and recently trona and sodium sesquicarbonate have been tested with varying results (Donker and Marx 1980; Erdman et al 1981; Geese et al 1981). This might have been due to testing buffers under different feeding regimes. An ideal buffer should show buffering capacity with all types of feedstuffs. It should be effective all year round, both summer and winter months. It should provide some nutrients and should be effective across all ages of cows (heifers and mature cows).

Sodium bicarbonate has been most effective when fed to multiparous cows in early lactation (Donker and Marx 1980; Erdman et al. 1980; Kilmer et al. 1979). It is also beneficial in corn silage based ration (Edwards and Poole 1983) and least effective with alfalfa based ration (Eickelberger et al. 1985; DePeters et al. 1983). However, when $NaHCO_3$ is used, sodium chloride should be replaced with potassium chloride to reduce the Na load. This would add K, which is essential in milk production. Trona and sodium sesquicarbonate have similar effects as $NaHCO_3$. Boerner et al. (1987) observed that trona ore was a more effective buffer than $NaHCO_3$. Both trona and sodium sesquicarbonate are reported to have more neutralizing capacity than $NaHCO_3$ (Chalupa and Schneider 1985).

Rumen-Mate^R, a manufactured mineral supplement with buffering capacity has its major reaction products as potassium chloride and bicarbonates of magnesium and sodium. In a study done with cows in mid-lactation Rumen-Mate^R increased milk fat test .46 percentage units when fed at the 1% level and .69 percentage units when fed at the 3% level (Staples and Lough 1985).

Milk fat % depression often occurs during hot weather (summer months). Cutting down forage intake during heat stress reduces the dietary potassium intake. Potassium content of milk is very high (0.15%) making K essential for milk production (Schneider et al. 1985). Potassium has been implicated as a positive addition to diet to reduce heat stress (West et al. 1987; Coppock et al. 1986).

Because K supplementation and buffering are needed during heat stress, it is logical to use a compound meeting both needs. Chemical composition of concentrate mixtures used in this study (Table 2) and dietary mineral intakes (Table 26) show higher K levels in Rumen-Mate^R and iso-nutrient product compared to control (basal) and $NaHCO_3$ supplemented diets. Thus like K_2CO_3, Rumen-Mate^R and iso-nutrient products furnish K and buffering capacity. Both RM and INP diets had higher Mg and Ca levels compared to control and SB diets. Sodium levels in RM and SB supplemented diets were similar.

This study shows DMI was significantly higher for cows fed SB and INP compared to control and RM groups. Some studies have shown that $NaHCO_3$ increases feed intake (Escobosa et al. 1984; Donker and Marx 1980; Erdman et al. 1980; Rodgers et al. 1985) when compared to unbuffered diets while others (Emery and Brown 1961; Eickelberger et al. 1985) observed that $NaHCO_3$ did not increase feed intake. Thomas et al. (1984) observed an increase in DMI and a gradual decrease in consumption when cows were fed 1.0% $NaHCO_3$ compared to MgO sources of varying particle sizes. They suggest that nature of diet, method of feeding, time on the diet, stage of lactation and dustiness of buffer may be important variables in determining effect of buffers on feed intake. However, cows supplemented with RM were more efficient in feed utilization compared to other groups. This is in contrast to findings of Eickelberger et al. (1985) who observed that buffers did not affect efficiency of milk production (kg FCM/kg DMI).

Uncorrected milk yield was significantly higher ($p<.05$) for cows on $NaHCO_3$ compared to other treatment groups. This agrees with studies done by Erdman et al. (1980); Erdman et al. (1982); Rodgers et al. (1985); and Donker and Marx (1980) while contrasting results of Arambel et al. (1988). English et al. (1983) found that weekly milk yield was not significantly affected by the addition of buffers when corn silage or hay crop silage plus corn silage were the sole forage sources. Cows receiving RM produced significantly more FCM ($p<.05$) compared to control cows and slightly more than cows fed SB and INP. Arambel et al. (1988) observed that 3.5% FCM was unaffected by buffers while West et al. (1986) observed a higher 3.5 % FCM for cows fed K_2CO_3 compared to those fed $NaHCO_3$. Older cows fed RM produced slightly more FCM compared to two, three and four year old cows.

Cows fed RM had higher fat % ($p<.01$) than the SB group. The control and INP group had higher fat % ($p<.05$) than the SB group. This agrees with results of Stokes et al. (1986); Erdman et al. (1980) who did not find any improvement in milk fat % when $NaHCO_3$ (and MgO) were added to the diet. Some studies have shown that buffers, especially $NaHCO_3$, improved milk fat % (Arambel et al. 1988; Emery and Brown 1961; Schneider et al. 1986; Rodgers et al. 1985; West et al. 1987). The effect of sodium (and potassium) bicarbonate on milk fat concentration may be attributed to its buffering action in the rumen (Edwards and Poole 1983).

Cows calving in winter months (January to April) tended to produce more milk with a slightly higher fat % while consuming the same amount of dry matter, but with improved feed efficiency than cows calving in summer months (May and June). This is supported by McDowell (1972) who indicated that heat stress reduced milk fat %. Other studies (Mallonee et al. 1985; Collier et al. 1981; Schneider et al. 1984) found no effect of hot environment on milk fat.

Cows on RM had higher ruminal acetate ($p<.05$) than the control group whereas ruminal acetate was intermediate for SB and INP groups. Ruminal propionate (%) was lower in RM compared to control and INP whereas, propionate % of SB and RM groups were similar. Some studies (Erdman et al. 1982; West et al. 1987; West et al. 1986; Kilmer et al. 1980) showed that buffers, especially $NaHCO_3$, increased ruminal acetate and decreased propionate % respectively while others (Boerner et al. 1987; Harrison et al. 1986) showed no effect of buffers on acetate. Total VFA was increased (Erdman et al. 1982); decreased (West et al. 1987); and unaffected by buffers (Boerner at al. 1987; Kilmer et al. 1986; DePeters et al 1984; West et al. 1986; Arambel et al 1988).

Acetate:Propionate ratio was higher for RM group compared to control. However, buffered diets tended to have similar A:P ratio. Some studies have shown that buffers, especially $NaHCO_3$, increased A:P ratio (Teh et al. 1985; Erdman et al. 1980; West et al. 1987). Kilmer et al. (1981) observed $NaHCO_3$ had lower A:P ratio compared to control while Stokes et al. (1986) observed lower A:P ratio for $NaHCO_3$ diet compared to other buffers. No effect of buffers on A:P ratio have also been reported (Eickelberger et al. 1985; Harrison et al. 1986).

Fecal pH was higher ($p<.05$) for cows fed RM compared to other groups. At week one postpartum (preliminary period), fecal pH was similar across treatments. It increased for RM and INP groups, decreased for SB and remained relatively constant for control group during the study. This disagrees with Kilmer et al. (1981) who observed that fecal pH did not differ between control and buffered diets or with time postpartum. Escobosa et al. (1984) observed a higher fecal pH when 2.28% $CaCl_2$ was fed compared to 1.7% $NaHCO_3$ and control (which contained 0.23% NaCl). Thomas et al. (1984) also observed an increase in fecal pH for Mg supplemented diets (MgO, $Mg(OH)_2$) compared to $NaHCO_3$ supplemented diets. Some studies have observed an increase in fecal pH by MgO, but not $NaHCO_3$ supplemented diets (Kilmer et al. 1980;

Erdman et al. 1980).

Urine pH was similar across treatments during the study. This agrees with Eickelberger et al. (1985) who observed no effect of buffers on urine pH when using an alfalfa hay based diet. Urine pH for alfalfa hay based diets is generally higher than that with corn silage based diets. Some studies (West et al. 1986; Rodgers et al. 1985; Kilmer et al. 1981) have observed an increase in urine pH when buffers were added to the diets.

Dietary Ca intake was higher in INP treatment than SB, but intermediate for control and RM while dietary P intake was highest for RM compared to other treatments. Dietary Mg was highest in RM, while dietary K was highest in INP. Both Mg and K dietary intakes were lowest in the SB and control groups. Sodium dietary intake was higher for SB and RM than INP and control.

Ruminal fluid Mg was increased significantly ($p<.05$) by INP supplementation. Thomas et al. (1984) observed a significant increase in ruminal fluid Mg by Mg supplementation (MgO and $Mg(OH)_2$) while control and cows fed $NaHCO_3$ had decreased ruminal fluid Mg. In this study control and cows fed SB and RM had an increase and then a decrease in ruminal fluid Mg. Blood plasma Mg tended to increase for SB and INP while it increased then decreased for RM and control. The increase in Mg in INP group might be due to the dietary Mg intake, if so a similar trend would be expected from RM treatment. Thomas et al. (1984) observed an increase in serum Mg concentrations when cows were fed diets supplemented with Mg sources. Escobosa et al. (1984) observed that differences in blood Mg were not significant. Urine Mg concentration tended to increase for all treatments and was highest for SB group. This is in contrast to work done by Thomas et al. (1984) who observed that feeding $NaHCO_3$ decreased Mg concentrations in the urine.

Ruminal fluid Ca concentration was lowest in RM group throughout the study, this may indicate an improved Ca absorption by cows receiving RM. Ruminal fluid Ca tended to increase over time in cows fed SB, INP and control diets. Plasma Ca concentrations tended to increase and then decrease for control and RM groups while it increased for SB and INP. Kilmer et al. (1981) observed higher serum Ca concentrations in cows fed $NaHCO_3$ (0.8%) than the control. They also noted a significant time effect on serum Ca by an initial decrease and then increase with time postpartum. Excess Ca from INP and RM could be lost through urine.

Ruminal fluid P concentration decreased in cows fed buffered rations while plasma P increased for all treatments. This may indicate improved P absorption by cows receiving buffers. Escobosa et al. (1984) observed lower blood P when 2.28% calcium chloride was added to the diet. No significant effect of time was observed on serum P when 0.6% and 0.7% $NaHCO_3$ was added to the diet pre and postpartum respectively (Kilmer et al. 1980). Urinary P increased for the control and SB groups, but tended to decrease for RM.

Ruminal fluid Na decreased with time for control, declined and then increased for SB and INP groups while it increased and then decreased for RM. Solubility of Na in the rumen appeared to be greater for $NaHCO_3$ (and INP) than the control and RM. Blood plasma Na increased and then remained constant for control, decreased and then remained constant for the SB group. It decreased for INP. RM had no effect on plasma Na. Studies have shown that buffers had no effect on blood Na (Erdman et al. 1982; Kilmer et al. 1980; Escobosa et al. 1984; Arambel et al. 1988). The decrease in plasma Na for SB treatment supports work done by Schneider et al. (1986) who observed that $NaHCO_3$ in the diet caused a slight depression in plasma Na concentrations when compared to diet without $NaHCO_3$. Serum Na was less for cows receiving buffered diets than for control (Thomas et al. 1984). Urinary Na decreased for INP and control groups while it increased and then decreased for the RM and SB groups. Thomas et al. (1984) observed that urinary excretion of Na was greatest for cows fed $NaHCO_3$.

Ruminal fluid K was not significantly different between treatments. There is a possibility of improved K absorption from rumen for all treatments. Urinary K increased for RM, INP and control groups. It was highest for the RM group at week 10 (although not significantly different from INP). It decreased and then increased for the SB group during study. Thomas et al. (1984) observed that cows fed $NaHCO_3$ had the least urinary K concentration.

Cows fed RM supplements had greater kidney filtration ratio (KFR) for Mg, Ca, K and Cl than other treatments. Thomas et al. (1984) observed that kidney filtration ratio of K was not significantly different among treatments though it was greatest for those fed Mg. This might explain why kidney filtration ratio for K was greatest for RM group, for Mg is one of its (RM) main ingredients. Phosphorus KFR was highest for SB group. This agrees with Thomas et al. (1984) who observed that cows fed $NaHCO_3$ had significantly greater phosphorus KFR than did cows fed control or Mg sources. Cows fed $NaHCO_3$ also had significantly greater kidney filtration ratio for Na than those fed control and Mg sources (Thomas et al. 1984).

SUMMARY AND CONCLUSION

Feeding Rumen-Mate^R to Holstein cows in early lactation resulted in significantly higher fat corrected milk (FCM) and milk fat percent than cows fed sodium-bicarbonate, iso-nutrient product and control. Sodium bicarbonate had a depressing effect on milk fat %, but increased uncorrected milk production. Fat corrected milk increased as dietary Mg (and K) increased.

RM did not affect dry matter intake relative to control, whereas $NaHCO_3$ and INP significantly increased DMI over control and RM treatments. This effect of $NaHCO_3$ and INP was observed across all ages of cows except three year old cows where DMI was similar across treatments. RM fed cows were more efficient in feed utilization. All cows irrespective of treatment were more efficient in feed utilization days 17 through 44 postpartum.

Feeding buffers increased uncorrected milk yield (kg/day). Milk yield increased as feed intake increased with highest DMI and milk yield observed from $NaHCO_3$ supplementation. This positive relationship was not observed by Thomas et al. (1984). Feeding buffers increased the mineral intake (K, Mg, Ca and Na) possibly influencing assimilation of nutrients and thus production responses

(Schneider et al. 1986). Potassium content of milk is higher than any other mineral, thus higher dietary K may enhance milk production. Cows fed buffers had consistantly lower somatic cell counts than control with RM group being significantly lower ($p<.01$) than control and INP and slightly lower than SB.

Cows on RM diet had higher ruminal acetate than control, there was no significant difference in acetate among buffered diets. Ruminal propionate was lower in RM fed cows comparatively. Acetate: Propionate ratio was higher for RM group compared to control while buffered diets tended to have similar A:P ratio. Fecal pH was higher for cows fed RM compared to other groups while buffers had no effect on urine pH which could have been due to enough neutral detergent fiber in the diet, since buffers have a positive effect on urine pH of fiber depressing diets (West et al. 1986; Rodgers et al. 1985).

Cows fed RM supplements had greater KFR for Mg, K, Ca and Cl than other treatments while KFR for P was highest for SB group.

Although INP furnishes K, Mg, etc. like RM, RM excelled in FCM production, feed efficiency and milk fat %) over INP.

This study suggests that Rumen-Mate[R] has some beneficial effects on dairy cows in early lactation relative to sodium bicarbonate and iso-nutrient product. Further, these beneficial effects are prevalent during both summer and winter months and across all ages of cows.

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Table 1. Ingredient Composition of Concentrate Mixtures

Ingredient (kg)	Concentrate Mixtures			
	C	RM	SB	INP
Cracked Corn	666.4	592.7	642.7	598.4
Soybean Meal (48%)	222.7	222.7	222.7	222.7
Monocalcium phosphate	5.7	5.7	5.7	5.7
Limestone	7.1	7.1	7.1	7.1
Magnesium Oxide	1.6	1.6	1.6	17.7
Trace Mineralized Salt	3.6	3.6	3.6	3.6
Vitamins ADE Premix	2.0	2.0	2.0	2.0
Rumen-Mate®	---	73.6	---	---
$NaHCO_3$	---	---	23.6	---
Trona	---	---	---	23.6
Dyna-K®	---	---	---	16.4
Dyna-mate®	---	---	---	11.8
TOTAL	909.1	909.1	909.1	909.1

Table 2. Chemical Composition of Concentrate Mixtures

	Concentrate Mixtures			
Ingredient	C	RM	SB	INP
Moisture (%)	13.0	12.61	12.97	12.43
Crude Protein (%)	17.83	15.23	16.83	17.79
Crude Fat (%)	2.43	2.98	2.58	2.41
Acid Detergent Fiber (%)	6.47	5.92	5.46	5.69
Total Digestible Nutrient (%)	75.06	74.68	75.45	74.83
Net Energy of lactation (kcal/kg)	.75	.74	,75	.74
Ash (%)	2.75	9.58	3.04	9.03
Calcium (%)	0.45	0.49	0.36	0.65
Phosphorus (%)	0.49	0.56	0.48	0.50
Potassium (%)	0.76	1.76	069	2.00
Magnesium (%)	0.28	1.46	0.23	0.82
Sodium (%)	0.86	1.29	1.23	1.11

TABLE 3. Chemical Composition of Corn Silage and Hay (DM Basis)

Nutrient	Corn Silage	Hay
Moisture (%)	61.97	13.47
Dry Matter (%)	38.04	86.54
Crude Protein (%)	6.48	16.04
Crude Fat (%)	1.95	2.11
Acid Detergent Fiber (%)	33.74	41.82
Total Digestible Nutrient (%)	64.59	54.29
Net Energy of Lactation (kcal/kg)	0.63	0.55
Ash (%)	5.29	6.50
Calcium (%)	0.31	1.40
Phosphorus (%)	0.20	0.18
Potassium (%)	1.07	2.43
Magnesium (%)	0.15	0.20
Sodium (%)	0.03	0.08

TABLE 4. Treatment Effects on Dry Matter Intake, Milk Production and Milk Composition[1]

Variable	Treatments[2] C	RM	SB	INP
Dry Matter Intake (kg/day)	20.5[a]	20.2[a]	21.3[b]	21.2[b]
Milk Production (kg/day)	31.7[a]	32.5[a]	34.5[b]	32.5[a]
Fat Corrected Milk (kg/day)	28.5[a]	30.5[b]	29.4[ab]	29.4[ab]
Feed Efficiency (kg feed/kg milk)	.72[a]	.68[b]	.72[a]	.74[a]
Fat Percentage (%)	3.36[a]	3.43[a]	3.13[b]	3.35[a]
Protein Percentage (%)	2.89	2.85	2.85	2.82
Solid not fat (%)	8.5	8.4	8.5	8.4
Somatic cell count (x 1000)	400[a]	101[c]	150[bc]	287[ab]

[1]Means within a row with different superscripts are significantly different (P< .05)
[2]C = Control
RM = Rumen-Mate®
SB = Sodium bicarbonate
INP= Magnesium oxide + Trona + Dyna-K® + Dyna Mate®

TABLE 5. Treatment Effect on Fecal pH, Urine pH and Ruminal Volatile Fatty Acid[1]

Variable[2]	Treatments			
	C	RM	SB	INP
Fecal pH	6.1[a]	6.4[b]	6.1[a]	6.2[a]
Urine pH	7.9	8.0	7.9	7.9
Volatile fatty acids (M%)				
Acetate	61.6[a]	64.7[b]	63.6[ab]	62.7[ab]
Propionate[3]	22.1[a]	19.8[b]	21.4[ab]	22.4[a]
Isobutyrate	1.2	1.2	1.2	1.3
Butyrate	11.8[a]	11.3[ab]	10.8[b]	10.5[b]
Isovalerate	1.8	1.7	1.7	1.7
Valerate	1.6[a]	1.3[b]	1.4[b]	1.5[ab]
Acetate:Propionate ratio	3.0[a]	3.4[b]	3.1[ab]	3.1[ab]

[1]Least square means
[2]Means within a row with differnt superscripts differ (P<.05) level
[3]Means within a row with different superscripts differ (P<.07) level

Table 6. Least Square Means Dry Matter Intake, Milk Yield and Milk Composition of Holstein Cows at Different Periods[1]

Variable	Period[2]				
	1	2	3	4	5[2]
Dry Matter Intake (kg/day)	20.3[a]	20.8[b]	21.0[b]	21.0[b]	21.0[b]
Milk production (kg/day)	32.7[a]	34.0[b]	33.0[a]	32.3[a]	32.0[a]
Fat Corrected Milk (kg/day)	30.1[a]	30.7[a]	29.9[a]	28.5[b]	28.1[b]
Feed efficiency	.69[a]	.69[a]	.72[ab]	.74[b]	.74[b]
Fat percentage (%)	3.46[a]	3.37[a]	3.36[ac]	3.19[b]	3.22[bc]
Protein percentage (%)	2.91[a]	2.84[b]	2.82[b]	2.83[b]	2.87[b]
Solid not fat (%)	8.5	8.4	8.4	8.4	8.5
Somatic cell count (x 1000)	276.1	189.6	166.8	293.2	246.7

[1]Means within a row with different superscripts differ ($P < .05$)

[2]pd1 = d17-30, pd2 = d31-44, pd3 = 45-58 pd4 = d59-72, pd5 = d73-86

TABLE 7. Dry Matter Consumed by Treatment and Age of Cow

Age group (yr)	Treatment				
	C	RM	SB	INP	$\bar{X}$
Two	20.9^{adc}	19.8^{g}	21.5^{cef}	21.5^{adef}	20.6^{a}
Three	21.3^{bce}	21.8^{bc}	21.5^{cef}	21.5^{bce}	21.4^{b}
Four and Five	20.0^{cef}	20.1^{dg}	21.3^{adfg}	21.3^{bce}	21.0^{a}
Older	19.9^{adg}	19.1^{adg}	20.4^{e}	20.4^{bcef}	20.4^{a}
	20.5^{a}	20.2^{a}	21.2^{b}	21.2^{b}	

^{abcdefg}Means with different superscripts are different (P<.05)

TABLE 8. Least Square Means Dry Matter Intake (kg/day) of Holstein Cows Fed Different Buffers

Month of Freshening	Treatment			
	C	RM	SB	INP
January	20.1	21.1	21.8	20.9
February	21.0^{a}	20.9^{a}	21.9^{ab}	23.1^{b}
March	20.0^{a}	19.7^{a}	21.6^{b}	21.4^{a}
April	20.0^{a}	20.6^{a}	21.7^{b}	20.5^{a}
May	21.5^{ab}	20.7^{b}	21.8^{b}	20.4^{a}
June	20.7^{a}	18.4^{b}	19.8^{a}	20.8^{a}

[1]Means within a row with different superscripts are significantly different (P<.05)

TABLE 9. Least Square Means Feed Efficiency (kg feed/kg milk) of Holstein Cows Fed Different Buffers[1]

Month of Freshening	Treatment			
	C	RM	SB	INP
January	.63[a]	.72[b]	.72[b]	.72[b]
February	.66[a]	.65[a]	.68[a]	.72[a]
March	.64[a]	.65[ab]	.64[a]	.73[b]
April	.71[ab]	.66[b]	.73[a]	.73[ab]
May	.86[a]	.75[a]	.81[a]	.75[a]
June	.83[a]	.69[b]	.75[ab]	.78[ab]

[1]Means within a row with different superscript are significantly different (P<.05)

TABLE 10. Least Square Means Fat Corrected Milk (kg/day) of Holstein Cows Fed Different Buffers[1]

Month of Freshening	Treatment			
	C	RM	SB	INP
January	33.2[a]	30.4[b]	31.0[a]	29.3[b]
February	26.5[a]	31.7[b]	30.4[b]	30.7[b]
March	29.9	32.2	32.2	30.3
April	26.6[a]	31.6[a]	31.0[bc]	28.5[ab]
May	27.7[a]	26.1[a]	26.1[a]	29.4[b]
June	27.5[a]	31.1[b]	25.4[a]	28.5[ab]

[1]Means within a row with different superscript are significantly different (P<.05)

TABLE 11. Milk Production by Treatment and Age of Cow

Age group (yr)	C	RM	SB	INP	$\bar{X}$
Two	30.5^{fg}	30.0^{fg}	28.9^{gh}	26.2^{h}	28.9
Three	30.8^{fg}	29.4^{gh}	32.4^{ef}	34.5^{bcd}	31.8
Four and Five	37.1^{cde}	33.5^{de}	38.9^{a}	32.8^{def}	35.6
Older	31.8^{efg}	36.9^{ab}	37.5^{a}	36.7^{abc}	35.7
$\bar{X}$	32.6	32.5	34.4	32.6	

^{abcdefg}Means with different superscripts are different (P<.05)

TABLE 12. Least Square Means Milk Production (kg/day) of Holstein Cows Fed Different Buffers[1]

Month of Freshening	Treatment			
	C	RM	SB	INP
January	32.8	32.7	34.7	34.3
February	29.0[a]	32.8[a]	37.1[b]	32.6[a]
March	30.9[a]	32.9[a]	37.1[b]	32.4[a]
April	35.0[ab]	34.2[b]	36.6[a]	37.6[a]
May	30.2[ab]	29.0[b]	31.7[a]	29.5[ab]
June	32.5[a]	33.7[a]	29.4[b]	29.0[b]

[1]Means within a row with different superscript are significantly different ($P<.05$)

TABLE 13. Milk Fat Percent by Treatment and Age of Cow.

Age Group	Treatment				
	C	RM	SB	INP	$\overline{X}$
Two	3.04^{cd}	3.45^{abc}	3.39^{abcd}	3.73^{a}	3.45
Three	3.60^{a}	3.51^{ab}	3.10^{cd}	2.94^{d}	3.29
Four and Five	3.32^{abc}	3.46^{abc}	2.90^{d}	3.41^{abcd}	3.27
Older	3.49^{abc}	3.32^{abc}	3.14^{bcd}	3.32^{abcd}	3.32
$\overline{X}$	3.36	3.44	3.13	3.35	

^{abcdef}Means with different superscripts are different ($P<.05$)

TABLE 14. Least Square Means Milk Fat (%) of Holstein Cows Fed Different Buffers[1]

Month of Freshening	Treatment			
	C	RM	SB	INP
January	3.89^{a}	3.61^{ab}	3.32^{b}	3.37^{b}
February	3.71^{a}	3.71^{a}	3.23^{b}	3.63^{a}
March	3.86^{a}	3.36^{b}	3.26^{b}	3.37^{b}
April	2.68^{a}	3.35^{c}	3.00^{b}	2.47^{a}
May	3.25^{a}	3.59^{b}	2.85^{b}	3.87^{a}
June	2.77^{a}	3.00^{a}	3.13^{a}	3.58^{b}

[1]Means within a row with different superscripts are significantly different (P<.05)

TABLE 15. Treatment and Age of Cow effects on Fat Corrected Milk Production.

Age Group (yr)	Treatments C	RM	SB	INP	$\bar{X}$
TWO	25.5^{e}	27.3^{de}	25.1^{e}	26.8^{de}	26.2
THREE	29.5^{cd}	27.5^{de}	28.3^{cde}	28.5^{cde}	28.5
4 & 5	30.7^{bc}	30.7^{bc}	32.4^{bc}	29.3^{cd}	30.8
OLDER	28.6^{cde}	36.6^{e}	31.5^{bc}	33.6^{ac}	32.5
$\bar{X}$	28.5	30.5	29.3	29.5	

[abcdef]Means with different superscripts are different ($P<.05$).

TABLE 16. Least Square Means Milk Protein (%) of Holstein Cows Fed Different Buffers[1]

	Treatment			
Month of Freshening	C	RM	SB	INP
January	2.99	2.82	2.91	3.13
February	3.20	2.91	2.93	2.53
March	3.09[a]	2.99[ab]	2.96[ab]	2.83[b]
April	2.72	2.85	2.81	2.88
May	2.66	2.81	2.79	2.80
June	2.71	2.69	2.72	2.77

[1]Means within a row with different superscripts are significantly different ($P < .05$)

TABLE 17. Treatment and Age of Cow effcts on Milk Protein Percent.

Age Group (yr)	Treatments				$\bar{X}$
	C	RM	SB	INP	
TWO	2.86^{bcd}	2.99^{ab}	2.95^{abc}	2.77^{cde}	2.89
THREE	2.93^{abcd}	2.87^{abcd}	2.83^{cde}	3.06^{a}	2.92
4 & 5	2.86^{bcd}	2.65^{e}	2.83^{cde}	2.65^{de}	2.75
OLDER	2.94^{abcd}	2.88^{abcd}	2.81^{cde}	2.77^{cde}	2.85
$\bar{X}$	2.90	2.84	2.86	2.81	

[abcdef] Means with different superscripts are different (P<.05)

TABLE 18. Least Square Means Somatic Cell Count (x 1000) in Milk from Holstein Cows Fed Different Buffers[1]

Month of Freshening	Treatment			
	C	RM	SB	INP
January	311	265	159	328
February	310	214	82	220
March	410	-49	68	141
April	450[a]	85[bc]	63[bc]	409[ac]
May	327[abc]	353[ab]	-121[c]	232[abc]
June	590[a]	-260[b]	648[a]	389[ab]

[1]Mean within a row with different superscripts are significantly different (P<.05)

TABLE 19. Least Square Means Solid Not Fat (%) in milk from Holstein Cows Fed Different Buffers[1]

Period[2]	Treatment			
	C	RM	SB	INP
1	8.4	8.4	8.6	8.5
2	8.3	8.4	8.4	8.4
3	8.4	8.4	8.5	8.5
4	8.5	8.4	8.4	8.4
5	8.5	8.5	8.6	8.5

[1]There were no significant differences between treatment means in a row (P>.05)

[2]pdl = d17-30, pd2 = d31-44, pd3 = 45-58, pd4 = 59-72, pd5 = d73-86

TABLE 20. Least Square Means Fecal pH of Holstein Cows Fed Different Buffers

Weeks postpartum	Treatment			
	C	RM	SB	INP
1	6.15	6.16	5.99	6.10
5	6.09[a]	6.45[b]	6.32[ab]	6.22[ab1]
10	6.09[x]	6.55[y]	6.14[x]	6.30[xy2]

[1]Means within a row with different superscripts differ ($P<.05$)

[2]Means within a row with different superscripts differ ($P<.03$)

TABLE 21. Least Square Means Urine pH of Holstein Cows Fed Different Buffers[1]

Weeks postpartum	Treatment			
	C	RM	SB	INP
1	7.96	7.98	7.94	7.99
5	7.80	7.96	7.93	7.96
10	7.95	8.03	7.86	7.87

[1]There were no significant differences between treatment means in a row (P>.05)

TABLE 22. Least Square Means Ruminal Acetate (M%) of Holstein Cows Fed Different Buffers

Weeks postpartum	Treatment			
	C	RM	SB	INP
1	63.9[a]	64.7[a]	66.4[a]	63.1[a]
5	59.6[b]	63.8[a]	62.4[ab]	61.1[ab1]
10	61.4[a]	65.7[b]	62.1[ab]	63.8[ab2]

[1]Means at week 5 are significantly different (P<.05)
[2]Means at week 10 are significantly different (P<.07)

TABLE 23. Least Square Means Ruminal Propionate (M%) of Holstein Cows Fed Different Buffers[1]

Weeks postpartum	Treatment			
	C	RM	SB	INP
1	19.1	19.6	18.7	22.0
5	23.8[a]	20.1[b]	22.5[ab]	23.2[ab]
10	22.8	19.7	22.8	21.9

[1]Means within a row with different superscripts are significantly different ($P<.05$)

TABLE 24. Least Square Means Ruminal Acetate:Propionate ratio of Holstein Cows Fed Different Buffers[1]

Weeks Postpartum	Treatment			
	C	RM	SB	INP
1	3.3	3.4	3.6	3.2
5	2.8	3.3	2.9	2.9
10	3.0	3.4	2.9	3.2

[1]There were no significant differences between treatment means in a row (P>.05)

TABLE 25. Treatment Effects on Mineral Profile of Cows

Item	Diet designation (treatment)[1]			
	Control	RM	SB	INP
Creatinine Plasma (ppm)	1.00	1.05	1.04	0.99
Urine (ppm)	61	58	69	65
Magnesium Ruminal (ppm)	151	167	157	167
Plasma (ppm)	40	39	40	36
Urine (ppm)	203	269	421	226
Calcium Ruminal (ppm)	344	335	354	330
Plasma (ppm)	112	112	114	109.3
Urine (ppm)	7.1[a]	16.3[b]	10.5[ab]	6.4[a]
Phosphorus Ruminal (ppm)	598	519	592	611
Plasma (ppm)	168	174	186	178
Urine (ppm)	200[a]	92[b]	271[a]	288[a]
Potassium Ruminal (ppm)	1080	1095	1126	1167
Plasma (ppm)	484	468	533	528
Urine (ppm)	6282[a]	7703[b]	7037a[b]	7023[ab]
Chlorine Ruminal (ppm)	550[ab]	508[a]	578[ab]	617[b]
Plasma (ppm)	4029	3362	3426	3408
Urine (ppm)	726[a]	1024[b]	850[ab]	709[a]
Sodium Ruminal (ppm)	2280	2079	2221	2303
Plasma (ppm)	2959[ab]	2931[a]	3078[a]	3007[ab]
Urine (ppm)	1564	1713	1352	1541
Kidney filtration ratio (KFR)[4]				
Mg[3]	17.6[a]	45.5[b]	12.6[a]	14.2[a]
Ca	.2[a]	.6[b]	.2[a]	.1[a]
P	4.6	2.2	5.7	5.1
Na	1.9	3.3	1.1	1.3
K[2]	42.9[a]	91.2[b]	33.8[a]	32.5[a]
CL[2]	.7[a]	1.9[b]	.7[a]	.6[a]

[1] C = control; RM = Rumen mate®; SB = Sodium bicarbonate; INP = Magnesium oxide, trona, Dyna-K® and Dynamate®

[2] Significant at P < .09

[3] Significant at P < 0.07

[4] Kidney Filtration Ratio = (Urine element/serum element)x(serum creatinine/urine creatinine)

TABLE 26. Estimated Mineral Intake (grams) of Holstein Cows Fed Different Diets.

Mineral	Treatment (Diet)			
	C	RM	SB	INP
Calcium	126	129	116	155
Phosphorus	75	83	74	77
Magnesium	49	191	44	119
Sodium	110	161	162	146
Potassium	237	355	225	384

TABLE 27. Treatment Effects on the Mineral Profile of Holstein Cows in Early Lactation

Mineral	Treatment (diet)[1]			
	C	RM	SB	INP
Calcium				
Intake (g)[2]	126	129	116	155
Rumen (ppm)	344	335	354	330
Plasma (ppm)	112	112	114	109
Urine[3] (ppm)	7.1^{a}	16.3^{b}	10.5^{ab}	6.4^{a}
KFR[6]	.2^{a}	.6^{b}	.2^{a}	.1^{a}
Phosphorus				
Intake (g)	75	83	74	77
Rumen (ppm)	598	519	592	611
Plasma (ppm)	168	174	186	178
Urine (ppm)	200^{a}	92^{b}	271^{a}	288^{a}
KFR	4.6	2.2	5.7	5.1
Sodium				
Intake (g)	110	161	162	146
Rumen (ppm)	2280	2079	2221	2303
Plasma (ppm)	2958^{ab}	2931^{a}	3078^{b}	3007^{ab}
Urine[3] (ppm)	1564	1713	1352	1544
KFR[4]	1.9	3.3	1.1	1.3
Magnesium				
Intake (g)	49	191	44	119
Rumen (ppm)	151	167	157	167
Plasma (ppm)	40	39	39	36
Urine (ppm)	203^{a}	269^{ab}	421^{b}	226^{a}
KFR	17.6	45.5^{b}	12.6^{a}	14.2^{a}
Potassium				
Intake (g)	237	355	225	384
Rumen (ppm)	1080	1095	1126	1167
Plasma (ppm)	484	468	533	528
Urine (ppm)	6282^{a}	7703^{b}	7037^{ab}	7023^{ab}
KFR	42.9^{a}	91.2^{b}	33.8^{a}	32.5^{a}
Chlorine				
Rumen (ppm)	550^{ab}	508^{a}	578^{ab}	617^{b}
Plasma (ppm)	4029	3362	3426	3408
Urine[3] (ppm)	726^{a}	1024^{b}	850^{ab}	709^{a}
KFR[5]	.7^{a}	1.9^{b}	.7^{a}	.6^{a}

[1]C = Control; RM = Rumen-Mate®; SB = Sodium Bicarbonate; INP = Magnesium Oxide, Trona, DYNA-K® and Dynamate®

[2]Estimated intake based on content in feedstuffs and average DM intake of cows within treatment groups.

[3]Means within a row are significantly different (P < .05)

[4]Significant at (P < .09)

[5]Significant at (P < .07)

[6]KFR=Kidney Filtration Ratio=(urine element/serum element)x(serum creatinine/urine creatinine)

Figure 1. Relationship Between Dry Matter Intake and Milk Production

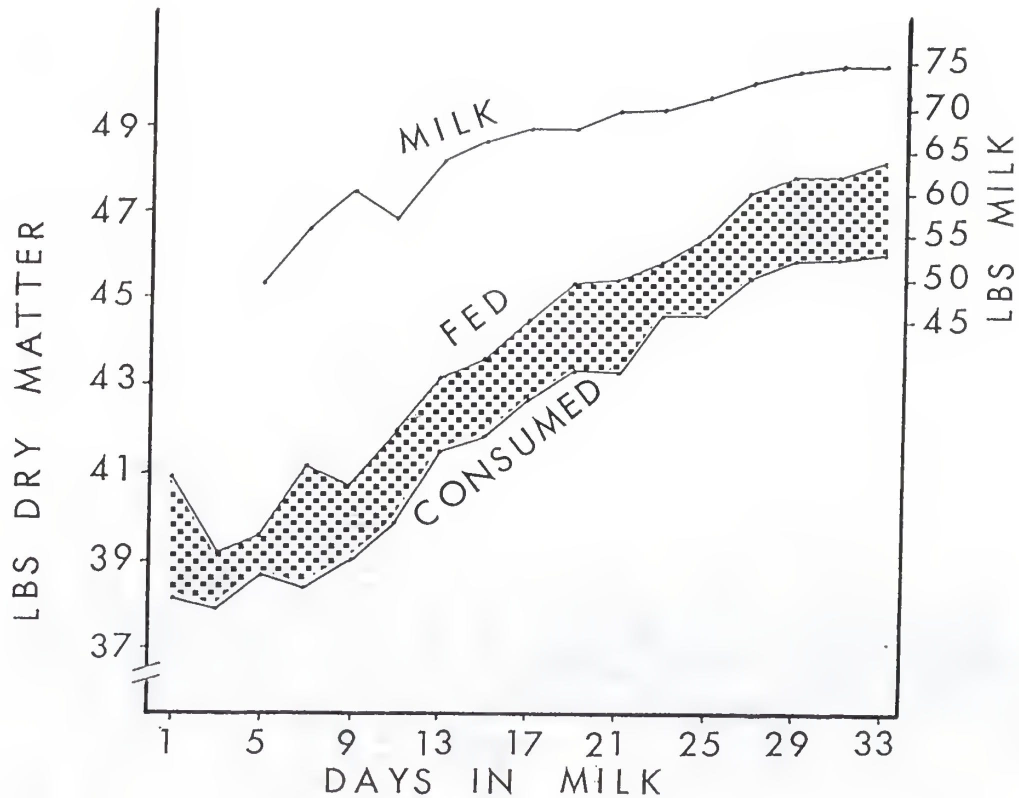
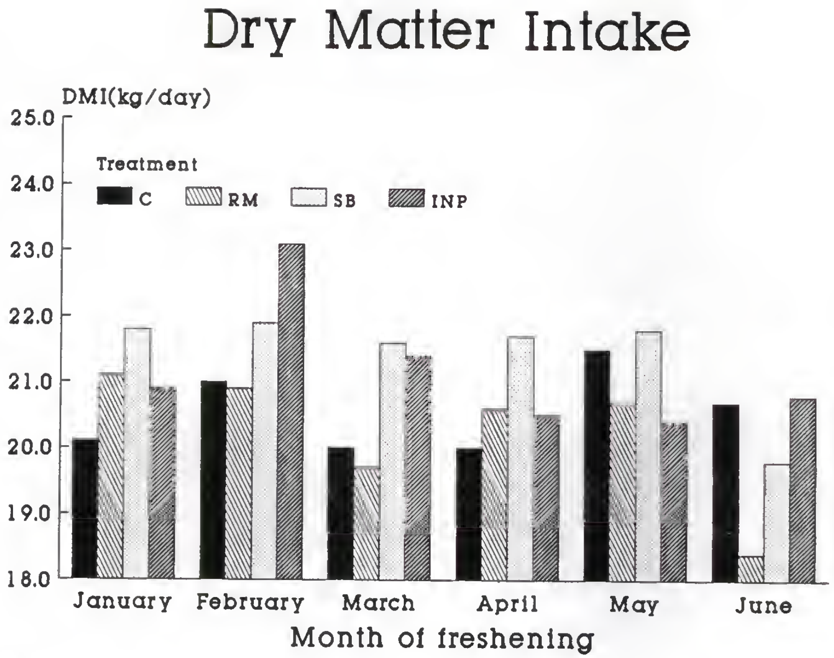

MILK
FED
CONSUMED
LBS DRY MATTER
49
47
45
43
41
39
37
75
70
65
60
55
50
45
LBS MILK
1
5
9
13
17
21
25
29
33
DAYS IN MILK

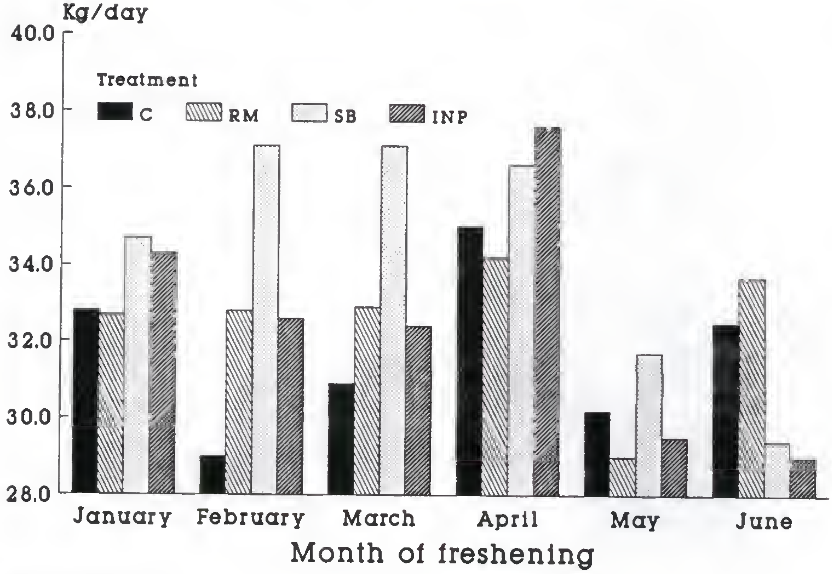
Figure 2. Dry Matter Intake (kg/day)



Least Square Means

Figure 3. Milk Production (kg/day)

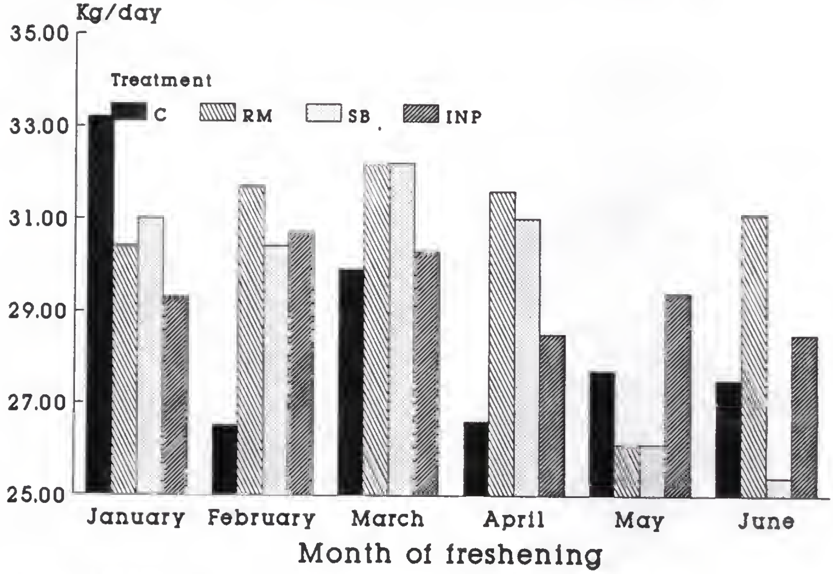
Milk Production



Least Square Means

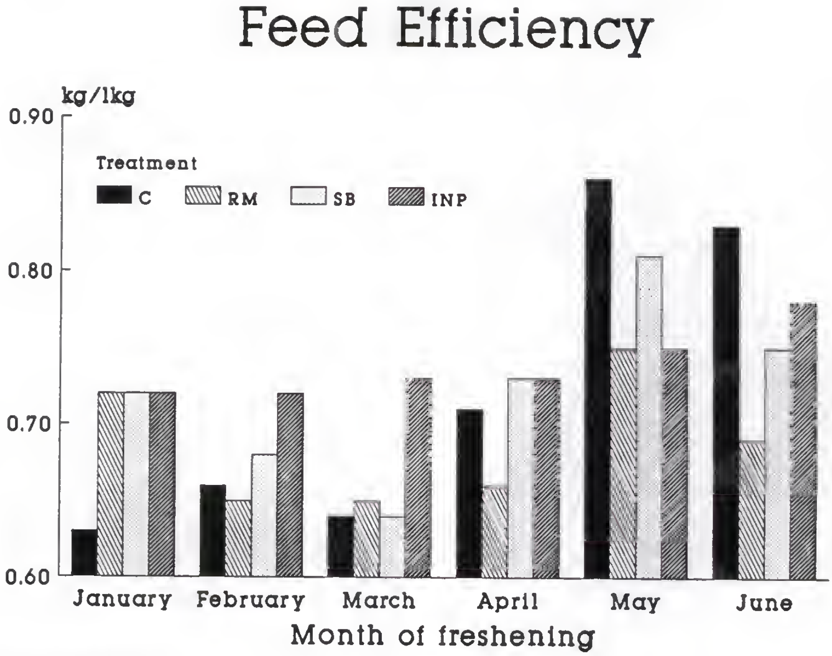
Figure 4. Fat Corrected Milk (kg/day)

Fat Corrected Milk



Least Square Means

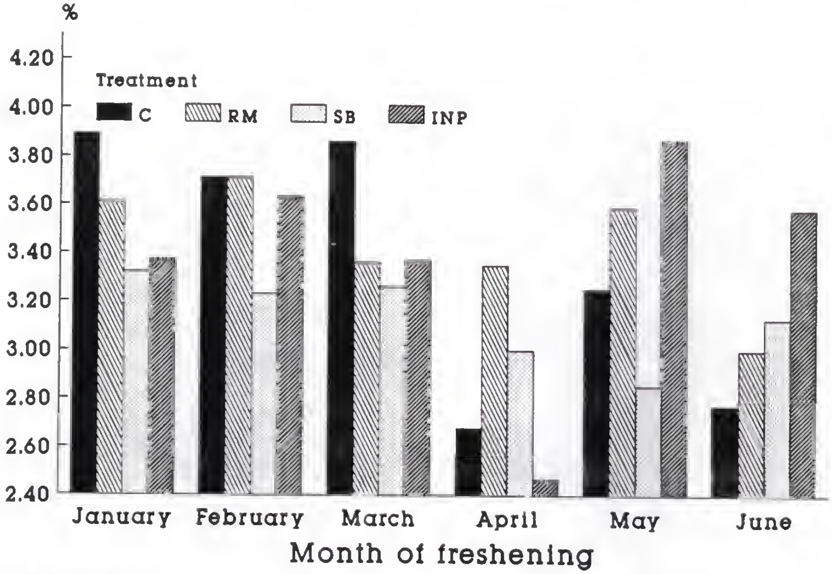
Figure 5. Feed Efficiency (kg feed/1 kg milk)



Least Square Means

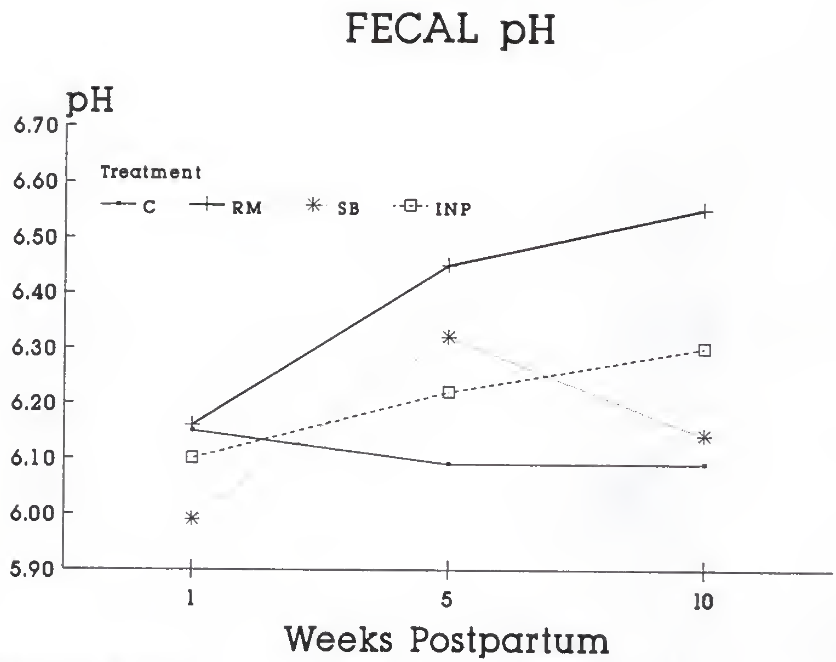
Figure 6. Milk Fat Percentage (%)

Milk Fat Percentage



Least Square Means

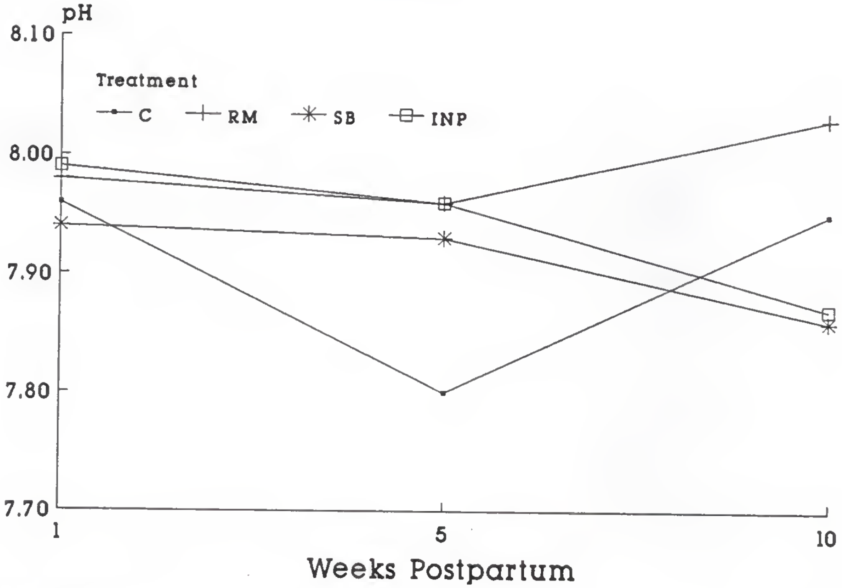
Figure 7. Fecal pH



Least Square Means

Figure 8. Urine pH

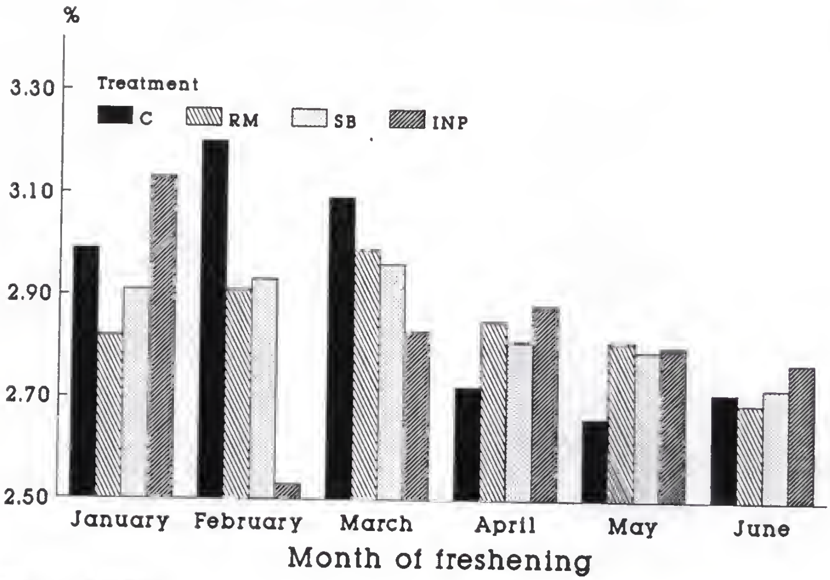
URINE pH



Least Square Means

Figure 9. Milk Protein Percentage (%)

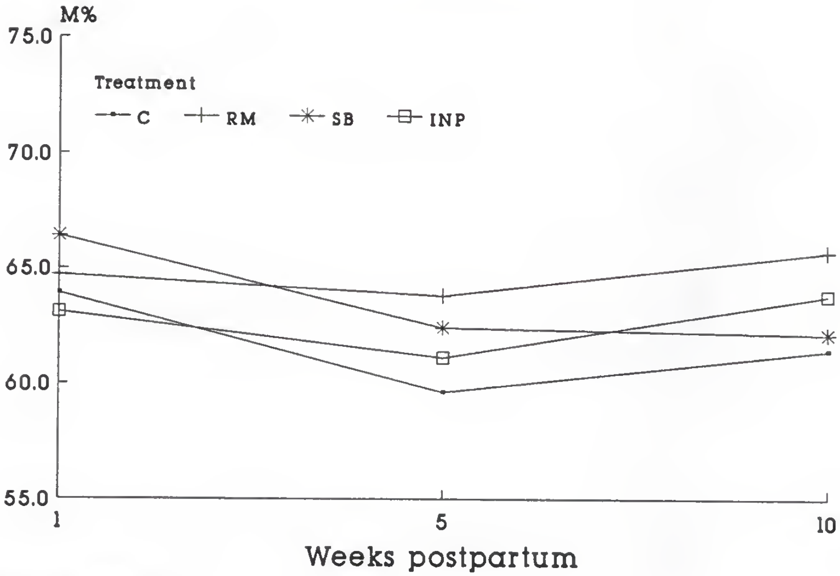
Protein Percentage



Least Square Means

Figure 10. Acetate (M%)

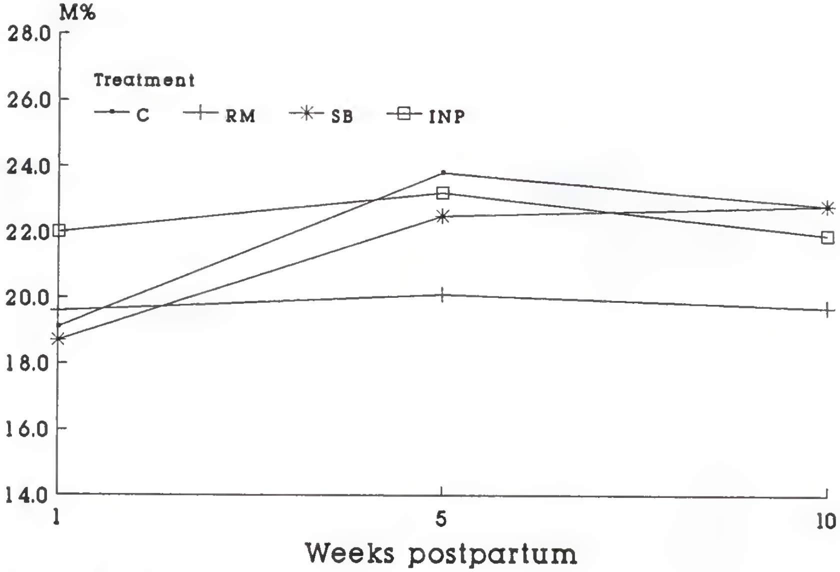
Acetate



Least Square Means

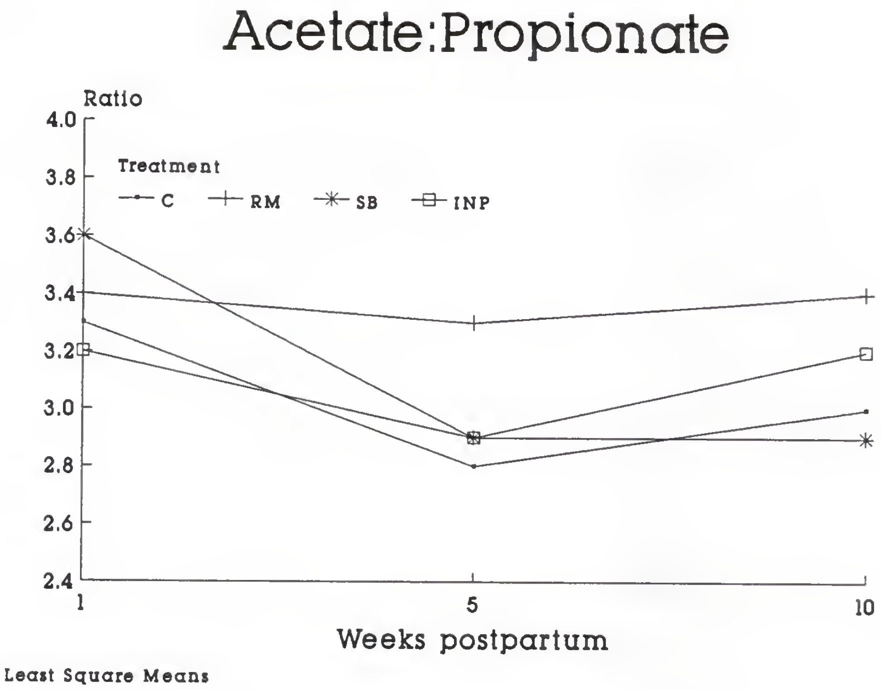
Figure 11. Propionate (M%)

Propionate



Least Square Means

Figure 12. Acetate:Propionate Ratio



Acetate:Propionate
Ratio
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
Treatment
C
RM
SB
INP
1
5
10
Weeks postpartum
Least Square Means

APPENDIX

APPENDIX TABLE I Least Square Means Various Minerals (ppm) in Urine of Holstein Cows Fed Different Buffers[1]

Mineral	Treatment C	RM	SB	INP
Sodium	1564 ± 137	1713 ± 144	1352 ± 138	1544 ± 133
Potassium	6282 ± 457[a]	7703 ± 481[b]	7037 ± 462[ab]	7023 ± 443[ab]
Calcium	7.1 ± 3.0[a]	16.3 ± 3.2[b]	10.5 ± 3.0[ab]	6.4 ± 2.9[a]
Phosphorus	200 ± 34[a]	92 ± 35[b]	271 ± 34[a]	288 ± 69[a]
Magnesium	203 ± 72[a]	269 ± 75[ab]	421 ± 72[b]	226 ± 69[a]
Chlorine	726 ± 86	1024 ± 90	850 ± 88	709 ± 84
Creatinine	61 ± 7	58 ± 8	69 ± 7	65 ± 7

[1]Means within a row with different superscript differ ($P < .05$)

APPENDIX TABLE II Least Square Means of Various Minerals (ppm) in Ruminal fluid of Holstein Cows Fed Different Buffers[1]

Mineral	Treatment C	RM	SB	INP
Sodium	2280 $\pm$ 86	2079 $\pm$ 88	2221 $\pm$ 87	2303 $\pm$ 88
Potassium	1080 $\pm$ 48	1091 $\pm$ 49	1126 $\pm$ 48	1167 $\pm$ 49
Calcium	344 $\pm$ 16	335 $\pm$ 16	354 $\pm$ 16	330 $\pm$ 16
Magnesium	151 $\pm$ 8	167 $\pm$ 8	157 $\pm$ 8	167 $\pm$ 8
Phosphorus	598 $\pm$ 46	519 $\pm$ 46	592 $\pm$ 46	611 $\pm$ 47
Chlorine	550 $\pm$ 37[ab]	508 $\pm$ 38[a]	578 $\pm$ 38[ab]	617 $\pm$ 38[b]

[1]Means within a row with different superscripts differ ($P<.05$)

APPENDIX TABLE III Least Square Means Various Minerals (ppm) in Blood Plasma of Holstein Cows Fed Different Buffers[1]

Mineral (ppm)	Treatments			
	C	RM	SB	INP
Sodium	2959 ± 47[ab]	2931 ± 48[a]	3078 ± 47[b]	3007 ± 46[ab]
Potassium	484 ± 48	468 ± 50	533 ± 48	528 ± 47
Calcium	112 ± 3	112 ± 3	114 ± 3	109 ± 3
Magnesium	40 ± 3	39 ± 3	39 ± 3	36 ± 3
Phosphorus	168 ± 8	174 ± 9	186 ± 9	178 ± 8
Chlorine	4029 ± 347	3362 ± 358	3426 ± 346	3408 ± 339
Creatine	1.00 ± 0.05	1.05 ± 0.05	1.04 ± 0.05	0.99 ± 0.05

[1]Means within a row with different superscripts differ ($P < .05$).

APPENDIX TABLE IV Least Square Means Creatine (ppm) in Urine at Different Weeks Postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	83.8 $\pm$ 13.3	37.2 $\pm$ 14.0	61.8 $\pm$ 11.2
RM	63.3 $\pm$ 12.1	46.3 $\pm$ 13.3	64.3 $\pm$ 10.8
SB	89.3 $\pm$ 12.1	54.1 $\pm$ 12.1	63.4 $\pm$ 12.6
INP	75.1 $\pm$ 11.2	136.8 $\pm$ 11.6	83.2 $\pm$ 11.2

[1]There were no significant differences between treatment means of (P>.05)

APPENDIX TABLE V Least Square Means Creatine (ppm) in Blood Plasma at Different Weeks Postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	0.97	0.96	1.07
RM	0.95	1.12	1.07
SB	0.97	1.04	1.11
INP	1.07	0.87	1.04

[1]There were no significant differences between treatment means (P>.05)

APPENDIX TABLE VI Least Square Means Sodium (ppm) in blood plasma at different Weeks Postpartum[1]

Treatment	Weeks Postpartum 1	5	10
C	2878 ± 73	2996 ± 78	3002 ± 91
RM	2922 ± 76	2953 ± 84	2919 ± 91
SB	3118 ± 78	3030 ± 81	3086 ± 84
INP	3084 ± 54	3055 ± 81	2888 ± 90

[1]There were no significant differences between treatment means ($P > .05$)

APPENDIX TABLE VII Least Square Means Potassium (ppm) in Blood Plasma at Different Weeks Postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	344 ± 76	424 ± 81	686 ± 94
RM	259 ± 78	479 ± 86	666 ± 94
SB	432 ± 81	496 ± 83	673 ± 86
INP	401 ± 76	594 ± 93	606 ± 86

[1]There were no significant differences between treatment means (P >.05)

APPENDIX TABLE VIII Least Square Means Sodium (ppm) in Urine at different Weeks Postpartum

Treatment	Weeks Postpartum 1	5	10
C	1975 ± 247	1676 ± 275	1041 ± 231
RM	1614 ± 267	2193 ± 297	1333 ± 231
SB	1322 ± 239	1687 ± 231	1048 ± 247
INP	1851 ± 218	1462 ± 239	1318 ± 231

[1]There were no significant differences between treatment means (P >.05)

APPENDIX TABLE IX Least Square Means Potassium (ppm) in Urine at Different Weeks Postpartum

Treatment	Weeks postpartum		
	1	5	10
C	6075 ± 827	6327 ± 815	6444 ± 773[a]
RM	6060 ± 893	7990 ± 975	9058 ± 773[b]
SB	7584 ± 779	6663 ± 773	6863 ± 827[a]
INP	6781 ± 729	6831 ± 799	7456 ± 934[ab]

[1]Means within a column with different superscripts differ (P <.05)

APPENDIX TABLE X Least Square Means Sodium (ppm) in Ruminal Fluid at Different Weeks Postpartum[1]

	Weeks postpartum		
Treatment	1	5	10
C	2451 ± 145	2207 ± 145	2183 ± 159
RM	2095 ± 154	2197 ± 149	1947 ± 154
SB	2343 ± 149	2069 ± 149	2250 ± 154
INP	2500 ± 145	2104 ± 154	2307 ± 159

[1]There were no significant differences between treatment means (P>.05)

APPENDIX TABLE XI Least Square Means Potassium (ppm) in Ruminal Fluid at Different Weeks Postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	1112 ± 81	1095 ± 80	1032 ± 86
RM	991 ± 86	1148 ± 82	1146 ± 86
SB	1073 ± 83	1104 ± 83	1200 ± 86
INP	1095 ± 80	1164 ± 86	1241 ± 89

[1]There were no significant differences between treatment means (P>.05)

APPENDIX TABLE XII Least Squares Means Calcium (ppm) in Ruminal Fluid at Different Weeks Postpartum[1]

Treatment	Weeks postpartum		
	1	5	10
C	280 ± 26	356 ± 26	385 ± 29[a]
RM	319 ± 28	374 ± 27	310 ± 28[b]
SB	255 ± 27	401 ± 27	404 ± 28[a]
INP	254 ± 26	345 ± 28	392 ± 29[a]

[1]Means within a column with different superscripts are significantly different ($P<.07$)

APPENDIX TABLE XIII Least Square Means Magnesium (ppm) in Ruminal Fluid at Different Weeks Postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	131 ± 13	164 ± 13	159 ± 14
RM	153 ± 13	188 ± 13	161 ± 13
SB	124 ± 13	175 ± 13	172 ± 13
INP	127 ± 13	180 ± 13	192 ± 14

[1]There were no significant difference between treatment means (P>.05)

APPENDIX TABLE XIV Least Square Means Calcium (ppm) in Urine at Different Weeks Postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	8.5 ± 5.5	6.8 ± 5.1	6.0 ± 5.1[a]
RM	20.9 ± 5.9	6.1 ± 5.5	21.9 ± 5.1[b]
SB	16.4 ± 5.3	9.0 ± 5.1	6.1 ± 5.5[a]
INP	5.6 ± 4.8	5.9 ± 5.2	7.8 ± 5.1[a]

[1]Means within a column with different superscripts are significantly different ($P<.05$)

APPENDIX TABLE XV Least Square Means Magnesium (ppm) in Urine at Different Weeks Postpartum

Treatment	Weeks postpartum		
	1	5	10
C	145 ± 128	203 ± 121	260 ± 121[a]
RM	177 ± 139	277 ± 129	354 ± 121[a]
SB	220 ± 124	261 ± 121	782 ± 129[b]
INP	176 ± 114	221 ± 124	278 ± 121[a]

[1]Means within a column with different superscripts are significantly different (P<.05)

APPENDIX TABLE XVI Least Square Means Calcium (ppm) in Blood Plasma at Different Weeks postpartum[1]

Treatment	Weeks postpartum 1	5	10
C	96.6 ± 5.1	122.1 ± 5.4	118.9 ± 6.3
RM	105.6 ± 5.2	117.3 ± 5.8	112.5 ± 6.3
SB	106.0 ± 5.4	115.1 ± 5.6	121.2 ± 5.8
INP	105.0 ± 5.1	110.1 ± 5.6	112.7 ± 5.8

[1]There were no significant differences between treatment means (P>.05)

APPENDIX TABLE XVII Least Square Means Magnesium (ppm) in Blood Plasma at Different Weeks Postpartum

	Weeks postpartum		
Treatment	1	5	10
C	23.6 ± 4.2	51.2 ± 4.4[a]	44.0 ± 5.2
RM	31.6 ± 4.3	44.8 ± 4.8[ab]	39.2 ± 5.2
SB	30.4 ± 4.4	42.5 ± 4.6	44.8 ± 4.8
INP	29.6 ± 4.2	37.7 ± 4.6[b]	40.8 ± 4.8

[1]Means withing a column with different superscripts are significantly different ($P<.05$)

APPENDIX TABLE XVIII Least Square Means Phosphorus (ppm) in Ruminal Fluid at Different Weeks Postpartum[1]

Treatment	Weeks Postpartum		
	1	5	10
C	676 $\pm$ 76	561 $\pm$ 76	575 $\pm$ 84
RM	594 $\pm$ 81	524 $\pm$ 79	441 $\pm$ 81
SB	681 $\pm$ 78	548 $\pm$ 79	546 $\pm$ 81
INP	737 $\pm$ 76	548 $\pm$ 81	547 $\pm$ 84

[1]There were no significant differences between treatment means (P>.05)

APPENDIX TABLE XIX Least Square Means Chlorine (ppm) in Ruminal Fluid at Different Weeks Postpartum[1]

Treatment	Weeks postpartum		
	1	5	10
C	573 ± 62	503 ± 62	573 ± 68
RM	522 ± 66	448 ± 64	553 ± 66
SB	536 ± 64	533 ± 68	665 ± 66
INP	616 ± 62	602 ± 68	632 ± 68

[1]There were no significant difference between treatment means (P>.05)

APPENDIX TABLE XX Least Square means Phsophorus (ppm) in Urine at Different Weeks Postpartum[1]

Treatment	Weeks Postpartum 1	5	10
C	190.9 ± 60.6	201.9 ± 56.7	207.7 ± 56.7[a]
RM	107.4 ± 65.5	106.1 ± 60.6	63.1 ± 56.7[ab]
SB	186.3 ± 58.6	289.6 ± 56.7	336.7 ± 60.6[ac]
INP	356.1 ± 53.5	245.6 ± 58.6	263.5 ± 56.7[ac]

[1]Means within a column with different superscripts are significantly different (P<.05)

APPENDIX TABLE XXI Least Square Means Chlorine (ppm) in Urine at Different Weeks Postpartum[1]

	Weeks postpartum		
Treatment	1	5	10
C	1019 ± 154	627 ± 477	532 ± 144[a]
RM	905 ± 166	1029 ± 701	1138 ± 149[b]
SB	1339 ± 149	639 ± 149	573 ± 160[a]
INP	643 ± 425	848 ± 154	635 ± 561[ab]

[1]Means within a column with different superscripts are significantly different (P<.05)

APPENDIX TABLE XXII Least Square Means Phosphorus (ppm) in Blood Plasma at Different Weeks Postpartum[1]

	Weeks Postpartum		
Treatment	1	5	10
C	131.9 ± 13.4	175.8 ± 14.2	195.0 ± 16.6
RM	139.8 ± 13.8	170.7 ± 15.3	211.4 ± 16.6
SB	150.7 ± 14.2	197.3 ± 14.7	209.0 ± 15.3
INP	145.5 ± 13.4	192.0 ± 14.7	197.7 ± 15.3

[1]There were no significant differences between treatment means (P>.05)

APPENDIX TABLE XXIII Least Square Means Chlorine (ppm) in Blood Plasma at Different Weeks Postpartum[1]

Treatment	Week postpartum 1	5	10
C	3521 ± 543	3295 ± 578[a]	3340 ± 674
RM	3421 ± 559	3339 ± 620[b]	3325 ± 674
SB	3519 ± 577	3349 ± 598[b]	3409 ± 620
INP	3538 ± 543	3332 ± 598[b]	3364 ± 620

[1]Means within a column with different superscripts are significantly different (P<.05)

APPENDIX TABLE XXIV Least Square Means Ruminal Isobutyrate (M%) of Holstein Cows Fed Different Buffers[1]

Weeks Postpartum	Treatment			
	C	RM	SB	INP
1	1.2	1.1	1.1	1.3
5	1.5	1.3	1.3	1.5
10	1.0	1.1	1.1	1.1

[1]There were no significant differences between treatment means in a row ($P>.05$)

APPENDIX TABLE XXV Least Square Means Ruminal Butyrate (M%) of Holstein Cows Fed Different Buffers[1]

Weeks Postpartum	Treatment			
	C	RM	SB	INP
1	12.4	11.6	11.1	10.4
5	11.6	11.6	10.5	10.9
10	11.6	10.8	10.9	10.4

[1]There were no significant differences between treatment means in a row (P>.05)

APPENDIX TABLE XXVI Least Square Means Ruminal Isovalerate (M%) of Holstein Cows Fed Different Buffers[1]

Weeks Postpastum	Treatment			INP
	C	RM	SB	
1	1.7	1.7	1.6	1.8
5	1.8	1.8	1.9	1.8
10	1.9	1.6	1.7	1.6

[1]There were no significant differences between treatment means in a row (P>.05)

APPENDIX TABLE XXVII Least Square Means Ruminal Valerate (M%) of Holstein Cows Fed Different Buffers[1]

Weeks Postpartum	Treatment			
	C	RM	SB	INP
1	1.4	1.4	1.3	1.5
5	1.9[a]	1.4[b]	1.5[b]	1.5[b]
10	1.7[a]	1.2[b]	1.4[ab]	1.4[ab]

[1]Means within a row with different superscripts are significantly different (P<.05)

LACTATIONAL AND METABOLIC RESPONSES TO RUMEN-MATE[R] AND SODIUM BICARBONATE IN DIETS OF EARLY LACTATION HOLSTEIN COWS

BY

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ABSTRACT

Sixty-eight Holstein cows in early lactation were used to evaluate the relative effectiveness of Rumen-Mate^{R} and $NaHCO_3$ on feed intake, milk yield and milk composition and to define certain ruminal and metabolic effects of these buffers. Forty-four multiparous and 24 primiparous Holstein cows were allotted to four groups balanced for pre-treatment (day 1-16 postpartum), milk yield, age, day of calving and body weight, and fed for 70 days. The experimental diets were 1) basal composed of 40% roughage (chopped alfalfa hay and corn silage) and 60% corn-soy concentrate (Control); 2) basal plus 2.5% Rumen-Mate^{R} (RM); 3) basal plus 0.8% $NaHCO_3$ and 4) basal plus 0.55% MgO, 0.8% Trona, 0.56% Dyna-K and 0.4% Dynamate (INP). Addition of experimental buffers to basal diets were substituted for corn grain on a DM basis. Dry matter intake was lower ($p<.05$) for control and RM compared to SB and INP. Cows on RM produced more ($p<.05$) 4% fat corrected milk than control and slightly more than SB and INP. Uncorrected milk yield was higher for SB ($p<.05$) compared to control, RM and INP. Fat percentage ($p<.05$) was lowest for SB treatment. Feed efficiency was improved ($p<.05$) by RM versus control, SB and INP. Protein and solids-not-fat percentage in milk was similar across

treatments. Cows on RM had significantly lower ($p<.05$) somatic cell counts than control and INP while the SB group was lower ($p<.05$) than control, but similar to INP. Ruminal acetate was higher ($p<.05$) in cows on RM than Control and slightly higher than SB and INP while ruminal propionate was less ($p<.05$) in cows fed RM than Control, SB and INP. Acetate:Propionate ratio was higher for RM group compared to control group ($p<.05$). Fecal pH was higher ($p<.05$) in cows fed RM than control and SB, but similar to INP.