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To the Graduate Council:

I am submitting herewith a thesis written by Carolyn L. Orr entitled "Sodium bicarbonate buffered diets for marketing and transportation stressed feeder steers." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

J. B. McLaren, Major Professor

We have read this thesis and recommend its acceptance:

K. M. Barth, Paul C. Smith

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Carolyn L. Orr entitled "Sodium Bicarbonate Buffered Diets for Marketing and Transportation Stressed Feeder Steers." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

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We have read this thesis and recommend its acceptance:

Karl M. Barth

Paul C. Smith DVM

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

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SODIUM BICARBONATE BUFFERED DIETS FOR
MARKETING AND TRANSPORTATION
STRESSED FEEDER STEERS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Carolyn L. Orr

August 1979

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ABSTRACT

Fifty-four weanling steer calves were subjected to one of three pre-shipment treatments: (1) normal industry stresses (Normal Industry); (2) fed a high-energy, high-antibiotic diet in the order-buyer barn (High Energy); or (3) preweaned and fed a concentrate diet for 30 days before marketing (Preweaned). After being exposed to commercial auction and order-buyer barn environments for 4 days, the steers were assigned to one of three post-shipment treatments: (1) nonbuffered control (Nonbuffered); (2) 40 grams of sodium bicarbonate per steer per day (40-gram-$NaHCO_3$); and (3) 80 grams of sodium bicarbonate per steer per day (80-gram-$NaHCO_3$) in a 3X3 factorial arrangement with pre-shipment treatments.

Ruminal pH and *in vitro* gas production values decreased as the steers progressed through the normal sequence of market-transit events (auction barn, order-buyer barn and trucking) and were significantly lower upon arrival at the feedlot than at the farm of origin or upon arrival at the auction barn. Pre-shipment concentrate feeding at the farm of origin or in the order-buyer barn significantly reduced ruminal pH and increased *in vitro* gas production. In steers subjected to normal industry market-transit stresses, increased gas production was observed in the 40- and 80-gram $NaHCO_3$-supplemented groups on feedlot sampling day 4, 11 and 32. However, in calves preweaned and fed a concentrate diet at the farm of origin or order-buyer barn no response to feedlot $NaHCO_3$ supplementation was observed until feedlot day 32 and these responses were inconsistent and of lower magnitude than in the normal-industry-stressed steers. Packed cell volume, total serum protein, red

blood cell count, white blood cell count and rumen protozoa concentration were not affected by feedlot sodium bicarbonate supplementation.

There was a significant pre- by post-shipment treatment interaction with respect to feedlot gain. Feeding 80 grams of $NaHCO_3$ to Normal-Industry stressed steers and feeding 40 grams $NaHCO_3$ to High-Energy steers resulted in higher cumulative ADG to feedlot day 11 than the respective Nonbuffered groups. In Normal-Industry $NaHCO_3$-buffered steers, feedlot time required to regain market-transit shrink was shorter, illness index was lower, and elevated early feedlot rectal temperatures returned to normal values quicker than in Nonbuffered steers. In High-Energy steers the 40 grams $NaHCO_3$ resulted in higher early-feedlot gains but had no effect on rectal temperatures and in Preweaned steers, the Nonbuffered steers gained faster to feedlot day 11 than the other $NaHCO_3$ groups. Although, $NaHCO_3$ increased the rate of feedlot adaptation, its beneficial effects were limited to the early feedlot period when used as a buffering agent with a high corn-silage ration.

Preweaned steers gained more weight at the farm of origin. High-Energy steers lost more weight during the auction-barn, order-buyer barn phase and Normal Industry steers lost more on the truck than steers in the other two groups, respectively. However, total market-transit weight loss was similar for the three pre-shipment treatments.

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CHAPTER I

INTRODUCTION

The beef cow population in Tennessee is approximately 1.1 million which produce .8 million feeder calves annually. However, Tennessee beef cattle producers are not accustomed to finishing cattle and prefer to sell their calves at weaning or soon thereafter. This establishes a geological imbalance resulting in the export of the majority of feeder calves produced annually (Rawls, 1979).

Only a small percentage of cattle finished for slaughter are born and raised on the same farm where they are finished. Thus the majority of calves raised in Tennessee and the Southeast are exposed to the marketing and transportation stresses prior to finishing. The reduced feedlot performance, death losses and cost of veterinary treatment associated with weaning and shipping feeder calves is an important problem for feedlot operators and Tennessee feeder calf producers. A 1973 USDA survey (Greathouse et al., 1973) found that the stress condition and exposure to pathogens associated with shipping of feeder calves was responsible for 80% of all death losses in feedlot cattle and this stress resulted in an additional cost of $10-$20 per animal during the initial feeding period (Herrick, 1969). The total losses were estimated at $500 million in 1975 (Fleming, 1975).

The Bovine Respiratory Disease Complex (BRDC) generally occurs during the first 21 days following shipment from the farm of origin. Hoerlein (1973) indicated that mild to severe respiratory inflammation that occurs during this time is accompanied by variable death losses, economic losses due to poor feed utilization, chronic depression of gain and treatment costs. Although the shipping fever complex has been found to be associated with a variety of stresses and exposures to nonbacterial pathogens and bacterial infections, the clinical symptoms are largely caused by the bacterial components (Collier, 1968).

During the marketing-transportation process the calves are subjected to extreme stress. Weaning, crowding, starvation, temperature extremes, dust and dampness combine with and cause anxiety, fright, fatigue, hunger, and dehydration. Weight losses are usually 10% or more, including digestive tract contents and tissue losses (Self, 1972). Two weeks or more are required for the calves to recover from this shrink (Church, 1967). Dehydration, hemoconcentration (Elam, 1976) and body salt and electrolyte imbalance may be a cause and/or an effect of stress. Calves are subjected to restricted feed and water intake in the auction barn and for long periods during marketing and shipping, as well as dietary changes upon arrival at the feedyard. These factors disrupt rumen metabolism and increase the time required for feedlot adaptation.

Numerous reports have dealt with the effect of various treatments on the incidence of BRDC. The practices of preconditioning on the farm of origin, as well as that of feeding a concentrate ration in the order buyer barn have resulted in variable success in reducing the incidence and severity of BRDC (Algeo, 1967; Cole et al., 1979; Herrick, 1973; Moody, 1976).

The purpose of this research was to study the effect of pre-shipment management practices and post-shipment sodium bicarbonate supplementation on market-transit and feedlot performance of marketing and transportation stressed weanling feeder steers.

CHAPTER II

REVIEW OF LITERATURE

I. PRE-SHIPMENT MANAGEMENT

In an attempt to reduce market and transportation stress many researchers and veterinarians (Cope, 1979; Greathouse et al., 1969; Herrick, 1969; Hoerlein, 1973; Norman, 1974) have recommended preconditioning practices (PC) at the farm of origin (FO) that are aimed at assisting the calf in making the transition to the feedlot (FL) with a minimum of stress. Recommended PC practices generally include vaccination, castration and weaning at least three weeks prior to marketing (Norman, 1974). Koers et al. (1975) found that feeding a high-energy, antibiotic-fortified ration to calves prior to shipment improved animal performance and health. According to Norman (1974), preweaning 3 to 4 weeks prior to marketing was the most important factor of the entire PC program. In work by Greathouse et al. (1969), early-weaned calves gained faster than calves left with their dams during the last 30 days on the FO (late-weaned). However, they suggested that much of the increased gain was due to fill, since early-weaned calves shrunk more during shipping than late-weaned calves. Early-weaned calves adapted more quickly to feedlot (FL) environment and gained 6 pounds more during the first five weeks than late-weaned calves. This difference was not evident in the later FL phases. However, results of different trials were extremely variable and no overall advantage in preweaning was observed. Preweaned calves gained faster at the farm of origin than unweaned calves but Cole et al. (1979) found that the preweaned calves required 27.2 kg of ration/kg of extra weight gain. Dry matter and water intake was greater in preweaned calves during the first month in the feedlot, but consumption was similar for all calves by day 149 of the feeding period.

Moody (1976) found that gain during the first few weeks in the feedlot was higher, death loss was less and the incidence of clinical respiratory disease was lower in calves fed a concentrate ration either at the FO or during the marketing process. Fleming (1975) reported that Cope and others found that feeding a specialized high-energy ration during the marketing process resulted in greater feed consumption, higher gain, reduced sickness and lower death losses during feedlot adaptation.

II. POST-SHIPMENT MANAGEMENT

Varying post-shipment management practices have been used after arrival at the feedlot (FL) to increase FL adaptation and to hasten regaining of purchase weight. Practices which reduce the incidence and severity of Bovine Respiratory Disease Complex are of greater importance to feedlot operators than to feeder steer producers. Therefore, the FL operators may be more receptive to the cost of preventative measures than are the producers who only see its effects second hand and receive little economic return for their effort of preconditioning calves prior to shipment (Meyer et al., 1970).

Post-shipment management practices may involve antibiotic treatment, vaccination for various diseases and the use of various dietary supplementations. Compounds are added to the feedlot ration to reduce the stress of FL adaptation and to reduce the severity of digestive upsets that results from sudden dietary changes. It has been reported that feed additives may correct digestive upsets, aid in the replacement of intercellular water and correct body salt and electrolyte imbalances that occur during shipment.

Addition of potassium to the FL receiving diet was found by Hutcheson et al. (1979) to result in lower incidence of sickness and quicker recovery of purchase weight. B-vitamin supplementation reduced sickness in late-weaned calves, increased morbidity in preweaned calves and had no affect on calves fed a fortified ration during the marketing process (Cole et al., 1979). Brethour and Deutsman (1972) found that the addition of thiamine to the ration of previously stressed calves tended to increase feed intake. Higher average daily gain during the initial 21 days of the feeding period seen by Huntington et al. (1977) was a result of the addition of low levels of sodium bicarbonate or sodium bentonite to the starter ration. Lassiter et al. (1963) found that the addition of sodium bicarbonate to the drinking water of steers during the initial feeding period had beneficial effects on the rumen protozoa.

III. STRESS RELATED RUMEN DYSFUNCTION

Disruption in the feeding schedule and diet changes of feeder calves during marketing and upon FL arrival tend to decrease saliva production; and therefore, disrupted the natural buffering mechanism of the reticulorumen (Emerick, 1976). During marketing and FL adaptation, ingestion of feeds rich in readily available carbohydrates and reduction in natural buffers often results in a condition termed acidosis. This condition has been called overeating, acute impaction, grain engorgement or overloading (Elam, 1976). Signs of this rumen dysfunction include anorexia, diarrhea, mucous in the feces, dehydration, incoordination and sometimes death. Dirkson (1970) suggested that this condition was a result of stress, and a decrease in saliva production associated with concentrate diet feeding and soluble carbohydrate intake of high grain diets which forces rumen pH down and causes the animal to go off feed. Reticulo-rumen fluid pH is influenced by dietary energy intake, physical form of ingested feeds, saliva production, microbial metabolism, volatile fatty acid production (VFA) and partial carbon dioxide pressure. The absorption of VFAs and exchange with bicarbonate ions across the rumen epithelium interact and affect the buffering capacity of the rumen contents and thus the rumen pH (Kromann and Meyer, 1972).

Elam (1976) summarized problems usually associated with acidosis as occurring when "(1) starting cattle on feed, (2) when graduating cattle to a higher concentrate ration, (3) after weather changes, (4) after periods in which some problem has resulted in the cattle being out of feed and hungry, and (5) while feeding cattle on a high-energy-finishing diet for long periods." The first four of these five situations may and usually do occur during the marketing-transportation process and FL adaptation phase to which newly-weaned calves are subjected when moved from farm of origin to feedlot.

Ruminal population adaptation to high-concentrate diets is dependent on an increased concentration of microbes which utilize starch to produce VFAs. These microbes compete with and prevent lactic-acid-producing bacteria from overpopulating the rumen (Allison, 1976).

However, if readily fermentable carbohydrates exceed the normal microbial fermentation capacity then Streptococcus bovis will become dominant. An increase in rumen liquor and blood lactic acid levels occurs and the blood and rumen pH is lowered.

Although lactic acid can be metabolized under normal rumen conditions, it is the high production of slowly-utilized D(-) lactic acid which creates the buildup of lactic acid during rumen dysfunction. This concentration may peak within 7-24 hours after acute overloading, but rumen pH may remain low for several days. In stress induced acidosis, its effects may extend for a period of weeks (Dunlop, 1972). Briggs et al. (1957) found a significant coefficient of regression of rumen pH on lactic acid concentration.

Rumenitis and epithelial sloughing of the rumen due to the destruction of intestinal-wall linings by unbuffered acids may result in slime in the feces (Dunlop, 1972). During rumenitis, the number of gram negative bacteria in the rumen decreased while the numbers of gram positive bacteria rose. McManus and Bigham (1978) found large increases in the Streptococcus bovis and Lactobacilli populations during rumenitis. It was hypothesized that the breakdown of the stratum granulosum contributed entry points into the body for toxins produced by gram positive bacteria (Huber, 1976; McManus and Bigham, 1978). Discrepancies between the concentrations of acids in the rumen and the severity of acidosis symptoms were observed by McManus and Bigham (1978). The effects of these gram positive bacteria toxic factors were similar to additional pathogenic factors (McManus and Bigham, 1978). Dougherty et al. (1975) detected endotoxin in the circulatory system of sheep and cattle after induced grain engorgement. In cattle overfed with soluble carbohydrates, McManus and Bigham (1978) found that lysis of gram positive ruminal flora produced a bacterial lipopolysaccharide endotoxin. The significance of these factors in the pathogenesis of the acidosis syndrome is the object of intensive research at this time (McManus and Bigham, 1978).

Pursor and Moir (1959) found that low rumen pH inhibited protozoal motility and had a toxic effect on rumen microbes. Allison (1976) found that the hydrogen ion concentration of the rumen affected the growth of the rumen protozoa, and rumen protozoa concentration has been observed to decrease during acidosis (Christenson, 1964). Evidence of major qualitative changes in the rumen microbial population and in the metabolic pattern in response to dietary changes which affect rumen pH has also been reported (Pursor and Moir, 1959).

Moir and Somers (1957) found that direct counts of "free" rumen bacteria and rumen pH values followed similar trends. However, they also found that the total concentration of viable bacteria in the rumen contents of animals adapted to concentrate rations was considerably greater than that of animals fed only hay and suggested that this indicated a required adaptation period for the rumen.

Production and absorption of ruminal VFA are sensitive to pH change (Esdale and Satter, 1972). Both the total quantity and the proportion of VFA have been shown to be affected. Volatile fatty acid absorption was directly related to rumen pH (Gray, 1948). Reid et al. (1957) found that low rumen pH resulted in a decline in the concentration of propionic and butyric acids. Changes in concentration of individual

VFAs at different pH levels may also reflect changes in the relative rates of absorption of the VFA. The decrease in rumen pH associated with the early stages of acute acidosis, as well as in less severe forms, may be aggravated by increased production of acids other than lactic, especially acetic acid (Fremere et al., 1968).

Huber (1976) found that as the pH of the rumen ingesta approached 5.0, the amplitude and frequency of contractions of the forestomach diminish and eventually attained stasis. Rumen stasis decreases the flow of rumen contents through the digestive tract and thus serves to curb the ruminant's appetite (Harrison et al., 1975). It further reduces the production of saliva, the flow of buffering compounds into the reticulo-rumen and the flow of by-products and waste products out of the rumen (Bartley, 1976).

The general condition of the animal undergoing these ruminal changes can be variable and is influenced by the degree and duration of the alteration of the rumen environment, blood composition and body metabolism. Pathogenic changes occurring during the various phases of severe acidosis are not uniform and other expressions of ruminal hyperacidity exist, including the low milk fat syndrome in dairy cows. Even subclinical acidosis may reduce weight gain and feed efficiency. Acidosis may even be a factor in bloat and founder (Kellaway et al. 1973; Phillipson, 1959). Therefore, the clinical designation of "rumen acidosis" is actually a collective term for several digestive disturbances that include depression of rumen pH as one of the predisposing factors. Allison (1976) reported that maintenance of rumen hydrogen ion concentration or pH within a narrow range has a high homeostatic priority. Regulation of pH appears to take precedence over the elimination of carbon dioxide or the retention of water. Economic functions rank very low in comparison with pH regulation and thus the growth and finishing of FL cattle cannot take place under suboptimum rumen conditions.

IV. METABOLIC MAINTENANCE OF HOMEOSTASIS

Hydrogen ion concentration in body fluids tends to be stabilized by several buffers. The first and quickest biological buffering mechanism is the fluid and tissue chemical buffer system which includes bicarbonate (HCO_3), plasma protein, phosphate and hemoglobin. According to Henderson (1908), these buffers neutralize acids or bases produced by the tissues through chemical reactions in which the conjugate base of a weak acid accepts a proton from a relatively stronger acid with the formation of a neutral salt from the stronger acid: $H^+ Cl^- + Na^+ HCO_3^- = Na^+ Cl^- + H^+ + HCO_3^-$. Hydrogen ions are buffered in the blood by protein, phosphate and HCO_3 systems. Bicarbonate is the most readily adaptable buffer because the respiratory system can rapidly adjust the carbonic acid component by eliminating or retaining CO_2 (Bartley, 1976). The HCO_3 system is thus the principle buffer in extracellular water. The sodium ions are actively reabsorbed and the conjugate bases are then free to accept protons from carbonic acid (hydroxylated CO_2) in the kidney tubular fluid (Henderson, 1908).

Ninety-nine percent of the filtered HCO_3 is reabsorbed along with the sodium (Michelle, 1977). The principal chemical buffers in the rumen system are sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$) and VFAs Saliva recirculates reabsorbed HCO_3 and smaller amounts of other buffers to the rumen. Bovine saliva is secreted from glands and glandular tissue in the mouth (Phillipson, 1959). Values reported for bovine salivary production are variable and range from 54 to 190 liters every twenty-four hours. The reticulo-rumen itself has no glandular tissue and the large volume of saliva secreted is important in the maintenance of well buffered fluid conditions that are necessary for proper rumen function.

The success of buffering systems is generally measured in terms of pH, rather than the actual hydrogen ion concentration. In comparison, a 5% decrease in pH from 7.4-7.0 gives a 250% increase in the hydrogen ion concentration. As long as this relationship is kept in mind, pH is a practical scale of acidity defined in terms of standards and is a good index of the chemical potential of the protons.

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V. THE USE OF BUFFERS IN THE DIET OF YOUNG RUMINANTS

Bovine saliva provides 70% of the water and most of the salts that enter the rumen (Kay, 1960). Saliva also serves to provide nitrogenous and mineral nutrients for rumen microbial metabolism (Bartley, 1975). The composition of paratid saliva has led to it being termed a bicarbonate phosphate buffer, recognizing that there is up to 18 times more sodium than potassium present. Salivary saliva contains less of these substances (Lassiter et al. 1963). Literature values for bovine salivary production show large variations ranging from 54 to 190 liters every twenty-four hours (Bartley, 1975; Phillipson, 1959) with a pH of 8.2 to 8.5 (Turner and Hodgetts, 1955).

Volatile fatty acid production would lower rumen pH to 3.0 if salivary secretion ceased (Turner and Hodgett, 1955), indicating the considerable buffering ability of the copious secretions of alkaline saliva as it neutralizes a large part of the acids produced.

Saliva production in the ruminant influences feed and water intake by increasing the rate of passage out of the rumen (Bhattacharya and Warner, 1966). Harrison et al. (1975) found that intraruminally infusing artificial saliva significantly increased the rumen dilution rate and reduced the rumen liquor molar proportion of propionate. Increased dilution rate increased the flow of amino acids into the small intestine and increased the efficiency of microbial protein synthesis in the rumen.

Saliva production quality and quantity are directly related to diet and mastication time (Bartley, 1976). Rate of saliva production is higher with roughages low in water than with those of a higher moisture content. Grain consumption decreases salivation (Turner and Hodgetts, 1955) and rumination (Lassiter et al., 1963), decreasing the recirculation of the mineral cations of the saliva. This results in altered rumen buffering capability, pH and microbial metabolism. Calves may have a greater need for roughage to stimulate saliva production than adult cattle due to lower saliva production in young ruminants in relation to gland size when compared to adult ruminants (Kelleway et al., 1973). Trenke, as reported by Newell (1978), found that young animals are most likely to benefit from the feeding of buffers.

Since the shifts and redistribution of substances like potassium, sodium, calcium and magnesium are as much a concern in the transportation of sheep or cattle as is the loss of water, it seems likely that the addition of buffers may be beneficial to the transportation stressed lambs or calves. Electrolyte losses may contribute to loss of thirst, despite the fact that the animals are dehydrated. Reduction of water intake will also reduce the rate of salivation (Michell, 1977) and result in greater tissue and rumen fluid electrolyte imbalances. Even though the resulting clinical conditions such as acidosis have been recognized, many milder conditions may have greater economic impact (Thorlacius and Lodge, 1973). Phillipson (1959) found that bloat only occurs when rumen pH is below 6.3. Kellaway et al. (1973) found that the feeding of buffers reduced the death loss due to bloat. Buffers are not foreign to the rumen environment and there has been much research in the utilization of additional buffers to replace those lost with reduced saliva production.

According to Matrone et al. (1957), the addition of the sodium salts of acetic, propionic and butyric acid to roughage-free purified diets improved performance of the animals. In subsequent research, Matrone et al. (1959) found that the addition of the fatty acids as the glycerol esters did not affect the performance. However, the addition of sodium or potassium bicarbonate to purified diets produced the same improvement in weight gains as the salts of the volatile fatty acids. It was theorized that the improved performance was due to either the cations or the increased buffering capacity and not the VFAs themselves.

Following the results of improved performance due to the addition of bicarbonates to purified diets by Matrone et al. (1959), other researchers began to study the use of these and other buffering compounds in practical rations. Chemical composition, levels and methods of adding single and mixed buffers to experimental rations are as varied as there are researchers in the field. Sodium and potassium carbonates and bicarbonates are the most frequently utilized (Kellaway et al., 1973). However, Emery (1976) reported a beneficial effect from adding calcium hydroxide or sodium bentonite. Calcium hydroxide significantly reduced feed intake (Embry, 1968), gains and feed efficiency when added to sorghum silage but improved gain during the last 160 days of a 272 day feeding trial when added to a corn-silage ration.

Calcium carbonate was shown by Raun et al. (1962) to have no significant effect on ruminal fermentation patterns and rumen pH (Emery, 1976). Nicholston et al. (1963b) reported inconsistent effects of 5.7% ground limestone added to a barley and oat ration on VFA production. High calcium ground limestone and urea were shown by Klosterman et al. (1960) to increase gain and improve feed efficiency of steers fed corn silage.

Intake of whole wheat by fattening lambs (Saville et al., 1973) increased when disodium hydrogen phosphate was added as a mineral buffer. Pryor and Laws (1972) reported the sodium acetate resulted in less decrease in rumen pH of calves fed a pelleted barley diet than in nonbuffered calves. Nicholson et al. (1963b) found that sodium propionate changed the average proportion of the various VFAs. Aluminum hydroxide added to grain diets of sheep (McManus and Bigham, 1978) increased the rumen microbial concentration and maintained a rumen flora of predominately gram negative organisms. Buffer-fed sheep had improved performance over animals fed the wheat and limestone basal diet.

On the theory that multicomponent buffer mixtures could better resist rapid changes in ruminal pH, McManus et al. (1972) used a control diet of whole wheat and 1.5% ground limestone and added 2% of a 1:1 mixture of sodium bicarbonate ($NaHCO_3$) and sodium phosphate or a 1:1:1:1 mixture of sodium phosphate, $NaHCO_3$, potassium bicarbonate ($KHCO_3$) and calcium phosphate. Both buffer mixtures resulted in significantly higher gains and feed efficiencies. Sodium bentonite and $KHCO_3$ in equal proportions increased ruminal pH (Horn et al., 1979) when fed to steers with subclinical lactic adicosis. Ruminal glucose, VFA and ruminal fluid osmolalities were not affected by this bentonite and $KHCO_3$ mixture. A 50:50 mixture of $NaHCO_3$ and $KHCO_3$ significantly reduced death loss due to bloat in pellet-fed calves (Kellaway et al., 1973). As the percentage of buffer in the feed increased, feed intake and growth increased. The growth response was linear up to 4% buffer in the diet and the authors concluded that the optimum supplementation rate would be higher. Nicholson and Cunningham (1961) found that a mixture of 2 parts limestone, 2 parts $NaHCO_3$ and 1 part $KHCO_3$ was not as effective in improving gains in calves on a concentrate ration as a 7.2% mixture of ground limestone and $NaHCO_3$. However, they found that a 6% level of the limestone mixture, $NaHCO_3$ and $KHCO_3$ mixture gave better results than a 9% level. Higher buffering capabilities resulted from an equal weight of $NaHCO_3$ than from mixed buffers (Nicholson et al., 1967a).

Sodium bicarbonate alone appears to produce the most consistent and reproducible results while still being economically justifiable. $NaHCO_3$ inclusion in high-concentrate diets for sheep resulted in the accumulation of L(+) lactate as the predominate isomer in the rumen fluid, whereas the D(-) isomer predominated in the rumina of nonbuffered sheep according to Lee and Matrone (1971). Rumen epithelial cells from $NaHCO_3$ supplemented sheep produced significantly less acetate and butyrate and significantly more propionate when cultured in vitro than did cells from unsupplemented sheep. Bunn and Matrone (1968) found lactate levels in the rumen of HCO_3 supplemented sheep to be much lower than in those sheep not receiving HCO_3. A tendency toward reduced acetate/butyrate ratios was also seen in HCO_3-supplemented sheep. Lactate fermentation proceeded more rapidly in a HCO_3 buffer than in a phosphate buffer at the same pH (Huber, 1976). Lactic acid accumulation was almost completely suppressed and VFA concentration was increased by dripping a $NaHCO_3$ solution into the rumen of sheep to prevent the rumen pH from falling below 5.8.

VanCampen and Matrone (1960) found more total VFA and a higher proportion of propionic acid in the rumen fluid of sheep when HCO_3 was added to a purified ration. Concentration of VFA decreased more rapidly with time after feeding in the nonsupplemented calves. Calves receiving $NaHCO_3$ had a higher proportion of butyrate, a decreased proportion of acetate and lower lactate levels than nonbuffered calves (Bunn and Matrone, 1968). The $NaHCO_3$ fed calves maintained higher rumen content pH throughout the feeding trial. Nicholson and Cunningham (1961) found that a high ratio of propionic to acetic acid in the rumen may lead to a higher efficiency of feed utilization. The addition of 3% $NaHCO_3$ to a high concentrate ration for steers increased rumen pH, feed intake, carcass weight, body fat, and rumen propionate and butyrate levels, while decreasing rumen acetate levels (Nicholson et al., 1963a). The steers fed $NaHCO_3$ had higher average daily gains (ADG), hot carcass weights, carcass fat content and carcass quality grades. Increased propionate levels in the rumen of finishing steers improved animal performance and weight gain (VanCampen, 1976). The addition of 6% $NaHCO_3$ to a concentrate ration had no effect on feed consumption or ADG, but dressing percentage was higher in buffer-fed steers (Nicholson et al., 1962a). The higher finish at slaughter of $NaHCO_3$-fed steers was thought to be due to a higher caloric value of gain. This level of $NaHCO_3$ did not affect digestibility or nitrogen retention. Kidney lesions were observed on all rations in this trial, but there was an increased incidence of lesions in the buffer-fed calves. Sodium is readily absorbed from $NaHCO_3$ and may increase urine excretion which may be related to an increase in kidney lesions.

To shorten the 2-4 weeks commonly required for adaptation from high roughage to high concentrate rations, and to prevent the digestive disorders and suboptimal performance that often occur at this time, Huntington et al. (1977) fed lambs 2% and 4% levels of $NaHCO_3$. The 2% $NaHCO_3$ fed lambs had higher ADG during the initial 21 day feeding period. Lambs fed 4% $NaHCO_3$ experienced digestive disorders as evidenced by a high incidence of diarrhea. The addition of low levels of $NaHCO_3$ may serve to benefit the performance of feedlot lambs during the early phases of the feeding period (Huntington et al., 1977). However, they warned against the use of higher levels over an extended period of time.

Saville et al. (1973) found that daily feed intake of a whole wheat and limestone diet increased due to the addition of 2% $NaHCO_3$, disodium hydrogen phosphate or sodium chloride. The authors postulate that this increase in body weight with the buffer was due to the added sodium, and reported that buffer addition is not warranted in sheep after adaptation to wheat diets.

Lassiter et al. (1963) added .5% $NaHCO_3$ to the drinking water of steers on a pelleted diet to supplement the recirculation of mineral cations decrease resulting from reduced saliva production on a pelleted or concentrate diet. During the first 11 days on feed the anaerobic population of the rumen increased in all animals. After 11 days, the anaerobic counts of animals without access to buffered water declined, while the anaerobic population in calves receiving buffered water continued to increase. When the calves were switched to other treatment groups, the rumen anaerobic count response was similar to that previously observed. Whether this was an effect on rumen environment or simply a method of meeting the nutrient needs of the microorganisms, was not specified. The anaerobic microbes may be affected by the carbon dioxide from $NaHCO_3$. They also found that aerobic bacteria increased rapidly during the first 21 days in buffered steers, followed by a gradual decline when the $NaHCO_3$ was withheld. There was no increase in aerobic bacteria in nonbuffered steers. The $NaHCO_3$ did not change the species of aerobic flora that predominated. Calves consuming the buffered water had higher intakes of water and increased urination, presumably eliminating the excess sodium in the urine. Even when untreated water was available, calves showed a preference to the buffered water. Average daily free-choice intake of the buffered water resulted in the consumption of 32.1-83.3 g of sodium bicarbonate daily.

The feeding of $NaHCO_3$ resulted in increased salivary production of HCO_3 and $NaHCO_3$ (Embry et al., 1968). Sodium bicarbonate at 5% or 12% of the diet was added to a low energy, low concentrate ration or to a high energy, high concentrate ration of wethers by Kromann and Meyer (1972). The amount of reticulo-rumen dry matter was higher on high energy diets than on low energy, high roughage diets. However, they found reticulo-rumen dry matter of calves fed a high energy diet decreased at a greater rate than the amount of reticulo-rumen dry matter of calves on the low energy diet. The $NaHCO_3$ significantly reduced the reticulo-rumen dry matter levels for both energy levels and physical forms. The buffer-fed wethers may have consumed more water, accounting for the decrease in reticulo-rumen dry matter. Rumen pH was lower in lambs fed high energy diets than in those fed the low energy diets. The addition of 12% $NaHCO_3$ to the ration significantly increased the rumen pH values, however, 5% $NaHCO_3$ had no effect on the reticulo-rumen pH. Sodium bicarbonate was not found to affect the total VFA production, but it increased acetate and butyrate concentration on the high-energy ration and lowered butyrate concentration on the low-energy diet.

The buffering capacity in relation to energy intake and rumen metabolism is a major contributing factor towards predisposition of parakeratosis (Kromann and Meyer, 1972). The addition of $NaHCO_3$ to a pelleted diet fed calves resulted in less decrease in pH of the rumen contents and reduced the incidence of hyperkeratosis and rumenitis (Pryor and Laws, 1972).

Addition of 9% of a ground limestone—$NaHCO_3$ mixture to timothy hay ration decreased gains, feed efficiency and consumption (Nicholson and Cunningham, 1961). However, a 7.2% of this mixture added to an all-concentrate ration improved gains and feed efficiency. The addition of $KHCO_3$ to make 9% buffers gave results intermediate to the 7.2% level and the nonbuffered control.

VI. USE OF BUFFERS IN SILAGE RATIONS

Some ruminant feeds contain performed organic acids which may result in limited feed intake. Grass silage was found to contain 7% VFA on a dry matter basis (Barnett, as reported by Emerick, 1976). Addition of $NaHCO_3$ to high moisture grass silage at feeding to neutralize the acidity of the ration was found to increase ash, raise pH and increase the osmolality values of the ration when added at 2.5% of the as fed weight (Lancaster and Wilson, 1975). Sodium bicarbonate depressed intake during the first week in the first trial and increased silage intake during the first 3 weeks in the next. These authors thought that the lack of response to the sodium bicarbonate supplementation may have been due to the use of mature animals which appear less responsive to feed additives than younger ruminants.

Dahmen et al. (1969) found that the addition of $NaHCO_3$ at ensiling of corn silage did not affect ADG but did significantly improve feed efficiency. Rye-grass silage with a pH of 3.8 was adjusted with $NaHCO_3$ to a pH of 5.4 by McLeod et al. (1970) and resulted in higher organic matter intake and digestibility. No differences in molar ratios of VFAs rumen pH or rate of cellulose digestion was seen. Returning this silage to a pH of 3.8 by the addition of lactic acid reduced dry matter intake from the buffered level by 22%. Brethour and Duitsman (1972) supplemented a high-silage diet with 100 g sodium bicarbonate per head per day. This resulted in a 4% increase in dry matter intake and an increase in weight gain during the 144 day feeding period.

Embry et al. (1968) added limestone, calcium hydroxide and $NaHCO_3$ at the rate of 90 g per day to a protein supplement fed with corn or sorghum silage. During the first 113 days of the 272 day feeding period the $NaHCO_3$ + corn silage fed calves had a 7.2% improvement in gain. Calcium hydroxide was not seen to have any benefits when it was added to the ration. There appeared to be a difference in the timing of the response to the buffers used in this trial.

VII. FACTORS AFFECTING BUFFER EFFICIENCY

A comparison of research with respect to the addition of buffers to ruminant rations shows a great deal of variability in the results obtained. These differences may be due to widely differing diet composition, buffering compounds, methods and levels of administration as well as prior rumen status. Buffers have been shown to be of more benefit in meal-fed animals than in those fed ad libitum (Bunn and Matrone, 1968). Sampling time has been shown to have a significant effect on rumen pH and microbes (Pursor, 1961). Thorlacious and Lodge (1973) found that buffer levels above that observed in the rumen of the fasting animal may raise the pH to a point where fatty acid absorption is reduced, thus explaining the detrimental effects seen by some researchers (Calhoun et al., 1974; Huntington et al., 1977) with the addition of high levels of mineral buffers. Variation in VFA concentration seen by Bunn and Matrone (1968) may be due to differences in sampling time in relation to feeding time (Kromann, 1972), or to the alternate pathways available for pyruvate metabolism during the fermentation of carbohydrate materials in the rumen. When this is considered it is not surprising that different experimental conditions lead to vastly different results.

CHAPTER III

THE EFFECTS OF PRE-SHIPMENT MANAGEMENT AND POST-SHIPMENT SODIUM BICARBONATE SUPPLEMENTATION ON PERFORMANCE, HEALTH AND CARCASS TRAITS OF MARKET-TRANSIT STRESSED WEANLING FEEDER STEERS

I. SUMMARY

Fifty-four weanling steer calves were subjected to one of three pre-shipment treatments, (1) normal industry stresses (Normal-Industry), (2) fed a high-energy, high-antibiotic diet in the order-buyer barn (High-Energy); or (3) preweaned and fed a concentrate diet free choice for 30 days before marketing (Preweaned). After being exposed to commercial auction and order-buyer barn environments for 4 days, the steers were assigned to one of three post-shipment treatments: (1) non-buffered control (Nonbuffered); (2) 40 grams of sodium bicarbonate per steer per day (40-gram-$NaHCO_3$); and (3) 80 grams of sodium bicarbonate per steer per day (80-gram-$NaHCO_3$) in a 3X3 factorial arrangement with pre-shipment treatments.

Preweaned steers gained more weight the last 30 days at the farm of origin. High-Energy steers lost more weight during the auction-barn, order-buyer barn phase and Normal-Industry steers lost more on the truck than steers in the other two groups, respectively. However, total market-transit weight loss was similar for the three pre-shipment treatments.

There was a significant pre-by post-shipment treatment interaction with respect to feedlot gain. Feeding 80 grams of $NaHCO_3$ to Normal-Industry stressed steers and feeding 40 grams $NaHCO_3$ to High-Energy steers resulted in higher cumulative ADG to feedlot day 11 than the respective Nonbuffered groups. In Normal-Industry-$NaHCO_3$-buffered steers feedlot time required to regain market-transit shrink was shorter, illness index was lower, and elevated early feedlot rectal temperatures returned to normal values quicker than in Nonbuffered steers. In High-Energy steers the 40 grams $NaHCO_3$ resulted in higher early-feedlot gains but had no effect on rectal temperatures. Preweaned, nonbuffered steers gained faster to feedlot day 11 than the other $NaHCO_3$ groups. Although, $NaHCO_3$ increased the rate of feedlot adaptation, its beneficial effects were limited to the early feedlot period when used as a buffering agent with a high corn-silage ration.

II. INTRODUCTION

On January 1, 1979 the Tennessee beef cow population was over one million and over .9 million calves will be produced in 1979 (Rawls, 1979). Only a small percentage of the calves produced in Tennessee are retained for finishing and about .8 million feeder calves per year will be exported out of Tennessee at weaning or as yearlings. Since only a few Tennessee and Southeast calves are finished for slaughter on the farms where they are produced, the majority of Tennessee and Southeastern calves are exposed to varying degrees of market-transit stress prior to reaching the location where they will be finished for slaughter.

Reduced feedlot performance, extra veterinary medical costs and often death losses are associated with weaning, marketing and shipping of feeder calves. The stress condition and exposure to pathogens associated with shipping cattle is responsible for 80% of feedlot death losses and results in costs of $10 to $20 per steer placed in feedlots (Greathouse et al., 1973).

Numerous pre-shipment procedures, such as early weaning and feeding a concentrate ration at the farm of origin (Cole et al., 1979; Woods, et al., 1970), preshipment vaccination (Knight et al., 1972), direct shipment from the farm of origin to the feedlot (Greathouse et al., 1973; Norman, 1974) and feeding a high-energy, antibiotic fortified diet during marketing (Cole, et al., 1979; Koers et al., 1975) have been evaluated with respect to their effectiveness in reducing the incidence of Bovine Respiratory Disease Complex (BRDC). Another opportunity to reduce BRDC losses exists in accelerated feedlot adaptation.

Sodium bicarbonate ($NaHCO_3$) has been used with varying degrees of success to reduce acidosis (Nicholson et al., 1963), increase feed efficiency (Brethour and Duitsman, 1972) and increase gains (Morris and Gartner, 1971) of feedlot cattle consuming high concentrate diets (Brethour and Duitsman, 1972; Morris and Gartner, 1971; Nicholson et al., 1963a; Preston et al., 1963) and high corn or sorghum silage diets

(Dahmen et al., 1969; Morris and Gartner, 1971). Hixson (1972) reported successful treatment of acidosis by oral and intraperitoneal administration of $NaHCO_3$ solutions. In a recent study conducted by Brethour (1976) feedlot calves receiving $NaHCO_3$ in their diets responded significantly better than the control calves to an epidemic of shipping fever.

The objectives of this study were to evaluate the effects of pre-shipment management and supplementation of feedlot diets with $NaHCO_3$ on market-transit, feedlot and health performance and on carcass traits of market-transit stressed feeder calves.

III. EXPERIMENTAL PROCEDURES

In the fall of 1977, 54 Hereford and Angus steer calves weighing 462 $\pm$ 21 lbs were selected at random from the farms of two cooperating Tennessee feeder calf producers. Nine of the calves at each farm were weaned 30 days prior to shipment from the farm of origin (FO) and fed a concentrate diet (Table 1) free choice until marketed. The other calves remained with their dams on pasture without supplemental feed until they were marketed (Table 2).

The calves were trucked to a commercial auction barn at Algood, Tennessee (50-75 miles from FO) where purchase weights were taken immediately after arrival. During the first 24 hours, the steers were subjected to normal-auction-barn environment (Billingsley et al., 1979) which included penning them in close confinement without access to feed or water. Following the auction-barn phase, the space allotment was increased to 15 to 30 sq. ft. per steer and feed and water was provided

Table 1. Diet ingredients.

Pre-shipment diet ingredient, lb./T	Concentrate ration fed to Preweaned calves at farm of origin	High-energy, high-antibiotic order-buyer barn
Corn # 2	623	640
Soybean meal	300	140
Molasses	100	80
Cottonseed hulls	840	900
Propylene glycol		100
Alfalfa meal pellets (17% CP)	100	
Fat (animal)	20	
Salt, T.M.	10	10
Vitamin premix	a	10
Tetracycline (TM100)	a	100
Dicalcium Phosphate		14
Calcium carbonate	7	6

[a]Contains 2 M^{iv} units vitamin A and 8,000 mg. tetracycline per ton.

[b]Provided 0.5 gram tetracycline per lb of complete feed.

Table 2. Description of preshipment management treatments.

Treatment designation	Management and Diets	
	Farm of origin[a] (30 days)	Order-buyer barn[b] (72 hours)
Normal Industry	with dam, no concentrates	mixed grass[c] hay, free choice
High Energy	with dam, no concentrates	high-energy, high antibiotic ration[c] (7.5 lbs./steer/day)
Preweaned	weaned and fed a 65% concentrate ration + hay or pasture during last 30 days[c]	mixed grass hay,[c] free choice

[a]All calves were allowed (.65 to .75 cm^3 of) pen space without feed or water during the 24 hrs. in the auction barn.

[b]Pen space was increased to 15 to 30 square feet during the 72 hrs. in the order buyer barn.

[c]Ingredients of the rations are shown in Table 1.

as the steers were subjected to order-buyer-barn environment for 72 hours. The 18 Preweaned steers and 18 other steers were fed hay (Normal-Industry). The remaining 18 steers were fed a high-energy, high-antibiotic ration (Table 1) during the order-buyer phase (High-Energy).

At the end of the order-buyer-barn phase, the steers were trucked 18 hours, 900 miles, to a feedlot at the Highland Rim Experiment Station, Springfield, Tennessee. Upon arrival at the feedlot the steers within each pre-shipment treatment were randomly assigned to three post-shipment treatments in a 3X3 factorial arrangement. The post-shipment treatments involved two levels of sodium bicarbonate ($NaHCO_3$) supplementation (40 and 80 grams per steer per day) and a nonbuffered control (Nonbuffered).

From feedlot day 0 to feedlot day 140 the steers were fed corn silage free choice plus four lbs cracked-shelled corn and one lb cottonseed meal per steer per day (Table 3). The $NaHCO_3$ was mixed with cottonseed meal at the rate of 10 lb $NaHCO_3$ per 100 lb cottonseed meal (40-grams-$NaHCO_3$) and 20 lb $NaHCO_3$ per 100 lb cottonseed meal (80-grams-$NaHCO_3$). Following feedlot day 140 the corn silage in the diet was gradually decreased and the proportion of corn was gradually increased until day 149 when the diet consisted of whole-shelled corn free choice and 1.1 lb of a commercial protein supplement (Tend-R-Leen) designed to be fed with whole shelled corn. After day 149, the whole shelled corn was top dressed daily with 40 or 80 grams of $NaHCO_3$ per steer.

Individual steer weights were taken at the farm of origin 30 days before auction barn arrival, upon arrival at the auction barn, prior to departure from the order-buyer barn and on feedlot days 0, 4, 11, 32 and 149. Daily rectal temperatures were taken during the first week in the

Table 3. Nutrient composition of feedlot ration.[a]

Ingredient	IRN[b]	Composition				
		Crude Protein	Crude Fiber	Ether Extract	NFE	Ash
Corn, aerial pt, ensiled, mature, well eared mn 30, mx 50 dry matter, (3)[c]	3-08-153	9.2	21.1	2.4	62.9	4.4
Corn, dent yellow, grain, gr 2 US mn 54 wt, (4)	4-02-93	10.2	2.1	4.9	81.7	1.3
Cotton, seed w some hulls, mech-extd grnd, mn 41 prot mx 14 for mn 2 fat, (5)	5-01-617	44.8	13.8	2.3	33.0	6.1

[a]Percent, dry matter basis.

[b]International reference number.

[c]33% dry matter, as fed.

feedlot. A steer was designated as sick and was treated for a minimum of three days when three of the five predesignated criteria [dyspnea (labored breathing), rectal temperature in excess of 104°, listlessness, anorexia, coughing and mucopurolent nasal discharge] were observed concurrently. Detailed health notes were maintained and an overall feedlot health index based on the five criteria was calculated for each steer.

Following the feedlot phase the steers were slaughtered at a local packing plant and carcass data were obtained. Least-squares procedures were used to evaluate the effects of the independent variables (pre- and post-shipment treatment and their interaction) on the dependent variables (performance, health status and carcass).

IV. RESULTS AND DISCUSSION

Pre-shipment Results

Pre-shipment gain. Pre-shipment management regimes significantly affected total market-transit weight changes (Table 4). Preweaned steers gained significantly more during the last 30 days at the farm of origin than nonweaned (Normal-Industry and High-Energy) steers. The 10.5 lbs farm-of-origin gain advantage of Preweaned steers over the nonweaned steers was similar to the 11.1 lbs advantage reported by Cole et al. (1979). The total auction-barn and order-buyer-barn weight loss of High-Energy and Preweaned steers was greater than that of Normal-Industry steers. Cole et al. (1979) and Koers et al. (1975) reported greater pre-transit weight loss in Normal-Industry stressed cattle. During the time the steers in this study were in the order-buyer barn, the barn was operated at maximum capacity due to the large number of other

Table 4. Weight changes at the farm of origin and during the market-transit phase.

Weight change during various segments of the market-transit phase, lb[d]	Pre-shipment treatments		
	Normal Industry	High Energy	Preweaned
Weight at farm of origin[a]	467	465	455
Gain farm of origin, [a]	58.3[b]	59.5[b]	69.4[c]
Auction and order-buyer barn, 96 hrs.	-8.1[b]	-23.9[c]	-16.4[bc]
On truck, 18 hrs.	-29.4[b]	-20.0[c]	-33.0[b]
Total market-transit phase	-37.5	-43.9	-39.4

[a]Weight taken 30 days prior to moving from the farm of origin.

[b,c]Means in the same row superscripted with different letters are different ($p < .05$).

[d]Average of 18 steers.

experimental cattle and heavy use of the barn by commercial order buyers. This congested barn condition and possible variation in palatability among feeds formulated in different years could have been responsible for the 1 to 3 lb per steer per day lower order-buyer-barn feed intake in this study compared to intakes reported by Cole et al. (1979) and Koers et al. (1975). However, transit weight loss (18 hr) of the High-Energy steers was less than that of Normal-Industry and Preweaned steers. Although this does not agree with transit-weight losses among preshipment management treatments observed by Cole et al. (1979) and McLaren (1979), it is logical since High-Energy steers sustained higher weight losses during the market phase. During the entire market-transit phase (114 hrs) mean weight loss of steers in the three preshipment management groups were similar. This agrees with the effect of preshipment treatment on total market-transit weight loss reported by Cole et al. (1979) and McLaren (1979) but the total market-transit weight loss of steers in this study was about 11 lbs less than in the other studies. This reduction in weight loss seen during the market-transit period in this study may possibly be due to less digestive tract loss resulting from the lower feed intake in the order-buyer barn.

Post-shipment Results

Feedlot gain. Analysis of variance of cumulative average daily gain (ADG) during the feedlot phase indicated a significant interaction between pre- and post-shipment treatments on feedlot days 4 and 11. This interaction also existed but was less pronounced ($p < .10$) on feedlot days 32 and 149. These interactions necessitated separate evaluation of the effects of $NaHCO_3$ on feedlot gain within each preshipment management treatment.

Normal-Industry steers. During the first four days in the feedlot Normal-Industry steers fed 80-grams $NaHCO_3$ per steer per day gained significantly faster (Table 5) than Nonbuffered and 40-gram-$NaHCO_3$ steers. By feedlot day 11, mean cumulative ADG of 40-gram-$NaHCO_3$ steers was higher than that of Nonbuffered and 80-gram-$NaHCO_3$ steers. By feedlot day 32, no differences in ADG among $NaHCO_3$ groups were apparent and similarity among these groups persisted during the remainder of the feedlot phase. The improvement in early feedlot ADG of the $NaHCO_3$-buffered steers resulted in fewer feedlot days required to regain purchase (arrival auction barn) weight.

High-Energy steers. The 40-gram-$NaHCO_3$, High-Energy steers gained faster during the first four days in the feedlot than Nonbuffered and 80-gram-$NaHCO_3$ steers (Table 5). By feedlot day 11 cumulative ADG of the 40-gram-$NaHCO_3$ steers were higher than that of 80-gram-$NaHCO_3$ steers and the gain of Nonbuffered steers was intermediate to the two $NaHCO_3$-buffered groups. The 40-gram-$NaHCO_3$ steers regained purchase weight one feedlot day earlier than the Nonbuffered and 80-gram-$NaHCO_3$ steers.

Preweaned steers. Nonbuffered, Preweaned steers had significantly higher cumulative ADG at feedlot days 4 and 11 than either of the $NaHCO_3$-buffered groups. The Nonbuffered steers regained purchase weight 5 and 9 days quicker than the 80-gram-$NaHCO_3$ and 40-gram-$NaHCO_3$ steers, respectively.

Table 5. Average daily gain of steers in the feedlot.

Cumulative average daily gain from feedlot arrival to feedlot day,[a] lb	Sodium bicarbonate fed per steer per day, gms		
	0	40	80
Normal-Industry steers[b]			
4	5.24[c]	4.90[c]	8.81[d]
11	3.74[c] (10.5)	5.30[d] (9.5)	3.75[c] (7.4)
32	3.28	3.12	2.96
149	1.64	1.73	1.74
Slaughter	2.04	2.05	2.07
High-Energy high antibiotic steers[b]			
4	6.03[c]	10.44[d]	4.76[c]
11	4.98[c,d] (9.8)	5.94[c] (7.9)	3.92[d] (9.5)
32	3.32	3.97	3.23
149	1.87	1.70	2.12
Slaughter	2.04	2.24	2.13
Preweaned steers[b]			
4	11.13[c]	3.67[c]	6.68[c,d]
11	6.53[c] (6.5)	2.38[d] (15.8)	4.13[d] (11.2)
32	3.00	2.60	3.16
149	1.65	1.75	1.80
Slaughter	2.06	1.86	2.07

[a]Average of 6 steers.

[b]Preshipment treatments are described in Table 2.

[c,d]Means in the same row superscripted with different letters are different ($p < .10$).

[e]Values in parentheses ( ) are the number of days required to regain purchase (arrival auction barn) weight.

Health Parameters

Rectal temperature. Analysis of variance of rectal temperatures taken at the farm of origin indicate no significance difference among mean temperatures of preshipment treatment groups. However, High-Energy steers had significantly lower (Table 6) rectal temperatures on feedlot day 0 than Normal-Industry steers and those of Preweaned steers were intermediate. The addition of $NaHCO_3$ to the high-corn-silage feedlot diet tended to reduce the elevated temperature of Normal-Industry steers by feedlot day 4 and 11. However, the differences were not statistically significant and no consistent patterns were observed with respect to the effects of $NaHCO_3$ on rectal temperatures of High-Energy and Preweaned steers on feedlot day 4 and 11.

Other health parameters. The illness index used in this study is a linear combination of both objective and subjective evaluations. Observations of dyspnea (labored breathing), coughing, listlessness and loss of appetite along with high rectal temperatures (above 105°F), diarrhea and mucopurulent nasal discharge were combined to produce an individual score which indicated the severity of clinical signs in individual steers. The score ranged from 0 to 10 with steers with higher scores being sicker.

Both preshipment management treatments and buffering the high-silage feedlot diet with $NaHCO_3$ significantly affected illness index values. Illness index values of Normal-Industry and Preweaned steers (Table 6) were significantly higher than those of the High-Energy steers. This reflects the residual effect of feeding a high-energy, high-antibiotic diet in the order-buyer barn on the total impact of the shipping fever

Table 6. Feedlot health parameters by pre-shipment treatment.

Parameter[c]	Pre-Shipment Management Normal-Industry	High-Energy	Pre-Weaned
Illness Index	4.95[a]	2.38[b]	3.83[a]
Dyspnea	.27	.23	.22
Coughing	.28	.26	.50
High Temperature	1.56	1.27	1.58
Nasal Discharge	.28	.26	.23
Rectal Temperature, °F			
Feedlot Day 4	103.5	104.1	104.3
Feedlot Day 11	104.1	102.9	102.9

[ab]Means in the same row superscripted with different letters are different (p < .05).

[c]Average of 18 steers.

complex on feedlot health. This could be due to the effect of the high antibiotic level in the order-buyer-barn ration on normal rumen microbial population or on respiratory pathogens or the effect of concentrate feeding on protozoa population and other microbes. The significantly lower mean (Table 7) illness-index value among the Normal-Industry and Preweaned steers for 40-gram-$NaHCO_3$ buffered steers compared to those of Nonbuffered and 80-gram-$NaHCO_3$ steers indicates the beneficial effect of the low level buffering of corn-silage rations fed to stressed steers on their health. It also illustrates the interaction between preshipment concentrate diets and postshipment buffering of feedlot diets on total early feedlot health.

Carcass Traits

Carcass traits. Carcass traits were not significantly affected (Table 8) by preshipment management practices or by the addition of $NaHCO_3$ to feedlot diets.

Feed intake and efficiency. No consistent $NaHCO_3$ effects with respect to dry matter intake (Table 9) during any feedlot phase were observed. During the first 11 days in the feedlot, supplementation of high corn-silage diets with 40 grams of $NaHCO_3$ per steer per day improved feed efficiency of Normal-Industry and High-Energy steers when compared to the nonbuffered steers (Table 10). However, during the same period, feed efficiency of Preweaned steers was decreased by the addition of $NaHCO_3$ to the ration.

Table 7. Health parameters at the feedlot.

Pre-shipment treatment and parameter[c]	Sodium bicarbonate fed per steer per day, grams 0	40	80
Normal industry steers[d]			
Illness index	3.73[a]	2.84[a]	8.28[b]
Dyspnea	.16[a,b]	-.02[a]	.68[a,b]
Coughing	.64[b]	.04[a]	.17[a,b]
High temperature	1.40	1.30	1.98
Nasal discharge	.37	.16	.31
Rectal temperature, °F			
Feedlot day 4	104.2	103.4	103.1
Feedlot day 11	104.5	103.9	103.8
High-Energy steers[d]			
Illness index	2.46	3.76	.92
Dyspnea	.17[a,b]	.53[b]	-.01[a]
Coughing	.35[a,b]	.42[b]	.03[a]
High temperature	1.20[a,b]	1.92[a]	.69[b]
Nasal discharge	.59[a]	.17[b]	.02[b]
Rectal temperature, °F			
Feedlot day 4	103.6	104.4	104.5
Feedlot day 11	102.8	103.0	102.8
Preweaned steers[d]			
Illness index	7.50[a]	.99[b]	3.01[a,b]
Dyspnea	.68[b]	-.01[a]	-.01[a]
Coughing	.80[a]	.03[b]	.68[a]
High temperature	2.30[a]	.54[b]	1.90[a]
Nasal discharge	.47[a]	.03[b]	.18[b]
Rectal temperature, °F			
Feedlot day 4	104.3	104.6	104.0
Feedlot day 11	102.3	102.9	103.6

[a,b]Means in the same row superscripted with different letters are different ($p < .05$).

[c]Average of 6 steers.

[d]Preshipment treatments are described in Table 2.

Table 8. Carcass traits.

Pre-shipment treatment and carcass trait[a]	Sodium bicarbonate fed per steer per day, grams		
	0	40	80
Normal industry[b]			
Fat thickness, in	.8	.8	1.0
Quality grade[c]	13.5	12.8	14.3
Yield grade[c]	3.1	3.0	3.8
Carcass weight, lb	649.3	658.4	642.5
Rib eye area, sq in	11.4	11.2	10.7
High energy steers[b]			
Fat thickness, in	1.0	.8	1.0
Quality grade[c]	13.3	13.5	13.8
Yield grade[c]	3.0	3.2	3.2
Carcass weight, lb	641.6	667.3	657.3
Rib eye area	11.2	12.1	11.6
Preweaned steers[b]			
Fat thickness, in	.8	.9	.8
Quality grade[c]	13.2	13.2	12.7
Yield grade[c]	3.1	3.3	3.4
Carcass weight, lb	646.0	615.8	670.8
Rib eye area	11.5	10.7	10.9

[a]Average of 6 steers.

[b]Preshipment treatments are described in Table 2.

[c]Assigned by official USDA graders.

Table 9. Dry matter intake.

Dry matter intake per steer per day from feedlot arrival to feedlot day:[a]	Sodium bicarbonate fed per steer per day, grams		
	0	40	80
Normal industry steers[b]		lb	
4	9.03	9.33	9.15
11	10.29	9.98	9.48
32	10.65	10.52	9.80
149	9.18	9.01	9.33
High-Energy steers[b]			
4	8.95	8.84	9.17
11	9.82	9.48	9.93
32	10.22	10.00	10.77
149	8.71	9.49	9.98
Preweaned steers[b]			
4	7.47	8.79	8.80
11	9.69	9.79	10.07
32	10.27	10.60	10.43
148	9.96	9.43	9.41

[a]Average of 6 steers.

[b]Preshipment treatments are described in Table 2.

Table 10. Feed efficiency.

Feed efficiency from feedlot arrival to feedlot day:[a]	Sodium bicarbonate fed per steer per day, grams		
	0	40	80
Normal Industry steers[b]	---------lb feed/lb gain---------		
4	1.52[c,d]	1.90[d]	1.09[c]
11	2.49[c]	1.89[d]	1.97[d]
32	3.08	3.39	2.85
149	5.64	5.41	5.27
High-Energy steers[b]			
4	1.43[c]	.97[d]	1.76[c]
11	1.93[c,d]	1.84[c]	2.37[d]
32	3.04	2.80	3.23
149	4.81	6.10	4.81
Preweaned steers[b]			
4	.71[c]	2.07[d]	1.26[c,d]
11	1.57[c]	3.63[d]	2.35[c,d]
32	3.65	3.86	3.23
149	6.43	5.84	5.37

[a]Average of 6 steers.

[b]Preshipment treatments are described in Table 2.

[c,d]Means in the same row are superscripted with different letters are different ($p < .05$).

CHAPTER IV

EFFECTS OF PRE-SHIPMENT MANAGEMENT AND POST-SHIPMENT SODIUM BICARBONATE SUPPLEMENTATION ON RUMEN AND BLOOD STATUS OF MARKET-TRANSIT STRESSED FEEDER STEERS

I. SUMMARY

Fifty-four weanling feeder calves purchased from two Tennessee feeder-calf producers were evaluated and sampled at the farm of origin, then subjected to industry auction barn, order-buyer barn and trucking stresses. The calves were then fed for 149 days on a high silage-limited cracked-shelled corn diet and sampled at various times during the feeding period. The objectives of this study were to determine the effects of three pre-shipment treatments [(1) Normal-Industry market-transit environment, (2) Feeding a high-energy, high-antibiotic diet in the order-buyer barn, and (3) early weaning and feeding a 50% concentrate diet for 30 days at the farm of origin], three post-shipment treatments (0, 40 and 80 grams of sodium bicarbonate—$NaHCO_3$—per steer per day) and their interactions on market-transit and feedlot ruminal and serological parameters. Ruminal pH and in vitro gas production values decreased as the steers progressed through the normal sequence of market transit events (auction barn, order-buyer barn and trucking) and were significantly lower upon arrival at the feedlot than at the farm of origin or upon arrival at the auction barn. Pre-shipment concentrate feeding (Preweaned) at the farm of origin or in the order-buyer barn, significantly reduced

ruminal pH and increased *in vitro* gas production compared to Normal-Industry steers. In steers subjected to normal industry market-transit stresses, increased gas production was observed in the 40- and 80-gram-$NaHCO_3$-supplemented groups on feedlot sampling day 4, 11 and 32. However, in calves preweaned and fed a concentrate diet at the farm of origin or order-buyer barn no response to feedlot $NaHCO_3$ supplementation was observed until day 32. These responses were inconsistent and of lower magnitude than in the normal-industry-stressed steers. Feedlot packed cell volume, total serum protein, red blood cell count, white blood cell count and rumen protozoa concentration were not affected by pre-shipment management treatment or feedlot sodium bicarbonate supplementation.

II. INTRODUCTION

The magnitude and interrelationship of market-transit stresses, bacterial and viral respiratory infections, feedlot adaptation procedures and other aspects of the shipping fever complex are well documented in the literature (Cole *et al.*, 1979; Hoerlein, 1973; Orr *et al.*, 1979; Woods *et al.*, 1973). In addition several studies (Cole *et al.*, 1979; Greathouse *et al.*, 1973; Koers *et al.*, 1975; Woods *et al.*, 1970) have addressed the problem of alleviating the effects of one or more of these factors and evaluated their impact on the cow-calf and feedlot segments of the beef cattle industry. Normal industry marketing procedures in the Southeast were described by Billingsley *et al.* (1979). It has been suggested also that a calf's ability to withstand the stresses of weaning, market-transit handling and feedlot adaptation may possibly be altered as a result of various pre-shipment practices (Cole et al., 1979; Koers et al., 1975; Woods et al., 1970). Purser and Moir (1959), Lassiter et al., (1967) and Esdale and Satter (1972) suggested that the reduction in rumen microbial activity occuring during severe stresses was in response to decreased rumen pH and that reestablishment of rumen microbes was very slow. Lassiter et al. (1963) and Nicholson et al. (1963a) reported that rumen microbial activity at the feedlot and total rumen volatile fatty acid production were increased by supplementing feedlot diets with $NaHCO_3$.

The objectives of this study were to evaluate the effects of pre-shipment management practices and $NaHCO_3$-supplemented-feedlot diets on rumen activity, blood parameters and feedlot adaptation of market-transit stressed weanling steer calves.

III. MATERIALS AND METHODS

Fifty-four Hereford and Angus feeder steer calves weighing 462 $\pm$ 21 lb were purchased from two cooperating Tennessee feeder calf producers. At the farm of origin the steers were assigned to the three pre-shipment treatments and subsequently subjected to the market and transit sequences and stresses described by Billingsley et al. (1979). Cole et al. (1979) and Orr et al. (1979). The pre-shipment treatments were: (1) steers subjected to normal industry environment and stresses without being fed any concentrates (Normal-Industry); (2) steers fed a high-energy, high-antibiotic concentrate diet during the order-buyer-barn phase (High-Energy); and (3) steers weaned 30 days prior to moving from the farm of origin and fed a 65% concentrate diet until marketed (Preweaned).

Auction barn and order-buyer barn environments were discussed in detail by Billingsley et al. (1979) and Orr et al. (1979) and the composition of the various pre-shipment diets were reported by Cole et al. (1979) and Orr et al. (1979). At the end of the order-buyer-barn phase the steers were shipped 18 hours, 700 miles to a feedlot at the Highland Rim Experiment Station, Springfield, Tennessee.

Upon arrival at the feedlot the steers were randomly assigned, within pre-shipment treatment group, to three post-shipment treatments, which were 0 (nonbuffered), 40 (40-gram-$NaHCO_3$) and 80 (80-gram-$NaHCO_3$) grams of sodium bicarbonate per steer per day. The post-shipment treatments were combined in a 3X3 factorial arrangement with the pre-shipment treatments. Feedlot diets, diet changes and chemical composition were described by Orr et al. (1979).

Samples of rumen fluid were obtained 30 days prior to marketing at the farm of origin, upon arrival at the auction barn, prior to departure from the order-buyer barn and on feedlot days 0, 11, 32 and 149 by orally inserting a stainless steel strainer attached to tygon tubing into the reticulo-rumens of the intact steers. Suction was applied with a 60cc syringe and a 120ml sample of rumen fluid was withdrawn. The pH of the fluid was determined immediately after sampling using a Fisher portable pH meter, with a glass electrode. A modification of methods described by Hungate et al. (1955a) using a 50% concentrate as a substrate for the rumen fluid rather than forages, were used for duplicate determination of in vitro gas producing potential of the rumen fluid. The remaining rumen fluid was immediately frozen for osmolality and volatile fatty acid analyses or diluted with formaldehyde for protozoal counts. Blood samples were taken at each sampling period by jugular vein puncture and packed cell volumes were determined by the microhematocrit procedure. A portion of each whole blood sample was preserved for differential cell counts. The remainder was centrifuged and the serum frozen for serological determinations. Standard hematological techniques were used for laboratory analysis of the serum.

Data were analyzed by least-squares procedures to determine the effects of the independent variables, (pre- and post-shipment treatments and their interactions) on the dependent variables (rumen and blood parameters). Vaccination treatment (superimposed on this study at the farms of origin) and weight at the auction barn were included in the model in order to hold these effects constant.

IV. RESULTS AND DISCUSSION

Pre-shipment Results

Rumen pH. Rumen pH values of steers at the farm of origin and during the market-transit phase are shown in Table 11. Mean rumen pH at the farm of origin was 7.21 ± 1.85 and there were no differences in mean rumen pH of steers assigned to the three pre-shipment management treatments. Mean rumen pH decreased in all pre-shipment treatment groups during the last 30 days at the farm of origin and delivery to the auction barn. However the rumen fluid of Preweaned steers was significantly more acidic upon arrival at the auction barn than that of the Normal-Industry and High-Energy steers which were with their dams on pasture during this pre-shipment farm of origin period. This significant increase

Table 11. Rumen pH, *in vitro* gas production of the rumen fluid and packed cell volume at the farm of origin and during the market-transit phase.

Location where sampled	Pre-shipment Treatment: Normal Industry	High Energy	Pre-Weaned
Rumen pH[c]			
Farm of Origin	7.13	7.28	7.22
Arrival at Auction Barn	7.03[a]	6.91[a]	6.57[b]
Departure Order-Buyer Barn	6.86[a]	6.72[b]	6.96[a]
Arrival at Feedlot	6.82	6.83	6.78
In vitro gas production of rumen fluid, cm^3[c]			
Farm of Origin	6.38	6.62	6.54
Arrival at Auction Barn	9.47[a]	9.56[a]	11.23[b]
Departure Order-Buyer Barn	2.91[a]	5.76[b]	2.91[a]
Arrival at Feedlot	3.28[a]	5.40[b]	4.20[a]
Packed Cell Volume, %[c]			
Farm of Origin	35.83	35.81	35.47
Arrival at Auction Barn	33.06	34.01	33.89
Departure Order-Buyer Barn	35.87	33.36	34.93

[a,b]Means within a row superscripted with different letters are different ($p < .05$).

[c]Average of 6 steers.

in rumen acidity was a result of the concentrate diet fed the Preweaned steers during the last 30 days at the farm of origin. Diets high in readily available soluble carbohydrates were reported to result in lower rumen pH values by Eadie *et al.* (1967), Emerick (1976) and Nicholson *et al.* (1963a).

At the order-buyer barn, the Normal-Industry and Preweaned steers were fed a diet of mixed-grass hay. At the end of the order-buyer-barn phase the rumen pH values of the Normal-Industry calves were similar to their auction-barn-arrival values. The pH values of the Preweaned steers increased during the order-buyer-barn phase and were similar to those of the Normal-Industry calves at the end of this phase. The concentrate diet fed to the High-Energy steers in the order-buyer barn significantly reduced their rumen pH compared to hay-fed steers. However, the changes in rumen pH due to pre-shipment treatments had no extended carryover effects on rumen pH in the feedlot since mean rumen pH values of all pre-shipment groups were similar at feedlot day 4.

In vitro gas production. *In vitro* gas production of rumen fluid is an indirect measure of the bacterial status of the rumen and the feedstuff digestion capabilities of the host (Hungate *et al.*, 1955b). Values presented in Table 11 indicate that there were no significant differences *in vitro* gas production among pre-shipment treatment at the time of treatment allotment on the farm of origin.

In vitro gas production of steers in each of the three pre-shipment treatments increased during the last 30 days at the farm of origin and during shipment to the auction barn. This was probably partly due to some dehydration occurring during the 40 to 75 mile haul from the farm of origin to the auction barn. Preweaned steers had significantly higher gas production than normal-weaned steers (Normal-Industry and High-Energy) upon arrival at the auction barn. This was probably due to the concentrate diet fed the Preweaned calves during the last 30 days at the farm of origin. Prior to departure from the order-buyer barn gas production of the High-Energy steers, which were fed a 50% concentrate diet in the order-buyer barn, was significantly higher than that of the steers fed only hay in the order-buyer barn (Normal-Industry and Preweaned) regardless of management during the last 30 days at the farm of origin. This higher gas production exhibited by the High-Energy steers did not necessarily indicate an increase in gas production of the concentrate-fed calves over the hay-fed steers, but it represented a maintenance of the rumen potential exhibited upon arrival at the auction barn in the High-Energy steers compared to a decrease in potential in the hay-fed steers.

The higher gas production of the High-Energy steers continued to be observed upon arrival at the feedlot 18 hours later. Steers fed hay in the order-buyer barn exhibited slightly higher gas production upon arrival at the feedlot than at departure from the order-buyer barn. This could also be a result of concentration of rumen fluid due to dehydration occurring during the 18-hour shipment.

Post-shipment Results

Rumen pH. At all feedlot sampling times there was a trend toward higher (more basic) pH levels in the 40- and 80-gram-$NaHCO_3$ steers than in the non-$NaHCO_3$ steers (Table 12). These differences were not significant

Table 12. Rumen pH and rumen protozoa concentration at the feedlot.

Feedlot Day Sampled	Sodium bicarbonate fed per steer per day, grams		
	0	40	80
Rumen pH[b]			
0	6.83	6.82	6.89
4	6.80	6.81	6.83
11	6.76	6.79	6.84
32	6.26	6.40	6.46
Rumen protozoa per ml rumen fluid[ab]			
0	20.9	37.5	15.2
4	97.8	91.0	69.7
11	23.9	23.2	19.9
32	23.1	24.6	20.1

[a]Actual count = table values X 10^4.

[b]Average of 18 steers.

($p > .05$). The steers in this study were fed a high-silage diet from feedlot day 0 to 140. This high-silage diet did not contain the high level of readily soluble carbohydrates present in the high-concentrate diets shown by Emerick (1976) and Nicholson et al. (1963a) to dramatically lower rumen pH.

In vitro gas production. Analysis of variance for the effects of $NaHCO_3$ supplementation on in vitro gas production indicated a significant interaction between $NaHCO_3$ supplementation and pre-shipment management on feedlot days 11, 32 and 149. On feedlot day 4 this interaction approached significance. Therefore, it was necessary to consider separately the effect of $NaHCO_3$ supplementation within each pre-shipment management group (Table 13). On feedlot day 4, Normal-Industry steers fed 40 grams of $NaHCO_3$ per steer per day had significantly higher in vitro gas production than the nonbuffered and 80-gram-$NaHCO_3$ steers. However, $NaHCO_3$ supplementation had no significant effect on feedlot day 4 in vitro gas production in steers that had been fed a concentrate diet either at the order-buyer barn—High Energy—or at the farm of origin—Preweaned. On feedlot day 4 gas production values for all High-Energy and Preweaned steers were similar to the values for Normal-Industry steers fed 40 grams $NaHCO_3$ per day. These differences in response to feedlot $NaHCO_3$ supplementation among pre-shipment treatment groups suggest that pre-shipment feeding of a concentrate diet at the farm of origin or in the order-buyer barn either prevented a severe depression in rumen activity or resulted in more rapid feedlot adaptation similar to the response to $NaHCO_3$ supplementation observed in the Normal-Industry steers. The lack of response observed in the 80-gram-$NaHCO_3$-fed steers

Table 13. In vitro gas production of rumen fluid at the feedlot.

	Sodium bicarbonate fed per steer per day, grams		
Feedlot Day	0	40	80
Control Steers[c]			
0	4.20	3.33	2.30
4	4.61[a]	8.46[b]	5.71[a]
11	6.96[a]	11.69[b]	5.96[a]
32	7.06[a]	11.71[b]	5.92[a]
149	11.20	13.13	12.46
High Energy Steers[c]			
0	7.51	5.33	4.38
4	9.82	10.32	8.11
11	8.43[a]	9.20[a]	6.35[b]
32	5.14[a]	7.45[b]	7.54[b]
149	6.63[a]	6.72[a]	17.19[b]
Preweaned Steers[c]			
0	3.86	3.49	5.26
4	7.76	9.55	7.31
11	9.66[a]	5.54[b]	8.30[a]
32	7.44[a]	5.58[b]	7.41[a]
149	8.77[a]	13.18[b]	9.16[a]

[a,b]Means in the same row superscripted with different letters are different ($p < .05$).

[c]Average of 6 steers.

in comparison with the 40-gram-$NaHCO_3$ steers may be a result of overbuffering of the rumen by the higher buffer level. Similar overbuffed response was seen by Huntington et al. (1977). On feedlot days 11 and 32, the 40-gram-$NaHCO_3$, Normal-Industry steers had significantly higher gas production than the Nonbuffered and 80-gram-$NaHCO_3$, Normal-Industry steers. On feedlot day 11 the 40-gram-$NaHCO_3$, High-Energy steers had significantly higher gas production than the 80-gram-$NaHCO_3$, High-Energy steers. The gas production of the non-$NaHCO_3$, High-Energy steers was intermediate to that of the buffered High-Energy steers. By feedlot day 11 gas production of 80-gram-$NaHCO_3$, High-Energy steers was similar to that of 40-gram-$NaHCO_3$ steers and both $NaHCO_3$ supplemented groups had significantly higher values than the Nonbuffered steers. However, on feedlot day 11 the Preweaned steers responded entirely different to $NaHCO_3$ supplementation than steers in the other pre-shipment groups. The nonsupplemented and 80-gram-$NaHCO_3$ steers had higher gas production values than the 40-gram-$NaHCO_3$ steers. This greater rumen activity in the nonsupplemented and 80-gram-$NaHCO_3$, Preweaned steers persisted through feedlot day 32.

By feedlot day 149, the steers were receiving a predominately whole-shelled-corn diet and both levels of $NaHCO_3$ supplementation tended to increase gas production in the Normal-Industry calves. The 80-gram-$NaHCO_3$, High-Energy steers had gas production values almost three times higher than those of the other High-Energy groups on feedlot day 149. However, in the Preweaned group the gas production of the 40-gram-$NaHCO_3$ steers was higher than that of the other two groups.

The beneficial effects on gas production observed on feedlot day 149 of steers supplemented with the higher $NaHCO_3$ levels may be due to the more acidic rumen contents resulting from the high-corn diet; therefore, enabling the higher buffering capacity of 80 grams of $NaHCO_3$ to be of benefit.

Rumen protozoa. Although pre-shipment management significantly affected rumen protozoa concentration on feedlot day 0, 4 and 11, $NaHCO_3$ supplementation of feedlot diets (Table 12) did not affect rumen protozoa concentration. Purser and Moir (1959) reported that rumen protozoal populations were affected by changes in rumen pH. They further suggested that rumen pH depression and the relationship of pH depression to time of feeding were the major factors influencing rumen protozoa concentration. However, rumen pH values reported by Purser and Moir (1959) were more variable than those observed in this study.

Serological parameters. Lower packed cell volume (PCV) and total serum protein values (Table 14) tended to be associated with higher in vitro gas production in Normal-Industry stressed steers. However, this relationship was not apparent in High-Energy and Preweaned steers. Walker et al. (1978) suggested that during rumen acidosis and other ruminal dysfunctions water moved out of the vascular system into the extracellular and rumen fluids resulting in increased PCV values. However, this data suggests that reduction in in vitro gas production may be influenced more by rumen microbial changes due to stress than to rumen fluid concentration resulting in increased PCV and serum protein due to dehydration. There were no effects of feedlot $NaHCO_3$ supplementation on lymphocyte, red blood cell or white blood cell counts.

Table 14. Serological changes at the feedlot.

Feedlot Day Sampled	Sodium bicarbonate fed per steer per day, grams		
	0	40	80
Packed Cell Volume, %[c]			
0			
4	34.0	33.1	34.2
11	34.1	32.5	33.0
20	36.1[a]	34.5[b]	36.6[a]
32	35.2[a]	33.0[b]	34.5[a,b]
149	37.9	37.2	37.3
Total Serum Protein, Mg/100 ml			
0	73.5	72.5	73.4
4	70.5	70.1	69.4
11	70.4	70.2	72.0
20	72.1	71.9	72.9
Lymphocytes[c]			
0	63.7	67.1	67.0
4	69.5	71.0	69.5
11	71.0	75.4	70.4
20	71.8	68.8	70.4

[a,b]Means in the same row superscripted with different letters are different ($p < .05$).

[c]Average of 18 steers.

CHAPTER V

SUMMARY

Fifty-four weanling steer calves were subjected to one of three pre-shipment treatments: (1) normal industry stresses (Normal-Industry); (2) fed a high-energy, high-antibiotic diet in the order-buyer barn (High-Energy); or (3) preweaned and fed a concentrate diet for 30 days before marketing (Preweaned). After being exposed to commercial auction and order-buyer barn environments for 4 days, the steers were assigned to one of three post-shipment treatments: (1) nonbuffered control (Nonbuffered); (2) 40 grams of sodium bicarbonate per steer per day (40-gram-$NaHCO_3$); and (3) 80 grams of sodium bicarbonate per steer per day (80-gram-$NaHCO_3$) in a 3X3 factorial arrangement with pre-shipment treatments.

Ruminal pH and _in vitro_ gas production values decreased as the steers progressed through the normal sequence of market-transit events (auction barn, order-buyer barn and trucking) and were significantly lower upon arrival at the feedlot than at the farm of origin or upon arrival at the auction barn. Pre-shipment concentrate feeding at the farm of origin or in the order-buyer barn significantly reduced ruminal pH and increased _in vitro_ gas production. In steers subjected to normal industry market-transit stresses, increased gas production was observed in the 40- and 80-gram $NaHCO_3$-supplemented groups on feedlot sampling day 4, 11 and 32. However, in calves preweaned and fed a concentrate diet at the farm of origin or order-buyer barn no response to feedlot,

$NaHCO_3$ supplementation was observed until feedlot day 32 and these responses were inconsistent and of lower magnitude than in the normal-industry-stressed steers. Packed cell volume, total serum protein, red blood cell count, white blood cell count and rumen protozoa concentration were not affected by feedlot sodium bicarbonate supplementation.

There was a significant pre- by post-shipment treatment interaction with respect to feedlot gain. Feeding 80 grams of $NaHCO_3$ to Normal-Industry stressed steers and feeding 40 grams of $NaHCO_3$ to High-Energy steers resulted in higher cumulative ADG to feedlot day 11 than the respective Nonbuffered groups. In Normal-Industry $NaHCO_3$-buffered steers, feedlot time required to regain market-transit shrink was shorter, illness index was lower, and elevated early feedlot rectal temperatures returned to normal values quicker than in Nonbuffered steers. In High-Energy steers the 40 grams $NaHCO_3$ resulted in higher early-feedlot gains but had no effect on rectal temperatures and in Preweaned steers, the Nonbuffered steers gained faster to feedlot day 11 than the other $NaHCO_3$ groups. Although, $NaHCO_3$ increased the rate of feedlot adaptation, its beneficial effects were limited to the early feedlot period when used as a buffering agent with a high corn-silage ration.

Preweaned steers gained more weight at the farm of origin. High-Energy steers lost more weight during the auction-barn, order-buyer barn phase and Normal-Industry steers lost more on the truck than steers in the other two groups, respectively. However, total market-transit weight loss was similar for the three pre-shipment treatments.

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