USE OF BUFFERS AND SUPPLEMENTAL POTASSIUM IN AN EARLY WEANING PROGRAM

by

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INTRODUCTION

Reports of the effects of $NaHCO_3$ on feed intake and weight gain of preruminant and growing calves vary. Results of a study by Curnick et al. (1983) have shown that the addition of $NaHCO_3$ to the starter ration of calves tended to improve dry matter intake. However, Kellaway et al. (1978), Leibholz et al., (1980) Wheeler et al. (1980) and Eppard et al. (1982) observed no effect on dry matter intake with supplemental $NaHCO_3$ in the calf starter. Muller and Kilmer (1979), Curnick et al. (1983) and Hart and Polan (1984) reported that the addition of $NaHCO_3$ to calf starters tended to improve weight gain. In contrast, results of several studies (Leibholz et al., 1980; Wheeler et al., 1980; Eppard et al., 1982; Wang et al., 1985) showed that addition of $NaHCO_3$ in the calf starter either decreased or did not alter weight gain of calves.

Little information is available on the effects of supplemental $KHCO_3$ and/or KCl in the diets of young calves. Wang et al. (1985) reported improved growth of 9 to 10 week old calves with the addition of dietary $KCHO_3$. Neatherly et al. (1980) found that the addition of KCl or $KHCO_3$ at 2% of the diet did not affect intake or growth, but a control diet was found more palatable in a cafeteria-style experiment.

Mineral buffers are often used in ruminant diets that contain high levels of concentrate to help stabilize pH in the digestive tract. While much research has focused on the effects buffers exert in the gastrointestinal tract, less has been done regarding the impact of these supplemental electrolytes on acid base balance. Fewer studies still have focused on the effects of supplemental buffers or electrolytes on the blood electrolyte levels and acid-base balance of preruminant and growing calves.

In work with dairy cows at various stages of lactation, Schneider et al. (1986) observed no effect of 1.3 or 1.8% total dietary potassium on serum sodium or potassium levels. This was consistant with results from studies by Pearson et al. (1948) and Fontenot et al. (1960) when 5% potassium bicarbonate ($KHCO_3$) was added to diets of ewes. Kunkel et al. (1953) reported a decrease in serum magnesium and an increase in serum potassium when ewes were fed a diet containing 5% $KHCO_3$.

Preston (1985) stated that potassium chloride (KCl) is metabolized in the body as fixed acids but $KHCO_3$ is metabolized to carbon dioxide and expired through the lungs, thereby circumventing any final impact on the acid-base balance of the animal.

The effects of supplemental $KHCO_3$ on acid-base balance of dairy animals was not reported in any of the literature reviewed. Kellaway et al. (1977) and Leibholz et al. (1980) reported an increase in blood pH, pCO_2, HCO_3 and base excess when calves were fed 3, 6 or 9% supplemental $NaHCO_3$ in the ration.

The objectives of these trials were to evaluate the effect of $NaHCO_3$, $KHCO_3$ and KCl on growth and intake and the effects of $KHCO_3$ and KCl on blood parameters of early weaned calves.

LITERATURE REVIEW

THE USE OF BUFFERS AND SUPPLEMENTAL POTASSIUM IN AN EARLY WEANING PROGRAM

Early Weaning

Benefits. The majority of dairy calves are weaned at 5 to 12 weeks of age. (1981). An alternative method of rearing calves is to early wean them at or less than 21 days of age. Reports conflict, however, when growth rates of early-weaned and conventionally-reared calves are compared. O'Donovan (1963) weaned nine calves at 11 weeks of age and nine calves at 3 weeks of age. Those weaned at 11 weeks, though lighter in weight at birth, had greater ($P<.05$) average daily gains between birth and 12 weeks of age than early-weaned calves. Klein and Kincaid (1986) weaned 20 heifers at 2 weeks of age and 20 heifers at 4 weeks of age. The two groups of heifers had similar growth rates. Thirty Freisan bull calves were divided into two groups by Harte and Curran (1964). One group of calves was fed whole milk at 10 percent of body weight from birth to four weeks of age, then received skimmed milk from 4 to 7 weeks at 5 percent of body weight. These calves were weaned at 7 weeks of age. The second group of calves was fed whole or skimmed milk (depending on availability) at 10 percent of body weight until weaning at 12 weeks of age. Average daily gains of the earlier- weaned calves at 12 weeks of age were greater than calves weaned at 12 weeks of age (.64 kg versus .57 kg). This difference was attributed to the greater meal consumption of the earlier-weaned calves.

O'Donovan (1963) also found that early weaned calves were less expensive to raise due to the decreased time the calves were fed milk. The decreased length of milk feeding reduced costs two ways: 1) reduced cost of liquid feed (if saleable or milk replacer was fed) and 2) decrease in labor cost due to having fewer milk pails to clean and sanitize.

Use of a prestarter. An early weaning program developed at Kansas State University utilizes a prestarter to stimulate dry feed intake. Morrill, et al. (1984) conducted a series of trials that evaluated the use of a prestarter in an early-weaning program. Twenty-one Holstein bull calves were allotted to three different treatment groups in trial 1. The treatments were: 1) starter only, 2) prestarter only, and 3) a 50-50 mix of starter and prestarter. They concluded from this trial that calves should be initially fed only prestarter, followed by increasing amounts of starter as they get older.

A second trial utilizing 18 calves was conducted. They concluded from the results of this trial that weaning at 2 weeks of age based on dry feed consumption was a possibility but needed more investigation due to the low number of calves they used. The addition of either the prestarter or the starter to the milk pail stimulated dry feed consumption.

Trial three was conducted at Union Center, Wisconsin. Twelve Holstein bull calves were offered prestarter ad libitum. Starter was added to appetite when the calf had consumed 326 g of prestarter 3 days in a row or at 14 days of age, whichever came first. All calves were weaned after 14 days on trial.

A final trial was conducted to determine if a smaller amount of prestarter (225 g) could be used. Morrill, et al. (1984) concluded from this series of trials that some dairy heifers can be weaned as early as 2 weeks of age and that it is feasible to use a prestarter at the rate of 225 g per day until 6 weeks of age. They also concluded that after calves are consuming the 225 g of prestarter per day, starter should be added to appetite.

Starter

Ways to improve starter consumption. The addition of sweet whey to the starter ration has been investigated as a way to increase dry feed consumption. This was evaluated by DePeters, et al. (1986) in relation to age at weaning. Twenty male and 24 female Holstein calves were assigned to four treatments. The calves were earlier-weaned (35 days) or later-weaned (70 days) and fed a pelleted starter containing 0 or 24.5 percent dried sweet whey. The assigned starter was given free choice beginning the eighth day of the trial. The authors concluded that the addition of 24 percent sweet whey to a pelleted starter ration depressed intake and rate of gain.

Morrill and Dayton (1974) conducted a series of experiments that evaluated the effects of different levels of whey on palatability of starter rations. Thirty-six calves were fed milk and their respective starters from birth to six weeks of age. The percent whey in the starter formulations varied from 0 to 40. Each calf had access to two different starters. They observed no effect on palatability when they replaced sorghum grain up to 20% if no supplemental minerals were added. There was a tendency for increased consumption with 10 percent whey and no mineral supplement. The mineral content of whey is high so special attention should be directed toward the mineral content of the starter ration when whey is fed.

Percent fiber. Research conducted by Miller et al. (1969) determined that a low fiber level in a complete starter reduced weight gain. They used 32 calves (16 heifers and 16 bulls) in this trial. The calves were fed milk and a starter until weaning occurred at 5 weeks of age. The calves were weighed 2 consecutive days at the beginning and at the end of the 8 week trial. During the trial they were weighed biweekly. The starter rations were either simplified, simplified with 10% added cottonseed hulls, complex, or complex with 10% added cottonseed hulls. The crude fiber (dry matter basis) of the starters were 3.2, 6.9, 5.2 and 8.9 percent, respectively. Dry matter intake was greater ($P<.05$) by the calves fed the complex starter with supplemental fiber when compared to the calves fed the starters without supplemental fiber. The calves fed the simple starter with 10% added cottonseed hulls did not consume significantly less starter than the calves fed the complex starter with 10% added cottonseed hulls. The calves fed the starters containing 10% added cottonseed hulls had greater ($P<.05$) weight gains overall. The authors attribute the benefit of supplemental fiber to the increase in feed intake.

Calves that consumed 15% of the ration dry matter as hay had average daily gains similar to calves fed 20-45% of the ration dry matter as hay (Noller et al., 1961). Noller et al. (1961) fed 78 8-day-old Holstein calves a starter with free choice hay or starters containing various levels (20-45%) of hay. They concluded that adding roughage to the starter is a way of increasing fiber consumption by the young calf.

Morrill and Dayton (1981) used 45 newborn Holstein calves in a trial that evaluated the addition of low quality roughage to a feeding regimen that used a pelleted starter containing 20% ground alfalfa hay. The calves were on experiment from birth to 3 weeks of age. The calves had free choice access to their respective diets. The use of a low quality roughage when calves were fed a starter containing 20% ground alfalfa hay was not beneficial in regard to weight gain.

Starter rations containing both the concentrate and a roughage source are often fed to eliminate the need to feed hay and grain separately. Two roughage levels in a complete starter ration for early- weaned calves were evaluated by Klein and Kincaid (1986). They divided 40 Holstein heifer and 16 bull calves into four treatment groups. The treatments were with or without prestarter and a starter containing either 10 or 20 percent alfalfa. They found no difference in final body weight.

Physical form. The physical form required of the starter ration is a controversial subject. One of the first studies done to evaluate pelleting of calf starter rations was by Lassiter et al. in 1955. They studied the effects of pelleting the concentrate portion when free choice alfalfa hay was fed. All rations contained the same ingredients. Three groups of 2-day-old dairy calves were assigned meal, pellets or meal plus pellets. The calves preferred the pellets if given a choice in a cafeteria style setting. The position of the various starters were changed twice a week. There was a slight but non-significant increase in average daily gain and starter consumption for calves receiving the pelleted or partially pelleted starter. No nutritional advantage was observed in regard to pelleting a starter ration for young calves. Gardner (1967) compared the acceptance, growth, consumption and TDN values of mash, pelleted and a complex pelleted commercial ration (contained complexity of protein sources, vitamins and minerals). Forty-eight Holstein calves were assigned to one of the three starter rations at birth. They were weaned at 6 weeks of age; and all calves were offered ad libitum alfalfa hay. The calves preferred the simple starter rations (either mash or pellets) as indicated by their greater average daily gain ($P<.05$) and higher consumption of starter. Pelleting the simple starter rations reduced feed wastage.

This was the only benefit to pelleting observed. Pelleting did not affect TDN or nitrogen availability of the starter ration.

Bartley (1973) conducted 2 experiments that compared a complete pelleted starter to starter and hay fed separately. The pellets of the complete starter were of two diameters (.95 and .48 cm). All calves received colostrum the first 3 days of life and then milk at 9% of body weight per day until weaning at 4 to 6 weeks of age. There were 18 calves in experiment 1 and 24 calves in experiment 2. The control calves in experiment 1 and 2 were fed long, good quality alfalfa hay and a calf starter in meal form separately, beginning at one week of age. The calves in group two (experiment 1 and 2) were fed a complete pelleted starter that was 3 parts control calf starter and 1 part ground alfalfa hay. The calves in experiment 1 that were fed the complete pelleted starter consumed more ($P<.05$) starter over the 16 week trial and gained more ($P<.001$) weight (week 8 through 16) than the calves fed the starter and hay separately. In experiment 2 the calves that were fed the complete pelleted starter consumed more ($P<.01$) starter and gained more ($P<.05$) weight (week 8 through 16) than the calves fed starter and hay separately. Bartley attributed the beneficial effect of the complete pelleted starter to increased feed intake.

Mineral supplement. Nicholson et al. (1960) evaluated the effect of a mineral supplement on the growth of calves. They fed 32 two-month old calves a basal ration or the basal ration plus 4.4% alfalfa ash, 3.0% special minerals or 40% alfalfa hay. There were 5 heifers and 3 bull calves in each treatment. The special mineral mix consisted of equal parts of ground limestone, sodium bicarbonate, magnesium carbonate and potassium carbonate. All calves were fed their respective diets and water free choice. The order of consumption of the rations (low to high) was; basal, alfalfa ash supplement, alfalfa hay supplemented and the ration containing the 3.2% special minerals was consumed the most. The ration containing the special minerals was consumed more ($P<.01$) readily than the basal ration.

Intake of the ration containing alfalfa ash was less ($P<.05$) than the ration containing alfalfa hay. Weight gains of the calves were not different between treatments. The calves fed the diet containing the special minerals were taller ($P<.05$), when measured by height at withers, than the calves fed the basal ration.

Rumen Development

Rumen Physiology. The rumen of a newborn calf is immature physically and physiologically. The presence of dry feed and the end products of fermentation (volatile fatty acids) are responsible for rumen development. Lengemann and Allen (1959) investigated the effects of liberal and limited milk feeding and limited milk plus a concentrate, with or without Aureomycin, on rumen development. Twenty four calves were allotted to four treatment groups. Treatment group one was fed a liberal amount of milk for 12 weeks with ad libitum access to clover-timothy hay and up to 3 pounds of concentrate per day. Groups two and three received milk for the first 3 weeks at 10 percent of body weight (maximum of 10 pounds per day) with a gradual decrease of milk until weaning at the end of week 7. These calves were provided clover-timothy hay ad libitum and a maximum of 3 pounds of concentrate per day. The concentrate given group 3 contained Aureomycin at the rate of 40 g of crystalline Aureomycin-hydrochloride per ton of concentrate. Group four was fed milk at 12 percent of body weight through 8 weeks of age. The amount of milk decreased rapidly to the end of week 11 when this group was weaned. The group four calves were offered clover-timothy hay and concentrate ad libitum beginning at week 9. Rumen samples were obtained by stomach tube. Group four calves had lower ($P<.05$) levels of butyric, propionic and acetic acids, when compared to the other three groups of calves, at week 2 through week 9. When group four calves were given access to roughage and starter, volatile fatty acid (VFA) levels rose rapidly to the levels of the other three groups. The VFA levels of groups one, two and three were similar. Levels of butyric acid similar to those of adults in the herd were reached in calves at 4 weeks of age, propionic at 3 weeks of age, and adult levels of acetic acid were obtained at 6 to 7 weeks of age in groups one, two and three. The authors concluded that the major factor affecting rumen development was diet. This was illustrated by the animals consuming diets containing a roughage and a concentrate rapidly developing the same rumen characteristics as those seen in adult animals.

It was concluded by Sanders et al. (1959) that butyric and propionic acid are responsible for rumen mucosal development. Twelve Holstein bull calves were fitted with ruminal cannulaes at 2 to 5 weeks of age in this study. The calves were placed in elevated tie stalls to prevent the consumption of bedding. These calves were divided into two groups and assigned milk only or milk plus one of the following; sodium acetate, sodium propionate, sodium butyrate, sodium chloride or glucose. The sodium salts of the fatty acids, sodium chloride and the glucose were administered through the cannulae. After 11 weeks the calves were slaughtered and the papillae of the reticulo-rumen were photographed and scored. Reticulum papillary growth was greatest in the calves fed sodium butyrate and sodium propionate.

Roughage. McGavin and Morrill (1976) used a scanning electron microscope to evaluate the development of rumen papillae in calves fed different amounts and forms of roughage. They allotted 20 neonatal calves to four treatments. In addition to milk, calves were given either: 1) pelleted concentrate plus alfalfa hay, 2) pelleted concentrate containing ground alfalfa hay, 3) pelleted concentrate, or 4) pelleted concentrate containing whey. Eight calves were euthanized at 4 weeks of age and 12 calves were euthanized at 6 weeks of age. Distinct differences in papillary development in response to diet were noted at 6 weeks of age. Rumen papillae of the calves that received a concentrate and roughage (groups 1 and 2) were tongue-shaped with little or no parakeratosis. The calves in groups three and four had rumen papillae that were small, nodular and blackened from heavy keratinization. These differences were noted in the 4 week old calves but did not appear as pronounced. The authors concluded that metabolic factors (not necessarily limited to butyric and propionic acid) and a rough textured forage are needed to stimulate normal ruminal epithelial development and to prevent the growth of "clumped" papillae.

Nocek et al. (1984) investigated the effect of roughage on rumen mucosa. Fifty-four Holstein bull calves were fed concentrate plus 40 percent (diet dry matter) ground hay or chopped hay or an all concentrate diet. The calves were on trial from 8 to 20 weeks of age. The calves were slaughtered at 20 weeks of age and the reticulo-rumen was weighed. The length, number and surface area of papillae were greater in calves fed hay. The frequency of morphological abnormalities of the rumen epithelium was higher in calves fed only concentrate. The rumen papillae of the calves fed concentrate lacked uniformity and were clumped with embedded hair and food particles. The authors concluded that roughage was necessary for normal development and maintenance of rumen mucosa. Godfrey (1961) investigated the relationships among diet preweaning, age at weaning and ruminal VFA levels. Fifteen calves were randomly assigned to three treatments. Each treatment group contained two males and three females. After 3 days of age all calves were fed milk diluted to 3.5 percent milk fat. From 3 to 8 weeks of age group A received milk at the rate of 675 g per 4.5 kg of live weight daily with no access to roughage. Group B received one third the milk rate of group A and was allowed to graze a third of the time group C spent grazing. The calves in group C were weaned at 3 weeks of age and given free access to pasture. The calves in groups A and B were given access to the same pasture as the calves in Group C. Rumen samples were obtained via stomach tube twice a week from 2 to 12 weeks of age. In groups B and C, which had access to pasture, VFA levels increased to 9 weeks of age while calves given only milk showed no changes in VFA levels from 2 to 8 weeks of age.Total VFA concentrations of calves in Group A increased to the levels of the other two groups (B and C) within a week of being weaned and given free access to pasture. Godfrey concluded that restricting the calf to an all milk diet prevented the development of mature levels of rumen acids until such time as pasture or roughage is available.

Nocek and Polan (1984) studied ruminal VFA concentrations of 54 Holstein bull calves fed ground hay (.2-2 cm), chopped hay (6-10 cm), or an all concentrate diet. Rumen fluid samples were taken by stomach tube at 8, 11, 14, 17 and 20 weeks of age. The authors determined that acetate concentrations were higher ($P<.05$) in calves fed ground hay than in calves fed chopped hay diets. Calves fed only concentrate had the lowest acetate levels. Calves that received the all concentrate diet had higher ($P<.05$) propionate concentrations than calves given either form of hay. Butyrate concentrations were unaffected by diet.

Effects of earlier weaning. Several studies have concluded that earlier weaned calves develop functional rumens at a younger age than later weaned calves, under the same conditions. Quigley et al. (1985) evaluated the effects of weaning age and ration form on development of ruminal function. Sixteen ruminally- and abomasally-cannulated Holstein bull calves were assigned a weaning age (4 or 8 weeks) and a starter ration (complete pelleted or unpelleted plus hay) at 1 to 3 days of age. The calves weaned at 4 weeks of age received 1.8 kg of milk twice a day to day 21. The amount of milk was reduced to 0 on day 28. Calves weaned at 8 weeks of age were fed 1.8 kg of milk twice a day to day 49. Milk was reduced until none was given on day 56. The assigned starter ration was available ad libitum beginning at 5 to 10 days of age. It was concluded that total VFA concentrations increased with age ($P<.01$) and reached adult levels within 2 weeks postweaning. This meant that calves weaned at 4 weeks developed adult rumen function an average of 4 weeks sooner than calves weaned at 8 weeks. This is a reflection of the greater intake of dry and fermentable feed consumed by the calves weaned at 4 weeks of age. The calves that were fed the complete pelleted starter rations also tended to maintain higher concentrations of ruminal VFA than calves fed the unpelleted starter plus hay. There were significant ($P<.01$) age by treatment interactions in regard to dry matter intake. Intake of dry feed tended to be higher weeks 4 through 7 for calves weaned at 4 weeks of age. The earlier-weaned calves fed the complete pelleted starter consumed more feed than any of the other groups of calves.

Agabawi et al. (1968) distributed 27 3-day-old bull calves among two treatment groups. The control calves were weaned at 12 weeks of age and fed 270 kg whole milk during the period. A second group was weaned at 31 days of age and given 115 kg of whole milk plus a calf starter ration. Freshly-cut berseem was fed free choice to both groups beginning at 7 to 10 days of age.Volatile fatty acid concentrations were determined for three calves in each group from rumen samples collected by a stomach tube. The control calves made more efficient gains than the group weaned at 31 days. Calves weaned at 8 weeks of age utilized roughage less efficiently than did those weaned at 31 days. This was determined by feeding calves roughage along in a trial that began when the calves were 12 weeks old and lasted for 72 days. Total VFA increased with age in both groups of calves but was higher in the earlier-weaned calves. The authors concluded that the development of an adult-type rumen fermentation is more rapid when calves are weaned early.

In the study by Klein and Kincaid (1986) (previously discussed) it was found that calves weaned at 2 weeks of age and fed a prestarter had hastened rumen development. This was determined by the greater weight of the empty reticulo-rumen of the early-weaned calves when compared to the weight of the empty reticulo-rumen of the later-weaned calves.

Use of sodium buffers

Field (1981) stated that for efficient rumen performance the pH of the rumen should not drop below 6.0. Optimum pH for cellulolytic bacteria is from 6.7 to 7.0. A rumen pH above 5.7 is required for protein synthesis. A rumen pH below 6.0 is commonly seen with cereal and mixed roughage diets, particularly in young animals, as saliva flow is less than adults (Field, 1981).

Growth. The benefit of a buffer in a starter ration to improve growth of the calf is a controversial subject. Curnick et al. (1983) used 48 newborn Holstein calves to evaluate the effect of sodium bicarbonate ($NaHCO_3$) in the starter ration of young calves. The starter contained 0 or 3 percent $NaHCO_3$ and was fed ad libitum from birth to 10 weeks of age. Ten percent chopped grass hay was added to both starters. The calves were fed fermented colostrum diluted 2:1 with water at 10 percent of birth weight to 4 weeks of age. The amount of fermented colostrum fed was then decreased to 5 percent of birth weight until weaning at 5 weeks of age. Calves fed the ration containing 3 percent $NaHCO_3$ tended to have higher dry matter intake throughout the 10 week trial. These calves also tended to have greater average daily gains which could be attributed to the higher dry matter intake. Hart and Polan (1984) conducted a experiment using 0 to 4.5% $NaHCO_3$ and 0 to 2.0% disodium phosphate in a starter ration fed to 34 7-week-old calves. Calves were given their respective starter beginning at 5 weeks of age. All calves were weaned at 6 weeks of age. The complete starter ration contained 27 percent ground orchard-grass. The starter rations varied in percent $NaHCO_3$ and/or percent disodium phosphate. Buffer was added to the ration at the expense of the total ration. The authors concluded that buffers appear to have a small ($P<.14$) but beneficial effect on average daily gain. Average daily gain and feed efficiency tended to be maximized at near 2 percent $NaHCO_3$ with no added disodium phosphate. Buffer levels higher than 2 percent tended to suppress animal growth, suggesting that this level was excessive. The authors felt that the percentage of hay in this diet may have stimulated saliva flow such that no significant response to an added buffer was observed.

Kellaway et al. (1977) studied the effect of increased sodium levels (due to supplemental sodium chloride (NaCl) and $NaHCO_3$) on growth of young calves. They placed 48 1-week-old Holstein bull calves on one of two diets comprised mainly of ground barley or ground barley plus grass hay. Within each diet NaCl or $NaHCO_3$ was added at 2, 11, 20 and 29 grams of sodium per kg of dry matter. This was equivalent to 0, 3, 6, and 9 percent added $NaHCO_3$. Calves were weaned at 5 weeks of age and given free access to their respective starter ration beginning at 1 week of age until they were 10 weeks old. The authors found that during the preweaning period (weeks 1, 2, 3, and 4) there were linear increases ($P<.05$) in dry matter intake and growth rate ($P<.01$) with increasing levels of sodium in the diet. Postweaning, the calves fed $NaHCO_3$ showed a linear increase ($P<.01$) in dry matter intake and growth rate with increasing levels of sodium in the diet up to 20 g of sodium per kg of dry matter (6 percent added $NaHCO_3$) when compared to the calves receiving 2 g of sodium per kg of dry matter (no added $NaHCO_3$). The author concluded that slightly over half (52% preweaning and 57% postweaning) of the increase in dry matter intake seen with the added $NaHCO_3$ was due to its buffering capacity. The other half of the benefits were obtained from osmotic effects in the rumen. They suggested that three factors were invloved in increasing intake and weight gain of calves fed

$NaHCO_3$; 1) cereal grain-based diets give rise to low ruminal pH, 2) saliva production when pelleted feeds are fed is one fifth of the saliva production when a similar weight of long roughage is fed, and 3) rates of saliva production are much lower in young ruminants, compared to adult ruminants.

Several researchers have concluded that buffers either did not affect or decreased dry matter intake and/or average daily gain when calves fed a buffered starter were compared to calves fed a nonbuffered starter. Leibholz et al. (1980) offered 60 Holstein bull calves starter diets containing supplemental NaCl or supplemental $NaHCO_3$. Calves were given free access to their respective starters, beginning at 3 weeks of age, to 11 weeks of age. All calves were weaned at 5 weeks of age. The sodium contents of the starter diets were 0, .3, 1.1, 1.9 and 2.85% of the diet for NaCl supplemented diets, and 1.1 and 1.9% for $NaHCO_3$ supplemented starter diets. Sodium chloride and $NaHCO_3$ were added at the expense of barley. Diets were pelleted and oat chaff was the roughage source. There were large differences in weight gain and dry matter intake and $NaHCO_3$ in the starter diet had no effect on average daily gain or dry matter intake when calves were between 3 and 5 weeks of age. Calves that received supplemental sodium as $NaHCO_3$ had nonsignificantly higher weight gains than calves with supplemental sodium as NaCl at similar levels. The authors concluded that the addition of $NaHCO_3$ to a starter diet slightly increased feed intake but did not improve weight gain.

Wheeler et al. (1980) conducted two trials utilizing 3.5 % NaCl or 5% $NaHCO_3$ and 35% alfalfa or 35% grass hay. A total of 62

Holstein calves were on trial from birth until 12-weeks-old. The treatment diets in trial one were: control, control plus 3.5% NaCl and control plus 5% $NaHCO_3$. The starter rations in trial one were complete pelleted rations containing 35% alfalfa hay. The treatment diets in trial two were: control, control plus 5% $NaHCO_3$ and control plus 5% $NaHCO_3$ plus loose, chopped grass hay. The control ration in trial two was complete pelleted ration containing 35% grass hay. The starter rations in trial one and two could be consumed ad libitum from birth until 12 weeks of age. Dry matter intakes were the same among treatment groups in both trials throughout the 12 week period. Mean dry matter intake was higher in trial one than in trial two. This could be attributed to the lower quality of roughage offered in trial two (grass hay versus alfalfa hay). There were no differences in average daily gain among treatments within trial one or trial two. The authors attributed this to the fact that the control animals were gaining well. The inclusion of 35% roughage may have stimulated saliva production so that supplemental buffering was not needed to maintain a favorable rumen environment. Therefore, the inclusion of $NaHCO_3$ had no effect on intake, thus growth rate was not improved. The control calves in trials one and two converted feed to gain more effeciently ($P<.01$, trial one) than the calves within their respective trial that were fed supplemental $NaHCO_3$. The authors concluded that $NaHCO_3$ is capable of improving feed efficiency of calves fed a high concentrate, low roughage diet but with large portions of roughage in the diet, $NaHCO_3$ impairs feed efficiency.

Eppard et al. (1982) investigated the effects of the addition of $NaHCO_3$ in colostrum (.6%), milk replacer (.6%) and the starter (2%) fed to calves. The calves were fed colostrum once a day from day 4 through day 14. Milk replacer was fed once a day from day 15 through day 28 and starter was available ad libitum from day 4 through day 84. Forage was not available to any of the calves. The results were based on data obtained from 54 Holstein and Jersey calves placed on trial at 4 days of age. The bull calves were on experiment for 42 days and the heifers were on experiment for 84 days. The calves were assigned to treatment within sex and breed. Starter intake, total dry matter intake and average daily gains were similar for all calves from day 4 to day 84.

It has been shown by Wang et al. (1985) that $NaHCO_3$ affects growth negatively and potassium bicarbonate ($KHCO_3$) affects growth positively. In their study, sixteen Holstein bull calves were allotted to four treatments: 1) no supplemental sodium or potassium 2) 150 meq of sodium as $NaHCO_3$ 3) 150 meq of potassium as potassium bicarbonate and 4) 150 meq of sodium as $NaHCO_3$ and 150 meq of potassium as $KHCO_3$. The sodium and potassium were supplemented to the basal diets. Diets were balanced to be similar in bicarbonate and ammonia. Calves were weaned at 7 to 8 weeks of age and were adapted to their respective diets over a 2 week period. Data were then collected on the calves for 30 days. The negative and positive effects of $NaHCO_3$ and $KHCO_3$, respectively, on growth became more significant as the trial progressed. The authors suggest that when using buffers in calf diets attention should be paid to the sodium and potassium levels and the ratio of the two.

Digestibility. There is controversy as to whether or not sodium buffers inhibit digestibility. Two studies have reported a benefit of buffers in promoting growth but differed in their results regarding digestibility. Curnick et al. (1983) evaluated digestibilty in four heifer calves that were 8 weeks old. The calves were dosed orally with chromic oxide for 10 days. Two fecal grab samples were taken daily from day 6 to 10. They reported that digestibility coefficients for all nutrients in the buffered diet were lower than those of the control diet. They concluded that this may have been the result of the increase in dry matter intake observed with the added buffer. Hart and Polan's (1984) findings were based on a digestion trial using calves that were 15 weeks old. They found that the digestion coefficients for acid detergent fiber and neutral detergent fiber appeared to be higher for diets containing buffers. This was especially evident in results with diets containing 1.5 and 3 percent $NaHCO_3$. Hart and Polan attributed this to a possible increase in ruminal pH caused by the buffer which provided a more favorable environment for cellulolytic activity. Digestibility of crude protein was not affected by buffer addition to the starter diet. In agreement with Curnick et al. (1983), they found a decrease in ash and starch digestibility. They believed the decrease in starch digestiblity was due to the high feed intake of the calves.

VFA. The effects of buffers and salts on the concentration and/or the proportions of VFA present in the rumen have been studied by numerous researchers, however results vary. Several studies

(Leibholz et al. 1980; Wheeler et al., 1980; Curnick et al., 1983; Hart and Polan, 1984) have reported no significant effect of sodium buffers on total concentrations or proportions of VFAs in calves 8 to 14 weeks of age. Hart and Polan (1984) found no effect on the proportions of VFA; but they did observe a linear increase in total VFA concentration with increasing percentages of buffer. Curnick et al. (1983) observed an increase in butyrate concentration and a decrease in total VFA concentration, but none of these differences were significant. Wheeler et al. (1980) observed that 8-week-old calves had a increased molar proportion of acetate and a decreased molar proportion of propionate when fed $NaHCO_3$.

Hart and Polan (1984) observed a decrease ($P<.05$) in the molar proportion of butyrate with the use of buffers. Eppard et al. (1982) demonstrated an increase ($P<.05$) in acetate and a decrease ($P<.05$) in propionate molar proportion when 2 percent $NaHCO_3$ was added to the starter diet. Most of the effects of buffers on VFA proportions in the rumen were attributed to an increased dry matter intake and/or increased rumen dilution rate.

Blood parameters. Venous blood samples taken from calves fed sodium buffers or salts had elevated ($P<.05$) blood pH, base excess, partial pressure of carbon dioxide and bicarbonate ion levels (Kellaway et al., 1977; Leibholz et al., 1980).

Use of potassium supplements

The main dietary source of potassium for the ruminant is roughage. The increasing usage of high concentrate and low roughage diets have made it possible that ruminants are borderline or deficient in potassium.

Palatibility and sources. The different sources of potassium vary in palatability. Neathery et al. (1980) investigated the effects of different sources and levels of potassium on feed palatability and toxicity. The authors used four sources and percentages of potassium in diets fed to 16 Holstein bull calves. The calves were approximately 4 1/2 months old. The palatability of the different diets were determined by a cafeteria-style experiment. The position of the feed troughs were changed daily. The sources of potassium used were potassium chloride (KCl), potassium acetate, potassium carbonate and $KHCO_3$. The control diet contained .77 percent potassium on a dry matter basis. Other diets were control plus 2, 4, or 6 percent potassium provided by the various sources. The calves preferred ($P<.01$) the control diet over all other diets. Palatability of the diets decreased ($P<.01$) as the percentage of potassium increased. Potassium acetate was determined to be equal in palatability to $KHCO_3$ while both were more palatable than KCl. Potassium carbonate was the least palatable. Toxicity signs from excess potassium were not seen in this experiment. After completing the palatability study the authors studied growth as related to level of potassium in the diet. The potassium source for this part increased fermenter pH when compared with the control or the fermenter that contained $KHCO_3$ in both the concentrate plus forage blend and the complete rations. This demonstrated that KCl and $NaHCO_3$ were approximately equal in buffering ability. The pH of the rumen for the $KHCO_3$ treatment was lowest, possibly due to greater VFA production. Since the increase in pH of the fermenter that contained the KCl and $NaHCO_3$ treatment did not result in increased acetate or change the acetate to propionate ratio the authors felt that the amount of buffer used (40% McDougall's) may have been high enough to have had an adverse effect on ruminal microbes from the concentrate plus forage blend diet. When the complete ration was used in the fermenter the molar percentages of acetate were increased by both additives when compared to the control. Potassium bicarbonate decreased the molar percentages of propionate while KCl and $KHCO_3$ both increased the acetate to propionate ratio when compared to the control. $NaHCO_3$ produced no changes in VFA proportions. The authors concluded that KCl may be a desirable potassium supplement in dairy cow diets with no adverse palatability effects. They believed that further investigation on optimal percentages of KCl is needed.

Blood parameters. Schneider et al. (1986) investigated the effects of heat stress and added $NaHCO_3$, NaCl and total dietary potassium on acid-base balance and mineral metabolism of lactating Holstein cows. Twenty-four cows were assigned to either shaded condition or no shade, then allotted to the various experimental diets. The eight diets were: 0 or 1% $NaHCO_3$ added to the basal diet, 1 or .73% NaCl of the study was KCl added to the control diet initially containing .77% potassium such that dietary potassium was 2 or 6 percent potassium on a dry matter basis. The calves were on their respective diets for 3 weeks. Average daily gains for the calves fed 6 percent potassium were less ($P<.05$) than those receiving the control diet the first 2 weeks and for the entire 3 week period. The difference in average daily gain of the calves fed 2 percent potassium and the calves fed the diet containing 6 percent potassium was significant ($P<.05$) only during week 1. This was attributed to adaptation of calves on the 6 percent potassium diet to the high potassium intake. All gains were similar during week 3. This suggested that calves were adapting to the increased level of potassium during the first 2 weeks of the trial.

Growth. Wang et al. (1985) have shown that $KHCO_3$ affected growth postitively and $NaHCO_3$ affected growth negatively.

VFA. The source of potassium used in the diet can affect growth and other physiological functions of the body. Preston (1985) stated, "Potassium chloride, potassium sulfate and potassium phosphate are metabolized in the body as fixed acids and potassium carbonate, potassium bicarbonate and potassium acetate are metabolized to carbon dioxide and expired through the lungs, thereby circumventing any final impact on the acid-base balance status of the animal."

The majority of the research that has been done concerning the use of supplemental potassium for farm animals has been in lactating dairy cows. West et al. (1986) fed 24 Holstein cows diets that contained 1) no buffer 2) 1.8 percent $KHCO_3$ 3) 1.2 percent potassium carbonate or 4) 1.5 percent $NaHCO_3$ in the concentrate portion of the diet. Diets were concentrate plus a forage blend (fed separately) or a complete ration (60% concentrate and 40% forage). The cows given supplemental potassium as KCl in the concentrate portion of the separate diet consumed slightly less concentrate. Palatability was not determined to be a problem with the addition of buffer to the basal diet. When KCl was added to the complete ration the cows had greater ($P<.05$) dry matter intake per 100 kg of body weight. The authors concluded that the increase in intake may have resulted from a more favorable rumen environment, which resulted in greater digetibility of feeds or a greater rumen turnover rate. Buffers did not change rumen pH. The authors believed buffering in the rumen of the cows fed KCl may have been greater than in the cows fed $KHCO_3$ or $NaHCO_3$, which allowed for the greater digestibility and intake. None of the additives affected ruminal VFA proportions significant, but there was a tendency for the cows fed KCl and $NaHCO_3$ to have greater total VFA concentrations and acetate:propionate ratios. The authors observed that even though KCl was offered in lower concentrations than $NaHCO_3$, its buffering capacity was equal to or greater than the other treatments. The authors also conducted an in vitro trial utilizing eight continuous fermenters of 500 ml capacity each. Rumen fluid from a ruminally-fistulated cow that was adapted to the basal diets was placed in each fermenter. A 2 day adaptation period was followed by 3 days of sampling. Potassium chloride and $NaHCO_3$

added to the basal diet and 1.3 or 1.85% total dietary potassium. NaCl and KCl were added to the basal diet at the expense of ground corn. Heat stress was determined by differences in black globe thermometer readings and increases in rectal temperature and respiration rate. Packed cell volume and plasma protein values were not affected by the environmental surroundings of the cow. Cows supplemented with NaCl and $NaHCO_3$ had higher blood bicarbonate and total carbon dioxide concentrations. The higher level of dietary potassium increased blood pH and the bicarbonate to partial pressure of carbon dioxide ratio. This may have been due to the alkalogenic effect of these cations. Sodium bicarbonate in the diet depressed plasma sodium concentrations but did not affect potassium levels in the plasma. Plasma sodium concentrations were lower in the cows that had no shade when compared to the cows in shade. Environment did not alter plasma potassium concentrations. The authors concluded that benefits of feeding supplemental sodium and potassium were apparent in both environments.

The effects of feeding high potassium rations to sheep on serum potassium, sodium, magnesium and/or calcium levels is a controversial subject. The results of two studies (Pearson et. al., 1948; Fontenot et al., 1960) determined there was no effect on these blood parameters when high levels of potassium were fed to sheep. The results of a study by Kunkel et al. (1953) was contradictive to the two studies mentioned above.

Pearson et al. (1948) evaluated the effects of 5% potassium (provided by $KHCO_3$) in the ration of six mature ewes. Twelve ewes were fed the basal diet. All ewes were fed a liberal amount of alfalfa hay and were limited in the amount of grain they could consume. The ewes were given a week to adjust to the experimental grain mixture. Jugular blood was drawn monthly for 4 months. Serum potassium, calcium and magnesium concentrations were determined. The ewes fed the 5% potassium grain mixture gained more ($P<.05$) weight than the control ewes during the trial. The addition of potassium did not influence the serum levels of calcium, magnesium or potassium. The authors believed this maintanence of normal serum potassium levels in the ewes to be due to the rapid elimination of potassium via the renal pathway.

Fontenot et al. (1960) fed six lambs a basal ration and six lambs were fed the basal ration that had been fortified with $KHCO_3$. The experimental ration contained 3 times the recommended potassium level for these lambs. The amount of feed which the lambs could consume was restricted. All of the lambs were used in two trials that consisted of 10 days adjustment and a 10 day collection period per trial. Venous blood was drawn prior to the start and at intervals during each trial. Sodium, potassium and magnesium were determined in the feed, feces, urine and blood plasma. The authors concluded that rations high in potassium may interfere with the absorption or retention of magnesium. The level of sodium in plasma was not altered by the 5% potassium diet. The consumption of the high potassium diets increased potassium retention but the plasma levels of potassium remained fairly constant.

Thirty adult Rambouillet ewes were fed a basal ration or the basal ration fortified to contain 5% potassium by Kunkel et al. (1953). The supplemental potassium was provided by $KHCO_3$. The ewes were fed a maximum of 1.8 kg of their respective diet. The basal diet was fed to all ewes 3 weeks prior to the experimental period. Blood samples were drawn 12, 48 and 62 days after the beginning of the trial. Serum magnesium, calcium, potassium, sodium and total serum protein was determined. The addition of $KHCO_3$ to the basal diet decreased consumption of feed by the experimental ewes. The ewes fed the 5% potassium diet gained less ($P<.01$) weight than the control ewes. Serum magnesium levels had decreased ($P<.01$) by the end of day 12 and remained low through the remainder of the trial in the ewes fed the 5% potassium diet. The serum potassium levels of the ewes fed the 5% potassium diet had increased ($P<.05$) by the end of day 12, compared to the control ewes. The serum potassium level of the experimental ewes was the same as the control ewes by the end of day 62. A decrease ($P<.05$) in serum calcium was observed in the ewes fed the 5% potassium diet by the end of day 12, but serum calcium had returned to "normal" by the end of day 62. Consumption of the 5% potassium diet did not alter serum sodium or total serum protein levels.

The authors concluded that the changes in serum potassium and calcium were minimal because the ewes had returned to normal levels by the end of day 62. The return to normal of the serum potassium may have been due to the ewe adjusting to the high potassium diet and the increased renal losses of potassium.

Acid-Base Balance

As the calf grows it experiences physical and physiological changes. The development of a functional rumen causes a decrease in blood pH due to the lowering of the pH in the rumen as it develops. Thus, the calf's physiological mechanisms adjust to maintain an optimum acid-base balance. The acid-base status of an animal can be evaluated by knowing the pH, pCO_2 and HCO_3 concentrations in the blood.

Significance of blood pH and gases. These were discussed by Kaneko (1980).

The predominant buffer system in the blood is the bicarbonate buffer system. This system is a combination of carbonic acid (H_2CO_3) concentration and salt of bicarbonate. The pH of the blood is affected by the ratio of H_2CO_3 to bicarbonate ion (HCO_3).

Measurement of partial pressure of carbon dioxide (pCO_2) in the blood evaluates the H_2CO_3 or carbon dioxide (CO_2) status of the animal. The HCO_3 status in the animal is determined by pCO_2. This is because H_2CO_3 disassociates into a hydrogen ion and HCO_3.

The HCO_3 level tells whether there is a base excess (BE) or a base deficit in the animal. The BE is mathematically derived from pH and pCO_2.

The total CO_2 level in the blood is an indication of HCO_3 status of the animal. This is because HCO_3 is approximately 95% of the total CO_2 in the animal.

When venous blood is used to determine the acid-base status of the animal, partial pressure of oxygen is of no value in evaluating the homeostatic status of the animal.

Changes in blood gas values with age. The changes that occur from 4 days of age to maturity in blood pH and bicarbonate ion levels of cattle were evaluated by McSherry and Grinyer (1954). Twenty animals that were 4 days to 10 weeks of age, 20 that were 4 to 10 months and 86 animals that were 2 to 13 years of age were used in this study. The mature aniamls were at various stages of lactation and pregnancy. Jugular blood was drawn. Venous blood pH and HCO_3 level did not change with age.

Butler et al. (1971) evaluated the changes in acid-base values from birth to 10 days of age in calves. They observed no changes in acid-base values during this time period.

Electrolyte levels of blood

Changes in serum electrolytes with age. Butler et al. (1971) collected blood samples from 150 "normal" calves. The calves were raised on the farm of origin. The initial blood samples were taken as soon as possible after birth. Additional blood samples were taken at 2 to 3 day intervals until the calf was 10 days old. Blood was drawn from the jugular vein. There were no significant differences in the acid-base values as a result of age. Serum potassium and sodium levels were not significantly different when related to age but changes were observed. As the calves got older, serum sodium concentrations tended to decrease and serum potassium concentrations fluctuated unpredictably.

Safwate et al. (1982) evaluated plasma sodium and potassium concentrations in calves from birth to 7 days of age. Ten Holstein bull calves were placed in metabolism crates immediately after birth for 7 days. The calves were fed twice a day. On day one they were fed colostrum. The following days they were fed milk replacer that contained 13 g of potassium and 9 g of sodium per kg of dry matter. Blood samples were drawn from the jugular vein. The initial sample was taken within 2 minutes after birth and then at 12 and 24 hours later. From day 1 to day 7 the blood sampes were drawn once a day before the morning feeding. Packed cell volume decreased ($P<.05$) from birth to 3 days of age (44 versus 36) and then stabilized at 33 until day 7. Plasma potassium concentrations did not vary from birth to day 7, both values being 5.2 mM. Plasma sodium concentration decreased ($P<.05$) 144 mM at birth to 139 mM at 6 days of age and decreased again on day 7 to 137 mM. There were increases ($P<.01$) in potassium and sodium intake from birth to day 7 due to the change from feeding colostrum to milk replacer.

The concentrations of plasma sodium and potassium of calves were compared to those of cows by Fisher (1960). The adult animals were "normal" members of the university herd. They were either dry or in varous stages of lactation. The calves were with their dams for the first week of life. Hay was given to the calves beginning at 3 weeks of age. At 4 weeks of age the amount of milk replacer given was gradually decreased until weaning at 5 weeks of age. Calf starter was given at 4 weeks of age. Blood samples taken from calves with diarrhea were not included. Arterial blood was drawn from the brachial artery at the base of the neck. There were significant differences between calves' mean plasma sodium (141.8 $\pm$

3.5 meq/l) and potassium (5.1 $\pm$ 0.4 meq/l) and cows mean plasma sodium (142.2 $\pm$ 2.0 meq/l) and potassium (4.4 $\pm$ 0.3 meq/l). As the calf matured plasma sodium increased and potassium decreased.

The changes in serum sodium and potassium concentrations from birth to 12 months of age were studied in sheep by Long et al., (1965). The authors used 202 lambs from Hampshire, Suffolk and Shropshire breeds. Blood was drawn from the anterior vena cava or the external jugular vein. Blood samples were drawn at birth and 6, 12, 24, and 48 hours of age and at 5, 8 and 14 days of age and at 1, 2, 3, 5, 8 and 12 months of age. The serum Na concentration was highly variable between birth and 12 months of age, ranging between 320 and 348 meq/l. The serum K concentration decreased slightly as growth and maturation occurred. The range of serum K concentrations was between 22.3 and 26.7 meq/l.

Changes in red blood cell electrolytes with age. Changes in red blood cell (RBC) K concentrations occur with age in sheep. The changes were evaluated by Drury and Tucker (1963) in 18 Clun Forest lambs from birth to 111 days. The lambs were of the low potassium (LK) and high potassium (HK) types. The blood potassium level in sheep is related to genetic make up. Jugular blood was drawn into a heparinized syringe. A "layering" technique was developed so the RBCs could be divided into populations of different mean ages. Layer 1 is composed of the youngest RBCs and layer 4 is composed of the oldest RBCs. The authors concluded that the number of RBCs in the blood is linerally related to age and body weights. Body weight was a better indicator of red cell volume than age. After birth there was a progressive decrease in RBC K in both types of sheep. The RBC K concentration of the HK type lambs decreased to adult levels about day 45. This level was reached by the LK type lambs at 2 months of age. When the RBCs of the HK type lambs were layered the potassium concentration decreased from layer 1 to layer 4. The potassium concentration of the layers of RBCs in the LK type lambs was highest in layer 4 and lowest in layer 1 at 5 days of age. At 50 days of age the K concentration of the layers of RBCs in the LK type lambs had switched to highest K concentration in layer 1 and the lowest K concentration in layer 4. These findings make it possible to distinguish LK from HK type lambs at 5 days of age. It is possible the high potassium concentration in layer 1 might be linked to the high degree of erythropoiesis in growing lambs. This was confirmed by bleeding a 41 day old lamb. After bleeding the K concentration of the RBCs in layer 1 was elevated, a slight increase in layer 2 was observed and the RBC K concentrations in layers 3 and 4 were normal. The authors have drawn two conclusions about these results: 1) if an unusually high K concentration is found in the blood of sheep this may be due to the presence of immature RBCs in the circulation and 2) after hemorrhage the return of the increased K concentration in the layers to normal values would give good evidence that full recovery has taken place.

Changes in serum electrolytes during scouring. Diarrhea causes a decrease in serum Na and serum K levels fluctuate unpredictably

(Roy et al., 1959; Dalton et al., 1965). Dalton et al. (1965) evaluated the changes in serum cation levels, body weight and hematocrit in calves 2 to 14 days of age affected with diarrhea. Sixteen calves were used in this experiment. All calves were fed 1.4 liters of milk replacer or cow's milk twice daily. Calves that did not consume their allottment were force fed via stomach tubes. The consistency of the feces of each calf was recorded daily. The calves were weighed every other day. Jugular blood samples were drawn the first day on trial and on every second or third day thereafter. The calves were divided into five groups depending on the number of consecutive days they had diarrhea. The groups were 2 to 3, 4 to 5, 6 to 7, 8 to 9 and then 10 consecutive days of diarrhea. Due to this way of grouping, the calves with diarrhea for more than 3 days were also assigned to other groups. The mean plasma Na and K values obtained when the calves had diarrhea were compared to the mean values obtained day 1 when all the calves had feces of normal consistency. The mean plasma Na and K levels day 1 were 140 $\pm$ 5 meq/l and 4.9 $\pm$ 0.4 meq/l, respectively. All calves with diarrhea had lower ($P<.001$) mean plasma Na levels. Hypoantremia occured in several of these calves. The mean plasma K levels of the calves with diarrhea for 4 to 5 and 6 to 7 consecutive days were lowered ($P<.02$). One case of hyperkalemia was diagnosed in each group of calves with diarrhea for 2 to 3, 4 to 5, or 8 to 9 consecutive days. One case of hypokalemia was diagnosed in each group. The calves with diarrhea lost weight and those without diarrhea gained weight.

Hematocrit values did not change if the calf experienced diarrhea. The lack of variation in hematocrit of the calves with diarrhea was explained by the authors as due to the plasma volume being maintained despite the dehydration, or the electrolytes were either destroyed as part of the catabolic response to diarrhea or moved out of the general circulation.

The effects of diarrhea on serum Na and K concentration of newborn calves was studied by Roy et al. (1959). The study evaluated 150 calves from birth to 3 weeks of age. At the onset of scouring, milk intake was reduced to a level required for maintenance of body weight. When the feces became of normal consistency the amount of milk was increased to the full daily allowance (.54 kg/5.4 kg of live weight). To verify that the changes in serum Na and K were due to diarrhea and not amount of milk consumed, two calves were fed enough milk to maintain body weight. Jugular blood samples were drawn at birth (before nursing), at 1 day of age and on alternating days until the calves were 3 weeks old. The two calves used to verify the scours results did not have different serum Na or K levels whether fed enough milk to gain .54 kg per day or enough milk to maintain weight. The authors concluded that the changes in serum Na and K levels associated with diarrhea were a direct result of diarrhea and not due to decreased milk intake. Mean serum Na values were 139-140 meq/l at birth for all calves. Calves that had diarrhea 1 day or not at all had serum Na levels that decreased to 125 meq/l at day 5 and then gradually rose to 135 meq/l at the end of the 3 week trial. When the incidence of diarrhea increased there was a greater change in mean serum Na. When the calf had diarrhea for 6 or more days the first 1 1/2 weeks of life the lowest level of serum Na (127 meq/l) was reached at 9 days of age. After this the serum Na levels rose to near normal levels by the end of the 3 week trial. The mean serum K level at birth was 5.8-6 meq/l and at 1 day of age it ws 6.1-6.5 meq/l, in all calves. The calves that scoured for 1 day or not at all had serum K levels that fell gradually to 5.8 meq/l by the end of the 3 week trial. When the incidence of diarrhea increased the serum K levels increased during 4 to 12 days of age. The mean serum K levels of the calves that had diarrhea for 7 or more days was 6.5 meq/l. Forty eight calves died during this trial. Twelve died from E. coli septicemia and 28 died from localized intestinal infection of E. coli. The serum Na and K levels of the calves that died from E. coli septicemia were similar to the calves that had had diarrhea but recovered. The calves that died from a localized intestinal infection of E. coli had extremely high levels of serum K (8.0-12.7 meq/l). The authors attributed the death of these calves to the high serum K levels.

Toxicity of electrolyte levels. The level of plasma K that causes toxicity in calves was studied by Bergman et al. (1954). They injected K into the calf via the jugular vein. A constant infusion mercury pump administered the K. Cardiac and respiratory responses of the calf to the K was recorded. There was no effect on heart rate until plasma K levels reached 8 meq/l, then the heart rate began to decrease. Respiration rate increased with the K infusion. Arterial flutter and complete atrioventricular block with nodal rhythm occured in 2 of the 8 calves given K intravenously. Temporary ventricular arrest of 8 second duration occured in one calf. A calf died when the plasma K level reached 12.7 meq/l. The death of the animal was due to a progressive cardiac arrest. The heart rate had decreased from 107 beats per minute to 43 beats per minute just prior to death.

Neathery et al. (1980) observed no signs of K toxicity in 41/2-month-old bull calves fed up to 7% K (dry matter basis).

PART II

USE OF BUFFERS AND SUPPLEMENTAL POTASSIUM IN AN EARLY WEANING PROGRAM. I. GROWTH

MATERIALS AND METHODS

Trial 1

The purpose of this trial was to evaluate the effect of sodium bicarbonate on growth of early weaned calves.

Animals. Thirty Holstein bull calves were assigned to one of two groups at 1 to 3 days of age. The calves were tethered to individual wooden hutches bedded with wheat straw. Body weight, packed cell volume and plasma protein values were determined 24 to 36 hours after birth. Packed cell volume and plasma protein levels were determined by microhematocrit and refractometer, respectively. Fecal consistency (Larson, 1977) was recorded twice daily, at feeding time. The calves were weighed weekly.

Diets. Colostrum was fed the first 3 days of life at 8 percent of birth weight per day. Calves were then fed whole milk at the same rate until weaning at 2 to 3 weeks of age. All liquid feedings were divided into two equal daily portions offered at 0800 and 1500 hours. Water was available ad libitum.

Calves in one group were fed control prestarter; those in the other group were fed buffered prestarter. Composition of the prestarters is shown in Table 1. Fifteen grams of the assigned prestarter was placed in the milk pail at each feeding. The assigned prestarter was available ad libitum to a maximum of 227 grams per animal per day. After the initial 227 g of prestarter was consumed in a day the starter (Table 2) was added according to appetite. When the calf consumed 227 g of prestarter plus 227 g of starter and was at least 2 weeks of age, or after 3 weeks on experiment (which ever came first) weaning occurred. After weaning, 227 g of the respective prestarter was mixed with starter according to appetite daily until the calf was removed from trial at 6 weeks of age. Orts were weighed and fresh feed offered at the evening feeding. The length of time required for the calves to consume the initial 227 g of prestarter was recorded.

Data Analysis. The data were analyzed by the General Linear Models Procedure (Statistical Analysis System 1982). Data collected from three calves were not used due to anatomical abnormality for one calf, broken protocol for another, and missing data for the third.

Trial 2

The purpose of this trial was to evaluate the effect of potassium chloride and potassium bicarbonate on growth and blood parameters (Part III) of early weaned calves.

Animals. Thirty-six Holstein bull calves were assigned to one of four treatment groups. The calves were tethered to individual hutches that were bedded with wheat straw. The calves were managed the same as the calves in Trial 1 for the first 24 hours of life. When coccidiosis and/or acidosis were encountered the calves were given an electrolyte solution (potassium chloride and sodium bicarbonate mixed in warm water) and/or sulfamycin boluses.

Diets. The feeding regimen and criteria for weaning was the same as Trial 1. The diets were 1) Control = control prestarter plus control starter (CC) 2) Control prestarter plus starter containing 2.0% $KHCO_3$ (CB) 3) Prestarter containing 1.5% KCl plus control starter (KC) and 4) Prestarter containing 1.5% KCl plus starter containing 2.0% $KHCO_3$ (KB). The control prestarter was the same as the non-buffered prestarter in Trial one. The composition and analysis of the two starters are in Tables 3 and 4, respectively.

Data Analysis. Data were analyzed according to the General Linear Models Procedures (Statistical Analysis System, 1982).

Growth

RESULTS AND DISCUSSION

Trial 1

Acceptability of the buffered and control prestarters were similar (Appendix Table I). This was shown by the similar lengths of time until the calves consumed the initial 227 g of either prestarter (P=.64).

Calves fed the buffered prestarter had a tendency to consume more starter (Table 5) than the control calves throughout the 6 week trial. This increased consumption approached significance (P=.06) during week 5.

The calves fed the buffered prestarter tended to gain more weight (Table 6) than the control calves, except during week 2 and 6.

The lower weight gain of the calves fed the buffered prestarter during week 6 may be related to the findings of Hart and Polan (1984). They determined that maximum growth was obtained with 1-2 percent $NaHCO_3$ in the starter fed to calves 7-14 weeks of age. Restricting calves to 227 g of buffered prestarter per day may not have provided sufficient buffer when the calf was also consuming 1.8 kg of starter per day.

The trends in weight gain and starter consumption that were established by the calves fed the buffered prestarter are consistent with those observed by Curnick et al. (1983).

Trial 2

Acceptability of the prestarter (Appendix Table III) containing KCl was not a problem. This is shown by the similar lengths of time (P=.34) required for the calves to consume the initial 227 g of either the control or KCl prestarter in a day. The two extremes in the number of days required to consume the initial 227 g of prestarter in a day were treatments KC (9 days) and KB (14 days).

The mean starter consumption (Table 7)for the 6 week trial (P=.98) showed no palatability problems with the starter containing $KHCO_3$. Starter consumption for all weeks, except week 2, did not differ (P>.05) between treatments. During week 2 the calves in treatment KB consumed more starter than calves in treatments CC (P=.06), CB (P=.05) and KC (P=.01).

Overall weight gains (Table 8) were not different (P>.05) between treatments. Calves in treatment CC were not able to maintain their weight the week following weaning (week 4) even though starter consumption was not depressed. It was at the end of this week that two of the control calves were diagnosed as acidotic.

Results of this study agree with those of Neathery et al. (1980). They found no benefit from the addition of 2% KCl in regard to dry matter intake and average daily gain. However, Wang et al. (1985) observed a positive effect on growth with addition of $KHCO_3$ in the starter.

An outbreak of coccidiosis at the calf unit may have affected the results of this experiment. While the incidence of coccidiosis was similar among treatment groups of trial 2, dry matter consumption and weight gain of control calves were lower than values observed for control calves in trial 1.

PART III

USE OF BUFFERS AND SUPPLEMENTAL POTASSIUM IN AN EARLY WEANING PROGRAM. II. BLOOD PARAMETERS

MATERIALS AND METHODS

Animals. Thirty-six Holstein bull calves were assigned to one of four treatment groups. Management procedures of these calves are described in Part II, Trial 2.

Sample Collection. The calves were weighed and two blood samples were taken weekly between 1100 and 1300 hours. Jugular blood was drawn into a 12 cc syringe coated with ammonia sulfate heparin. The air was expelled and the syringe was capped and placed in an ice water bath until analysis. A 15 cc vacutainer was filled with blood at the same time.

Blood Processing. The heparinized blood was analyzed for pH and blood gases using an Instrumentation Laboratory Model 813 pH/blood gas analyzer[1]. Packed cell volume was then determined using a microhematocrit. This blood sample was centrifuged, the supernatant was discarded, and the red blood cells were washed three times with isotonic choline[2]. After the final washing the choline was drawn off and packed cell volume of the red blood cells (RBC) determined before freezing the red blood cells.

The vacutainer with the blood was centrifuged. Following centrifugation the serum was removed and frozen.

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[1] Instrumentation Laboratory, Lexington, Massachusetts
[2] 21.4984 g of 70% choline chloride/liter of distilled deionized water

Blood Analysis. Serum and RBC sodium and potassium levels were determined by flame emission[1]. The serum and the RBC were allowed to thaw, then were diluted with deionized distilled water at the rate of 1:100 and 1:50, respectively. The slit width and the wavelength were set according to the manual for the instrument. Standards were developed by diluting 100 ug/ml stock solutions. Potassium standards used were 100, 80, 65, 50, 25, 15, 5, 1, and .5 ug/ml. Sodium standards were 100, 80, 65, 50, 40, 30, 20 and 10 ug/ml. Triplicate samples were analyzed. An entire set of samples collected during the 6 week period for four calves, one from each treatment, was analyzed at one time.

Data Analysis. Data were analyzed according to the General Linear Models Procedure. The Chi Square analysis was used to check the validity of the results. The Pearson and Spearman Correlation Coefficients were also calculated (Statistical Analysis System, 1982).

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[1]Varian 1475 double beam atomic emission Varian Instrument, Division 611 Hansen Way, Palo Alto, California 94303

RESULTS AND DISCUSSION

Blood Parameters

The dry matter intake and growth of these calves is recorded in Part II. Treatment did not affect ($P<.05$) RBC sodium and potassium (Appendix Table VI and VII) or serum sodium and potassium levels (Tables 10 and 11, respectively). Weekly differences ($P<.05$) were observed within treatments.

Red blood cell sodium levels (Figure 1) increased ($P<.05$) in all the calves as they became older. Adult levels (52-96 meq/l; Kaneko, 1980) were reached by all calves by six weeks of age. The sodium RBC level in treatment KC and KB calves did not change ($P<.05$) from week 5 to week 6.

Potassium RBC levels (Figure 2) decreased ($P<.05$) from week 1 through week 6 in all calves. By the end of week 6 all calves had approached adult red blood cell levels (10-45 meq/l; Kaneko, 1980).

The red blood cell potassium level was positively correlated ($P<.05$) with total feed consumption during weeks 1 ($r=.34$), 4 ($r=.38$) and 5 ($r=.34$).

A weekly increase ($P<.05$) within all treatments was observed in the RBC sodium to potassium ratio (Table 9). This was due to the changes observed in the individual RBC sodium and potassium levels. Sodium is more abundant in the RBC than potassium (minimum ratio of 1.16; Kaneko, 1980). This ratio was obtained by the calves in treatment KB during week 5. Treatment CC, CB and KB calves achieved this RBC sodium to potassium ratio in week 6.

The tendency to have higher serum sodium (Table 10) levels in week 6 than in week 1 was evident in all treatments. Some of the calves achieved adult serum sodium levels (132-152 meq/l) (Kaneko, 1980) during the trial but were unable to maintain these levels. There were no weekly differences (P<.05) in serum sodium levels in the treatment KB calves. The calves in treatments CC, CB and KC had variable (P<.05) changes in serum sodium levels.

Serum potassium levels (Table 11) tended to be lower in week 6 than in week 1 in all treatments. Adult serum potassium levels (3.9-5.8 meq/l; Kaneko, 1980) were reached during different weeks between and within treatments but these levels were never maintained. The weekly serum potassium level throughout the six week trial did not change (P<.05) in treatment CB and KC calves.

The serum potassium level was positively correlated (r=.42, P<.05) with starter consumption in week 3.

There were dramatic fluctuations in the serum sodium to potassium ratio (Table 12) but an upward trend was evident when comparing week 1 through week 6. This ratio varied (P<.05) within treatments CB and KC. The adult serum sodium to potassium ratio is approximately 30.0 (Kaneko, 1980). This ratio was obtained by the different treatment calves during different weeks but it was never maintained.

The calves in treatment CC had a lower venous blood (Table 13) pH during week 1 (P=.11) and on the average throughout the 6 week (P=.11) trial when compared to the calves in the other three treatments.Venous blood pH tended to be higher in week 6 than in week 1 in all calves. This change in pH varied (P<.05) throughout the 6 week trial in the calves in treatment CC and CB. The calves in treatments KC and KB maintained a "normal" (7.35) venous blood pH (Kaneko, 1980) throughout the trial.

The venous blood HCO_3 levels (Table 14) were different between treatments during weeks 1 (P=.01) 2 (P=.03) and 4 (P=.18) and within (P<.05) treatments CC and KC. Although the HCO_3 level varied significantly all calves were within the expected range of 20-30 mmol of bicarbonate ion per liter of blood (Kaneko, 1980) at all times.

The calves in treatments CC, CB and KC did not maintain a constant pCO_2 (Table 15) level throughout the 6 week trial. All calves had higher pCO_2 levels than expected (35-44 mm Hg; Kaneko, 1980). The calves on treatment KB maintained a relatively constant pCO_2 level. The calves in treatment CC had a lower (P<.05) venous blood pCO_2 during week 4 (P=.04) than the calves in treatments CB, KC and KB.

Mean base excess (BE) (Table 16) for the 6 week trial differed (P=.03) between treatments. The calves in treatment CC had an overall lower (P<.05) BE than the calves in the other three treatments. The calves in treatment CC had a lower (P<.05) BE in week 1 than the calves in treatments CB, KC and KB. Differences (P<.05) in BE were also observed between treatments during week 2. The calves in treatment KC had higher (P<.05) BE values than the calves in the other three treatments. The BE of the calves in treatment KB was the same as the calves in treatment CB but higher (P<.05) than the calves in treatment CC during week 2.

Average daily gain (ADG) over the six week trial was positively correlated (r=.317, P<.05) with mean pH, BE and HCO_3 levels. The mean BE and HCO_3 levels were different (P=.03, P=.03, respectively) between treatments.

A positive correlation (P<.05) with BE and HCO_3 in regard to starter consumption was obtained in weeks 1 (r=.34) and 4 (r=.46). The calves in treatment CC had lower (P<.05) BE and HCO_3 level during these weeks than the calves in the other three treatments, the exception being BE during week 4 which was not different (P=.21) between treatments.

The decrease in RBC potassium concentration as the calf ages is consistant with the results of Drury and Tucker (1963). They observed this trend in sheep from birth to 111 days of age.

Information pertaining to RBC sodium levels in calves was not found in the literature that was reviewed.

The serum sodium and potassium levels obtained in week 1 were higher than those observed in two studies (Safwate et al., 1982; Lynch and Bond, 1983). The serum potassium levels obtained are similar to those in the study of Butler et al. (1971). The differences cited above may have been due to analytical variation.

The upward trend of serum Na and the downward trend of K is consistent with the results of Lynch and Bond (1983). Long et al. (1965) observed a decrease in serum potassium and highly variable fluctuations in serum sodium in lambs as they matured.

Schneider et al. (1986) observed a depression in serum sodium concentration in cows fed 1.0% (DM) $KHCO_3$. This is not consistent with the serum sodium levels of the calves in treatments CB and KB.

The exceptionally low (P<.05) venous blood pH, HCO_3 and PCO_2 of the calves in treatment CC during week 1 is an indication of metabolic acidosis (Kasari et al., 1985). When a calf has metabolic acidosis renal losses of potassium are decreased. When renal loss of potassium decreases an increase in serum potassium is observed (Kaneko, 1981). This may explain the elevated serum potassium levels of the calves in treatment CC during week 1. The acidotic condition of these calves during week 1 could have been caused by the consumption of a dry feed that did not have any supplemental potassium or buffer.

The high serum potassium level during week 1 of the calves in treatment KB may have been due to potassium intake. The calves in treatment KB consumed more prestarter and starter than the calves in treatments CC, CB and KC during week 1. The intake of a ration with supplemental potassium increased the serum potassium level in sheep (Kunkel et al., 1953). This was contradicted by the results of a study by Fontenot et al. in 1960.

Following weaning, an increase in starter consumption occurs. This increase in dry feed consumption can cause lactic acidosis (Kaneko, 1980). The calves in treatment CC had lower (P<.05) venous blood pH, pCO_2 and HCO_3 values during week 4 than during week 3. These values were also lower (P<.05) of calves than the same values in the other treatments. The change that occurred in the pCO_2 value suggests the calves in treatment CC were compensating for their acidotic condition (Kaneko, 1980).

Over the six week trial the calves in treatment KB did not have a change (P<.05) in venous blood pH, pCO_2 or HCO_3. The maintenance of relatively constant pH and HCO_3 of the calves in treatment KB is consistant with the results of McSherry and Gimyer (1954). They observed no difference in pH and HCO_3 values obtained from 4-day to 10 month old calves when compared to values obtained from 2 to 13 year old cows. Butler et al. (1971) observed no change in blood gases from calves at 3 days of age when compared to samples from calves that were 10 days old. These calves also obtained adult red blood cell sodium and potassium levels and an adult sodium to potassium ratio a week sooner than the calves in treatments CC, CB and KC, suggesting that the potassium and supplement buffer aided the calves in maintaining homeostasis during the physical and physiological changes that occur from birth to 6 weeks of age. This is further emphasized by the fact that of the four calves that were treated for acidosis three were in treatment group CC. The other calf was in treatment group KC.

I would recommend the addition of KCl and $KHCO^3$ in the ration fed to early weaned calves. Further research is needed to evaluate the optimum amount of KCl and/or $KHCO_3$ that needs to be present in the prestarter and starter, respectively.

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Table 1. Composition and analysis of control prestarter in trial 1.

Ingredient[1]	Percent	Nutrient	Percent
Whey, dried	46.0	Crude protein	22
7 - 60[2]	23.0	Crude fat	12
Skim milk, dried	19.0		
Sodium caseinate	12.0		
Additives	+		

1 Buffered prestarter differed only in that it contained 3% sodium bicarbonate.

2 Mixture of milk solids and fat containing 7% protein and 60% animal fat

Table 2. Composition and analysis of starter[1] in trial 1.

Ingredient	Percent	Nutrient	Percent of Dry Matter
Alfalfa hay	25.0	Crude protein	15.61
Oats	20.0	Moisture	7.20
Corn	30.0	Fat	3.36
Sorghum grain	7.5	Acid detergent fiber	19.95
Soybean meal	10.0		
Molasses, dry	5.0		
Mineral supplement[2]	1.5		
Vitamin supplement[3]	1.0		

[1]Pellets were 4.8 mm in diameter.

[2]Supplied 3.2 kg dical, 1.4 kg limestone, 1.1 kg salt and 1.14 kg trace mineral salt/454 kg complete diet.

[3]Supplied 1 million IU vitamin A, 150,000 IU vitamin D_3 and .98 g sodium selenite/454 kg complete diet.

Table 3. Composition of starter[1] in trial 1.

	%	
Ingredient	$KHCO_3$	Control
Dehydrated alfalfa	25.0	25.0
Oats	20.0	20.0
Corn	30.0	30.0
Sorghum	6.5	7.5
Soybean meal	10.0	10.0
Molasses, dry	5.0	5.0
Mineral supplement[2]	2.5	1.5
Vitamin supplement[3]	1.0	1.0

[1]Pellets were 4.8 mm in diameter.

[2]Supplied 4.6 kg potassium bicarbonate in $KHCO_3$ starter, 3.2 kg dical, 1.36 kg limestone, 1.14 kg salt and 1.14 kg trace mineral salt/454 kg complete diet.

[3]Supplied 1 million IU vitamin A, 150,000 IU vitamin D_3, .98 g sodium selenite/454 kg complete diet.

Table 4. Analysis[1] of starter in trial 1.

	%	
Nutrient	$KHCO_3$	Control
Moisture	10.81	10.47
Protein	16.87	16.30
Fat	3.28	3.21
Crude fiber	10.55	11.11
Ash	6.77	6.37
Nitrogen free extract	62.52	63.02
Acid detergent fiber	13.19	13.89
Sodium (ppm)	3091.02	2864.72
Potassium	1.52	1.21

[1]As fed basis.

Table 5. Mean starter consumption (kg) ± SE of calves in trial 1.

Week	Control prestarter	$NaHCO_3$ prestarter	p[1]
1	.05 ± .03	.05 ± .03	.94
2	.16 ± .10	.21 ± .10	.71
3	.86 ± .25	1.11 ± .25	.55
4	4.48 ± .44	5.47 ± .46	.33
5	8.31 ± .46	9.63 ± .48	.06
6	11.98 ± .58	12.53 ± .60	.52
Overall mean	4.37 ± .23	4.83 ± .24	.17

[1]Probability of a difference between treatments.

Table 6. Mean weight gain (kg) ± SE of calves in trial 1.

Week	Control prestarter	$NaHCO_3$ prestarter	p[1]
1	2.09 ± .45	2.18 ± .47	.89
2	2.25 ± .72	0.52 ± .74	.11
3	2.44 ± .57	3.18 ± .59	.38
4	3.50 ± .63	3.74 ± .64	.80
5	5.53 ± .74	7.10 ± .77	.16
6	7.26 ± .75	5.92 ± .78	.23
Overall mean	3.85 ± .23	3.77 ± .24	.83

[1]Probability of a difference between treatments.

Table 7. Mean starter consumption (kg) ± SE of calves in trial 2.

Week	Control prestarter: Control starter	Control prestarter: $KHCO_3$ starter	KCl prestarter: Control starter	KCl prestarter: $KHCO_3$ starter	P[1]
1	.06 ± .05	.11 ± .05	.04 ± .04	.14 ± .05	.39
2	.19[ab] ± .07	.18[a] ± .07	.07[a] ± .06	.32[b] ± .08	.01
3	.95 ± .11	1.51 ± .47	1.38 ± .36	1.56 ± .56	.34
4	3.97 ± .55	4.45 ± .54	3.54 ± .60	4.28 ± .57	.57
5	6.01 ± .76	7.79 ± 1.17	6.45 ± .88	6.99 ± .74	.36
6	9.03 ± .85	9.73 ± 1.49	9.47 ± 1.07	9.61 ± .69	.84
Overall mean	3.37 ± .50	3.96 ± .60	3.49 ± .54	3.81 ± .53	.98

[a,b]Means in a row bearing different superscripts differ (P<.05).

[1]Probability of a difference between treatments.

Table 8. Mean weight gain (kg) ± SE of calves in trial 2.

	Control prestarter		KCl prestarter			
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	+SE	P[1]
1	1.76	2.07	1.28	2.32	1.94	.42
2	1.36	1.76	1.46	2.27	1.79	.49
3	3.28	3.88	2.72	2.77	3.89	.57
4	-0.40	0.50	0.55	0.55	8.72	.86
5	3.93	4.13	3.88	3.68	7.56	.99
6	4.69	5.90	5.14	5.19	12.27	.91
ADG	0.35	0.43	0.36	0.40	.03	.71

[1]Probability of a difference between treatments.

Table 9. Mean red blood cell sodium to potassium ratio $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P[1]
1	$0.24^{A} \pm .05$	$0.29^{A} \pm .03$	$0.28^{A} \pm .04$	$0.27^{A} \pm .05$	.93
2	$0.36^{B} \pm .06$	$0.46^{B} \pm .04$	$0.46^{B} \pm .04$	$0.46^{B} \pm .06$	.88
3	$0.59^{C} \pm .07$	$0.61^{C} \pm .05$	$0.60^{C} \pm .03$	$0.63^{C} \pm .05$	.93
4	$0.75^{D} \pm .08$	$0.75^{D} \pm .06$	$0.80^{D} \pm .04$	$0.83^{D} \pm .05$	.86
5	$0.93^{E} \pm .09$	$0.96^{E} \pm .10$	$0.93^{E} \pm .06$	$1.05^{E} \pm .12$	.92
6	$1.11^{F} \pm .08$	$1.13^{F} \pm .11$	$1.12^{F} \pm .07$	$1.15^{E} \pm .09$	.99

[A,B,C,D,E,F] Means in a column bearing different superscripts differ ($P<.05$).

[1] Probability of a difference between treatments.

Table 10. Mean serum sodium (meq/l) $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P[1]
1	$126.4^{AB} \pm 4.2$	$125.7^{ABC} \pm 9.9$	$118.1^{A} \pm 6.0$	124.3 ± 7.9	.85
2	$120.8^{B} \pm 5.3$	$118.7^{A} \pm 7.4$	$130.6^{B} \pm 6.5$	125.3 ± 4.2	.50
3	$123.1^{B} \pm 5.4$	$121.8^{AC} \pm 5.1$	$125.1^{AB} \pm 7.7$	126.9 ± 4.2	.87
4	$127.0^{AB} \pm 6.7$	$131.7^{BC} \pm 4.8$	$129.0^{B} \pm 3.1$	124.1 ± 4.5	.59
5	$127.9^{AB} \pm 4.8$	$132.8^{B} \pm 4.1$	$127.2^{BC} \pm 4.7$	124.4 ± 5.9	.62
6	$133.2^{A} \pm 2.4$	$129.0^{BC} \pm 4.2$	$124.6^{AB} \pm 5.2$	128.3 ± 4.7	.64
Overall mean	126.4 ± 2.0	126.7 ± 2.4	125.8 ± 2.3	125.6 ± 2.12	.30

[A,B,C]Means in a column bearing different superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Table 11. Mean serum potassium (meq/l) ± SE of calves in trial 2.

Week	Control prestarter: Control starter	Control prestarter: $KHCO_3$ starter	KCl prestarter: Control starter	KCl prestarter: $KHCO_3$ starter	P[1]
1	$8.38^{A} \pm 1.05$	6.64 ± 1.64	7.01 ± 1.10	$8.70^{A} \pm 1.19$	.60
2	$5.54^{BC} \pm 0.89$	6.34 ± 0.63	6.47 ± 1.06	$6.54^{AB} \pm 0.53$	.82
3	$5.88^{BC} \pm 0.73$	5.30 ± 0.89	6.08 ± 1.23	$5.81^{B} \pm 0.60$	.95
4	$7.66^{AC} \pm 1.03$	5.54 ± 1.01	5.81 ± 0.67	$6.55^{AB} \pm 1.37$	.48
5	$5.52^{BC} \pm 0.76$	6.42 ± 1.04	6.57 ± 0.83	$6.77^{AB} \pm 1.58$	.95
6	$5.88^{BC} \pm 0.58$	5.07 ± 0.80	5.28 ± 0.55	$6.28^{B} \pm 0.45$	.74
Overall mean	6.48 ± 0.37	5.83 ± 0.39	6.20 ± 0.37	6.78 ± 0.45	.91

^{A,B,C}Means in a column bearing different superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Table 12. Mean serum sodium to potassium ratio $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P^1
1	17.0 ± 2.2	$25.5^{A} \pm 6.8$	$19.7^{B} \pm 2.6$	16.1 ± 1.7	.23
2	27.8 ± 5.4	$19.7^{A} \pm 1.4$	$24.6^{B} \pm 4.0$	20.1 ± 1.7	.31
3	25.0 ± 4.8	$67.6^{B} \pm 42.2$	$62.1^{A} \pm 39.0$	23.1 ± 1.8	.65
4	19.7 ± 3.3	$33.3^{AB} \pm 7.7$	$27.3^{AB} \pm 6.5$	27.3 ± 7.0	.53
5	37.6 ± 15.4	$28.5^{A} \pm 6.8$	$22.4^{B} \pm 3.4$	29.6 ± 9.6	.80
6	25.3 ± 3.7	$36.1^{AB} \pm 9.6$	$25.3^{B} \pm 2.3$	23.2 ± 2.1	.38
Overall mean	25.4 ± 3.0	35.5 ± 7.7	30.2 ± 6.7	23.2 ± 2.0	.82

^{A,B,C}Means in a column bearing different superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Table 13. Mean venous blood pH ± SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P[1]
1	7.297^{A} ± .02	7.360^{A} ± .02	7.348 ± .01	7.352 ± .01	.11
2	7.322^{AC} ± .01	7.320^{BC} ± .02	7.351 ± .01	7.348 ± .01	.29
3	7.356^{BC} ± .01	7.365^{A} ± .01	7.342 ± .02	7.347 ± .01	.44
4	7.315^{A} ± .02	7.352^{AC} ± .01	7.344 ± .01	7.340 ± .01	.35
5	7.363^{B} ± .01	7.354^{AC} ± .01	7.361 ± .01	7.365 ± .01	.89
6	7.371^{B} ± .01	7.363^{A} ± .01	7.367 ± .01	7.366 ± .01	.42
Overall mean	7.337 ± .01	7.352 ± .01	7.352 ± .01	7.350 ± .01	.11

^{A,B,C}Values in a column bearing different superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Table 14. Mean venous blood bicarbonate (meq/l) $\pm$ SE of calves in trial 2.

	Control prestarter				KCl prestarter				
Week	Control starter		$KHCO_3$ starter		Control starter		$KHCO_3$ starter		P[1]
1	25.06^{aA}	$\pm$ 1.43	29.94^{b}	$\pm$ 0.93	28.13^{bAC}	$\pm$ 0.48	29.60^{b}	$\pm$ 1.08	.01
2	27.61^{ABC}	$\pm$ 0.98	28.59^{ac}	$\pm$ 0.56	30.63^{bB}	$\pm$ 0.52	29.87^{c}	$\pm$ 0.74	.03
3	28.80^{B}	$\pm$ 0.50	28.91	$\pm$ 0.56	28.82^{AB}	$\pm$ 0.56	28.09	$\pm$ 0.71	.74
4	25.52^{aAC}	$\pm$ 1.90	29.01^{b}	$\pm$ 0.34	26.99^{abA}	$\pm$ 1.12	28.47^{ab}	$\pm$ 0.81	.18
5	29.64^{B}	$\pm$ 0.91	28.94	$\pm$ 0.42	29.40^{BC}	$\pm$ 0.69	29.67	$\pm$ 0.59	.86
6	28.93^{B}	$\pm$ 0.55	28.98	$\pm$ 0.70	29.30^{AB}	$\pm$ 0.67	29.10	$\pm$ 0.76	.98
Overall mean	27.59	$\pm$ 0.51	29.05	$\pm$ 0.24	28.87	$\pm$ 0.32	29.15	$\pm$ 0.32	.03

[a,b,c]Means in a row bearing different lower case superscripts differ ($P<.05$).

[A,B,C]Means in a column bearing different upper case superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Table 15. Mean venous blood partial pressure of carbon dioxide (mm Hg) $\pm$ SE of calves in trial 2.

Week	Control prestarter: Control starter	Control prestarter: $KHCO_3$ starter	KCl prestarter: Control starter	KCl prestarter: $KHCO_3$ starter	P[1]
1	$53.32^{AB} \pm 3.62$	$55.06^{ABC} \pm 1.86$	$53.28^{AB} \pm 1.44$	55.38 ± 2.00	.95
2	$55.22^{B} \pm 1.48$	$58.17^{A} \pm 2.22$	$57.67^{A} \pm 1.67$	56.69 ± 1.25	.60
3	$53.56^{AB} \pm 1.44$	$52.56^{B} \pm 1.30$	$55.67^{AB} \pm 2.64$	53.10 ± 0.95	.60
4	$50.68^{aAB} \pm 1.66$	$54.37^{bABC} \pm 0.90$	$51.32^{abB} \pm 1.57$	$54.92^{b} \pm 1.95$	.04
5	$54.30^{B} \pm 1.89$	$53.93^{ABC} \pm 0.68$	$53.97^{AB} \pm 1.08$	54.01 ± 1.30	.99
6	$49.66^{A} \pm 2.98$	$52.88^{C} \pm 0.98$	$53.05^{AB} \pm 1.40$	55.21 ± 1.57	.32
Overall mean	52.79 ± 0.94	54.48 ± 0.61	54.18 ± 0.72	54.89 ± 0.62	.82

[a,b,c] Means in a row bearing different lower case superscripts differ (P<.05).

[A,B,C] Means in a column bearing different upper case superscripts differ (P<.05).

[1] Probability of a difference between treatments.

Table 16. Mean venous blood base excess (meq/l) $\pm$ SE of calves in trial 2.

Week	Control prestarter: Control starter	Control prestarter: $KHCO_3$ starter	KCl prestarter: Control starter	KCl prestarter: $KHCO_3$ starter	P[1]
1	$-0.24^{aA} \pm 1.59$	$5.28^{b} \pm 1.14$	$3.42^{bAB} \pm 0.63$	$4.59^{b} \pm 1.03$	.01
2	$2.38^{aBC} \pm 1.07$	$3.12^{ac} \pm 0.63$	$5.59^{bA} \pm 0.52$	$4.86^{c} \pm 0.75$	.02
3	$3.97^{B} \pm 0.49$	4.31 ± 0.64	$3.84^{AB} \pm 0.54$	3.14 ± 0.69	.57
4	$0.23^{AC} \pm 2.18$	4.03 ± 0.34	$2.19^{B} \pm 1.18$	3.40 ± 0.87	.21
5	$4.73^{B} \pm 0.87$	3.99 ± 0.46	$4.48^{AB} \pm 0.74$	4.72 ± 0.56	.85
6	$4.33^{B} \pm 0.76$	4.23 ± 0.69	$4.55^{AB} \pm 0.73$	4.10 ± 0.82	.98
Overall mean	2.57 ± 0.57	4.14 ± 0.28	4.00 ± 0.33	4.14 ± 0.32	.03

[a,b,c]Means in a row bearing different lower case superscripts differ ($P<.05$).

[A,B,C]Means in a column bearing different upper case superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Figure 1. Red blood cell sodium (meq/l).

□ CC
■ CB
○ KC
● KB

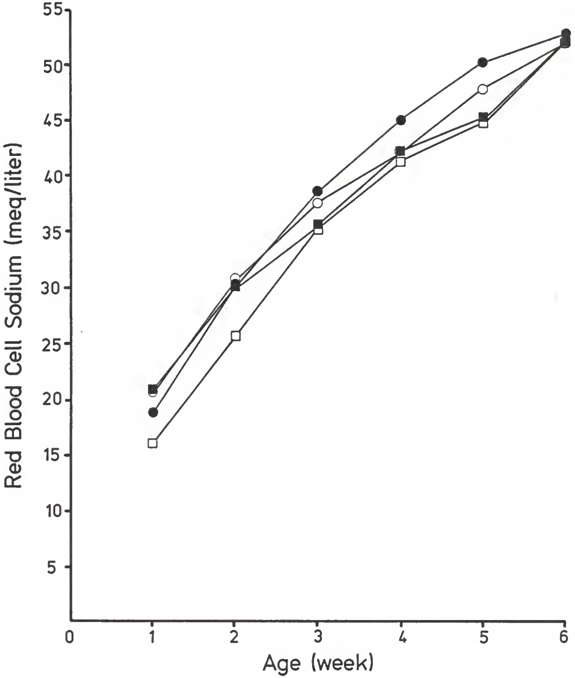
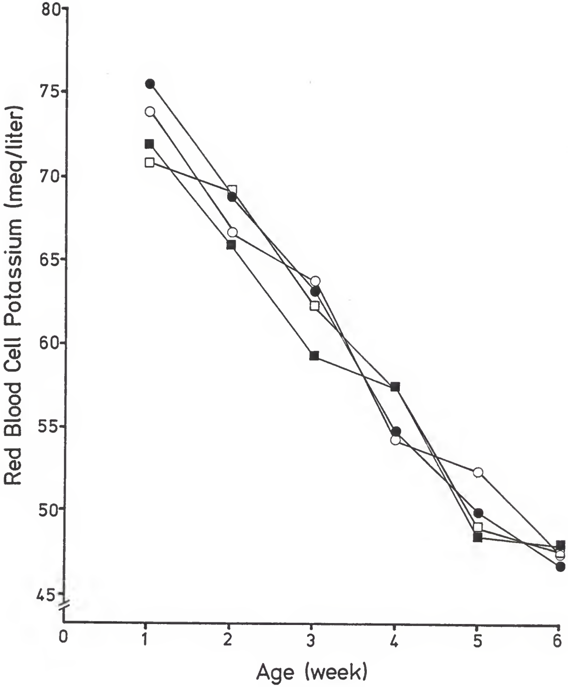

55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
Red Blood Cell Sodium (meq/liter)
Age (week)

Figure 2. Red blood cell potassium (meq/l).

□ CC
■ CB
○ KC
● KB


80
75
70
65
60
55
50
45
Red Blood Cell Potassium (meq/liter)
0
1
2
3
4
5
6
Age (week)

APPENDIX

Appendix Table I. Mean prestarter consumption (kg) ± SE of calves in trial 1.

Week	Control prestarter	Buffered prestarter	P[1]
1	.45 ± .12	.41 ± .12	.81
2	.65 ± .11	.52 ± .12	.42
3	1.21 ± .09	1.24 ± .10	.80
4	1.3 ± .06	1.38 ± .06	.36
5	1.43 ± .06	1.36 ± .06	.45
6	1.43 ± .02	1.41 ± .03	.55
Overall mean	1.08 ± .04	1.05 ± .04	.65

[1]Probability of a difference between treatments.

Appendix Table II. Mean fecal consistency ± SE of calves in trial 1.

Week	Control prestarter	Buffered prestarter	P[1]
1	1.7 ± .1	1.7 ± .1	.97
2	2.2 ± .2	2.5 ± .2	.27
3	1.6 ± .1	1.5 ± .1	.34
4	1.3 ± .1	1.3 ± .1	.80
5	1.2 ± .1	1.2 ± .1	1.00
6	1.1 ± .1	1.1 ± .1	.66

[1]Probability of a difference between treatments.

Appendix Table III. Mean prestarter consumption (kg) ± SE of calves in trial 2.

Week	Control prestarter		KCl prestarter		
	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P[1]
1	.38 ± .10	.38 ± .07	.30 ± .07	.38 ± .11	.91
2	.68 ± .06	.53 ± .10	.61 ± .10	.68 ± .13	.72
3	1.13 ± .05	1.10 ± .08	1.20 ± .08	1.09 ± .12	.71
4	1.14 ± .07	1.21 ± .05	1.07 ± .09	1.22 ± .06	.22
5	1.26 ± .05	1.30 ± .04	1.30 ± .03	1.34 ± .01	.49
6	1.34 ± .03	1.24 ± .12	1.30 ± .04	1.34 ± .04	.65
Overall mean	.98 ± .05	.99 ± .05	.97 ± .06	1.01 ± .06	.89

[1]Probability of a difference between treatments.

Appendix Table IV. Mean fecal consistency $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P[1]
1	1.9 $\pm$ .1	1.9 $\pm$ .1	2.1 $\pm$ .1	2.0 $\pm$ .1	.77
2	2.7 $\pm$ .2	2.4 $\pm$ .1	2.4 $\pm$ .2	2.4 $\pm$ .2	.18
3	1.7 $\pm$ .1	1.7 $\pm$ .1	1.6 $\pm$ .1	1.7 $\pm$ .1	.74
4	2.0 $\pm$ .2	1.6 $\pm$ .1	1.4 $\pm$ .2	1.6 $\pm$ .2	.35
5	1.9 $\pm$ .2	1.4 $\pm$ .1	1.6 $\pm$ .1	1.6 $\pm$ .1	.61
6	1.3 $\pm$ .1	1.5 $\pm$ .2	1.4 $\pm$ .1	1.2 $\pm$ .1	.61
Overall mean	1.9 $\pm$ .1	1.7 $\pm$ .1	1.7 $\pm$ .1	1.8 $\pm$ .1	.52

[1]Probability of a difference between treatments.

Appendix Table V. Mean red blood cell sodium (meq/l) $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P[1]
1	$16.09^{A} \pm 3.10$	$20.74^{A} \pm 2.05$	$20.54^{A} \pm 2.56$	$18.90^{A} \pm 3.10$	.71
2	$25.68^{B} \pm 3.14$	$29.83^{B} \pm 2.20$	$30.46^{B} \pm 1.98$	$30.29^{B} \pm 2.73$	.82
3	$35.09^{C} \pm 2.34$	$35.50^{C} \pm 1.94$	$37.64^{C} \pm 1.48$	$38.60^{C} \pm 1.53$	.59
4	$41.34^{D} \pm 2.83$	$41.98^{C} \pm 2.40$	$42.19^{C} \pm 1.19$	$45.03^{D} \pm 2.46$	.78
5	$44.61^{D} \pm 2.95$	$45.10^{D} \pm 2.89$	$47.70^{D} \pm 0.83$	$50.11^{E} \pm 3.66$	.70
6	$52.02^{E} \pm 2.30$	$51.98^{E} \pm 2.56$	$52.02^{D} \pm 2.13$	$52.83^{F} \pm 2.68$	.99
Overall mean	35.91 ± 2.00	37.80 ± 1.72	38.52 ± 1.64	39.31 ± 1.98	.97

[A,B,C,D,E]Means in a column bearing different superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Appendix Table VI. Mean red blood cell potassium (meq/l) $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P^1
1	$70.83^A \pm 4.22$	$71.90^A \pm 2.92$	$73.75^A \pm 3.79$	$75.58^A \pm 5.47$	.93
2	$69.22^A \pm 3.87$	$65.88^B \pm 2.87$	$66.67^B \pm 3.05$	$68.87^B \pm 4.99$	.93
3	$62.43^B \pm 3.77$	$59.38^C \pm 2.86$	$63.70^B \pm 2.64$	$63.16^B \pm 4.66$	.84
4	$57.38^B \pm 3.84$	$57.38^C \pm 3.09$	$54.33^C \pm 2.30$	$54.73^C \pm 2.35$	.85
5	$49.06^C \pm 2.18$	$48.60^D \pm 2.45$	$52.53^{CD} \pm 2.65$	$49.99^{CD} \pm 3.37$	.77
6	$47.73^C \pm 2.10$	$47.86^D \pm 2.71$	$47.41^D \pm 2.41$	$46.81^D \pm 2.17$	.99
Overall mean	59.46 ± 1.84	58.24 ± 1.64	59.60 ± 1.67	59.79 ± 2.12	.84

^{A,B,C,D}Means in a column bearing different superscripts differ ($P<.05$).

^{1}Probability of a difference between treatment.

Appendix Table VII. Mean venous blood carbon dioxide count (mmol/l) $\pm$ SE of calves in trial 2.

Week	Control prestarter: Control starter		Control prestarter: $KHCO_3$ starter		KCl prestarter: Control starter		KCl prestarter: $KHCO_3$ starter		P^1
1	26.69^{aA}	$\pm$ 1.49	31.60^{b}	$\pm$ 0.94	29.77^{bAC}	$\pm$ 0.48	31.26^{b}	$\pm$ 1.12	.01
2	29.28^{aBC}	$\pm$ 1.00	30.38^{ab}	$\pm$ 0.57	32.39^{bB}	$\pm$ 0.55	31.68^{c}	$\pm$ 0.76	.03
3	30.43^{B}	$\pm$ 0.53	30.50	$\pm$ 0.58	30.53^{AB}	$\pm$ 0.61	29.71	$\pm$ 0.73	.75
4	27.09^{aAC}	$\pm$ 1.95	30.64^{b}	$\pm$ 0.37	28.57^{abA}	$\pm$ 1.16	30.14^{ab}	$\pm$ 0.84	.18
5	31.31^{BC}	$\pm$ 0.95	30.60	$\pm$ 0.43	31.60^{BC}	$\pm$ 0.71	31.36	$\pm$ 0.62	.86
6	30.52^{B}	$\pm$ 0.56	30.58	$\pm$ 0.70	30.93^{AB}	$\pm$ 0.70	30.67	$\pm$ 0.74	.98
Overall mean	29.22	$\pm$ 0.52	30.70	$\pm$ 0.24	30.53	$\pm$ 0.33	30.80	$\pm$ 0.33	.04

[a,b,c]Means in a row bearing different lower case superscripts differ ($P<.05$).

[A,B,C]Means in a column bearing different upper case superscripts differ ($P<.05$).

[1]Probability of a difference between treatments.

Appendix Table VIII. Mean packed cell volume $\pm$ SE of calves in trial 2.

	Control prestarter		KCl prestarter		
Week	Control starter	$KHCO_3$ starter	Control starter	$KHCO_3$ starter	P^1
1	32.3 ± 2.1	33.9 ± 1.8	$37.9^{AB} \pm 2.2$	35.3 ± 1.6	.22
2	33.3 ± 2.5	36.0 ± 1.9	$36.8^{B} \pm 1.8$	34.7 ± 1.3	.62
3	32.1 ± 2.3	35.3 ± 1.6	$37.4^{B} \pm 1.6$	34.4 ± 0.9	.18
4	34.8 ± 1.5	36.8 ± 1.7	$40.4^{A} \pm 2.2$	36.9 ± 1.0	.17
5	33.4 ± 1.4	36.2 ± 1.6	$35.2^{B} \pm 1.51$	34.3 ± 1.0	.80
6	31.8 ± 1.0	32.7 ± 1.13	$33.0^{B} \pm 1.70$	33.4 ± 0.8	.73

^{A,B}Means in a column bearing different upper case superscripts differ ($P<.05$).

^{1}Probability of a difference between treatments.

USE OF BUFFERS AND SUPPLEMENTAL POTASSIUM IN AN EARLY WEANING PROGRAM

by

KIM JOANN JORDAN

B.S., Kansas State University, 1983

AN ABSTRACT OF A MASTER'S THESIS

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The Use of Buffers and Supplemental Potassium in an Early Weaning Program

ABSTRACT

Two trials were conducted to evaluate the effects of different buffers and mineral supplements in feeds used in an early weaning program, utilizing a prestarter feed. Calves in both trials were placed on trial at 1 to 3 days of age. In the first trial the control prestarter and prestarter containing 3% sodium bicarbonate ($NaHCO_3$) as buffer were compared. The buffered prestarter was readily consumed. Calves fed buffered prestarter consumed more starter, but the difference was not significant. These calves did not gain as much weight as the control calves during weeks 2 and 6. In the second trial the treatments were: control prestarter plus control starter (CC), control prestarter plus starter containing 2.0% potassium bicarbonate (CB), prestarter containing 1.5% potassium chloride plus control starter (KC) and prestarter containing 1.5% potassium chloride plus starter containing 2.0% potassium bicarbonate (KB). Feeds containing supplementary potassium were consumed readily. The calves fed the diets containing both of the potassium sources consumed more ($P<.05$) starter during week 2. The control calves lost weight the week following weaning. A tendency for increased starter consumption was apparent when $NaHCO_3$, $KHCO_3$ or KCl was used in a early weaning program. Potassium bicarbonate in the starter tended to improve weight gain. The second trial was also conducted to evaluate the changes in blood parameters of calves fed supplemental potassium in an

early weaning program utilizing a prestarter feed. There were no differences ($P>.05$) between treatments regarding red blood cell and serum sodium and potassium levels. The calves in treatment CC had a lower ($P=.11$) venous blood pH over the 6 week trial then calves in the other treatments. Venous blood bicarbonate ion (HCO_3) levels were different between treatments in weeks 1 ($P=.01$), 2 ($P=.03$) and 4 ($P=.18$) and within ($P<.05$) treatments CC and KC during the 6 week trial. Calves in treatments CB and KB maintained relatively constant blood HCO_3 levels throughout the 6 week trial. Calves in treatments CC, CB and KC did not maintain a constant partial pressure of carbon dioxide (pCO_2) whereas calves in treatment KB maintained a relatively constant pCO_2 level. Results of this study show a benefit from feeding supplementary potassium and buffer in aiding the calf to maintain homeostasis.