QUANTITY OF MILK, METHOD OF WEANING, AND POTASSIUM AND BUFFER SUPPLEMENTATION IN STARTER DIETS ON DAIRY CALVES IN AN EARLY WEANING PROGRAM

by

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CHAPTER 1.

FACTORS CONCERNING QUANTITY OF MILK FED AND METHOD OF WEANING ON RESPONSES OF DAIRY CALVES

Introduction

Young calves require a highly concentrated source of nutrients that can be digested easily by enzymes and secretions of the abomasum, pancreas, salivary glands, and intestinal tract (Otterby, 1983). At birth the calf secretes large quantities of lactase, but the amount secreted decreases with age (Radostits and Bell, 1970). This may reflect, to some extent, the animals decreasing dependency on milk. Pancreatic proteases, lipase and amylase increase during the first weeks of life. The increased secretions allow the calf to digest a larger variety of feedstuffs (Otterby, 1983). The rumen of the newborn calf is not fully developed anatomically, physically, or microbially, and dry feed fermentation end products and fiber are responsible for rumen development (Brownlee, 1956; Lengemann and Allen, 1959; Tamate et al., 1961; Sander et al., 1959).

Weaning is designated as the time that liquid feeding is completely terminated and only dry feed is fed to calves. Dry feed consumption at an early age allows for earlier weaning and should be encouraged (Morrill, 1977).

Early Weaning

An early weaning program refers to a program that enables the dairyman to wean replacement heifers earlier than the current average weaning age of 5 to 11 wk reported by Ainslie and Bringe (1981). Two approaches of early weaning programs have been the development of prestarters, and increasing palatability of starters.

An early weaning program developed at Kansas State University utilizes an all-milk product prestarter that is palatable to the young calf. It is fed in small amounts and encourages consumption of a less expensive starter (Morrill, 1984).

Starters should be palatable and provide adequate nutrients to the calf. Composition of starters has been studied extensively. A properly balanced simple starter supported growth as well as a more complex starter (Gardner, 1967; Harrison et al., 1960; Miller et al., 1969). Grains that are coarsely ground or rolled are preferred by calves over a finely ground mixture (Otterby, 1983; Morrill, 1977).

Benefits. Studies involving weaning calves at early ages have produced varying results. Studies done as early as 1929 (Bender and Bartlett) showed that calves could be weaned as early as 30 d. Many early weaning studies have been reported since then, which show benefits over conventional weaning. These benefits include earlier ruminal development and capacity (Tamate et al., 1961; Lengemann and Allen, 1959; Poe et al., 1969; Anderson et al., 1987), decreased labor and feed costs (Davies and Owen, 1967; Harrison et al., 1960; Caffrey, 1974), and decreased incidence of digestive disturbances (Roy, 1964; Hart and Curran, 1964; Leaver and Yarrow, 1972; Jorgenson et al., 1970).

Winter (1978) weaned Ayrshire calves at 2, 3 or 5 wk and Holstein calves at 2.5, 3, 3.5, 4 or 5 wk of age. He found no significant differences in weight gains or feed intake due to treatment of Ayrshires or Holsteins to 15 or 12 wk of age, respectivley. There was a growth check, after weaning, observed in calves weaned before three weeks. Therefore, Winter recommended weaning healthy calves at 3 wk of age.

Jorgenson et al. (1970) found no differences in weight gains at 26 wk when calves were weaned at 3, 5 or 7 wk. Calves weaned at 3 wk consumed more ($P<.01$) starter than the calves weaned at 5 or 7 wk. Efficiency of growth, as measured by body weight gain/megacalorie net energy intake, was not affected by weaning age. O'Donovan (1963) compared weaning at 3 wk with weaning at 11 wk. The conventionally weaned calves gained more ($P<.05$) weight from birth to 12 weeks. The daily live weight gain for the earlier weaned calves was, however, over 454 g gain/day, which concurs with current suggested daily gains (NRC, 1988). Feed and labor costs were considerably lower for the earlier weaned calves. Harte and Curran (1964) compared early weaning (milk fed at 10% of body weight until 28 d and then 5% of bodyweight from 29-35 d) with a traditional program of milk fed at 10% body weight until d 84, using a mixture of whole and skim milk. After 84 days, no significant differences in live weight gains or wither height were noted between groups. The early weaned calves had greater ($P<.01$) chest girth measurements.

Owen and Larson (1982) compared weaning at 42 d or 21 d. Daily weight gains to 6 weeks for the calves weaned at 42 d were greater than for the early weaned (.46 kg vs .37 kg). Dry feed consumption was 36% higher for the early weaned group during this time. Growth measurements at 6 months and older did not differ significantly. Services/conception and 305 day mature equivalent milk yields were similar for both treatments.

Quigley et al. (1985) found a significant age x treatment interaction with respect to dry feed intake for calves weaned at 4 vs 8 weeks. Feed intake tended to be higher between 4-7 weeks for calves weaned at 4 weeks of age. Feed intake from week 9 to 11 was similar between treatment groups.

Hibbs and Conrad (1978), in a series of studies comparing different roughage sources in starters, concluded that calves could be weaned as successfully at 3 weeks as at 7 weeks when the starter was adequately supplemented.

Klein and Kincaid (1986) weaned heifers at 2 or 4 weeks of age and observed no treatment differences with regard to final (age unspecified) body weight, plasma glucose, blood urea nitrogen or acetate:propionate ratio.

Adverse Effects. DePeters et al. (1986), in studying the effect of dry whey added to starter, found calves weaned at 35 d gained less (.61 k/day vs .74 k/day; P<.05) during 14 weeks than calves weaned at 70 d. Wither height at 14 weeks in the early weaned calves was also lower (14.1 cm vs 17 cm, P<.05)).

Quantity of Milk Fed

It has frequently been stated that if calves are to be weaned at an early age they should be encouraged to eat dry feed as soon as possible to stimulate rumen development (Morrill, 1977; Morrill et al., 1981; Hogdson, 1965). Many researchers have found that feeding higher quantities of milk to calves increases preweaning live weight gains (Dalzell and Allen, 1970; Fischer et al., 1985; Hodgson, 1971; Harte and Fallon, 1984; Harrison et al., 1960; Huber et al,. 1984); however, this also results in a decrease in preweaning dry feed consumption (Caffrey, 1974; Gleeson and Cliffe, 1981; Leaver and Yarrow, 1972). Low dry feed intake at weaning, resulting in poor growth during the postweaning period, may negate any positive inital live weight gain incurred from feeding high quantities of milk (Kaiser, 1976; Jenny et al., 1982; Caffrey, 1974). Kaiser (1976) studied the effects of feeding calves milk at 8, 10, 12, or 14% of live weight daily. Calves had constant access to pasture and were weaned at 12 weeks. Preweaning gains, weaning live weight and carcass weight at weaning all increased as percent milk fed increased. However, calves fed high levels of milk gained less up to 8 weeks postweaning. At 36 weeks live weights were not significantly different among treatments. At 12 weeks of age (at weaning) calves fed less milk had greater reticulo-rumen and omasum size when expressed as a percentage of total stomach weight. These calves also had a higher reticulo-rumen to abomasum ratio.

Jenny et al. (1982) fed milk to calves at 6, 8, or 10% of their body weight. Calves were weaned at 4 weeks and observed until 6 weeks. Their findings agree with those of Kaiser (1976). Feeding large quantities of milk resulted in higher preweaning gains, but decreased concentrate intake. There was a post- weaning check in growth of calves fed high quantities of milk, resulting in overall weight gains being similar. The calves fed milk at 8% of body weight exhibited a decreased incidence of scours at 2-3 weeks of life and tended to have slightly higher average daily gains and starter intake than calves in other treatment groups.

Fischer et al. (1985) compared milk fed at 8 vs 12% bodyweight. Keys et al. (1980) compared 10% vs 8%. In both cases, feeding the higher quantity (12% and 10%) of milk did not improve overall weight gains to 10 weeks and 30 days, respectively, as compared with 8%.

Dalzell and Allen (1970) concluded that overall gains were similar when feeding low quantities of milk as compared with medium or high. The authors suggested that part of the check on postweaning growth was due to incomplete development of functional forestomach tissue. In a study by Leaver and Yarrow (1972), calves offered a greater quantity of milk took a greater number of days to reach concentrate intake necessary for weaning.

Schingoethe et al. (1986) reported that during cold weather calves benefited from a greater quantity of milk. Calves fed 4.5 kg of milk/day had greater ($P<.05$) weight gain and dry feed intake from week 1 until week 10 than did calves fed 3.6 kg milk/day.

Fallon and Harte (1986) suggested that a calf could benefit from a greater quantity of milk replacer, (25 kg/wk vs 50 kg/wk), during it's preruminant and semiruminant stage, since during this time the calf is unable to utilitze sufficient quantities of dry feed. Their studies showed poor live weight gain from offering additional quantities of milk replacer after these stages. In their experiment, an extra 25 kg milk replacer per week was fed, during the period of 27-84 days, to calves that were already offered either 25 or 50 kg of milk replacer. The calves fed additional milk replacer had significantly reduced concentrate intake without significantly increased liveweight gains. Huber and coworkers (1984) found no benefit of steadily increasing the milk increment, up to 2 weeks, and then keeping a constant high quantity until weaning, as opposed to feeding a constant low quantity. Feed efficiency was similar in both treatments and feeding larger quantities of milk was deemed uneconomical.

Another study was done by Harte and Fallon (1984) in which Freisian bulls were put on either a high (50 kg) or low (25 kg) amount of milk replacer. Calves were weaned at 8 weeks and fed similarly until slaughtered at 104 weeks of age. The calves in the high (50 kg) group were significantly heavier from 8 weeks on than the low (25 kg) group. The high group produced heavier carcasses, which offset the higher cost of milk feeding.

Weaning Criteria

The three common criteria for determining weaning time in an early weaning program are age of calf, feed consumption, and weight of the calf. Depending on management practice, one or more of these may be used to determine when a calf will be weaned.

In 1965, Lawrence and Pearce studied the effects of certain variables on the performance of early weaned calves. They concluded that weaning at either a given live weight or at a given amount of concentrate intake produced optimal results. They recommended weaning when feed consumption reached 670 gm/day.

Fallon (1975) weaned calves using 5 different weaning programs. Calves were weaned either at 56 days of age, when consuming .70 kg feed for 3 consecutive days, when consuming 1.0 kg feed for 3 days, upon reaching 55 kg body weight, or upon reaching 65 kg body weight. Overall weight gains, (d 7-84), were greatest for calves weaned at 56 days, when body weight reached 65 kg, or when consuming 1.0 kg feed for three days. However, the calves weaned on basis of feed consumption (1.0 kg) were weaned one week earlier than calves weaned on age (56 days) or weight (65 kg). Owen and Plum (1968) also studied performance of calves as influenced by weaning according to age, weight gain or feed intake. Calves weaned according to age (21 d) or feed consumption (454 g/day) weaned sooner ($P<.05$) than calves weaned on weight (5.5 kg gain since birth). Method of weaning had no significant effect on weight gains, wither height or feed consumption at 12 weeks.

Warner (1970) recommended weaning when the calf is consuming 454 g -

670 g dry feed/day on a regular basis.

Many researchers have reported the successful weaning of calves on the basis of age (Preston, 1956; Winter, 1978; O'Donovan, 1963; Owen and Larson, 1982; Agabuwi et al., 1968). Harrison et al. (1960) fed calves at a rate of 114 kg milk over 5 weeks or 159 kg over 7 weeks. It was observed that 72% of the calves fed 114 kg milk gained over 454 g/day and 80% of the calves receiving 159 kg milk did the same. Twenty-seven percent of the calves on the 114 kg milk diet and 20% of those on the 159 kg milk diet gained less than 454 g/dy. The author concluded that the poorer performing calves would have profited by increased milk and therefore individual calf health and performance must be considered when weaning.

Methods of Weaning

Calves can be weaned either abruptly or gradually. Abruptly weaned calves are fed a specified quantity of milk during the preweaning period, then milk feeding is abruptly terminated. A gradual weaning program allows for a decrease in the amount of milk fed over a specified length of time prior to weaning.

Preston (1959) compared abrupt weaning at 21 d with gradual weaning at 31 d and found no overall marked difference in growth. O'Donovan (1963) studied the effects of abrupt weaning at 3 weeks with a "traditional" Irish weaning program of gradual weaning at 12 weeks. All abruptly weaned calves were fed 2.7 kg/milk/day for 3 weeks. The traditionally weaned calves were fed increasing amounts of milk starting from 2.7 kg and increasing to 4.5 kgs over the first 4 weeks and the amount was then gradually decreased to zero by 12 weeks. The traditionally weaned group gained significantly ($P<.05$) more weight than the early weaned calves over the 12 week period. However, daily live weight gains for both groups were over 454 g/day. Feeding and labor costs for the early weaned group were substantially lower.

Harte and Curan (1964) compared gradually early weaning at 5 weeks with abrupt weaning at 12 weeks. Gradually weaned calves were fed milk at 10% body weight to d 28 and 5% from d 28 to 35. Calves weaned abruptly were fed varying ratios of milk and skim milk at 10% body weight throughout the 12 weeks. Live weight gains and wither height gains from day 5 to day 84 were higher for the early weaned calves, but not significantly so. Chest girth gain from d 58-84 was greater (25.9 cm vs 21.0 cm, P<.01) for the early weaned calves. Overall meal consumption was higher in the early weaned group but hay consumption was greater for the traditional group.

Abrupt weaning is considered an acceptable practice (Otterby and Linn, 1983) and usually stimulates dry feed consumption. Gradual weaning, however, may decrease stress associated with weaning (Hodgson, 1965).

Stress Associated With Weaning

Weaning is a stressor to the young calf. One way to measure the degree of stress a calf suffers during the weaning period is to measure adrenal response to adrenocortocortrophic hormone. Kilgour and Delangen (1970) defined stress as a generic term for immensely dissimilar events which have the common property of stimulating adrenocorticotrophic hormone (ACTH) secretion. They cite a definition and mnemonic, as suggested by Amoroso (1967), for stress as Situations That Release Emergency Signals necessary for Survival.

Stressors such as trauma, infection, intense heat or cold, injection of sympathomimetic drugs, restraint, or surgery cause an immediate increase in ACTH secretion by the anterior pituitary followed shortly by a large increase in secretion of cortisol from the adrenal gland (Guyton, 1986). Guyton (1986) speculates that the reason for this surge is because of ability of glucocorticoids to rapidly mobilize stored amino acids and fats, making them available to the body for energy and synthesis of other compounds such as glucose. Laden et al. (1985) investigated the effects of stress, as a result of dehorning, on feed intake, growth, and blood constituents of calves. One group of calves was electrically dehorned at 8 weeks, while the control group remained horned through the 12 week trial period. There were no noted changes in feed intake or growth due to dehorning. Plasma cortisol levels peaked 30 minutes post dehorning and had returned to baseline after 2 hours.

Macaulay and Friend (1987) measured relative stress due to three castration methods (surgical, Burdizzo, or chemical). E'evated serum cortisols and decreased kicking and cantering in an open field test indicated increased stress due to treatment. Surgical castration was deemed the most stressful with Burdizzo and chemical causing less stress, respectively, to the calf.

Friend et al. (1985) measured adrenal response of confined calves by injecting exogenous ACTH. Blood was sampled at various times post injection and analyzed for cortisol. Calves were confined in either a stall, pen, hutch or yard. Stalled calves showed the greatest adrenal response and yard calves exhibited the least. Friend et al. (1977) noted an increase in adrenal response with crowding and social disruption of cows.

Shaw and Nichols (1962) studied the effects of intravenous and intramuscular injection of ACTH on calves and cows. Following I.V. injection, the corticoid levels of calves rose slowly and peaked at 2 hours, while highly significant changes were observed at 1/2, 1 and 2 hours in cows. After intramuscular injection, significant changes in values for calves were obtained at 1 through 8 hours and from 1/2 hour to 8 hour for cows. Paape et al. (1974) have shown that neither dose nor route (I.V. or I.M.) alters the magnitude or duration of plasma corticoid response.

LITERATURE REVIEW

CHAPTER 2.

POTASSIUM AND BUFFER SUPPLEMENTATION IN DAIRY CALF STARTERS

Potassium

Functions. Potassium is the third most abundant mineral in the body, two-thirds of which is located in the skin and muscle (Anonymous, 1981). Potassium is present in intracellular fluids and affects osmotic balance and acid-base balance within the cell (Clanton, 1980). Other functions of potassium include; ionic balance controlling cellular excitability and activity, water balance, activation of several enzyme systems, and O_2 and CO_2 transport in blood (Beede et al., 1983b). The concentration of potassium in milk, .15%, is higher than for any other mineral.

The kidney plays an important role in potassium homeostasis. It is quite efficient at removing excess potassium from the body, but has little capacity to conserve potassium when potassium is deficient (Anonymous, 1981). The dairy cow has little capacity to store potassium. Beede et al. (1983b) stated that a high producing cow can secrete up to 40% of her potassium intake into milk. The trend in dairy management today is to increase concentrates fed and decrease forages to encourage increased production and growth. Since forages are generally a much better potassium source than concentrates it is easy to foresee possible potassium deficiencies in today's dairy animals.

Requirements. Hemken (1980) reported that for many years the potassium requirement of ruminants was based on a study done by Dutoit et al. (1934). In this study one experimental animal was utilized and it was concluded that .34% potassium in ration dry matter would sustain production of 7.5 kg milk/day. Studies done by Devlin et al. (1969) and Roberts and St. Omer (1965) established a higher requirement of .5-.7% K of ration dry matter. Dennis et al. (1976) studied the effect of dietary potasssium concentration on lactating dairy cows. They reported significant increases in feed intake when cows, previously fed diets containing .45 and .55% K of the dry matter, were fed rations containing .66% K. Dennis and Hemken (1978) investigated K requirements of early and mid-lactation dairy cows. They concluded that .7% K in ration dry matter appeared adequate. However, high producers in early lactation might require higher levels.

NRC (1988) currently recommends .9%-1.00% for lactating animals and .65% for dry cows, calves and bulls.

Neathery et al. (1980) found that potassium as potassium chloride (KCl) did not affect feed intake in calves until supplemented at a concentration of 6%, and observed no clinical effects when supplemented as high as 7%.

Wang et al. (1985) found that an addition of 150 mEq potassium as potassium bicarbonate ($KHCO_3$) to a basal diet of barley, soybean meal and bromegrass hay had a positive effect on calf growth.

Sources and Palatability. Neathery et al. (1980) compared the palatability of potassium chloride (KCl), potassium acetate (CH_3COOK), potassium carbonate (K_2CO_3), and potassium bicarbonate ($KHCO_3$). The KCl supplemented feed was more palatable than the K_2CO_3 feed but less than the $KHCO_3$ or

CH_3COOK supplemented feeds. As percent dietary K increased, palatability decreased.

When studying the effects of sodium bicarbonate ($NaHCO_3$), $KHCO_3$, KCl and a mixture of $KHCO_3$ and KCl on heat stressed dairy cows, Schneider et al. (1984) reported that $KHCO_3$ supplemented at 1% of diet dry matter reduced intake and production. They speculated that the unpalatablity of the $KHCO_3$ was not adequately masked in the diet. Emery and Brown (1961) noted no such negative palatability effects when $KHCO_3$ was added to alfalfa hay or alfalfa pellet-based diets.

West et al. (1986) reported greater acceptance of K_2CO_3 than $KHCO_3$ and $NaHCO_3$ when supplemented in complete mixed diets for lactating dairy cows.

Toxicity. Excess potassium causes a severe dearrangement of acid-base balance (Neathery et al. 1979). Elevation of blood potassium to only 8-12 mEq/L (2-3 times that of normal) can cause heart rate to slow and block conduction of cardiac impulses through the A-V bundle (Guyton, 1986). Normally, however, excess potassium is excreted rapidly through urine (Anonymous, 1981).

Neathery et al. (1980) fed calves a control diet containing .77% K (dry matter basis), or control plus 2, 4, or 6% potassium from various sources. During the first week of the trial, as amount of K increased, feed intake and average daily gain (ADG) decreased. After the first week calves adapted to the diets and feed intake, along with ADG, increased. The authors were unsure if the adaptation was due to increased palatability or to changes in the K homeostasis mechanisms of the body by excretion of excess K via urine. No chemical toxicity signs were observed in any of the calves; however, supplementation of 6% K decreased overall weight gains.

Neathery and coworkers (1979) orally dosed Holstein calves, approximately 6 months of age and 260 kg body weight, with the following K doses; .29, .58, 1.15, 1.73, 2.31 or 2.88 g K/kg body weight. With doses higher than .29 g/kg BW, plasma K, total solids, and packed cell volume (PCV) increased. At high doses of K, plasma Na also increased. Generally, increasing doses of K resulted in a trend toward metabolic acidosis as indicated by a drop in blood pH, and bicarbonate (HCO_3) and an increase in respiration rates. Toxic signs, including leg muscle tremors, excessive salivation, and excitability were often seen in calves dosed with 1.15 g K/kg body weight and above.

Bergman and Sellers (1954) intravenously administered K to calves and found no regular effect on the heart until K plasma concentrations were 8 mEq/L. At this rate, respiration increased and heart rate became progressively slower. Intraventricular block was indicated by disorganization of the QRS complex and T wave. Duration of electrical systole became progressivley prolonged as plasma K levels rose to a lethal level of 12.7 mEq/L.

Effect of Potassium on Mineral Metabolites

Potassium has been known to interact with other minerals such as magnesium (Mg), calcium (Ca), and sodium (Na).

It is possible that the high K content of wheat pastures interferes with Ca and Mg utilization, causing symptoms characteristic of grass tetany. Pearson et al. (1949) fed ewes a ration containing 5% K and found no significant differences in serum Ca, Mg, K, K:Ca or K:Mg as compared with controls fed a standard non potassium-supplemented diet. Kunkel et al. (1953)

also fed ewes a 5% K ration. They observed a lower ($P<0.01$) serum Mg content in the ewes fed the 5% K ration. Although hypomagnesemia was observed, no tetany was apparent. Serum Ca, Na, K and total protein were not altered.

Erdman and Hemken (1980) studied the effect of dietary Ca and Na on K requirements of dairy cows and concluded that dietary Ca and Na had no sparing effect on potassium for lactating dairy cows.

Pradhan et al. (1974) found a negative correlation between Ca and K balance in dairy cows. As stated by Hemken (1980), Erdman (1977) did not detect any Ca x K interaction in lactating dairy cows.

Beede et al. (1982a) reported that in chronically heat stressed cows, higher concentrations of supplemental K were most efficacious for increasing feed intake and milk production when accompanied by higher Na levels than recommended by NRC (1978). He suggested that increased Na is needed for adequate excretion and for renal conservation of K.

Concentrations of Potassium From Birth to Maturity

Butler et al. (1977) reported serum potassium levels of $5.4 \pm .08$ mEq/L in healthy calves from birth to ten days.

Safawate and coworkers (1982) observed plama K concentrations in calves from birth to 7 days to be $5.2 \pm .01$ mM. From d 2 to d 6, daily urinary K excretion gradually increased. Fecal K decreased to d 5, then increased to d 7. Potasssium balance was always positive during the calves' first week of life.

Fisher (1960) determined that calves have a higher serum K concentration than do mature cows (5.1 ± 0.4 mEq/L vs 4.4 mEq/L, respectively).

Drury and Tucker (1963) showed a gradual decrease in red cell potassium of lambs from birth until maturity.

Jordan (1986) observed a decrease in red blood cell potassium, from approximately 73 mEq/L during the first week of life to approximately 47 mEq/L by week six, in early weaned calves.

Heat Stress and its Relationship to Potassium Requirements

Effects of Heat Stress. As environmental temperatures rise above 29 C, feed intake, milk yield and reproduction are adversely affected in dairy cows (Beede et al., 1983b). Heat stress can negatively influence the growth of neonatal calves (Collier et al., 1982). Heat stress reduced IgG_1 in calves and was associated with an increase in cortisol concentration, which influenced disease resistance of newborn calves (Stott et al., 1976). Heat stressed cows have been shown to produce calves of lower birth weights than cows with access to shade (Collier et al., 1982).

Physiological Adaptations to Heat Stress. Physiologically, the cow has several mechanisms to enable itself to adapt to high ambient temperatures.

1) Feed Consumption. Feed intake is reduced to maintain body core temperature during thermal heat stress (Collier et al., 1982). Data of McDowell et al. (1976), adapted by Huber and Higginbotham (1986), show that the maintenance requirements of lactating cows increase 30% if the temperature is raised from 30 to 42 C for 6 hours daily, but voluntary feed consumption drops to 55% of that of non heat-stressed animals. There was a greater percent reduction in hay intake than percent reduction in concentrate intake.

2) Increased Respiration. Increases in heat load result in subsequent increases in respiration (Niles et al., 1980; Mallonee et al., 1985). Schneider et

al. (1984) reported respiration rates of 133 respirations/minute in non-shaded animals. Increased respiration alters alveolar ventilation, causing a change in acid-base balance. CO_2 is eliminated faster than it is produced, thereby lowering pCO_2, increasing blood pH, and sending the animals into a state of respiratory alkalosis (Beede, 1983b). The drop in pCO_2 causes an increased loss of alkali reserve in the urine so a drop in blood HCO_3 is also observed. This decrease in blood HCO_3 combined with a loss of carbon dioxide through ventilation reduces the bicarbonate pool available for buffering (Schneider et al., 1984). Schneider et al. (1986) observed an increase ($P<0.01$) in blood pH, and decrease in pCO_2, $pHCO_3$ ($P<0.01$) and total CO_2 ($P<0.05$) in non-shaded versus shaded cows.

Niles et al. (1980) observed a lower rumen pH in heat stressed cows as compared with controls.

3) Increased Water Consumption. Collier et al. (1982), in a table adapted from McDowell (1972), reported a 58% increase in total body water loss when the ambient temperature was increased from 20 C to 30 C. Water consumption increased 29% when temperatures went from 18 C to 30 C. Collier et al. (1982) suggested that this large water loss is a contributing factor to acid-base and electrolyte balance. They also suggested that the increased water consumption decreased rumen osmotic pressure, causing a reduction of electrolytes such as Na and K in rumen fluid.

4) Sweating. Water loss via body surface has been determined to increase 2.5 times when cows were subjected to 30 C environments as compared to 20 C (Collier et al., 1982).

Singh and Newton (1978) subjected bull calves to 40.5 C with a relative humidity of 50% for eleven days. Both K and Na secretions of the skin increased greatly during the last 4-5 days of the trial. By day 11 there was a 340% greater increase of K loss over Na.

Jenkinson and Mabon (1973) exposed Ayrshire calves, 7 months of age, to 15, 25, 35, or 40 C temperatures for 6 hour intervals every second day. Sweat loss of Na, K, Mg, Ca and Cl were all significantly correlated with sweating rate and with each other. Potasssium ion loss was the greatest of all the ions. A 28-fold increase in potassium loss was noted as temperatures were increased to 40 C. At 40 C the total K loss via skin was estimated to be approximately 11.5% of K intake. Total K loss through skin at 25 C was 1% of K intake.

Potassium Requirements During Heat Stress

A decrease in forage intake (Huber and Higginbotham, 1986), an increasing water and electrolyte loss via body skin (Singh and Newton, 1978; Jenkinson and Mabon, 1973), and possible increase of urinary excretion of potassium (Collier et al., 1982), along with lactational demands for potassium may put the dairy cow in a precarious state of potential potassium deficiency.

Mallonee et al. (1985) observed a curvilinear effect on total daily milk yields when increasing dietary K in heat stressed early- to mid-lactation Holsteins and Jerseys. Daily milk production of cows fed diets containing 0.66%, 1.08% and 1.64% K (dry matter basis) was 15.2, 16.6 and 16.1 kg/day.

Schneider et al. (1984) evaluated the influence of total dietary K (1% or 1.5% DM), $KHCO_3$ (0 or 1%) and $NaHCO_3$ (0 or .85%) on heat stressed cows. $KHCO_3$ reduced intake and production due to a palatability effect. Total dietary K at 1.5%, however, increased milk production over 1% total dietary K. They concluded that supplementing rations to 1.5% K was beneficial but not when supplemented as $KHCO_3$.

Schneider et al. (1986) reported an increase in feed intake and actual milk yield in heat stressed cows fed rations containing 1.8% K as compared to 1.3% K.

West et al. (1986) compared the effects of $KHCO_3$, K_2CO_3 and $NaHCO_3$ on feed intake and buffering ability. Cows fed the K_2CO_3 ration had a higher total dry matter intake and produced more 3.5% fat corrected milk and solids corrected milk than cows in any other group.

Beede et al. (1983a, 1983b) reported that higher concentrations of K for heat stressed cows were most efficacious when accompanied by concentrations of Na higher than recommended by NRC (1978).

Supplemental Sodium Buffers

Kellaway et al. (1977) demonstrated that a cause for restricted intake of calves offered ground or pelleted diets was due to reduced salivation, which lowered rumen buffering capacity. Addition of buffer improved feed intake (Kellaway et al., 1978). Buffers may also increase rumen osmolality (Kellaway, 1977). Hart and Polan (1984) studied the effects of 0 to 4.5% dietary sodium bicarbonate ($NaHCO_3$) on calf growth and performance. A complete ration based on corn, soybean meal and 27% orchard grass was fed. The authors concluded that buffer had a small effect ($P<.14$) on average daily gain. Maximal rate of gains occured between 1 and 2% $NaHCO_3$, however no significant differences among treatments were observed. Feed efficiency, rumen pH, and molar proportions of volatile fatty acids were not significantly affected. Rumen osmolality, though highly variable, tended to increase with addition of $NaHCO_3$. The authors suggested that the quantity of hay, addition of limestone, and low starch content in the diet prevented an acidotic state in the calves, thereby preventing any significant response to the buffer.

Curnick et al. (1983) fed 48 Holstein calves a complete starter ration containing 10% chopped hay and 0 or 3% $NaHCO_3$. Addition of sodium bicarbonate stimulated greater growth during the preweaning weeks (weeks 0-5) and higher feed intake from 0-10 weeks. Rumen pH and acetate:propionate ratio was higher in the buffer-fed calves at 9 weeks. Digestibilities of all nutrients measured at nine weeks were decreased with added $NaHCO_3$. This was attributed in part to higher feed intake, which would increase rate of passage.

Okeke and Buchanan-Smith (1982) found that addition of 15 g $NaHCO_3$/kg DM to a cracked maize, maize silage, chopped oat straw diet increased average daily gain, feed intake and feed efficiency over a 12 week period as compared to controls. ADG and feed efficiency were higher ($P<.05$) during weeks 5 through 8.

Kellaway et al. (1977) fed calves pellets containing either ground barley or ground barley and grass meal (6:4) as the main ingredient. $NaHCO_3$ was added at 2, 11, 20 or 29 g Na/kg DM. A linear increase in feed intake was noted with increasing levels of bicarbonate during the preweaning period. After weaning this linear response in feed intake and growth was seen with sodium levels up to 20 g (6% $NaHCO_3$). Postweaning, a diminished response was observed in calves fed the 29 g Na/kg DM diet (9% $NaHCO_3$). A change in acid-base balance, progressing toward metabolic alkalosis, was detected in these calves.

Preston et al. (1962) found no difference in feed intake, liveweight gain or feed efficiency when comparing starter and 1.25% $NaHCO_3$, starter + 2.5% $NaHCO_3$ or starter with 10% grass meal. When the diet containing 1.25%

$NaHCO_3$ was replaced by a 7.5% $NaHCO_3$ supplemented diet, significant increases were obtained with regards to DM intake, digestibility and rumen pH.

Some researchers have observed no response with calf starters supplemented with sodium bicarbonate. Wheeler et al. (1980) observed no improvement in feed intake, weight gain or ruminal pH of calves fed a pelleted diet containing 35% forage and 5% $NaHCO_3$ (1.4% Na) compared to calves fed the same starter with no buffer. Feed efficiency was reduced, ruminal acetate and butyrate increased while propionate decreased, water intake increased, as did incidence of free gas bloat in calves fed the $NaHCO_3$ diet. As with Hart and Polan (1984), it was felt the amount of hay in the diet provided adequate buffering.

Eppard et al. (1982) also noted no response in starter intake, total DM intake, or ADG for calves fed starter with 2% added $NaHCO_3$, as compared to controls, over an 84 day period. The bicarbonate-fed calves had a higher molar % acetate and lower molar % propionate than calves not fed buffers.

Leibholz et al. (1980) supplemented calf starters with $NaHCO_3$ at concentrations of 1.1 and 1.9% Na. The basal diet consisted of barley, meat meal, urea and 15% oat straw. Calves fed the 1.1 and 1.9% Na supplemented diets consumed 8 and 15% more feed, respectivly, than did controls. However, intake of organic matter, feed efficiency and liveweight gains were not significantly different.

Acid-Base Balance

Significances of Blood Gas Values. Tasker (1980) states that the most abundant buffer pair in plasma is that of bicarbonate-carbonic acid

(HCO_3-H_2CO_3). The pH of plasma is dependent on the concentration, and more importantly, the ratio of these two. The measurement of partial pressure of carbon dioxide (pCO_2) evaluates the carbonic acid or carbon dioxide in the blood. When CO_2 enters erythrocytes it is quickly converted to H_2CO_3. A large proportion of this H_2CO_3 dissociates into hydrogen and bicarbonate (HCO_3) ions. The HCO_3 level determines whether or not there is a base excess (BE). The base excess value is derived mathematically from pH and pCO_2.

Effect of Buffers on Acid-Base Balance. Leibholz et al. (1980) observed increases in blood pH, pCO_2, HCO_3 and BE when supplementing sodium bicarbonate at 1.1 and 1.9% Na as compared to NaCL supplemented diets of 0.3, 1.1, 1.9 and 2.8% Na.

Curnick et al. (1983) noted an increase ($P<.01$) in blood pH for calves fed a $NaHCO_3$ supplemented diet as compared to calves fed a nonsupplemented diet. Partial pressure of carbon dioxide was elevated slightly in the $NaHCO_3$ fed calves, but not significantly so.

Kellaway et al. (1977) observed that the relationships between $NaHCO_3$ and sodium content and acid-base measurements (pH, pCO_2, HCO_3 and BE) were linear and positive.

Jordan (1986) observed that calves fed a $KHCO_3$ supplemented diet tended to have higher blood pH, HCO_3 and pCO_2 values than calves fed a nonbuffered starter. Base excess values of the calves fed the buffered diet were significantly higher than controls.

EXPERIMENT ONE. THE EFFECT OF QUANTITY OF MILK AND METHOD OF WEANING ON DAIRY HEIFERS IN AN EARLY WEANING PROGRAM.

ABSTRACT

Forty Holstein heifers were used from birth to 8 wk of age. They were assigned to blocks of four calves at birth. Calves within blocks were assigned randomly to one of four treatments. Treatments were milk fed at 8% or 10% of birthweight per day and either gradual or abrupt weaning. All calves were fed colostrum until 3 d of age, then milk, at the assigned amount, until weaning. Along with milk, calves were fed a highly palatable prestarter until they consumed 227 g/d and then a mixture of 227 g prestarter and all the starter they would eat daily. Abruptly weaned calves were weaned at 3 wk of age or when consuming 454 g dry feed/d, whichever came first. Gradually weaned calves were fed their morning portion of milk for one additional week after 3 wk of age, or when consuming 454 g dry feed/d, whichever came first. Calves fed milk at 8% and weaned gradually had greater weight gains than those of other treatments. The 8% gradual group ate more dry feed than the 10% gradual calves. Calves fed milk at 8% consumed more dry feed from wk 1 to wk 6 than calves fed milk at 10%. The calves fed milk at 10% and weaned gradually consumed less dry feed than any treatment group. The 10% abrupt group exhibited the largest check in growth at weaning. Mean blood urea nitrogen, measured at 4 and 8 wk, was significantly lower for the 8% gradual calves than for calves in other treatment groups. Fecal scores and lymphocyte stimulation index were not affected by treatment. The 10% gradual calves exhibited less increase in serum cortisol in response to ACTH at 4 wk of age than the remaining treatment groups. Mean weekly concentrations of cortisol in serum were similar among treatments, however, the 10% gradual group tended to exhibit the lowest overall mean. Using this early weaning program, feeding calves milk at 8% and weaning gradually resulted in superior weight

gains as compared to calves in the other treatment groups.

INTRODUCTION

Anatomically, physiologically, and microbiologically, the rumen of the neonatal calf is not fully developed. Dry feed fermentation end products and fiber are known to be responsible for rumen development (Brownlee, 1956; Lengemann and Allen, 1959; Tamate et al., 1961; Sander et al., 1959).

The earlier a calf can be encouraged to consume dry feed and stimulate rumen development, the earlier successful weaning can be accomplished. The benefits of earlier weaning include: earlier rumen development (Tamate et al., 1961, Poe et al., 1969; Anderson et al., 1987), decreased labor and feed costs (Davies and Owen, 1967; Caffery, 1974), and decreased incidence of digestive disturbances (Harte and Curran, 1964; Leaver and Yarrow, 1972; Jorgenson et al.,1970). Early weaning programs utilize prestarters or palatable starters to encourage dry feed consumption. Calves can be weaned as early as three weeks with no compromise to overall feed intake or growth (Winter, 1978; Jorgenson et al., 1970; Owen and Larson, 1982).

The amount of dry feed a calf will consume before weaning is influenced by the amount of milk or milk replacer fed. Feeding calves milk at 8% of body weight did not alter gains in body weight compared to milk fed at 10% or higher (Kaiser et al., 1976; Jenny et al., 1982; Keys et al., 1982).

Schingoethe et al.(1986) reported that calves benefit from being fed a higher quantity of milk during cold weather. Harte and Fallon (1984) found that bull calves fed 50 kg milk replacer produced heavier carcasses at 104 weeks than did calves fed 25 kg milk replacer.

Weaning is a well known stressor to the calf. Preston (1959) found no difference in growth between gradually or abruptly weaned calves. O'Donovan

(1963) reported that calves weaned abruptly at 3 wk and calves weaned gradually at 12 wk of age gained over 454 g/d during a 12-wk trial. Harte and Curran (1986) found that calves weaned gradually at 5 wk performed slightly better than calves weaned abruptly at 12 wk. Abrupt weaning may stimulate dry feed consumption at a faster rate, but gradual weaning may be less stressful to the calf.

The objectives of this research were to determine which amount of milk, 8% or 10% of birth weight, and which method of weaning, abrupt or gradual, would result in optimal performance and less stress to the calf.

MATERIALS AND METHODS

Animals. Forty Holstein heifers were assigned to blocks of four calves according to birth date, and calves within blocks were assigned randomly to one of four treatments. The experiment was conducted from September to March. Treatments were milk fed at 8% or 10% of birthweight per day and either gradual or abrupt weaning. Calves were housed individually in wooden hutches. The experimental period ended when calves were 8 wk of age.

Feeding Procedure. Colostrum was fed for the first 3 d, then milk was fed daily, at the assigned level, in two equal portions. Dry feed consisted of an all milk prestarter and a conventional calf starter. Compositions of the feeds are shown in Tables 1 and 2. Calves were encouraged to consume dry feed by placing approximately 15 g prestarter in the milk. The heifers were allowed to consume prestarter ad libitum until consuming 227 g/d, then they were fed a mixture of 227 g prestarter plus all of the starter they would consume daily. Orts were weighed and recorded each evening. Fecal scores (Larson et al, 1977) and general appearance scores were recorded twice daily. Fecal scores were rated on a scale of 1 to 4, one being normal consistency to 4 being watery. General appearance scores were rated as poor, fair or good.

Weaning Procedures. Two methods of weaning were used. Abruptly weaned calves were weaned at 3 wk of age or when consuming 454 g dry feed per day, whichever came first. Gradually weaned calves were fed their morning (a.m.) portion of milk for one additional week after 3 wk of age, or when consuming 454 g dry feed per day, whichever came first.

Blood Sampling and Analysis Procedures

Cortisol. Blood serum was obtained at 2, 3, 5, and 7 wk of age at 9:00 h; on the day of weaning (9:00 and 17:00 h); at 24 h postweaning (9:00 h); and 7 d postweaning (9:00 h). Serum was analyzed for cortisol by radioimmunoassay (Skaggs et al., 1986).

ACTH Challenge. An ACTH challenge was performed using 16 heifers (four per treatment group). Calves were 4 wk and 1 d of age at the time of the challenge. Crude porcine adrenocorticotropic hormone[1] was solubulized in physiological saline solution to a dilution of 9 IU ACTH/ml diluent. A blood sample was collected (0 h) immediately before the calf was injected via the jugular vein with a dose of 1.03 IU ACTH/kg body weight$^{.75}$. This dose was based on previous research by Friend et al. (1985). Jugular blood was sampled at .5, 1, 1.5, 2, 2.45 and 4 h after ACTH. Serum was analyzed for cortisol by radioimmunoassay (Skaggs et al., 1986).

Lymphocyte Blastogenesis Test. Jugular blood was sampled on day of weaning, 24 h post weaning, and 7 d post-weaning. Lymphocytes were isolated from freshly heparinized blood and used in the test, with slight modifications, described by Reddy et al. (1986). The lymphocyte suspension was adjusted to contain 2.5×10^4 cells/ml. The cell suspension with or without specified concentration of mitogens was distributed in 200 µl allotments/well in quadruplicate in a flat-bottom tissue culture plate. After a 48-h incubation at 37° C in a humidified 5% CO_2 incubator, 3H-thymidine[2] (1 µCi/culture) was added. Cultures were harvested 24 h later on glass fiber filter in an automated

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[1] Sigma Chemical Co., St. Louis, MO 63178.

[2] Thymidine, sp. act. 6.7 Ci/mmole, ICN Biomedicals Inc., 2727 Campus Drive, Irvine, CA 92715

cell harvester[3]. Filters were counted in a liquid scintillation counter[4] to determine the incorporation of 3H-thymidine in lymphocytes. The lymphocyte stimulation index (LSI)=disintergrations per minute (DPM) of stimulated cultures/DPM of control cultures.

The concentrations of mitogens used were: phytohemagglutinin (PHA)[5] 2.5 µg/ml and pokeweed mitogen (PWM)[5] 2.5 µg/ml.

Metabolic Profiles. Samples of blood serum obtained at 4 and 8 wk of age were analyzed for creatinine, glucose, calcium, phosphorous, alkaline phosphatase, urea nitrogen, carbon dioxide, chloride, potassium, sodium, albumin, and total serum protein by Sequential Mutiple Auto Analyzer 12/60 Micro.[6].

Statistical Analysis

Data were anlayzed as a completely randomized split plot design by least square analysis of variance according to the general linear model procedure of Statistical Analysis System (1982).

[3]PHD Cell Harvesting System, Cambridge Technology, Cambridge, MA 02140.
[4]LS 6800 Model, Beckman Instrument Inc., Fullerton, CA 92634.
[5]Sigma Chemical Co., St. Louis, MO 63178.
[6]Technicon Instruments Corp., Torytown, NJ 10591.

RESULTS AND DISCUSSION

Growth Characteristics

Initial weights of calves in the four treatment groups were similar. Calves fed milk at 8% of birthweight and weaned gradually gained ($P<.05$) more weight than calves in any other treatment group (Table 3). The 8% gradual calves also consumed more dry feed, however, it was only greater ($P<.05$) than the feed consumption of the 10% gradual group (Table 4).

The calves fed milk at 8% of birthweight tended to consume more dry feed from wk 1 to wk 6 than calves fed milk at 10% of birthweight. This agrees with findings of Jenny et al.(1982), Fisher et al. (1985), and Gleeson and Caffrey (1981), who determined that feeding calves lesser amounts of milk stimulated dry fed consumption.

Excluding wk 6, the calves fed milk at 10% of birthweight and gradually weaned consumed the least dry feed of any treatment group. The feed consumption of this group was lower ($P<.05$) than the consumption of the 8% gradual group from wk 3 to wk 8. The 10% abruptly weaned calves, however, consumed amounts closer to that of the 8% groups. The extended feeding of a large quantity of milk may have further discouraged the consumption of dry feed. The 10% abrupt calves had a greater increase in feed consumption from wk 3 (weaning) to wk 4 than did the 10% gradual calves. The abrupt termination of milk, when fed at 10% birthweight, seems to have stimulated dry feed consumption to a greater extent than gradual reduction of milk.

The 8% gradual treatment group had the most consistent weight gains over the 8 wk period. There appeared to be a slight decrease in weight gains observed only during wk 4, the week in which milk feeding was reduced to once daily in the gradually weaned group. Their overall consistent increase in weight gains corresponds to the consistent increase in dry fed consumption for this group. The 8% abrupt calves increased in weight after weaning, however, they experienced an unexplained, significant check in growth during wk 7. Kaiser (1976) and Caffrey (1974) observed that calves consuming the most dry feed preweaning have the least check in growth when weaned.

The calves in the 10% abrupt group experienced a large check in weight gain at weaning compared to gradually weaned calves (Table 3.). The initial stress of abrupt weaning from a large quantity of milk probably caused the large decrease ($P<.05$) in weight gain. Evidently the abrupt termination of milk stimulated dry feed consumption (Table 4.). The weight gains for the 10% abrupt group for the following week, and throughout the rest of the trial, thenceforth were consistent with even the 8% gradual calves.

The 10% gradual calves did not experience the same growth check as the 10% abrupt calves. The 10% gradual calves had a nonsignificant decrease in weight gain during the first week when milk was totally eliminated. This may signify that gradual weaning of calves fed milk at a high percent of birthweight allows for a less stressful adaptation for the calf to a total dry feed diet. When feeding milk to calves ad lib, Hodgson (1965) observed less liveweight loss in calves weaned over 14 d as compared to calves weaned over 7 days. Although the 10% gradual calves seemed to adapt to the weaning period better than the 10% abrupt group, weekly dry feed consumption and weight gains for the 10% gradual calves were consistently lower than those of the 10% abrupt group from week 5 to the end of the trial.

Contrary to other studies (Dalzell and Allen, 1970; Fisher et al., 1985; Harte and Fallon, 1984), feeding greater quantities of milk did not improve preweaning gains.

As previously stated, the 8% abrupt calves experienced a significant decrease in weight gain during wk 7 of the trial. Both groups of calves fed milk at 10% showed a check in weight gain, though not significant, during week eight. At this age weaning procedure or amount of milk fed would not have been the attributing cause. The calves in these groups did not appear ill at either time. Fecal scores were normal, averaging approximately one, and general appearance scores were good. Since the 8% gradual calves exhibited no set back toward the end of the trial it is hard to determine what caused these decreased weight gains.

Fecal scores were unaffected by treatments (Table 5.). All treatment groups had elevated fecal scores during wk 2, which corresponds to the decrease in weight gains observed for all treatments.

Lymphocyte stimulation indexes (Table 6) were highly variable among calves and no significant differences among treatments were noted, and neither were any week within treatment differences noted. Therefore, amount of milk fed and type of weaning had no effect on the calf's immune system responsiveness as measured by this method.

Calves weaned gradually had higher ($P<.05$) mean blood glucose concentrations than the abruptly weaned calves (Table 7); however, they were receiving milk at the 4 wk sampling period. Blood serum glucose samples taken at eight weeks were not significantly different among treaments.

Mean blood urea nitrogen concentration of the 8% gradual calves was lower ($P<0.5$) than other treatment groups (Table 7). Dry feed fermentation end products and fiber are responsible for ruminal development (Brownlee, 1956; Tamate et al.,1961; Lengemann and Allen, 1959). Anderson et al. (1987)

observed that earlier weaned calves ate more and had earlier ruminal metabolic development, as evidenced by lower pH and increased total VFA concentrations, than later weaned calves. Since the 8% gradual calves were consuming similiar or greater amounts of dry feed compared to other treatment groups, probably their rumen was more developed, and they were better able to utilize ruminal ammonia and excrete less into the blood as urea.

The ACTH challenge given at 4 wk was used to determine relative stress of weaning on the calves. Concentrations of cortisol in serum peaked at 1.5 to 2.0 h post-injection for calves in all treatment groups. The calves in the 10% abrupt group secreted less ($P<0.5$) cortisol after injection of ACTH than the 8% abrupt group (Table 8).

Decreased corticosteroid output is suggestive of a decreased state of stress, making interpretation of these results difficult. During wk 4, dry feed consumption of the 10% abrupt (A) calves was consistent with other groups. However, weight gains of the 10% A group were greatly decreased as compared to other groups. Poor weight gain is suggestive of increased stress. A possible explanation is adrenal cortical dysfunction (Dickson, 1984). Weight loss can result in adrenal cortex hypofunction. Also, if the calves were extremely stressed after being weaned, the endogenous demands on the adrenal cortex may have been so great, that adrenal "washout" or dysfunction occurred. Therefore, at the time of the challenge, the calves were unable to optimally respond to the exogenous ACTH.

Mean weekly cortisol values, though highly variable among calves and not significantly different among treatments, showed the 10% abrupt calves to have the lowest overall cortisol mean (Table 9), suggesting that the ability of their adrenal gland to secrete cortisol was decreased.

Overall performance data from this study indicates that when utilizing an early weaning program as described in this paper, a program of feeding milk at 8% birthweight and gradual weaning should be followed. However, if weaning is to be abrupt, results indicate slightly better performance with milk fed at 10% birthweight.

TABLE 1. Composition and analysis (dry matter basis) of prestarter.[1]

Ingredient	(%)	Nutrient	(%)
Whey, dried	46	Crude protein	22
7-60[2]	23	Crude fat	12
Skim milk, dried	19		
Sodium caseinate	12		
Additives[3]	+		

[1]Calfweena, Merricks, Union Center, WI.
[2]A mixture of milk solids and fat containing 7% protein and 60% animal fat.
[3]Includes chlortetracycline (200 g/ton), preservatives, vitamins, minerals, and flavoring compounds.

TABLE 2. Composition and analysis (dry matter basis) of starter.[1]

Ingredient	(%)	Nutrient	(%)
Alfalfa, ground	25	Crude protein	15.61
Corn, cracked	30	Ether extract	3.36
Oats, rolled	20	Acid detergent fiber	19.95
Sorghum grain, rolled	8.5		
Soybean meal	10.0		
Molasses, dry	5.0		
Dicalcium phosphate	.7		
Limestone, ground	.3		
Salt	.25		
Trace mineral salt	.25		
Vitamins A and D[2]	+		

[1]Pellet, 4.8 mm diameter.
[2]2200 IU vitamin A and 300 IU vitamin D/kg.

TABLE 3. Mean weekly weight gains (kg) of calves.

	Abrupt Weaning		Gradual Weaning	
	milk fed (% birthweight)		milk fed (% birthweight)	
Week	8%	10%	10%	8%
1	1.86	2.26	1.95	1.31
2	.87	0.95	1.04	1.17
3	1.72[a]	3.81[b]	2.58[ab]	3.81[b]
4	2.13[ab]	0.81[a]	3.26[b]	3.26[b]
5	4.62[ab]	3.90[ab]	3.22[a]	5.08[b]
6	6.44	5.76	5.62	5.98
7	4.71[a]	6.66[b]	6.07[ab]	6.89[b]
8	5.03[a]	5.85[ab]	5.57[ab]	7.12[b]
Overall Mean	3.42[a]	3.75[a]	3.67[a]	4.35[b]

LSD week within treatment = 1.7
LSD treatment within week = 1.63
LSD treatment main effect = .58

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

TABLE 4. Mean dry feed consumption (kg) by calves.

Week	Abrupt Weaning milk fed (% birthweight) 8%	10%	Gradual Weaning milk fed (% birthweight) 10%	8%
1	.51	.49	.28	.59
2	.73	.75	.53	.92
3	1.95	1.84	1.34	2.81
4	5.73[b]	4.81[ab]	3.46[a]	5.53[b]
5	9.46[ab]	8.69[a]	8.18[a]	10.40[b]
6	13.40[bc]	11.58[a]	11.78[ab]	13.83[c]
7	14.30[a]	14.76[ab]	13.97[a]	16.32[b]
8	15.12[a]	16.20[ab]	14.90[a]	17.57[b]
Overall Mean	7.65[ab]	7.38[ab]	6.80[a]	8.49[b]

LSD week within treatment = 1.30
LSD treatment within week = 1.72
LSD treatment main effect = 1.18

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

TABLE 5. Mean treatment fecal scores for calves fed milk at 8% or 10% of birthweight and weaned abruptly or gradually.

Treatment	Mean Fecal Score
8% abrupt	1.17
10% abrupt	1.25
10% gradual	1.22
8% gradual	1.17

LSD treatment main effect = .10

TABLE 6. Lymphocyte stimulation index (LSI) treatment means for calves.

Milk fed (% birthweight) and type of weaning	Mitogen Used	
	Phytohemagglutinin[1]	Pokeweed mitogen[2]
8% abrupt	21.36	24.75
10% abrupt	20.64	21.43
10% gradual	25.64	22.28
8% gradual	22.97	25.85

[1]LSD treatment main effect = 6.22

[2]LSD treatment main effect = 7.10

TABLE 7. Mean selected serum metabolites (SMA_{12}) for calves.

SMA_{12}	Abrupt Weaning milk fed (% birthweight) 8%	Abrupt Weaning milk fed (% birthweight) 10%	Gradual Weaning milk fed (% birthweight) 10%	Gradual Weaning milk fed (% birthweight) 8%	LSD[1]
Creatinine (IU/dl)	.97	1.00	.96	.99	.11
Glucose (mg/dl)	87.50^{a}	88.55^{a}	99.65^{b}	100.5^{b}	9.1
Calcium (mg/dl)	9.66	9.75	9.81	9.98	.33
Albumin (g/dl)	3.42	3.43	3..38	3.38	.15
Protein (g/dl)	5.35	5.49	5.51	5.57	.27
Chloride (meq/L)	103.35	102.60	103.26	101.91	2.19
Alkaline phosphatase (IU/dl)	260.05^{a}	272.00^{a}	282.65^{ab}	329.58^{b}	53.08
Blood urea nitrogen (mg/dl)	9.85^{b}	9.25^{b}	9.65^{b}	7.47^{a}	1.64
Carbon dioxide (meq/L)	27.80	27.60	27.50	26.53	2.31
Potassium (meq/L)	5.44	5.88	5.72	5.34	.55
Sodium (meq/L)	141.75	140.85	140.80	140.12	3.16
Inorganic phosphorus (mg/dl)	7.69^{a}	7.75^{a}	8.28^{b}	7.65^{a}	.57

[1]LSD treatment main effects

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

TABLE 8. Cortisol treatment mean for ACTH challenge performed on calves.

Milk fed (% birthweight) and type of weaning	Cortisol (ng/ml)
8% abrupt	15.9^{b}
10% abrupt	12.2^{a}
10% gradual	14.6^{ab}
8% gradual	14.9^{ab}

LSD treatment main effect = 3.17

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

TABLE 9. Cortisol treatment mean for calves.

Milk fed (% birthweight) and type of weaning	Cortisol (ng/ml)
8% abrupt	4.71
10% abrupt	4.08
10% gradual	4.85
8% gradual	4.68

LSD treatment main effect = 1.32

EXPERIMENT TWO. POTASSIUM AND BUFFER SUPPLEMENTATION IN DAIRY CALF STARTERS.

ABSTRACT

Sixty Holstein heifers were used from birth to 8 wk of age. Calves were blocked by birth date and calves within blocks were assigned randomly to one of six treatments. Starter diets were formulated with and without Trona, a natural buffer, at potassium levels of .9%, 1.25% or 1.5% of ration dry matter. The sodium concentration of all diets was constant. Calves were fed colostrum until 3 d of age and then milk at 8% birth weight/d, divided equally into an a.m. and p.m. portion and were weaned gradually at 3 wk of age. They also were fed a palatable prestarter until they consumed 227 g/d and then a mixture of 227 g/d prestarter and all the appropriate starter they would consume. After wk 6 calves were fed only the starter diet. There was a trend toward a potassium x week interaction on weight gain. The calves fed the 1.25% K diet tended to gain more weight from wk 6 to wk 8 than calves on the .9% K or 1.5% K diet. There was a significant buffer x week interaction on feed intake. Calves fed nonbuffered starter consumed more dry feed from wk 6 to wk 8 than calves fed a buffered starter. There were no potassium x buffer interactions on feed intake or weight gain. Fecal scores, blood gases, concentrations of cortisol, lymphocyte stimulation indexes, and red blood cell potassium concentations were unaffected by treatment. Calves fed a buffered diet tended to have increased blood acetate concentrations. Increasing the potassium concentration to 1.25% K of ration dry matter appeared to increase feed intake. Addition of buffer was not beneficial.

INTRODUCTION

Although potassium is the third most abundant mineral in the body and has many vital functions, (Anonymous, 1981) little information is available on the potassium requirements of calves.

Neathery et al. (1980) determined that calves given a choice of diets containing varying amounts of potassium consistently consumed less of the higher potassium content diet. However, when 3-mo old calves were offered only one diet, those calves fed the control diet (.77% K) plus 2% added potassium had similar feed intakes and gains when compared to calves fed the control diet. Calves fed the control diet plus 6% added potasium had lower feed intake and gains. NRC (1988) currently recommends .65% K of diet dry matter for calves.

Results of recent research suggested that potassium requirements of dairy cows are increased during hot weather (Mallonee, 1985; Schneider et al, 1986; Schneider et al, 1984). Two physiological reactions to heat stress that are potentially potassium-depleting can occur in cows: reduced forage intake (Huber and Higginbotham, 1986), and increased water loss via body surface (Collier et al., 1982). One of the symptoms of potassium deficiency is reduced feed intake. Mallonee et al. (1985), Schneider et al. (1984, 1986), and Beede et al. (1983b) all observed increased feed intake and milk yield when increasing concentrations of potassium were fed to heat-stressed lactating dairy cows.

Singh and Newton (1978) reported that subjecting calves to increasing heat resulted in increased potassium and sodium secretions from the skin. Jenkinson and Mabon (1973) subjected 7-mo old calves to increasing heat and found that of Na, K, Mg, Ca, and Cl, the potassium ion loss was greatest. There was a 28-fold increase in potassium loss when temperature was increased from 15 C to 40 C.

Supplementing starter diets with buffers has been beneficial with regard to feed intake, rumen pH, and acetate:propionate ratios (Curnick et al., 1983; Okeke and Buchanan-Smith, 1982; Kellaway et al., 1977). Other researchers have found no benefit from addition of buffers (Wheeler et al., 1980; Eppard et al., 1982). Early weaned calves have lower ruminal pH than conventionally weaned calves (Anderson et al., 1987). This lower pH was seen as early as 4 wk of age. These data suggest that a buffer in the starter may be beneficial when early weaning calves.

MATERIALS AND METHODS

Animals. Sixty Holstein heifers were used from birth until 8 wk of age. Calves were blocked by birth date and calves within blocks were assigned randomly to one of six treatments. Calves were housed individually in wood hutches. The experiment was conducted from August to March.

Feeding. The prestarter used in this experiment was the same as used in experiment one. Composition of the starters are shown in Table 1. The starters were formulated with and without buffer to contain potassium levels of 0.9%, 1.25% or 1.5% of the total ration, and equal amounts of calcium, phosphorus, magnesium, and sodium. Chlorine concentrations were balanced as nearly equal as possible and all starters were calculated to contain 16% crude protein. Analysis of the nonbuffered .9, 1.25, and 1.5% K starter showed actual potassium concentrations of .94, 1.37, and 1.41% K of ration dry matter, respectively. Analysis of the buffered .9, 1.25, and 1.5% K starter showed actual potassium concentrations of 1.02, 1.32, and 1.41% K, respectively.

Calves were fed colostrum for 3 d and then fed milk at 8% of birth weight per day, divided equally into a morning (a.m.) and evening (p.m.) portion. All calves were encouraged to consume dry feed by placing 15 g of the prestarter in the milk. The heifers were allowed to consume prestarter ad libitum until consuming 227 g/d, after which they were fed 227 g prestarter daily mixed with all the appropriate starter they would consume. After 6 wk of age, calves were fed only starter. Orts were weighed and recorded each evening. Fecal scores (Larson et al., 1977) and general appearance scores, (poor, fair, good) were recorded twice daily. Calves were weighed weekly. All calves were weaned gradually beginning at 3 wk of age by feeding their a.m.

portion of milk for one additional week after reaching 3 wk of age.

Blood Sampling and Analysis Techniques

Cortisol. Jugular blood was collected into a sterile nonheparanized collection tube at 2, 3, 4, 6, and 8 wk of age. The blood was centrifuged and serum was frozen in plastic vials at -20 C until ready for analysis by radioimmunoassay (Skaggs et al., 1986).

Lymphocyte Stimulation Index. Lymphocyte blastogenesis test was used to determine a Lymphocyte Stimulation Index, which is a measurement of the calf's cell mediated immune responsiveness. Jugular blood samples were collected in sterile sodium heparanized vacutainers when the calves were 3, 4 and 6 wk of age. The lymphocyte blastogenesis test was started no longer than 1 h postsampling. Lymphocytes were isolated from freshly heparanized blood and used in the procedure of Reddy et al. (1986), with slight modifications, as described in Experiment One.

Blood Gas and pH. Jugular blood was collected into 12 cc ammonium sulfate heparanized syringes when the calves were 2, 3, 4, 6, and 8 wk of age. The syringes were immediately placed in an ice bath and the blood was analyzed on an Instrumentation Laboratory Model 813 pH/blood gas Analyzer[1] within one hour of sampling.

[1]Instrumentation Laboratory, Lexington, MA 02173.

Red Blood Cell Preparation. Jugular blood samples of at least 5 ml were drawn into ammonium sulfate heparinized syringes. Samples were collected at 2, 3, 4, 6 and 8 wk of age and immediately placed on ice. Red blood cells were prepared as follows. An isotonic choline chloride solution containing 30.71 g choline chloride (70% solution) plus 70 µl ammoniated heparin/liter was prepared and stored in a refrigerator. Hematocrit was determined on all samples, after which they were centrifuged. Plasma was placed in a plastic vial and frozen at -20 C for later analysis for sodium and magnesium. An equal volume of isotonic choline was added to the red blood cells to replace plasma that was removed. Samples were centrifuged and the supernatant removed and discarded. This wash was repeated three times. Hematocrit was determined again and then the cells were frozen at -20 C until analyzed for potassium.

ACTH Challenge. An ACTH challenge was performed on calves on the 0.9% and 1.5% potassium buffered diets when the calves were 6 wk of age. Procedures followed were the same as Experiment One.

Blood Volatile Falty Acids (VFA's), Glucose, and Blood Urea Nitrogen (BUN). Jugular blood samples were drawn at 6 and 8 wk of age. Samples were centrifuged and serum was frozen at -20 C until ready for analysis. Blood VFA's were determined by gas chromotography (Harmon et al., 1985). Glucose and BUN were analyzed by International Minerals Corporation, Mundelein, Illinois.

Statistical Analysis. Data were analyzed as a completely randomized split plot design by least squares analysis of variance according to the general linear model procedure of Statistical Analysis System (1982).

RESULTS AND DISCUSSION

This experiment was designed to study the effects of supplemental potassium in heat-stressed and nonheat-stressed environments. Due to mild weather after the trial was started, none of the calves were subjected to severe heat stress. Therefore, comparisons of heat stressed versus nonheat stressed calves were not possible.

There were no significant differences in calf birthweights between treatments.

Average weight gain, feed consumption and fecal scores are presented in Table 2. Average weekly feed consumption was 7.2 kg, which was lower than expected. In comparison, the weekly average for feed consumption for the 8% gradual calves in experiment one was 8.5 kg. In this experiment prairie hay, instead of alfalfa hay, was the main source of forage in the starter diet. This, combined with the addition of supplemented potassium, seemed to have decreased palatability.

The calves fed the 1.25% buffered ration had a lower mean weight gain than calves in any other group. Average weight gains (2.9 kg and 2.8 kg, nonbuffered and buffered respectively; p=.13) were not affected by buffer supplementation. There was a trend (P=.08) toward a potassium x week interaction, therefore weight gains on the different concentrations of potassium are shown by weeks in Table 3. The calves fed the 1.25% K diet lost weight during wk 1. Since the calves normally consume only prestarter and little to no starter during wk 1, this loss in weight probably was not associated with the treatment. It was, in fact, the calves in this group that tended to gain more weight from wk 6 to wk 8 than calves in the other treatment groups. Wang et al. (1985) reported an increase in weight gains when calves were fed a starter supplemented with 150 mEq potassium as $KHCO_3$, compared to controls fed a nonsupplemented starter. Jordan (1986) observed a tendency for increased weight gains with early weaned calves fed a starter supplemented to 1.5% K, compared to calves fed a starter containing 1.2% potsssium.

There was a significant (P=.002) buffer x week interaction affecting feed intake (Table 4). The calves fed nonbuffered starter diets consumed more dry feed from wk 6 through wk 8 than calves fed buffered starter. These findings contradict those of Okeke and Buchanan-Smith (1982) and Curnick et al. (1983), who reported increased feed intake and live weight gain with the addition of sodium bicarbonate to starter diets. As with Hart and Polan (1984) and Wheeler (1980), the amount of forage present in the diets (25% of ration dry matter), probably provided sufficient buffering capacity to prevent any acidotic state in the calves. This is supported by blood gas values presented in Table 5. Of the 300 blood gas measurements recorded, six had negative base excesses. All six were from different calves, on different treatments, at different times.

There has not been extensive research done on Trona and information on palatability is sparse. It is possible that addition of Trona decreases palatability. Coppock et al. (1986), however, reported similar intakes when feeding cows AlkaTen compared to $NaHCO_3$. Alkaten is a buffer produced directly from high purity trona ore.

There were no potassium effects or potassium x buffer interactions on feed intake. Kincaid et al. (1984) reported similar dry matter intakes for calves fed either a diet containing 1% or 1.4% K of ration dry matter. Work by

Jordan (1986) showed a slight, nonsignificant advantage in feed intake when calves were fed a $KHCO_3$-supplemented starter, compared to when they consumed a conventional starter. Wang et al. (1986) reported similar intakes for calves supplemented with 150 mEq of K as $KHCO_3$, compared to calves fed a nonsupplemented diet or calves fed diets supplemented with 150 mEq Na as $NaHCO_3$. The authors reported an increase in feed intake when calves were fed a diet containing both 150 mEq of K and Na supplemented as $KHCO_3$ and $NaHCO_3$, respectively, compared to calves in the treatments previously mentioned. Beede et al. (1982) reported that, in heat-stressed cows, higher concentrations of K in diets were more efficacious when accompained by higher concentrations of sodium.

NRC (1988) currently suggests a K:Na ratio of 6.5 for calf starter diets. Beede et al. (1983b) reported higher milk yields when feeding heat-stressed cows diets combining 1.5% K and .67% Na, or a 2.2:1 ratio. Both Wang et al. (1986) and Beede et al. (1983b) speculated that when supplementing potassium, it is important to consider the potassium:sodium ratio.

The sodium content is this diet was .4% of ration dry matter, which is higher than currently recommended by NRC (1988). It is possible that the calves fed the high K diet were not receiving adequate Na for optimum K utilization. The K:Na ratio for the diet was 3.75:1, which is still greater than that used by Beede et al. (1983b).

The amount of KCl and K_2SO_4 in the high K diet also may have contributed to an adverse palatability effect. Neathery et al. (1980) reported that as dietary K fed as KCl in the diet increased, palatability decreased.

Fecal scores were similar among treatments (Table 2). None of the treatment groups exhibited severe scours and all groups had an average fecal score of slightly above one.

Weekly cortisol concentrations in blood serum were highly variable among calves and no significant differences among treatment means were observed (Table 5).

Cortisol concentrations for the ACTH challenge performed on calves fed either the 1.5% K or .9% K buffered diets showed no significant differences between treatments. Cortisol in both treatment groups peaked at 2 h postinjection, which corresponds to the peak time reported in experiment one. The overall cortisol means were 25.2 ng/ml and 23.0 ng/ml (P=.1) for the calves fed the 1.5% K and .9% K diets, respectively. Similar adrenal response in these two groups suggests that relative stress of the calf at 6 wk was unaffected by potassium concentration or addition of buffer to the diet.

Blood gas values, pH, pCO_2, BE and HCO_3, were similar among treatments (Table 5) and were in normal ranges (Tasker, 1980).

Liebholz (1980) and Kellaway (1977) observed an increase in blood gas values when supplementing $NaHCO_3$ to calf diets.

Curnick et al. (1983) observed an increase in blood pH in calves fed a buffered diet compared to calves fed a nonbuffered ration.

Jordan (1986), however, reported a decrease in mean base excess for calves fed a conventional starter compared to calves fed a $KHCO_3$ supplemented diet. In the study by Jordan (1986) there was a high incidence of acidosis in the control group. Acidosis was not a problem in this study. The starter formulated by Jordan (1986) contained 25% ground alfalfa, a more readily fermentable roughage than prairie hay, which composed 20% of the starter used in this trial. Wheeler et al. (1980), however, reported no beneficial effect when supplementing either a 35% alfalfa hay or a 35% grass hay starter with buffer.

When orally dosing calves with KCl, Neatherly (1979) observed that the potassium-dosed calves tended to have a lower blood pH, which tended toward development of an acidotic state. This was not observed in calves not dosed. Potassium doses in Neatherly's (1977) trial were much larger than those supplemented in the diets of our trial. Oral dosing would also result in much quicker metabolism and enhance the effects of excess potassium.

Blood samples for volatile fatty acids were taken via the jugular vein. A large percentage of the butyrate and propionate has been metabolized by time the blood reaches the jugular and the majority of VFA's left in the blood is acetate. Concentration of acetate for all treatments was between 1.5 to 3.0 mmole (Table 6), consistent with adult values reported by Bjorkman and Forslund (1986). Calves fed buffered starter tended to have a slightly higher acetate concentration and acetate:propionate ratio than calves fed a nonbuffered starter.

Wheeler et al. (1980) observed an increase in ruminal acetate:propionate ratio in calves fed a buffered diet. Hart and Polan (1984), however, found that molar proportions of ruminal VFA's or acetate:propionate ratio were not influenced by buffers.

Lymphocyte stimulation indexes were determined on five or six calves per treatment. At the 3-wk sampling, three out of five calves in the 1.25% K group exhibited elevated responses, which significantly increased overall treatment means (Table 7). This same response was seen from both mitogens. Since very little starter was consumed by the 3 week old calves, these elevated responses mostly likely were not due to a treatment effect. This is supported by the fact that these responses were not seen at 4 or 6 weeks of age, times when feed consumption was increased. Therefore, neither potassium or buffer had an effect on the young calf's cell mediated immune responsiveness.

Significant differences in red blood cell potassium content were seen only at 2 and 3 weeks of age (Table 8). Since calves were eating only a small amount of feed at this time these differences are not attributed to a treatment effect. No significant differences were noted at 4, 6, and 8 weeks. Overall means for red blood cell potassium content were not significantly different. As calves increased in age, potassium content in RBC's decreased. This agrees with results reported by Jordan (1986) and Drury and Tucker (1963).

Kincaid et al. (1984) did not measure red blood cell potassium. However, they observed that plasma potassium was highly variable among calves and tended to be higher in calves fed diets supplemented with 1.4% K compared to 1% K. The calves fed the 1.4% K diet had greater potassium retention.

Supplemental potassium to 1.25% K may have had a beneficial effect on feed intake. This supplementation effect may have been greater had sodium also been supplemented. Work by Beede et al. (1983b), with heat stressed cows, suggests a K:Na ration of approximately 2.5:1. Further research concerning the optimum ratio for calves is needed. Buffer was not beneficial in this study and tended to depress dry matter intake slightly. Since this contradicts with recent research (Jordan, 1986), further investigation in this area is needed.

TABLE 1. Ingredient composition of starters.[1]

Ingredient	Nonbuffered Starter			Buffered Starter		
	1.5% K	1.25% K	.9% K	1.5% K	1.25% K	.9% K
Corn, rolled	19.80	20.30	21.10	19.50	20.00	21.10
Soybeans, whole processed	18.00	18.00	18.00	18.00	18.00	18.00
Oats, rolled	30.00	30.00	30.00	30.00	30.00	30.00
Molasses	3.00	3.00	3.00	3.00	3.00	3.00
Prairie hay, ground	20.00	20.00	20.00	20.00	20.00	20.00
Alfalfa hay, ground	5.00	5.00	5.00	5.00	5.00	5.00
Dicalcium phosphate	.50	.50	.50	.50	.50	.50
Salt, plain	.76	.76	.76	--	--	--
Limestone	.68	.68	.68	.50	.27	--
Potassium chloride	.63	.36	--	.63	.36	--
Potassium sulfate	.63	.36	--	.63	.36	--
Calcium chloride	--	--	--	.25	.55	.90
Trona[2] (buffer)	--	--	--	1.00	1.00	1.00
Vitamin and trace mineral premix[3]	+	+	+	+	+	+

[1]Pellet, 4.8 mm diameter.

[2]Buffer provided by International Minerals and Chemical Corp., Mundelein, IL 60060.

[3]2200 IU vitamin A, 300 IU vitamin D, and 55 IU vitamin E per kg starter.

TABLE 2. Weekly weight gains, feed consumed and fecal scores (Mean $\pm$ SEM) for calves.

Item	Nonbuffered Starter			Buffered Starter		
	1.5% K	1.25% K	.9% K	1.5% K	1.25% K	.9% K
Weight gain (kg)	$3.0 \pm .06^{b}$	$2.9 \pm .06^{b}$	$2.8 \pm .06^{ab}$	$2.6 \pm .06^{a}$	$3.0 \pm .06^{b}$	$2.9 \pm .06^{b}$
Feed consumed (kg)	$7.7 \pm .40^{b}$	$7.3 \pm .39^{ab}$	$7.7 \pm .40^{b}$	$6.3 \pm .40^{a}$	$7.3 \pm .43^{ab}$	$6.9 \pm .43^{a}$
Fecal Score[c]	$1.1 \pm .04$	$1.1 \pm .04$	$1.2 \pm .04$	$1.2 \pm .04$	$1.1 \pm .04$	$1.1 \pm .04$

[a,b]Means within rows with different superscripts differ ($P<.05$).
[c]1=normal to 4=watery (Larson et al., 1977).

TABLE 3. Potassium effect on weight gain (kg) of calves.

	Potassium content of starter (% ration DM)		
Week	1.5% K	1.25% K	.9% K
1	1.36^{b}	$-.08^{a}$	1.74^{b}
2	.49	1.61	.30
3	2.90	1.87	1.75
4	1.61^{a}	2.49^{ab}	3.24^{b}
5	4.19	4.74	4.93
6	5.03	5.36	5.09
7	4.30	4.83	3.87
8	5.54^{a}	5.90^{b}	4.44^{a}

LSD treatment within week = 1.4.
LSD week within treatment = 1.5.

[a,b]Means with different superscripts differ ($P<.05$).

TABLE 4. Buffer effect on feed intake (kg) for calves.

Week	Nonbuffered Starter	Buffered Starter
1	.6	.6
2	.9	.8
3	2.1	2.0
4	4.3	4.0
5	8.7	8.0
6	12.6[b]	11.1[a]
7	14.5[b]	13.4[a]
8	16.9[b]	15.0[a]

LSD treatment within week = .9
LSD week within treatment = .7

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

TABLE 5. Blood gas and cortisol measurements of calves.

	Nonbuffered Starter			Buffered Starter			
Item	1.5% K	1.25% K	.9% K	1.5% K	1.25% K	.9% K	LSD[1]
pH	7.371	7.372	7.372	7.372	7.373	7.370	.01
pCO_2 (mmHg)	52.49	50.86	52.75	52.82	52.84	52.56	2.18
Base excess (meq/L)	4.55	4.18	4.87	4.84	4.89	4.48	.92
HCO_3 (meq/L)	29.27	28.78	29.58	29.69	29.57	29.23	1.06
Cortisol (ng/ml)	6.26	5.57	5.72	5.59	5.25	7.04	1.90

[1]LSD treatment main effects.

TABLE 6. Plasma volatile fatty acids[1] (mmoles and molar percentages) of calves.

Volatile	Nonbuffered Starter			Buffered Starter			
Fatty Acid	1.5% K	1.25% K	.9% K	1.5% K	1.25% K	.9% K	LSD[2]
MMole							
Acetate	1.89^{ab}	1.62^{a}	1.61^{a}	1.92^{ab}	2.25^{b}	1.53^{a}	.48
Propionate	$.26^{b}$	$.19^{a}$	$.19^{a}$	$.22^{ab}$	$.20^{ab}$	$.17^{a}$	.06
Butyrate	$.11^{ab}$	$.09^{a}$	$.09^{a}$	$.11^{ab}$	$.14^{b}$	$.07^{a}$	.04
Molar Percentage							
Acetate	83.6^{ab}	85.3^{ab}	81.6^{a}	86.0^{b}	84.7^{ab}	85.2^{ab}	3.6
Propionate	11.4^{ab}	9.9^{ab}	12.3^{b}	9.27^{a}	9.6^{a}	10.7^{ab}	2.5
Butyrate	4.9^{ab}	4.7^{ab}	6.0^{b}	4.7^{ab}	5.6^{ab}	4.0^{a}	1.4

[1]Samples collected via jugular vein.

[2]LSD's treatment main effect values.

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

TABLE 7. Lymphocyte stimulation index treatment for calves.

Mitogen Index	Nonbuffered Starter			Buffered Starter		
	1.5% K	1.25% K	.9% K	1.5% K	1.25% K	.9% K
Phytohemagglutinin[1]	15.8^{ab}	24.2^{b}	14.0^{ab}	13.4^{ab}	16.9^{ab}	13.1^{a}
Pokeweek mitogen[2]	14.9^{ab}	18.3^{b}	12.1^{ab}	13.8^{ab}	15.3^{ab}	10.1^{a}

[1]LSD treatment main effect = 7.6.

[2]LSD treatment main effect = 7.3.

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

TABLE 8. Red blood cell potassium content (ppm) of calves.

Week	Nonbuffered Starter			Buffered Starter		
	1.5% K	1.25% K	.9% K	1.5% K	1.25% K	.9% K
2	2625.2^{abA}	2634.1^{abA}	2568.7^{abA}	2449.4^{aA}	2671.2^{abA}	2926.3^{bA}
3	2449.1^{bA}	2266.5^{abA}	1904.8^{aB}	2145.8^{abA}	2563.9^{bA}	2221.9^{abB}
4	1807.5^{B}	1679.5^{B}	1833.7^{B}	1547.3^{B}	1981.4^{B}	1700.2^{C}
6	1498.5^{B}	1144.6^{C}	1200.0^{C}	1315.8^{B}	1198.4^{C}	1109.6^{D}
8	929.7^{C}	883.7^{C}	884.3^{C}	1201.5^{B}	851.5^{C}	912.0^{D}
Overall mean	1776.9	1882.6	1720.1	1794.8	2027.6	1746.5

LSD week within treatment = 373.7
LSD treatment within week = 438.6
LSD treatment main effect = 784.2

^{a,b}Means within a row with different lowercase superscripts differ ($P<.05$).

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

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QUANTITY OF MILK, METHOD OF WEANING, AND POTASSIUM AND BUFFER SUPPLEMENTATION IN STARTER DIETS ON DAIRY CALVES IN AN EARLY WEANING PROGRAM

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Forty Holstein heifers were used from birth to 8 wk of age. They were assigned to blocks of four calves at birth. Calves within blocks were assigned randomly to one of four treatments. Treatments were milk fed at 8% or 10% of birthweight per day and either gradual or abrupt weaning. All calves were fed colostrum until 3 d of age, then milk, at the assigned amount, until weaning. Along with milk, calves were fed a highly palatable prestarter until they consumed 227 g/d and then a mixture of 227 g/d prestarter and all the starter they would eat. Abruptly weaned calves were weaned at 3 wk of age or when consuming 454 g dry feed/d, whichever came first. Gradually weaned calves were fed their morning portion of milk for one additional week after 3 wk of age, or when consuming 454 g dry feed/day, whichever came first. Calves fed milk at 8% and weaned gradually had significantly greater weight gains than those of other treatments. The 8% gradual group ate more feed than the 10% gradual calves. Calves fed milk at 8% consumed more dry feed from wk 1 to wk 6 than calves fed milk at 10%. The calves fed milk at 10% and weaned gradually consumed less dry feed than any treatment group. The 10% abrupt group exhibited the largest check in growth at weaning. Mean blood urea nitrogen, measured at 4 and 8 wk, was significantly lower for the 8% gradual calves than for calves in other treatment groups. Fecal scores and lymphocyte stimulation indexes were not affected by treatment. The 10% gradual calves exhibited less increase in serum cortisol in response to injected ACTH at 4 wk 1 d of age than the remaining treatment groups. Mean weekly concentrations of cortisol were similar among treatments, however, the 10% gradual group tended to exhibit the lowest overall mean. Of treatments compared, feeding calves milk at 8% and weaning gradually resulted in superior performance.

In another experiment, sixty Holstein heifers were used from birth to 8 wk of age. Calves were blocked by birthing order and calves within blocks were assigned randomly to one of six treatments. Starter diets were formulated with and without Trona, a natural buffer, at potassium levels of .9%, 1.25% or 1.5% of ration dry matter. The sodium concentrations of all starters were constant. Calves were fed colostrum until 3 d of age and then milk at 8% of birth weight/d, divided equally into an a.m. and p.m. portion. Calves also were fed a palatable prestarter until they consumed 227 g/d and then a mixture of 227 g/d prestarter and all the appropriate starter they would consume. After wk 6, calves were fed only the starter diet. Calves were weaned gradually at 3 wk of age. There was a trend toward a potassium x week interaction on weight gain. The calves fed the 1.25% K diet tended to gain more weight from wk 6 to wk 8 than calves on the .9% K or 1.5% K diet. There was a significant buffer x week interaction on feed intake. Calves fed nonbuffered starter consumed more dry feed from wk 6 to wk 8 than calves fed a buffered starter. There were no potassium x buffer interactions on feed intake or weight gain. Fecal scores, blood gases, blood cortisol, 'ymphocyte stimulation indexes, and red blood cell potassium concentrations were unaffected by treatment. Calves fed a buffered diet tended to have increased blood acetate concentrations. Increasing the potassium concentration to 1.25% K of ration dry matter may have been beneficial to feed intake. Addition of buffer was not beneficial.