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I am submitting herewith a dissertation written by Walter Stephen Damron entitled "Ruminal Characteristics of Feeder Calves." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

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RUMINAL CHARACTERISTICS OF FEEDER CALVES

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

CRANES CREST

Walter Stephen Damron

March 1982

3058073

DEDICATED TO

Mother
Randy and Ann
Dawne
Grandmother and Granddad
Mornie and Max

They always believed.

To Kat

She solved the mystery of why.

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ABSTRACT

Most feeder calves marketed in the Southeast are subsequently exposed to the stresses of marketing and transporting which alter rumen metabolism and delay feedlot adaptation. A review of the literature established the need of a multidisciplinary approach in studying the nutritional aspects of animals subjected to these market-transit stresses.

Rumen samples were taken and weight, body measurements, and backfat thickness were determined for 360 unweaned, 6- to 10-month-old calves at 22 farms before the calves entered the market-chain during the Falls of 1977 and 1978. Mean weight, body length, height at the wither, body depth at the fore chest, width at the point of the shoulder, backfat at the 12th rib, rumen liquid volume, in vitro gas producing potential, total volatile fatty acids, ciliated protozoa (Spirotricha and Holotricha), and rumen pH were 202 ± 1.97 kg, 97 ± 0.37 cm, 93 ± 0.49 cm, 48.0 ± 0.19 cm, 32 ± 0.15 cm, 1.47 ± 0.05 mm, 26 ± 0.54 l, 6.3 ± 0.18 cm^3, 63.1 ± 1.29 mmol/l, 31.25 x 10^4 ± 1.72 x 10^4/ml (28.37 x 10^4 ± 1.71 x 10^4/ml and 2.87 x 10^4 ± 0.20 x 10^4/ml), and 7.0 ± 0.02, respectively.

One-hundred-eighty-four weanling steer calves were subjected to the stresses associated with the normal industry procedures for marketing and transporting Southeastern feeder calves from the farms where they were raised to commercial backgrounding and/or finishing facilities.

Body weight decreased during the auction barn phase, increased slightly during orderbuyer barn phase, and decreased during transit. Total market-transit weight loss was 13% of the arrival auction barn weight. Rumen liquid volume, rumen gas producing potential, rumen total VFA concentration, and rumen protozoal concentration decreased significantly (25.6%, 71%, 25%, and 50%, respectively) during the auction barn phase. During the auction barn starvation period, rumen pH increased. This was followed by a decrease in pH during the orderbuyer barn phase. Weight and all other rumen parameters increased during the orderbuyer barn phase.

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CHAPTER I

INTRODUCTION

The beef cattle industry of the Southeast is composed predominantly of small cow-calf operations. Most of the calves are marketed as feeder calves at weaning and shipped to Western or Cornbelt feedlots or Western wheat pastures for backgrounding and/or finishing (Billingsley, 1979). For example, in 1979, 0.8 million calves representing about 90% of the production from the 1.1 million Tennessee beef cows were shipped out of Tennessee for backgrounding and/or finishing (Rawls, 1979).

During the process of marketing and transporting, calves are subjected to a variety of stresses. These stresses often include weaning, crowding, starvation, dust, and drastic changes in temperature, precipitation, and humidity (Crenshaw, 1967; Pierson, 1968; MacLean, 1978; Wiseman, 1978; McKercher, 1978). During the market-transit process, calves are often frightened, fatigued, fasted, and become dehydrated. Self (1972) suggested that animals may loose 10% or more of their body weight in the form of loss of the digestive tract contents and tissue water losses during this phase and Church (1967) found that two weeks were required to recover this market-transit loss. Nutritional stress is particularly evident since the calves are subjected to periods of intermittent starvation and refeeding during marketing and transporting. Even when feed and water are available, pasture-reared calves may be reluctant to eat or drink from a trough or consume dry hay. Further

dietary alterations, in the form of diet changes, occur upon arrival at the feedlot. These factors imposed during marketing and transporting alter rumen metabolism and delay feedlot adaptation (Baldwin, 1967; Orr, 1979).

These stresses are usually associated with exposure to several viral and bacterial pathogens and have been implicated as primary factors in the etiology of a feeder calf disease complex commonly referred to as Bovine Respiratory Disease Complex (BRDC). This complex was reported to be responsible for 80% of all death losses in feeder cattle (Greathouse et al., 1973). Although clinical signs of BRDC are generally stress induced, they are largely due to bacterial infections (Collier, 1968) and include depression, gauntness, anorexia, high fever, mucopurulent nasal discharge, cough, and increased respiratory rate (Hoerlein and March, 1957). In addition to death losses, economic losses incurred by feeder calf producers and feedlot operations include excessive shrink (body weight loss), reduced feed efficiency during feedlot adaptation, marketing delays, and treatment expenses (Jensen et al., 1976). Much of this loss is due to inapparent infections (sub-clinical) where only mild clinical signs are expressed (McKercher, 1968). The cost of veterinary treatment following market-transit has been estimated to be between $10 and $20 per calf (Sinha and Abinanti, 1962; Herrick, 1969). Fleming (1972) estimated the total annual loss to the U. S. beef cattle industry due to BRDC to be $500 million.

Although several reports have dealt with the effects of specific factors on the incidence of BRDC in market-transit stressed calves (Sinha and Abinanti, 1962; Jensen and Mackey, 1971), the literature

abounds with inconsistent statements as to the effects of these factors and how to alleviate them (Orr, 1979; Billingsley, 1979; Su, 1980; Wills, 1980). A more thorough understanding of the etiology of BRDC is necessary before satisfactory management practices for its control can be implemented (McKercher, 1968). Wiseman (1978) believed that elucidation of the influence of environmental stress factors and their interrelationships to the pathogenic factors should be given high priority in new BRDC studies. Considering the state of the knowledge regarding the complex etiology of BRDC, McKercher (1968) warned against the unrealistic expectation that the answers to the control of BRDC would be found by any single discipline. Instead, he emphasized the necessity of a multi-disciplinary approach involving clinicians, microbiologists, epizootiologists, pathologists, physiologists, and nutritionists. These sentiments were echoed by Self (1972) who called for "shifts by both researchers and administrators in the traditional order of priorities within the livestock research fraternity," and Collier (1968) who called for a multi-disciplinary approach to "characterize stress."

In full agreement with this, McLaren (1978) described the initiation of The National Shipping Fever Study which was a comprehensive, cooperative field and laboratory study of the etiology of BRDC. Cooperating institutions included The University of Tennessee, Texas A & M University, Oklahoma State University, The National Animal Disease Laboratory, and other USDA-SEA and state experiment station research groups. The study was designed to identify and study the complex

nutritional, physiological, environmental, and microbial parameters and their interactions which have been implicated in the etiology of BRDC.

The overall objectives of the present study conformed to those of the National Shipping Fever Study (McLaren, 1978). The more specific objectives were: (1) to define the population of Tennessee feeder calves with respect to ruminal status and body measurements; (2) to measure ruminal parameter changes in weaning feeder calves subjected to normal industry market-transit stresses and to subsequent feedlot adaptation; (3) to study the relationship among various pre- and post-transit ruminal parameters and performance traits; and (4) to evaluate the influence of various pre- and post-transit nutritional management practices on rumen parameters.

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CHAPTER II

REVIEW OF LITERATURE

A. ENVIRONMENT STRESS AND DISEASE

Temperature, light, wind, humidity, nutrition, and disease causing organisms are generally considered the major environmental influences on animal health. Measuring the individual and combined effects of these factors on livestock performance is of major concern to researchers (Self, 1972). The task is manifoldly complicated when one considers the many possible deviations from normal with respect to each factor and their diverse influence on animals. Stress may be defined as the state resulting from altering one or more environmental conditions to the extent that the animal is adversely affected.

Disagreement concerning the role of stress in several diseases is extreme. This lack of information is due in part to lack of research and partially to the lack of satisfactory or precise techniques for parameter measurement. However, an even greater part is attributable to the inability of the researcher to establish "cause and effect" relationships, due to the nebulous nature of stressors and animal reactions to them. The following discussion of temperature as a stressor and the intensification of its effects caused by interaction with other environmental factors will serve to illustrate this problem.

When animals are exposed to reduced ambient temperatures severe enough to chill the body surface, a chain of physiological reactions that favor infections is initiated (Bruner and Gillespie, 1973). Cold

weather causes animals to seek whatever protective shelter is available. Available shelter is often crowded, and, thus, an ideal situation may be established for the spread of infectious airborne agents. Even a slight wind will add to the problem by reducing the insulating properties of the animal's coat by necessitating an increased metabolic rate to maintain body temperature (Halpin, 1975). Since animals are not as motivated to leave their shelter in order to seek feed and water during cold weather, lowered nutrient intake further complicates the problem.

Heat also is a stressor in animals unaccustomed to high ambient temperature (Halpin, 1975). When dogs were held in rooms which were hot and humid (Bruner and Gillespie, 1973), it was observed that the acidity of the gastric juice was decreased. This allowed an increased passage of bacteria from stomach to intestine. These dogs were much more easily poisoned by Salmonella toxins than were the nonstressed controls.

Tremendous breed differences have been observed in the ability of animals to withstand extreme heat. Cattle of Indian origin, such as Brahman or Zebu, have pendulous dewlaps and sheaths which radiate heat. Their coats are light colored and reflect rather than absorb solar radiation. They can be observed grazing in the hottest part of the day, long after increased ambient temperature has forced cattle of European breeds to seek shade. Many other examples in the literature evidence the complexity of interrelationships of environment, stress, and disease.

B. RESPIRATORY DISEASE

Current evidence suggests that Parainfluenza 3 (PI3) virus, Mycoplasma, Pastuerella, infectious bovine rhinotracheitis (IBR), enteroviruses, hemolytic cocci, Alkaligenes sps, and Actinobacillus are all involved in the etiology of bovine respiratory disease (Reisinger et al., 1959; Collier et al., 1960; Bruner and Gillespie, 1973). However, the repeated failure of inoculation of animals with known disease-producing pathogens to cause clinical respiratory disease has led to the acceptance of the hypothesis that environmental stress on the animal is necessary for these agents to express their full pathogenicity (Bruner and Gillespie, 1973; Wiseman, 1978). This hypothesis was stated by Hoerlein (1973) as follows: physiological stress + nonbacterial (virus) infection + bacterial infection = shipping fever.

Stress factors involved in shipping fever or bovine respiratory disease complex (BRDC) include weaning, irregular feeding and watering, exposure to unusual weather conditions, overcrowding, fear and fatigue, chilling, transportation, and exposure to pathogens and contaminated quarters during transit (Hoerlein and March, 1957; King et al., 1958; McKercher, 1978; Wiseman, 1978; Jensen and Mackey, 1979). The ways in which animals respond to these stressors influence the development of BRDC (Hoerlein and March, 1957; Sinha and Abinanti, 1962; Wiseman, 1978; McKercher, 1978). The nature of the interactions between microorganisms, environmental factors, and the host animal remains obscure (Miller et al., 1978). This lack of knowledge concerning the true cause of BRDC indicates that the problem is complex and precludes taking advantage of

managerial practices which might afford some degree of control (McKercher, 1968). One area that should be studied intensively is the effect of nutritional stress on BRDC.

C. NUTRITIONAL STRESS

A simple definition of nutritional stress is the deprivation of the animal of necessary nutrients at critical times (Farlin, 1976). There are many situations in which nutritional stress is the primary stress. The association of famine and pestilence has been repeatedly observed. However, aside from reports of the effects of gross deficiency, there are few published experimental results indicating the relationship of diet and resistance to disease (Halpin, 1975). Although many advances have been made in ruminant nutrition, the knowledge of nutritional stress has advanced very little (Algeo, 1967).

Nutrient intake, or lack of it, may influence disease in several different ways. One possibility is a general lowering of the animal's resistance to pathogens. Dubos et al. (1955) reported that 24-hour-fasted mice were more susceptible to Mycobacterium tuberculosis than were non-fasted mice. A degree of resistance returned within 24 hours following refeeding. This is much too soon for any known immune mechanism to have an effect. Schneider and Zinder (1956) reported a series of experiments designed to study the relationship of diet and disease resistance in mice. They demonstrated unequivocably the importance of diet in a mouse's ability to withstand pathogenic attacks. Brownlie and Grau (1967) reported that limited starvation (2-3 days) predisposed calves to infection by Salmonella and enteropathogenic Escherichia coli.

They suggested that this could be an important factor in the predisposition of market-transit stressed calves to disease.

The area of nutritional stress and its relationship to BRDC has received some recent attention (Koers et al., 1975; Phillips et al., 1978; Cole et al., 1979). However, most investigators have approached the problem indirectly. Bridson (1972) stated that nutritional stress prior to the calf's arrival at the feedlot reduces resistance to infection. Hubbard (1967) referred to "pre-existing nutritional deficiencies that lower resistance" and stated that many calves are suffering from "malnutrition" after being subjected to market-transit stresses. Wiseman (1978) stated that respiratory disease is influenced by diet, but he did not elaborate. Kolveit (1967) referred to the "starvation-refeeding syndrome" of newly arrived feeder calves as being one of the most complicated problems facing the feedlot operator. Algeo (1967) stated that the nutrition of the feeder calf during feedlot adaptation is of top priority. However, these references offer, for the most part, only cursory observations, at best, made in support of or explanation of the other variables.

Actual studies of the nutrition of ruminants during stress have been limited. Available data from studies on intense, short-term stress are even less numerous. In addition, reports of such studies are limited primarily to situations involving energy expenditure during thermal stress, water restriction, and starvation. There are many voids in the present knowledge of the relationship of nutrition to stress. Restricted feed intake as a component of market-transit stress is probably one of the most severe stresses imposed on feeder calves (Church, 1967);

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however, reliable estimates of the nutritional requirements of stressed calves are not available (Crenshaw, 1967). Optimum intakes for protein, energy, and vitamins by calves during and following market-transit stress are more important than minimum requirements but these optimum values remain unknown (Algeo, 1967). Neither measures of weight change nor measures of feed efficiency (both slow and nonspecific) are adequate indicators of the effectiveness of nutritional treatments during or following market-transit stress (Crenshaw, 1967). More knowledge of rumen response to environmental stress is urgently needed (Scheffner and Weinberg, 1975).

In this literature search not a single paper has been found which characterized the rumen response to collective nutritional stresses such as those imposed on animals during marketing and transporting. In the absence of such studies, a review of the effects of individual stresses on specific rumen parameters commonly used as measures of rumen function was conducted.

D. RUMEN PROTOZOA

Function

No mammal is known to produce an enzyme which will digest cellulose or lignocellulose. Rumen microorganisms (both protozoa and bacterial) are capable of this activity and render these substances available to ruminants (Hastings, 1944). Protozoa are generally considered to be one-celled animals, are both flagellated and ciliated, but most rumen protozoa are of the class Ciliata. The sub-classes, Holotricha and Spirotricha (often referred to in earlier reports as

Oligotrichs) are of greatest importance in domestic ruminants (Hungate, 1966). Isotricha, Dasytricha, Charon, Beutschchilla and Paraisotricha are holotrich genera. Important spirotrich genera include Diplodinium, Entodinium, Epidinium, and Ophryoscolex. Rumen protozoa have been extensively studied since Becker (1929), and Becker and Everett (1929) published the results of their first experiments with protozoa-free animals. Under favorable conditions the ciliated protozoa in the rumen may contribute up to 20% of the host animal's nutritional requirements (Hungate et al., 1955b; Oxford, 1955; Gutierrez, 1958).

The number, weight, and species distribution of protozoa varies greatly with diet, environmental conditions, and even among different animals of the same age and breed fed the same ration. Protozoal concentrations ranging from 0 to several million per cm^3 of rumen fluid have been reported. According to Hungate (1966), the highest concentration of $3.14 \times 10^6/cm^3$ was reported by Moir and Somers (1957) in sheep fed a mixed grain and roughage diet in four equal feedings daily. However, Eadie et al. (1970) later reported a concentration of 3.34×10^6 in a heifer fed a restricted barley diet.

Ciliated rumen protozoa can be both beneficial and detrimental to digestion. Benefits of protozoa include higher VFA production and a reduction in the ratio of acetic acid concentration to propionic acid concentration (Abou Akkada and El-Shazly, 1964; Hungate, 1966; Eadie and Mann, 1970; Hinkson et al., 1976). Protozoa store amylopectin starch for later use by the host animal (Annison and Lewis, 1962; Eadie and Mann, 1970). According to Oxford (1955), protozoal protein is of high biological value. However, digestion by protozoa may result in the waste

of feed and bacterial protein, destruction of B-vitamins, and increased concentrations of lactic acid in the rumen. Bird and Leng (1978) reported that when 180 kg feeder cattle were defaunated and fed rations containing significant proportions of by-pass proteins they gained faster than defaunated animals fed normal protein sources. This indicated a detrimental effect of protozoa on the digestion or the absorption of by-pass proteins. Observations by Pounden and Hibbs (1950), Bryant and Small (1960), and Eadie (1962a) suggested that the absence of ciliated protozoa did not significantly affect the growth, health, or general performance of growing ruminants. However, results reported by Abou Akkada and El-Shazly (1964) obtained from a larger number of animals indicated that protozoa are of substantial benefits to growing lambs.

Factors Affecting Rumen Protozoa

Diet. The effect of diet on rumen protozoa has been studied extensively (Purser and Moir, 1966). Specific kinds of rumen protozoa have often been found in conjunction with diets containing certain feedstuffs. Significant numbers of Ophryoscolex were found frequently in the rumens of animals fed green alfalfa and epidinia were most frequently found in animals fed fresh red clover (Hungate et al., 1964).

Most entodinomorphs, with the exception of some of the small entodiniua, utilize starch while holotrichs use soluble sugars (Hungate, 1966). Therefore, entodinomorphs are usually found in greater numbers in the rumens of animals fed high concentrate rations and holotrichs appear in the greatest numbers in animals consuming hay or forages

containing high levels of soluble sugars (Warner, 1965). Studies by Nakamura and Kanegasaki (1969) showed that, in general, higher rumen protozoal numbers were observed in animals fed diets containing both hay and concentrate. Some Entodinium flourish also in the rumen of cattle consuming rations abundant in readily available forms of carbohydrates, such as starch (Oxford, 1955; Warner, 1956; Barnett, 1961; Annison and Lewis, 1962; Warner, 1964a; Abe et al., 1973; Hinkson et al., 1976). However, other researchers found that the number of Entodinium was sharply depressed or that they were completely eliminated from the rumen of animals consuming rations with high levels of starch and little or no forage (Annison and Lewis, 1962; Slyter et al., 1965; Hungate, 1966; Mackie et al., 1978). Warner (1964a) reported that protozoa numbers increased when starch was fed to sheep in moderate amounts. As the starch content of the ration increased, rumen pH decreased. Streptococci numbers increased due to the lower pH environment, and the increased Streptococci population reduced pH to the extent that significant lactobacillae populations were established. The drastic reductions in pH caused defaunation.

pH. In several reports, lower rumen pH has been linked to the reduction or disappearance of rumen ciliated protozoa (Oxford, 1955; Purser and Moir, 1959; Warner, 1964a; Hungate, 1966; Eadie and Mann, 1970; Abe et al., 1973). Results reported by Purser and Moir (1959) suggested that the major factors controlling rumen protozoa concentration were the degree of rumen pH reduction and the length of time the reduced pH was maintained. They found the correlation between rumen pH

and mean daily protozoa concentration ($r = 0.90$) to be highly significant. This led them to conclude that rumen pH exerts greater influence on the diurnal fluctuations of microbial numbers than does any other factor. In addition, Quin et al. (1962) reported that rumen protozoa perished when rumen pH was outside the range of 5.5 to 8.0 in a continuous in vitro system.

In calves with low rumen pH, Eadie (1962b) found that the Entodinium species were the first ciliates to increase significantly when pH increased. Concentration of the Isotricha species increased next, followed by other species. When rumen pH dropped, the Entodinium and Isotricha species were the last to disappear from the rumen.

Eadie (1962a) and Eadie (1967) concluded that low rumen pH values during all or part of the daily feeding cycle was responsible for the inability of ciliates to become established when all-concentrate diets were fed. In contrast, Eadie et al. (1970) demonstrated that animals fed a restricted all-barley diet maintained sufficiently high numbers of ciliate protozoa to comprise a significant fraction of the rumen microflora even though pH was as low as 5.2. In interpreting these results, one must consider also that the rumen flow rate for the barley-fed animals was roughly one-half that in animals receiving the hay-barley diet.

Rate of flow. Rate of passage of ingesta from the rumen was judged by Christiansen et al. (1964) to be a major factor affecting the numbers of rumen protozoa. When identical diets were fed in different forms the larger feed particles supported the slowest rate of passage

and the largest protozoal populations. As particle size decreased, so did the number of rumen protozoa. They also reported that increased protozoal numbers resulted from increased frequency of feeding. Dehority and Purser (1970) and Eadie et al. (1970) further demonstrated that reduced feed intake slowed rate of passage and increased the holotrich population in the rumen.

Rumen volume. Clarke (1965) found that although rumen protozoal concentrations decrease rapidly during and shortly after feeding, much of this variation was the result of dilution effects. When counts were reported on a total rumen content basis, protozoal population size increased very rapidly from the time of feeding until two hours post-feeding, which indicated rapid protozoal multiplication during this period. He demonstrated also that the observed variations in protozoal populations were primarily due to changes in concentration of holotrichs. Entodinomorphs were much less severely affected by feeding time. Purser and Moir (1966a) believed that rumen volume may have a double influence on rumen microbes by additionally influencing the microbe substrate relationships within the rumen. This would be most pronounced when animals with different rumen volumes are fed at the same level of feed intake. An animal with a small rumen would tend to eat over a longer period of time and the microbial growth period would be extended. In this case, rumen protozoal concentrations would more nearly resemble those of animals fed more frequently. An animal with a large rumen would consume its allotted diet in a shorter time and provide a high ratio of substrate to microorganisms for a shorter period of time. An

effect on population composition and metabolic relationships should be expected from these widely different ecological environments. The second effect of variable rumen volumes, which Purser and Noir (1966a) considered to be substantial, was the fact that different dry-matter percentages of rumen contents could easily occur. They suggested that animals of similar rumen volume should be used for microbiological as well as rate of passage studies.

Starvation. MacLean (1972) considered the intermittent feeding and watering of cattle during marketing and shipping to be the major cause of rumen microorganism "starveout." A practical problem associated with this type starveout is the "lag" time associated with slow recovery of rumen protozoa concentration and the more rapid recovery of the bacteria population size. The following discussion of this phenomenon was taken from Baldwin (1967). Rumen bacteria tend to recover more slowly in stressed calves offered a low concentrate feedlot "starter" ration than in calves fed a high concentrate starter ration. The lower energy intake allows the animals to remain weak and susceptible to disease. When more concentrated diets are fed, the bacterial population of the rumen recovers more rapidly. However, without an adequate, balanced protozoal population an "explosive" fermentation may result and lactic acid buildup in the rumen may precipitate acidoses and dehydration. The effects of starvation and subsequent refeeding on rumen protozoa were studies by Meiske et al. (1958). When animals were starved for 24 h, protozoa were less active and bacterial numbers were decreased. When starvation was extended to 48 h, very few

holotrich or oligotrich protozoa were present in the rumen. Samples taken after 72 h of starvation were devoid of holotrichs and contained only a few oligotrichs and bacterial numbers were noticeably decreased. Once refeeding began, bacterial numbers increased in three hours. Oligotrichs were observed to increase relatively rapidly; however, holotrichs required five days to become observable in one trial and 25 days in another.

Diurnal variations, osmolality and sampling site. Purser and Moir (1959) and Warner (1962) observed a diurnal rhythm with respect to Entodinium concentration in sheep. This same phenomenon was observed by Purser (1961) and Warner (1964a) with respect to Dasytricha. Clarke (1965) worked with total rumen population counts and demonstrated a marked diurnal variation in the size of holotrich populations. He also found greatly increased total rumen protozoal populations from 0 to 2 h post-feeding, followed by a rapid decrease from 2 to 5 h post-feeding. He attributed this fluctuation to cell-wall rupture of the reserve polysaccharide-rich organisms.

Purser and Moir (1959) and Boyne et al. (1957) found similar protozoal concentrations at different sites in the rumen. Dehority and Males (1974) found no direct association between rumen numbers of holotrichs and rumen osmotic pressure.

E. GAS PRODUCTION

Importance

The total microbial degradation of feed and metabolites in the rumen is a product of both protozoal and bacterial action. Fermentation

rate has been shown to be a linear function of microbial population size (El-Shazly and Hungate, 1965). An in vitro measure of this fermentation rate has been demonstrated to be a fast and accurate measure of change in viable microbial populations in the rumen (El-Shazly and Hungate, 1965, 1966; El-Din and El-Shazly, 1969b). A useful measure of the rate of fermentation is the rate of in vitro gas production (Quin, 1943; McAnally, 1943; Hungate, 1956; El-Shazly and Hungate, 1965, 1966).

Estimation of the microbial contributions to the nutrition of the ruminant from in vitro gas production potential has been a fertile research area. This and several other methods of estimating the rumen bacterial content and activity have been devised (McAnally, 1943; Elsden, 1945; Marston, 1948; Burroughs et al., 1951; Johns, 1951; McBee, 1953; Doetsch et al., 1953; Carroll and Hungate, 1954). An excellent review of these techniques was presented by Su (1980).

The various techniques for measuring gas production are similar. Rumen inoculum and a suitable substrate are maintained in a closed anaerobic system at physiological temperatures. The system is attached to a manometer or syringe, and the volume of gas produced during a given time (usually 1 h) is measured. The general consensus, according to published reports, appears to be that this is a reliable method of measuring the net growth of rumen microorganisms over a limited period of time.

Factors Affecting In Vitro Gas Production

Several factors have been shown to affect in vitro gas production from rumen samples. No attempt will be made here to discuss fully each

of these factors, since an in-depth review of the subject was published by Su (1980). The method of sample collection, time of sample-collection in relation to feeding, length of animal starvation, microbial variations (diurnal), pH of rumen contents, and type of in vitro substrate are all factors which could affect in vitro gas production values in a fashion often analogous to their effects on protozoal populations.

Method of sampling. Several reports support the use of stomach tubes inserted orally for collection of rumen fluid. Although problems associated with this sampling technique with regard to other rumen parameters have been discussed previously, this does not appear to be a problem with gas production. Work by Hungate et al. (1955a), El-Shazly and Hungate (1965), and El-Din and El-Shazly (1969a, 1969b) has established that differences in gas production values recorded from samples taken at various locations in the rumen and by both fistula and stomach tube were less than 5%.

Substrate. The substrate used for in vitro fermentation depends on the needs of the research. A mixture of concentrates and straw was shown by El-Din and El-Shazly (1969a) to support maximum fermentation rate when compared to several purified substrates. They reported also that maximum gas production was obtained when the animal's feed was used as the substrate. The greatest gas production and, therefore, the greatest microbial growth was recorded on substrates with carbon to nitrogen ratios similar to those in the animal's feed. This indicates that rumen microbes need time to adjust to differing feedstuffs.

Time of inoculum collection. Time of inoculum collection in relation to feeding exerts a powerful influence on gas-producing ability. El-Din and El-Shazly (1969a) reported the highest gas production rate when samples of rumen fluid were taken 15 to 20 minutes post-feeding. The rate decreased steadily for 3 h and remained low until the animal was fed again.

Starvation. Complete starvation or inadequate feeding was shown by Quin (1943) to influence the fermentative ability of the rumen contents. A starvation period of 3 days caused a lag of 3 additional days until normal consumption was resumed. A "normal" level of gas production was not observed until the tenth day post-feeding. Meiske et al. (1958) and Warner (1962) also reported declining rumen microbial concentrations following starvation and a delay of up to 4 days for recovery of pre-starvation concentrations.

pH. The pH of the ruminal contents significantly affects gas producing potential. Myburgh and Quin (1943) found in vitro glucose fermentations to be greatest within a pH range of 6.8 to 7.8. Gas production declined progressively to zero at both the lower and upper pH levels of 5.0 and 8.35, respectively. Cheng et al. (1955) reported similar findings.

F. VOLATILE FATTY ACIDS

Function

It has long been recognized that volatile fatty acids (VFA) are the normal end-products of anaerobic fermentation in the ruminant

stomach (Tappeiner, 1883; Kellner, 1900; Phillipson and McAnally, 1942; Reid et al., 1957; Annison and Lewis, 1962; Blaxter, 1962; Hungate, 1966). Although VFA produced in the rumen were once considered to be of little nutritional significance to the animal, it is now well known that they are a major source of energy for the ruminant. Work by Elsden et al. (1946) demonstrated that VFA were nearly completely utilized by the animal. Carroll and Hungate (1954) and Warner (1964b) reported that 70% of the total energy requirement of the ruminant is met by VFA production in the rumen. Hungate et al. (1961) found that VFA accounted for 70 to 90% of the requirement of lactating cows. The VFA normally found in the rumen are formic, acetic, propionic, butyric, isobutyric, valeric, isovaleric, caproic, and heptanoic (Gray et al., 1951, 1952; Church, 1976). The predominant acids are acetic, propionic, and butyric. In most discussions, the other acids are either ignored or grouped as "higher acids" (Church, 1976).

The actual uses of VFA in the body have been studied extensively but have not been completely elucidated. Acetic acid is used by the animal as a readily available source of energy for muscular work and for the synthesis of milk and body fat (Stoddard et al., 1949; Kleiber et al., 1952; Jarrett et al., 1952). Studies by Reid (1950), McClymont (1951), Pennington and Sutherland (1956), Leng and Annison (1963), Leng et al. (1967), and others established a definite glucogenic role for propionic acid. Butyric acid has been shown to have a high energy value (Kiddle et al., 1951; Pfander and Phillipson, 1953; Johnson, 1953) and is generally considered to be used for energy by the rumen epithelium during absorption.

Factors Affecting Rumen VFA Concentrations

Church (1976) listed VFA concentration ranges for several species consuming diverse diets. The values ranged from approximately 60 to 150 mmol/l. Molar percentages ranged from 56 to 70 for acetate, 17 to 29 for propionate, and 9 to 19 for butyrate. Concentration of individual or total ruminal VFA is influenced by several factors: (1) rate of VFA production; (2) rate of absorption; (3) rate and extent of passage from the rumen; (4) dilution rate; (5) rate of microbial utilization; and (6) conversions of VFA to other acids and/or other rumen metabolites (Annison and Lewis, 1962; Wheaton et al., 1970). Thus, the concentration of a particular VFA is not always indicative of the rate of production of the VFA (Annison and Lewis, 1962; Wheaton et al., 1970).

Several studies have indicated that rumen contents are nonhomogeneous within the rumen with respect to VFA concentration (Pearson and Smith, 1943; Balch, 1950; Wheaton et al., 1970; Church, 1976). Wheaton et al. (1970) observed the highest VFA concentration in samples taken from the ventral floor of the rumen of animals consuming an all-grain diet. This was probably due to higher acid production occurring in the semi-solid fraction of the rumen contents. VFA concentration measured as molar percentages in samples from various rumen sites were similar.

Method of sampling. Studies by Raun and Burroughs (1962) and Lane et al. (1968) demonstrated that total VFA levels of rumen contents were usually lower in samples taken by stomach tube than in samples

taken through a fistula. These same studies indicated that when VFA concentrations were converted to molar percentage, the values were similar in rumen fluid collected by the two methods. This is probably influenced by both salivary dilution and point of sampling within the rumen. Raun and Burroughs (1962) concluded that the observed differences were consistent enough that comparative measurements may still be made on the molar proportions of volatile fatty acids in rumen fluid taken from animals subjected to different treatments.

VFA absorption. Work by McAnally (1943), McAnally and Phillipson (1942), and Barcroft et al. (1944) established the fact that volatile fatty acids were absorbed from the rumen. The absorption mechanism is probably dependent on a concentration gradient (Blaxter, 1962). Several factors influence this absorption. Pfander and Phillipson (1953) and Sutton et al. (1963) demonstrated the effect of chain length on absorption. The rate of absorption increases with the increasing length of the carbon chain. The pH of the rumen has also been shown to affect VFA absorption. Gray (1948), Sutton et al. (1963), and Thorlacius and Lodge (1973) reported low VFA absorption when the pH was above 7.0. Blaxter (1962) indicated that the free-acid forms of the VFA associated with lowered ruminal pH values were more readily absorbed by the rumen wall than the anion form found at higher rumen pH levels. Pfander and Phillipson (1953) indicated that concentration of the acids in the rumen was more important than pH as far as VFA absorption is concerned.

Diet. Many researchers have studied the effects of time post-feeding on VFA concentrations in the rumen. In general, a dramatic

increase was observed to occur shortly after feeding, with peak concentration occurring around four hours post-feeding. An intensive treatment of the subject is provided by papers of Phillipson (1952), Balch and Rowland (1957), Ghorban et al. (1966), Williams and Christian (1966), Weller et al. (1967), Omori et al. (1969), and Fenner et al. (1970).

Diet has a highly significant impact on rumen VFA concentrations. Reid et al. (1957), Annison and Lewis (1962), Raun et al. (1962), Blaxter (1962), Hungate (1966), and Hinkson et al. (1976) reported that high-energy rations usually support higher total VFA concentration and higher proportions of propionate relative to acetate and butyrate than do low-energy, forage rations. Increases in VFA production were accompanied by a reduction in ruminal pH. Church (1976) reported that diets composed of immature grasses, concentrate and protein-rich diets, diets promoting higher intakes, and pelleted roughage diets tend to result in increased VFA concentrations. El-Shazly (1952), Davis et al. (1957), Haskins et al. (1967), and Mahmoud (1977) reported increased VFA production with increased levels of dietary protein. It has been well established that both molar percentages and total VFA concentrations are changed when the diets consumed by the animals are modified (Church, 1967). Factors involved in the changes in VFA concentration and the mode of VFA action are less well defined. However, it has been shown that alteration of rumen environment results in changes in the microbial populations of the gut. Studies involving pure cultures indicate that different microorganisms form different end products (Hungate, 1942; Gutierrez, 1955; Hungate, 1966). Therefore, it is safe to hypothesize

that changes in microbial population sizes account for most of the differences in relative rumen VFA concentrations. This is further substantiated by the changes in the ruminal VFA concentrations observed when animals are fed certain antibacterial and antiprotozoal agents (Hungate et al., 1955b). O'Connor et al. (1970) found that antibiotics (chlorotetracycline and oxytetracycline) often used in the receiving rations of market-transit stressed calves caused a reduction in total VFA produced and also increased the in vitro ratio of acetate to propionate (A/P). Propylene glycol (a high energy source) caused an increased level of propionic acid and thus lowered the A/P ratio. The effects of buffers added to receiving rations were discussed by Orr (1979).

G. pH

Significance

Several rumen phenomena, acting together and individually, exert influence on the pH of the rumen contents. These factors can be generally classed as endogenous secretions, exogenous dietary constituents, and rumen metabolites. As the rumen microbes digest feed constituents, several organic acids are produced. These acids cause the rumen contents to acidify. If there were no salivary secretions, the VFA could lower the pH of rumen contents to 3.0. In order for rumen microbial populations to be maintained, the pH must be buffered by saliva.

There is some disagreement as to the optimum rumen pH range. Phillipson (1955) gave the normal range of pH values within the rumens

of animals on conventional rations as 5.9 to 7.4 for cattle and 5.3 to 7.3 for sheep. Briggs et al. (1957) reported that ruminal pH values outside the range of 4.5 to 7.4 could be expected to cause clinical disturbances.

Factors Affecting Rumen pH

Diet. It is generally conceded that pH changes in the rumen depend on the ration being consumed (Moir and Somers, 1957). Constituents, form, and frequency of feeding are all important. Beghelli (1959) concluded that salivary secretion rate was affected by the moisture content of the feed consumed. This in turn affected ruminal pH. McDougall (1948) reported that a reduced salivary flow reduced the ruminal buffering capacity and resulted in lower ruminal pH. Work by Gordon (1958) indicated that reduced mastication associated with high-concentrate diets resulted in reduced salivary flow. Similar findings were reported by Bailey (1961).

The form of the ration indirectly influences the pH of rumen contents by influencing the mastication process (Bailey, 1961). If the character of the feed requires extensive mastication then salivary secretion is increased and, thus, also the buffering ability of the rumen. Clark and Weiss (1952) and Gordon (1958) demonstrated that mastication and rumination were significantly decreased when high concentrate diets were fed and a decreased salivary flow to the rumen resulted. They reported that high concentrate diets provided less mechanical stimulation to the cardiac region of the rumen, thus reducing salivary flow. McDougall (1948) indicated that such a salivary reduction

reduced the buffering capacity of the rumen ingesta, thereby allowing rumen pH to decrease substantially.

Kick et al. (1938), Hungate et al. (1952), Thomas and Hodgetts (1955), Moir and Somers (1957), Balch and Rowland (1957), Raun et al. (1962), Moore (1964), Kromann and Meyer (1972), and Latham et al. (1971) found reduced pH values associated with concentrate feeding as compared to those found with diets higher in fiber content. Kick et al. (1938) reported that the addition of corn to alfalfa diets caused a decline in pH. Moore (1964) reported that a reduction in rumen pH occurred when finely ground and pelleted roughage or high energy feedstuffs were fed. McAnally and Phillipson (1942), Reid et al. (1957), and El-Shazly et al. (1961) suggested that pH of the rumen contents was a function of VFA concentration. Three recent reports also indicate that ruminal pH decreases as VFA concentration increases (Emmanuel et al., 1969; Rumsey et al., 1970; Mullen, 1973). However, VFA concentration as a predictor of ruminal pH was less valuable with high lactic acid concentrations (Church, 1976). Briggs et al. (1957) reported that when high levels of lactic acid were found in the rumen, ruminal pH was significantly and inversely related to lactic acid concentration. In the absence of high lactic acid concentrations, however, they found the partial regression coefficient of pH on volatile fatty acid concentration to be significant.

Variations in protein solubility also may influence ruminal pH values. Reports by Clark and Weiss (1952) and Briggs et al. (1957)

indicated that the relationship between pH and volatile fatty acids may be modified by the level of ammonia nitrogen in the rumen.

Mishia et al. (1969) studied the effect of ambient temperature on ruminal pH. Regardless of diet (roughage or concentrate), cows maintained in cool environments had higher ruminal pH values than cows maintained in hotter environments. Phillipson and McAnally (1942) suggested that the pH of rumen contents was a function of volatile fatty acid concentration. Cason et al. (1954) theorized that the ash concentration of the rumen contents exerts a greater influence on ruminal pH than VFA concentration. Lactic acid concentration was believed by Briggs et al. (1957) to be the greatest influence on pH. They observed that in the presence of high concentration of ruminal lactic acid, an inverse relationship of pH and lactic acid existed; sometimes this occurred regardless of large changes in total VFA concentration. However, the regression of pH on total VFA concentration also was significant and negative.

Method of sampling. The pH values for rumen samples are subject to several errors. Salivary contamination was suggested by Myburgh and Quin (1943) and Clark and Lombard (1951) to be a major source of error when samples were taken by stomach tube. Olson (1941) and Clark and Lombard (1951) suggested that aeration of the sample results in CO_2 loss and could be responsible for some seemingly high values reported by earlier workers. Time of sampling after feeding has been shown to influence ruminal pH values. Briggs et al. (1957) and Monroe and Perkins (1939) reported depression in pH after feeding, followed by a

gradual increase to the highest level just prior to the next feeding. Meiske et al. (1958) also recorded a continuous rise from an initial pH value of 6.8 to one of 7.9 during 3 days of starvation. Reports by several workers (Smith et al., 1956; Blake et al., 1957; Lampilia and Poutiainen, 1966; Leng et al., 1967) indicated that pH of rumen contents varies with the origin of the sample from within the rumen. Monroe and Perkins (1939) and Smith et al. (1956) found differences in pH between samples collected from the upper and samples collected from the lower part of the rumen of a fistulated steer. Monroe and Perkins (1939) found the lowest pH in samples taken from the front of the rumen. However, samples from six different locations in the rumen had a range of 0.47 pH units. Samples taken at consistent time during the day were much less variable.

Clark and Lombard (1951) reported that pH of rumen fluid taken from sheep by stomach tube was 0.4 to 0.6 pH units higher than that of fluid taken from the same animals by fistula, pH of the fistula samples ranged from 6.5 to 7.3. They attributed this to a greater proportion of saliva in the forestomach compared to that in the distal portions of the rumen. In general, the literature indicated higher pH of rumen fluid samples taken from the dorsal and cranial sacs of the rumen and the reticulum than of samples taken elsewhere in the rumen. It was the opinion of Church (1976) that this was a collective result of (1) higher dry matter content in the dorsal sac of the rumen, (2) washing out and absorption of VFA, and (3) the saliva entering the reticulum and cranial rumen.

H. RUMEN VOLUME

Rumen volume, along with its relationship to other rumen parameters and its relationship to animal performance, has received increasing attention. Since the rumen contents can be as much as 20% of the total weight of an adult bovine (Hastings, 1944), this is an area deserving of this attention. Freer and Campling (1963) and Purser and Moir (1966b) reported that rumen volume had an effect on intake and digestibility of feedstuffs. Feed intake is controlled in some cases by the capacity of the rumen (Conrad et al., 1964; Montgomery and Baumgardt, 1965). Many inconsistencies in the literature with respect to rumen parameters have been explained on the basis that rumen volume was not estimated. Many factors have been shown to influence rumen volume in cattle. Water consumption, feed intake, retention time, feed digestibility, body fatness, and pregnancy have all been implicated. A review of these factors as well as the methodology of measuring rumen volume was reported by Church (1976) and Su (1980). One very important characteristic of rumen volume is the fact that it is not constant either within or between animals and that it varies with many factors.

I. SUMMARY

Economic losses due to market-transit stress of feeder calves have been documented. Numerous reports have suggested that nutritional stress due to intermittent fasting and refeeding could be the most serious problem encountered in marketing and transporting feeder cattle. Factors influencing various rumen parameters, methods of sampling,

evaluation of these parameters, and their relationships to other rumen and performance traits have been studied in controlled studies using simulated stress conditions. Techniques which are applicable to field studies, such as sampling via orally inserted stomach tube, measurement of gas producing potential, and marker techniques for estimation of rumen volume, appear satisfactory for comparison of rumen parameter changes in animals subjected to different treatments and/or environments. This review establishes the necessity of a multi-disciplinary approach in studying the nutritional aspects of BRDC.

CHAPTER III

EXPERIMENTAL PROCEDURES

A. INDUSTRY MARKET-TRANSIT PROCEDURE

In preparation for and prior to the initiation of a large cooperative multi-regional Bovine Respiratory Disease Complex (BRDC) study, the cooperating institutions conducted a survey to determine prevailing procedures for marketing feeder calves in the Southeast (Billingsley, 1979; Orr, 1979; Su, 1980; Wills, 1980). Mean intensities of stressors on feeder calves during marketing and transporting were also determined. Most Southeastern cow herds which produce feeder calves (FO) are small (28 cows per herd in Tennessee). Results of the survey indicate that few calves were shipped directly from farm of origin to wheat pastures and feedlots; rather, the calves were transported to the auction barn (AB) and sold on the day they were weaned. The calves spent 19 to 36 h (mean = 24 h) in the AB in close confinement (0.65 to 0.95 m^2/calf) without feed or water. Orderbuyers purchased the calves at the AB. They were moved to an orderbuyer barn (OBB), comingled with calves from other farms in the local area, and until a truckload (20,000 kg) of similar calves were assembled to fill a specific order. The mean time a calf remained in the OBB was 72 hours. This varied from 1 to 4 days in the intensive fall marketing season to over 10 days during seasons when fewer calves were marketed.

CRANESHOT CREST

B. EXPERIMENTAL MARKET-TRANSIT PROCEDURES

In order for the experimental conditions to duplicate as closely as possible the current market-transit conditions, an actual market facility at Algood, Tennessee, was used for these BRDC studies. This commercial facility served as a weekly auction market and as an intermediate assembly point for several orderbuyers. The market environment and management practices to which calves in these studies were subjected were based on results of the survey. Pen space allotted to calves and times spent in each of these phases were the mean survey values of these variables.

C. FARM AND MARKET PRETRANSIT TREATMENTS

A total of 2,236 weanling feeder steer calves, weighing 136 to 303 kg, studied in 16 groups (shipments) were purchased from Tennessee and Kentucky feeder calf producers during the fall marketing seasons of the years 1975 through 1981. The calves at each farm within each shipment were allotted to at least one of three preshipment dietary treatments, shown in Table 1, 30 days prior to being transported from FO to AB. These basic preshipment treatments consisted of: (1) subjecting steers to normal industry treatment (NI); (2) feeding steers a high-energy, high-antibiotic concentrate diet during the OBB phase (HE); (3) weaning steers at the FO 30 days prior to the AB phase and feeding a 65% concentrate diet until marketed (PW). The compositions of the diets used for the HE and PW treatments are given in Table 2. Allotment of calves within shipment to various dietary treatments is presented in

TABLE 1. DESCRIPTION OF PRESHIPMENT MANAGEMENT TREATMENTS

Treatment Designation	Management and Diets	
	Farm of Origin (FO) (30 days)	Orderbuyer Barn (OBB) (72 hours)
Normal Industry (NI)	with dam on pastures, no concentrates	mixed grass hay, free choice
High Energy (HE)	with dam, no concentrates	high-energy, high antibiotic ration (3.4 kg/steer/day)
Preweaned (PW)	weaned and fed a 65% concentrate ration + hay or pasture during last 30 days	mixed grass hay, free choice

TABLE 2. COMPOSITION OF PRETRANSIT RATIONS[a]

Ingredient	IRN[b]	Ration[c] PW	Ration[c] HE
Corn, grain, flaked	4-02-859	31.2	32.0
Cotton, seed hulls	1-01-599	42.0	45.0
Soybean, seed solv-extd, grnd, mx 7 fbr	5-04-604	15.0	7.0
Sugarcane, molasses	4-04-696	5.0	4.0
Alfalfa, aerial part, dehy meal	1-00-23	5.0	--
Animal-fat, heat rendered	4-00-375	1.0	--
NaCl, trace mineralized	6-04-152	0.5	0.5
Limestone, grnd (nm) 33 Ca	6-02-632	0.3	0.7
Calcium phosphate dibasic, commercial	6-01-080	--	0.3
Propylene glycol	--	--	5.0
Vitamin A palmitate, commercial[d]	7-05-143	+	--
Oxytetracycline[e]	--	+	--
Vitamin-antibiotic premix[f]	--	--	5.5

[a]Percent, dry-matter basis.

[b]International Reference Number.

[c]PW = ration fed to preweaned calves at the farm of origin.
HE = 3-day high-energy, high-antibiotic diet fed at the order-buyer barn.

[d]To supply 5000 IU of vitamin A per kg of ration.

[e]To supply 20 mg of oxytetracycline per kg of ration.

[f]To supply 1100 mg of oxytetracycline and 5000 IU of vitamin A per kg of ration.

Table 3. Prior to initial sampling at FO, all calves were with their dams and consuming fescue or fescue-legume pastures. During the last 30 days at FO, NI and HE calves remained with their dams until transported to the AB. Calves were transported from 40 to 100 km from their FO to AB. They were confined to 0.65 to 0.75 m^2 during the 24-hour AB phase and 1.42 to 2.80 m^2/steer during the 72-hour OBB phase. Calves were not allowed access to feed or water during the AB phase but during the OBB phase they received the diets indicated in Table 1.

D. TRANSIT AND POSTTRANSIT TREATMENTS

At the end of the OBB phase, steers were loaded on trucks and transported to one of three feedlots. Approximate distances traveled, transport time, and feedlot location are given in Table 3 for each shipment. Upon arrival at the feedlot (or wheat pasture), calves were allotted to various postshipment treatments which included: (1) the addition of potassium, B-vitamins and/or sodium bicarbonate at varying levels in the receiving diet; (2) varying periods allowed for adaptation to high-energy finishing rations; and (3) studies of various implants, vaccinations, and treatment regimes. Due to the complexity of the studies and the fact that certain studies could not be conducted concurrently, not all studies were conducted each year.

A partial listing of the pre- and posttransit treatments is shown in Table 4, along with a listing of the various individual treatments imposed on calves in the respective shipments.

TABLE 3. OWNERSHIP OF CALVES, FEEDLOT LOCATION, SHIPPING DISTANCE, AND TRANSPORT TIME

Ownership of Experimental Cattle[a]	Shipment No.	Year	Feedlot Location	No. of Calves	Approx. Shipping Distance, km	Approx. Transit Time, h
TN-AES	1	1975	Garden City, KS	184	2002	52
HRES	1a	1975	Springfield, TN	54	483	5
TN-AES & TX-AES	2	1976	Bushland, TX	275	1600	26-34
HRES	3	1976	Springfield, TN	54	483	18[b]
Okla-AES	3a	1976	El Reno, OK	60	1360	20
TX AES	4	1977	Bushland, TX	189	1600	26-34
TN-AES	5	1977	Bushland, TX	185	1600	26-34
TCFA	6	1977	Bushland, TX	187	1600	26-34
HRES	7	1977	Springfield, TN	54	1440	18[b]
Okla-AES	8	1977	El Reno, OK	60	1360	20
TCFA	9	1978	Bushland, TX	168	1600	26-34
TN-AES	10	1978	Bushland, TX	195	1600	26-34
HRES	11	1978	Springfield, TN	54	483	8[b]
Okla-AES	12	1978	El Reno, OK	64	1360	20
TN-AES	13	1979	El Reno, OK	196	1360	20
HRES	14	1979	Springfield, TN	54	483	15[b]
TN-AES	15	1980	El Reno, OK	95	1360	24
HRES	16	1980	Springfield, TN	54	200	12
HRES	17	1981	Springfield, TN	54	200	20[b]

[a]TN-AES = Tennessee Agr. Exp. Sta.; HRES = Highland Rim Exp. Sta.; TX-AES = Texas Agr. Exp. Sta.; Okla-AES = Oklahoma Agr. Exp. Sta.; TCFA = Texas Cattle Feeders Assoc.

[b]Part of the transport time from Algood to HRES was simulated.

TABLE 4. A GENERALIZED EXPLANATION OF THE EXPERIMENTAL TREATMENTS AND TYPE OF DATA COLLECTED DURING SPECIFIC SHIPMENTS

	General Treatments			Data Collected								
Shipment[a]	Preshipment[b]	Postshipment[c]	Special[d]	Rumen Samples	Blood Samples	Size Shape	Carcass	Telemetry[e]	CMI[e]	Nasal Swabs[e]	Antibody Isolation	Clin. Exam
1	NI, HE, PW				X							X
1A	NI, HE, PW	Ralgro Rumensin			X							X
2	NI, HE, PW	B-Vit. Complex			X	X	X	X		X	X	X
3[f]	NI, HE, PW	CL-Time			X	X						X
3A	NI, HE	Energy Level			X		X	X				X
4	NI, HE	K	IBR, Vac.	X	X	X		X	X			X
5	NI, HE, PW, $NAHCO_3$			X	X	X	X	X			X	X
6	NI, HE	Energy Level		X	X	X		X				X
7	NI, HE, PW	$NAHCO_3$	IBR Vac.	X	X	X	X		X	X	X	X
8[f]	NI	CL-Time, Energy			X	X						X
9	NI, HE	K			X	X		X				X
10	NI, PW	B-Vit. Complex		X	X	X	X	X			X	X
11	NI	$NAHCO_3$	IBR Vac.	X	X	X	X		X	X		X
12[f]	NI, OBB TIME	CL-Time		X	X		X					X
13	NI	K, Protein	Past. Vac.		X					X	X	X
14	NI, Ralgro	Ralgro	IBR Vac.		X					X	X	X
15[f]	NI, Ralgro	K, Protein	Past. Vac.		X					X	X	X
16	NI, Ralgro	Ralgro			X							X
17[f]	NI, K, B-Vit.	K, B-Vit.		X	X	X	X					X

[a]Number of cattle, ownership of cattle and feedlot location are given in Table 3.

[b]Preshipment management treatments are described in Table 1. OBB time = length of time the calves were at the orderbuyer barn.

[c]Postshipment generally involved supplementation of receiving rations with varying levels of protein, energy, $NAHCO_3$, B-vitamins complex, potassium (K), or Ralgro implants, conditioning lot (CL) time before moving to wheat pasture.

[d]Special treatments included preshipment vaccination against infectious Bovine Rhinotracheitis (IBR) or Pasturella Hemolytica (Past.).

[e]Temperature, respiration, and other parameters of a small sample of calves and transport truck environment were monitored by radio telemetry. CMI = cell mediated immune studies, nasal swabs for pathogen isolation. Clinical examinations included rectal temperatures, nares examination, and evaluation of general health or Bovine Respiratory Disease signs.

[f]Cattle in shipments 3, 8, 12, 15, and 17 were used to develop and test various hormonal and serological indexes for measuring the extent individual animals were stressed.

E. DATA COLLECTION

Sampling points at which data and/or samples were collected were: (1) at FO 30 days before the calves entered the marketing chain; (2) upon arrival at the auction barn (AAB); (3) 24 hours after arrival at the auction barn or the beginning of the orderbuyer barn period (AOBB); (4) departure from the orderbuyer barn (DOBB); (5) arrival at the feedlot or when unloaded from the trucks after 18- to 34-h haul (AFL); and (6) on various sampling dates at the feedlot (FLX).

Due to the complexity of the various studies involved in this BRDC study, different data were recorded and different samples collected at different sampling points. A partial listing of pre- and posttransit treatments imposed on calves in the various shipments and a listing of the various items of information recorded and samples taken at the designated sampling points for each shipment are presented in Table 4. In all cases, the design of the secondary experiments and allotment of animals to specific treatments allowed for major or secondary treatment effects to be held constant.

Samples of rumen fluid were obtained at FO 30 days prior to marketing, upon arrival at AB, 24 hours later at the beginning of the OBB phase, prior to departure from OBB, upon AFL, and at various intervals following AFL. Samples were taken by orally inserting a stainless steel strainer attached to tygon tygon tubing into the reticulo-rumen of the intact steers. Suction was applied with a 60cc syringe and a 120 ml 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 the substrate rather than forages, was used for duplicate determinations of in vitro gas producing potential of the rumen fluid immediately after collection. The remaining rumen fluid was immediately frozen for osmolality and volatile fatty acid analyses, or diluted with formaldehyde for protozoal counts. The rumen fluid volume of each calf was also estimated using either polyethylene glycol or lithium sulfate as markers.

F. STATISTICAL ANALYSIS

Data were analyzed by least-squares procedures to determine the effects of the independent variables (pre- and postshipment treatments and their interactions) on the dependent variables (rumen parameters). Vaccination treatment (superimposed on this study at F0) and weight at the auction barn were included in the model in order to hold these effects constant. These analyses will be more fully discussed in subsequent chapters.

CHAPTER IV

BODY MEASUREMENTS AND RUMEN PARAMETERS OF SOUTHEASTERN FEEDER STEERS

A. SUMMARY

Rumen ingesta samples were taken and weight, body measurements, and backfat thickness were determined for 360 unweaned, 6- to 10-month-old calves at 22 farms (FO) before the calves entered the market chain during the Falls of 1977 and 1978. Mean weight, body length, height at the withers, body depth at the forechest, width at point of shoulder, backfat at 12th rib, rumen liquid volume, in vitro gas producing potential, total VFA concentration ciliated protozoa (Spirotricha and Holotricha), and rumen pH were 202 ± 1.97 kg, 97.1 ± 0.37 cm, 93.5 ± 0.28 cm, 48.0 ± 0.19 cm, 325 ± 0.15 cm, 1.5 ± 0.05 mm, 25.9 ± 0.54 l, 6.3 ± 0.18 cm^3, 63.1 ± 1.29 mmol/l, 31.25 x 10^4 ± 1.72 x 10^4/ml (28.37 x 10^4 ± 1.71 x 10^4/ml and 2.87 x 10^4 ± 0.20 x 10^4/ml), and 7.0 ± 0.02. Year, FO within year and calf weight accounted for 55 to 71% of the variation in body measurements, 46% of the variation in fat thickness, 40 to 64% of the variation in rumen volatile fatty acid concentration, 32 to 40% of the variation in protozoal subclasses, 45% of that in rumen volume, and 43% of that in gas producing potential. Intrafarm correlations were calculated from data obtained from calves (37% of the total) sampled at farms which supplied calves in both years. These correlations and stepwise analyses of variance suggested that significant FO within year effects (which contained both the true FO

effects and the FO x year interaction) represented a true FO effect on body measurement, propionate and butyrate concentrations, rumen volume, gas producing potential, and protozoa genera (Entodinium, Diplodinium, and Dasytricha) which comprise the major subclasses. Weight, acetate, higher VFA, rumen pH and fat thickness appeared to be influenced to a greater extent by the FO x year interaction than by factors intrinsic to specific FO. This interaction was attributed to environmental factors.

B. INTRODUCTION

The ruminant occupies a unique position in the world food chain due to its ability to utilize cellulose, to function under extensive as well as intensive management conditions, and because of the complementary nature of some aspects of ruminant and plant production. The ruminant is likely to be even more important in future red meat production because of an expected increase in nonruminant competition for concentrated energy feed sources. This will necessitate more efficient use of high-energy feeds and a greater dependence on roughage and by-product feeds. These special abilities are largely attributable to the rumen itself and its microbial population.

During the last one-half century there has been an explosion in the amount of investigative study directed toward the rumen and its function, and subsequently in the amount of knowledge derived therefrom. Although many advances have been made in recent years, the area of rumen function during nutritional stress has not been extensively

investigated. The studies which have been conducted in this area have, for the most part, been controlled laboratory studies.

Nowhere in the beef cattle industry does a problem of greater magnitude exist than that of the bovine respiratory disease complex. Nor is there a more overlooked relationship than that of rumen function and its influence on the health and well-being of shipped and/or stressed feeder calves.

The overall objective of this and concomitant experiments was to investigate the effects of weaning, marketing and transporting on rumen function and subsequent performance of feeder calves in field studies. The purpose of this study was to: (1) assess problems associated with field studies involving rumen parameters, (2) define the status quo of the population to which the research was to be applied, and (3) evaluate the relationship of rumen function to other parameters.

C. EXPERIMENTAL PROCEDURES

Animals

The animals used were a subsample of 360 6- to 10-month-old steer calves from a larger sample of 2236 calves and represented 22 of the 50 different farms (FO) of Tennessee and Kentucky feeder calf producers used in a larger study. The steers were assembled and shipped in seven groups (shipments). Four of the shipments were made in the Fall of 1977, and three were made in the Fall of 1978. Both the farms and the calves within each farm were chosen at random. The calves were predominantly of beef breeding. All were castrated, dehorned, and healed males (steers) that had been vaccinated against blackleg and malignant

edema. All calves and their dams at each farm were pastured together. At all farms, tall fescue (Fescuta arundinacea Schreb.) was the basic pasture grass used in varying combinations with ladino clover (Trifolium repens L.), orchardgrass (Dactylis glomerata L.), bermuda-grass (Cynodon dactylon Var. dactylon), and lespedeza (Lespedeza stipulacea). Calves were gathered in the early morning, and, generally, sampling began at 0700. The calves were not provided water between gathering and completion of sampling. Ambient temperature and other environmental conditions varied greatly, but no attempts were made to adjust for this variation.

Samples

Portable scales and restraining equipment were assembled at each FO, and weights, body measurements, rumen samples, and blood samples were taken before any of the calves were weaned. In addition, detailed notes with respect to the general health status and any clinical signs were made concerning on each calf by a veterinarian or trained technician. Rumen samples were taken by orally inserting a stainless steel strainer attached to tygon tubing (Raun and Burroughs, 1962) into the reticulo-rumens of the intact steers. Suction was applied with a 60-cc syringe, and approximately 60 ml of rumen fluid was drawn and discarded before collecting 120 ml of experimental use. Samples which were thick and serous were considered to be contaminated by saliva and were discarded. The position of the strainer was altered until a satisfactory sample was obtained.

Rumen fluid pH was determined immediately after sampling using a Fisher portable pH meter with a glass electrode. A modification

(El-Din and El-Shazly, 1969a) of the method described by Hungate et al. (1955a), using a 50%-concentrate substrate, was employed for duplicate determinations of in vitro gas producing potential of the rumen fluid immediately after its collection. The remaining fluid was immediately frozen for VFA (Bendix gas chromatograph 2600) analyses or diluted with formaldehyde for differential ciliate protozoal counts (Purser and Moir, 1959). The rumen fluid volume of each calf was estimated, using either polyethylene glycol (Hyden, 1955) or lithium sulfate (Emmel et al., 1977).

Body Measurements

The calves at each farm were weighed, the fat thickness over the loin between the 12th and 13th ribs was estimated (Bronson Sonoray, Model 12) and 4 body measurements were taken. The body measurements (Billingsley, 1979) were height at the wither (HT), width at the point of the shoulder (WD), depth of body at the chest (DP), and length from the anterior end of the first thoracic vertebra to the posterior prominence of the pin bone (LEN). The HT, WD, and DP measurements were taken with steel, graduated calipers, and LEN was measured with a steel tape.

Statistical Analysis

Preliminary least-squares analyses of variance were conducted to assess the effect of year of sampling, shipment within year, and farm within shipment-year on the dependent variables (body measurements and rumen parameters). Evaluation of the preliminary analyses suggested

that variation in the dependent variation attributed to shipment within year was actually due to farm variables. All calves from each farm were included in the same shipment group each year, and only a few farms were represented in both years. The shipment within year term was deleted from the models, and, in general, the fraction of the variation in the dependent variables attributable to farm was increased; but the overall coefficients of determination were slightly decreased. Since much of the variation between farms was probably due to environmental differences between farms, which generally affect animal weight, the covariate weight was added to the model containing terms for year and farm within year in the final analyses.

Although calves from all farms were not included in both years, 49.4% of the calves were from farms represented both years. Some calves which were not considered representative of the respective farms were deleted, and about 37.5% of the calves which were from repeated farms were used to calculate intrafarm correlations across years.

D. RESULTS AND DISCUSSION

Measurement Variables

Means, standard errors, and maximum and minimum values for weight, backfat thickness, and body measurements are presented in Table 5. These statistics characterize the sample of calves in this study and provide a general description of the feeder-calf population from which the sample was drawn. It is important to remember that this description applies to calves at the farms where they were produced, 6- to 10-month-old calves, before exposure to the stresses of weaning, and before entering the

TABLE 5. OVERALL MEANS OF BODY MEASUREMENTS AND RUMEN PARAMETERS

	N	Mean	S.E.	Minimum	Maximum
Description of calves					
Age, days	360			180	300
Weight, kg	359	202	1.97	118	306
Height, cm	360	93.5	.28	53.5	108.8
Length, cm	360	97.1	.37	71.1	130.6
Depth, cm	360	48.0	.19	37.6	57.8
Width, cm	360	32.5	.15	24.8	39.6
Fat thickness, mm	353	1.5	.05	0	5.0
Rumen parameters					
pH	357	7.0	.02	5.8	7.9
Gas producing potential, cm^3	356	6.3	.18	0	23.0
Volume, l	315	25.9	.54	5.0	85.0
Volatile fatty acids					
Total VFA, mmol/l	344	63.1	1.29	15.7	140.81
Acetic, moles/100 moles	344	69.6	.72	47.8	77.98
Propionic, moles/100 moles	344	15.5	.39	8.2	43.76
Butyric, moles/100 moles	344	10.7	.20	3.0	19.79
Higher acids, moles/100 moles	344	4.7		0	13.45
Ciliate protozoa[a]/cm^3, x 10^4					
Entodinium	319	24.20	1.57	0	183.04
Diplodinium	319	2.33	.16	0	25.76
Epidinium	319	1.85	.58	0	181.76
Ophryoscolex	319	0	0	0	0
Spirotricha total	319	28.37	1.71	0	184.96
Paraisotricha	319	.14	.05	0	9.28
Beutschlia	319	>.01	>.01	0	.40
Charon	319	.04	.01	0	3.60
Isotricha	319	.23	.03	0	3.36
Dasytricha	319	2.46	.18	0	27.20
Holotricha total	319	2.87	.20	0	27.20
Ciliate protozoa total	319	31.25	1.72	0	184.96

[a]Actual values = table values x10^4 for mean standard error, minimum and maximum.

normal industry market chain. Weights, body measurements, and rumen samples were taken in September and October. Although the exact ages of individual calves were not available at some farms, all producers were able to provide inclusive dates for their calving season. From these approximate dates a range in age was calculated. The median age of calves was 240 days, and mean weight was 202 kg. McLaren et al. (1979) reported a mean weaning age of 221 days and a mean weaning weight of 194 kg for 18,393 calves enrolled in the Tennessee Beef Cattle Improvement Program, and McLaren (1970) found that 23,939 calves enrolled in the Alabama testing program averaged 195 kg at a mean age of 240 days. Similarity of these weights, similarity of feeder-calf quality grades assigned calves in this study by official Tennessee Department of Agriculture graders and those assigned to calves at Tennessee and Kentucky Feeder Calf Sales (Billingsley, 1979), and visual evaluation by feeder-calf producers and orderbuyers suggest that the sample was representative of Southeastern feeder calves.

Means of the measurement variables by year are given in Table 6. In 1977, the calves were lighter ($P < 0.01$), deeper bodied ($P < 0.1$), and wider at the point of the shoulder ($P < 0.001$) than were those in 1978. Preliminary analyses also indicated significant differences among shipments within year and among FO within year-shipment with respect to most measurement variables. Since all calves from each farm were included in the same shipment group each year, the effect of shipment within year was confounded with FO effect. When the term for shipment within year was deleted from the model used in the preliminary analyses, the R^2 values were smaller.

TABLE 6. MEANS OF BODY MEASUREMENT BY YEAR, SHIPMENT, AND FARM

	N	Body Weight, kg	Body Measurements				Backfat, mm
			Height	Length	Depth	Width	
			cm				
YEAR 1977	222	200	93.2	96.6	48.1	31.7	1.4
Shipment 4	48	184	90.9	92.4	46.7	31.2	2.3
Farm 19	7	217	92.8	93.9	50.1	34.3	2.3
Farm 20	13	207	95.1	100.3	47.4	30.8	2.3
Farm 21	3	206	95.8	99.4	48.6	30.8	2.7
Farm 22	13	154	84.0	83.4	44.4	31.2	2.5
Farm 25	12	168	91.6	91.0	46.0	29.9	1.9
Shipment 5	66	203	92.7	96.9	48.5	31.7	0.6
Farm 1	8	230	95.2	100.8	49.3	31.8	0.6
Farm 13	13	209	94.4	97.5	48.5	32.5	0.6
Farm 14	8	177	90.1	90.8	47.2	29.3	0.6
Farm 16	5	210	93.2	98.6	52.1	33.1	0.6
Farm 28	14	232	96.9	103.4	50.8	34.0	0.6
Farm 29	6	155	88.2	89.7	45.1	28.7	0.5
Farm 31	8	175	89.8	91.5	46.4	28.6	0.6
Farm 34	4	204	83.9	95.8	46.5	34.0	0.5
Shipment 6	54	200	94.1	96.7	48.1	31.1	1.5
Farm 3	6	182	92.1	93.6	44.7	31.0	1.3
Farm 4	11	178	94.1	96.3	47.0	29.1	1.3
Farm 12	12	171	92.7	94.7	46.0	30.1	1.2
Farm 30	13	253	97.4	102.9	52.9	34.0	2.1
Farm 32	12	200	93.0	93.7	47.9	30.9	1.2
Shipment 7	54	210	94.9	100.1	48.9	33.0	1.5
Farm 3	27	222	94.8	99.8	48.2	33.7	1.7
Farm 12	27	198	95.0	100.4	49.5	32.2	1.3
YEAR 1978	138	204	94.0	97.8	47.8	33.6	1.6
Shipment 10	20	183	91.5	94.5	46.9	32.8	1.4
Farm 13	10	179	91.8	94.8	46.4	32.1	1.3
Farm 30	10	189	91.1	94.3	47.4	33.5	1.5

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TABLE 6 (continued)

	N	Body Weight, kg	Body Measurements				Backfat, mm
			Height	Length	Depth	Width	
			cm				
YEAR 1978 (continued)							
Shipment 11	54	220	96.3	101.4	48.9	34.1	1.8
Farm 3	27	220	94.9	100.2	48.0	34.8	1.8
Farm 12	27	219	97.6	102.6	49.9	33.4	1.7
Shipment 12	64	198	92.9	95.8	47.1	33.4	1.4
Farm 41	18	195	92.5	95.3	47.0	33.5	1.7
Farm 42	16	215	94.0	98.0	48.8	35.2	1.6
Farm 43	15	212	93.7	97.1	48.5	34.4	1.3
Farm 44	15	167	91.4	92.8	44.2	30.6	1.0

Some components of FO differences were discussed by Orr (1979) and Billingsley (1979). They were not able to account for the total FO effect by these components (weight, breed, rate of gain, fatness, etc.). Potential FO effects include several factors such as age of calf, breed of calf, age of dam, and other variables which are generally classified as management practices. These variable management practices include vaccination programs, fly control practices, age at castration, nutrition of the dam, pasture quality and quantity, and numerous other practices. Effects of most of these management variables tend to be reflected in calf weight. When the covariate, weight, replaced the shipment within year term in the model containing year, shipment within year and farm within shipment-year for analysis of the management variables, the resulting R^2 values (Table 7) were similar to or greater than those yielded by analyses according to the original model. This suggests that differences in measurement variables attributed to shipment within year were a combination of FO effects and differences in weights of calves from farms included in various shipment groups. Including FO and weight in the model defined these differences more precisely. These results also point out the importance of FO as a source of variation and the need to consider FO effects in evaluation of field studies involving rumen parameters.

Although the statistical analyses suggested that large FO within year effects on body measurement variables existed, it has not been determined whether farm effects are associated with specific farms across years or whether the effects of a specific farm are different in different years. Repeatibility of the individual measurement variables

TABLE 7. ANALYSIS OF VARIANCE FOR THE EFFORTS OF YEAR, FARM OF ORIGIN, AND WEIGHT ON WEIGHT, BODY MEASUREMENTS, FAT AND RUMEN PARAMETERS

Source	df	Weight	Length	Height	Width	Depth	Fat	Volatile Fatty Acids, Moles/100 Moles: Acetic	Propionic	Butyric	Higher	Total VFA, mmol/l	Rumen: pH	Rumen: Liquid Volume, l
		Partial mean square												
Yr	1	67	50 †	50	231	31†	2	<1	42	48	<1	12593†	6	18
FO/yr	24	7844***	86***	54***	13***	14***	4***	130***	103***	52***	25	4942***	<1***	201***
Weight	1		5876***	2603***	893***	1890***	27***	6	<1	3	2	245	0	3175***
Residual		928	16	14	3	5	<1	14	10	3	3	222	<1	44
Residual df		333	333	332	332	332	325	316	316	316	316	316	329	289
R^2		.38	.71	.55	.69	.66	.46	.43	.45	.60	.40	.64	.56	.43
		% Of variation explained by sequentially adding elements												
Yr		0	.6**	.6*	9.9***	.2	.7†	.01	.01	.10	0	2.8***	31.4***	1.3*
FO/yr		.38	38.1***	29.8***	29.3	26.3***	35.6***	.42	.44	.50	.40	61.0***	24.5***	43.7***
Weight			32.4***	25.1***	29.8***	39.6***	9.8***	0	0	0	0	.1	0	.2
Intrafarm correlation[a]		.01	.28	.27	.07	.40	.01	0	.75	.96	0	.00	.01	.22

Source	df	Rumen ciliated protozoa/ml: Spirotricha[b] En[c]	Spirotricha[b] DI[d]	Spirotricha[b] EP[d]	Spirotricha[b] Total[c]	Holotricha[b] PI[e]	Holotricha[b] BP[f]	Holotricha[b] Charon[g]	Holotricha[b] Isotricha[h]	Holotricha[b] Dasytricha[i]	Holotricha[b] Total[i]	Total ciliated protozoa[c] /ml	Gas producing potential cm^3
		Partial mean squares											
Yr	1	657	6	26	701	359	238	71	4	201	397	811	56
FO/yr	24	336***	18***	66	438***	197***	353***	822	533***	388***	475***	428***	70**
Weight	1	134†	17†	992**	409**	78	115	63	87	56	17	425**	7
Residual		54	7	107	59	59	78	670	227	76	91	62	7
Residual df		291	291	291	291	291	291	291	291	291	291	291	328
R^2		.37	.18	.08	.42	.22	.28	.09	.18	.31	.32	.40	.45
		% Variation explained by sequentially adding elements											
Yr		4.0	<.1	.3	4.0***	.5	.5	0	0	.7†	2.0***	4.4***	1.3**
FO/yr		32.8***	16.7***	4.9	36.4**	21.6***	27.6***	9.5	18.6	30.0***	31.3***	34.5***	43.7***
Weight		.5†	.7†	2.9***	1.4*	.4	.4	3	.1	.2			.1
Intraclass correlation[a]		.44	.15	0	.44	0	0	.05	.02	.18	.18	.40	.22

†P < .10; *P < .05; **P < .01; ***P < .001.

[a]Intrafarm correlations were calculated from farms repeated in both years.

[b]EN = Entodinium; DI = Diplodinium; EP = Epidinium; PI = Parisotricla; BP = Beutschlia Parva.

[c]Actual value x 10^9. [d]x 10^8. [e]x 10^6. [f]x 10^3. [g]x 10^4. [h]x 10^5. [i]x 10^7.

(intrafarm correlation) was calculated for farms repeated in both years. The values obtained are presented in Table 7.

Repeatability of calf height, length, and depth (0.28, 0.27, and 0.40, respectively) suggests that the significant change in the coefficients of determination obtained by adding FO within year to the model containing year (0.381, 0.298, and 0.396 for the three measurements, respectively) can be attributed to true farm differences. However, the low repeatability of calf width and fat thickness indicates that the variation in these variables is due to FO x year interaction and that farm effects with respect to these variables differ across years. Billingsley (1979) suggested that body width was a reflection of overall body condition as was fat thickness. Low heritability (<0.10) of all traits measuring general body condition (visual condition scores, fat thickness, body width) reported by Robertson et al. (1963) suggests that these traits are dependent on environmental conditions which vary from year to year at individual farms. Variation in pasture quality, pasture quantity, and calf condition attributed to year (climatic) variation by High et al. (1965) and Fribourg et al. (1979) support the conclusion that the repeatability of the effect of FO per se on calf condition is small. These results suggest that the effects of FO on weight and body measurements are definite and they should be considered in any analysis of field data.

Rumen Parameters

Individual rumen parameters were estimated to define normal values in nonweaned feeder calves at the farms where they were raised.

Overall means, standard errors, and ranges are presented in Table 5 (p. 47), and mean for years, shipments, and farms are in Table 8. Preliminary analyses of variance similar to those discussed for the body measurement variables were conducted to evaluate the effects of year, FO, and calf weight on the rumen parameters. The model including year, FO within year, and weight explained more variation in various rumen parameters than the model containing year, shipment within year, and FO within year shipment. Results of the final analyses and repeatabilities (intrafarm correlations) of all rumen parameters are presented in Table 7. Significant FO within year effects were observed for acetic acid, propionic acid, butyric acid, and total VFA concentrations. The major component of total VFA was acetic acid (70%); therefore, the two parameters were extremely confounded, and factors affecting acetic acid concentration also affected total VFA concentration. The near-zero intrafarm correlation for acetic acid suggests that the significant FO within year component was a reflection of a large FO x year interaction resulting from yearly variation in forage intake, forage quality, and/or other environmental factors, at specific farms.

The large intrafarm correlations for propionic and butyric acid suggest that a large fraction of the significant FO within year component is a reflection of true FO differences. This result can probably be explained by the fact that at low concentrations (15 and 11 moles/ 100 moles) these acids are not as susceptible to yearly fluctuation in environmental conditions as is acetic acid.

Addition of FO within year to a model containing year explained an additional 36.4, 30.9, and 34.4% of the total variation in

TABLE 8. MEANS OF RUMEN PARAMETERS BY YEAR, SHIPMENT, AND FARM

Year, Shipment, Farm	N	pH	In Vitro GP	Volatile Fatty Acids					Rumen Liquid Volume	
				Acetic	Propionic	Butyric	Higher[a]	Total	N	l
				moles/100 moles				m moles/l		
YEAR 1977	220	7.2	6.0	70.1[a]	15.7	10.0	4.2	66.2	178	26.0
Shipment 4	48	7.2	3.6	71.2	12.3	11.8	4.7	62.7	48	23.1
Farm 19	7	7.0	4.1	70.4	11.9	12.7	5.0	80.2	7	26.0
Farm 20	13	7.3	3.8	70.0[a]	12.4	14.4	3.4	62.2	13	28.7
Farm 21	3	7.0	6.1	71.3	14.0	12.4	2.3	87.1	3	22.5
Farm 22	13	7.6	1.9	73.7	11.2	8.3	6.8	38.7	13	14.1
Farm 25	12	7.0	4.4	70.2	13.3	12.5	4.0	73.1	12	25.4
Shipment 5	65	7.0	6.4	68.6	16.7	11.2	3.6	89.2	40	25.6
Farm 1	8	7.4	12.6	58.0	26.6	12.1	3.2	97.1	0	--
Farm 13	13	6.9	5.9	71.5	14.5	11.7	2.3	104.5	12	26.4
Farm 14	8	6.8	4.0	69.8	15.1	12.3	2.9	100.9	3	28.0
Farm 16	5	7.2	5.6	71.6	13.8	10.4	4.2	77.6	5	27.0
Farm 28	13	7.2	7.8	70.0	14.3	10.4	5.3	83.8	8	24.2
Farm 29	6	7.1	4.5	68.1	15.4	14.2	2.4	90.3	5	20.6
Farm 31	8	6.7	3.6	64.4	22.2	8.4	5.0	57.7	7	27.2
Farm 34	4	7.3	5.0	73.2	14.1	10.3	2.4	97.8	0	--
Shipment 6	53	7.1	7.2	69.4	17.1	9.4	4.1	67.6	36	29.5
Farm 3	6	7.2	7.0	73.4	16.7	5.8	4.1	39.7	5	21.1
Farm 4	11	7.1	8.4	71.9	14.3	11.1	2.7	96.6	7	29.2
Farm 12	12	7.2	6.0	65.1	20.5	9.1	5.2	47.4	8	26.3

TABLE 8 (continued)

Year, Shipment, Farm	N	pH	In Vitro GP	Volatile Fatty Acids					Rumen Liquid Volume	
				Acetic	Propionic	Butyric	Higher[a]	Total	N	l
				moles/100 moles				m moles/l		
YEAR 199 (continued										
Farm 30	12	7.2	5.7	65.0	20.3	8.7	5.1	55.0	8	35.0
Farm 32	12	7.1	8.7	72.9	13.4	10.1	3.5	83.3	8	32.8
Shipment 7	54	7.2	6.5	71.4	16.2	7.8	4.5	41.2	54	26.6
Farm 3	27	7.2	6.9	71.8	17.3	6.5	4.4	39.9	27	26.6
Farm 12	27	7.2	6.1	71.1	15.2	9.1	4.6	42.5	27	26.7
YEAR 1978	137	6.8	6.8	69.0	15.0	11.8	4.2	57.9	138	25.8
Shipment 10	19	6.8	7.0	69.4	14.1	12.6	3.8	62.4	20	24.1
Farm 13	10	6.6	8.3	69.6	14.5	12.2	3.7	69.7	10	22.0
Farm 30	9	6.9	5.6	69.4	14.0	12.8	3.8	60.9	10	26.2
Shipment 11	54	6.8	6.8	65.7	16.6	11.6	6.1	56.4	54	25.1
Farm 3	27	6.7	10.2	64.1	18.7	10.9	6.3	59.2	27	31.7
Farm 12	27	6.8	3.6	67.4	14.6	12.2	5.8	53.5	26	18.3

TABLE 8 (continued)

Year, Shipment, Farm	N	pH	In Vitro GP	Volatile Fatty Acids					Rumen Liquid Volume	
				Acetic	Propionic	Butyric	Higher[a]	Total	N	l
				moles/100 moles				m moles/l		
YEAR 1978 (continued)										
Shipment 12	64	6.9	6.7	71.6	13.9	11.7	2.8	58.4	64	26.8
Farm 41	18	6.8	6.8	69.5	13.9	13.5	3.0	56.2	18	29.6
Farm 42	16	6.8	5.1	73.8	14.0	9.8	2.5	64.7	16	27.5
Farm 43	15	7.0	5.8	72.8	13.7	11.0	2.5	50.1	15	29.1
Farm 44	15	6.8	5.1	70.7	13.8	12.4	3.0	62.7	15	20.5

[a]Only 214 VFA samples were taken in 1977. One sample was missing from farms 5 and 12 and 2 each were missed from farms 1 and 20.

[b]Higher VFA included all acids except acetic, propionic, and butyric.

Spirotricha, Holotricha, and total ciliated protozoa, respectively. Repeatabilities of 0.44, 0.18 and 0.40 for the three variables, respectively, indicate that a large fraction of these components are probably true farm effects. Similar effects were observed with respect to the protozoal genera Entodinium (EN), Diplodinium (DI), and Dasytricha (DA). The significant change in R^2 due to adding FO within year to the model in the analysis of data on other individual genera may indicate a large farm x year interaction effect or may be an artifact of the all-or-none type effect caused by the fact that these genera were not observed at many farms and were observed at low concentrations at other farms.

pH

Mean rumen pH was 7.0 ± 0.02, and individual values ranged from 5.8 to 7.9 (Table 5, p. 47). These values are in general agreement with the range in pH values reported by Phillipson (1955) and Briggs et al. (1957). Briggs et al. (1957) stated that when rumen pH values are above 7.4, clinical disturbances are expected. Examination of other rumen parameter values and clinical examination results for the 20 calves (approximately 5% of the total) with pH values above 7.4 indicated that the other rumen parameters were generally normal and no clinical signs were observed. An increase of 0.5 units above the upper optimum limit should not be as severe as 0.5 units below lower optimum limit due to the logarithmic scale used to express hydrogen ion concentration. In addition, clinical signs of acidosis would probably be expressed to a greater degree than clinical signs of alkalosis.

Although the pH measurement of the rumen samples were taken as quickly as possible after sampling (1 to 3 min), a constant source of error across all collections was possible. Aeration of the sample is known to liberate CO_2 (Olson, 1941; Clark and Lombard, 1951) thus making possible the recording of slightly high values.

Sampling of calves began at about 0700 at each farm; however, the time of sampling of the last calf at a farm varied due to the different numbers of calves sampled at various farms. Monroe and Perkins (1939) found that time of sampling was a negligible factor influencing rumen pH of cows on pasture. Calves in this study were on pasture until just before sampling; hence, the error due to sampling time was considered to be small.

Large mean differences in pH values between calves sampled in 1977 and 1978 were observed. The mean pH value in 1977 was 7.2 and in 1978 the value was 6.8. A majority of the mean pH values for individual farms were below 7.0 in 1977 and above 7.0 in 1978. No plausible explanation for the large difference in mean pH across year can be offered. Different pH meters were used during the two years. However, both were carefully calibrated each time they were used, and the same electrode was used both years. A possible biological explanation is that 1977 was a dryer year than 1978 and the pastures were not as lush in the fall. Beghelli (1959) found that salivary secretion rate was affected by moisture content of the feed. Higher-moisture feeds induced less salivation. A lower salivary flow reduces the ruminal buffering capacity and results in a lower ruminal pH.

VFA

Mean total VFA was 63.1 mmol/l (Table 5, p. 47), and the maximum and minimum values were 15.7 and 140.8 mmol/l, respectively. The maximum values are similar to values reported by Hungate (1966) and Church (1967) for animals consuming diets containing concentrates. They reported higher minimum values than the minimum values found in this study; however, many of the values were determined in sheep. Numerous factors in addition to diet, animal species, analytical techniques and sampling techniques have been found to influence rumen fermentation (Hungate, 1966). Total VFA concentrations were lower when the fluid samples were obtained with a stomach tube than when they were taken via a rumen fistula (Bryant and Small, 1960; Leng and Annison, 1963). Therefore, values reported here could be consistently lower than those observed in other studies.

Hungate (1966) stated that in well-fed animals, VFA absorption could never reduce the rumen VFA concentration below 40 mmol/l. He theorized that the continuous nature of the fermentation and the distance the acids must diffuse across the large mass of digesta to reach the rumen wall for absorption physically prevent VFA concentrations from attaining values lower than 40 mmol/l except during starvation. Jamieson (1959) reported a range of 32 to 153 mmol/l in grazing sheep. Of the 344 animals sampled in this study, 16.6% had total VFA concentrations below 40 mmol/l. It is possible that these samples containing the low VFA concentrations were contaminated with saliva. However, only six of the samples had extremely low in vitro gas producing potential (GP)

values. Also protozoa counts for these samples were similar to those of samples containing higher VFA concentration. If the samples had been contaminated with saliva, GP and protozoa counts would be lower than uncontaminated samples containing higher VFA concentrations. Closer observation revealed that 51 of the 57 calves (90%) with low VFA concentrations (less than 40 mmol/l) were from three farms but only 39% of the total samples were taken at these farms. In addition, 22 calves (6.4% of the total sample) had VFA concentrations of less than 30 mmol/l and 90% of these came from 2 of the 3 farms. Therefore, the low VFA values were considered an expression of FO differences attributed to low forage intake and/or quality, fasting, transient ruminal upset, or other factors intrinsic to those farms.

Pfander and Phillipson (1953) substantiated reports from several other studies to the effect that the mean steady state distribution of the three principal VFA in the rumen was 63% acetic, 21% propionic, and 15% butyric acid in sheep. The values in cattle appear to be somewhat different and are very diet dependent (Hungate, 1966). Jamieson (1959) and Hungate (1966) reported acetic acid concentrations as high as 70% and as low as 38%. The mean concentration of acetate in this study was 69.6 moles/100 moles, and the individual values range from 47.8 to 78.0 moles/100 moles of total VFA. The mean acetate-to-propionate ratio was 4.2 which was slightly higher than those reported in older cattle.

Rumen Volume

Rumen liquid volume as estimated in this study was a measure of "physiological fill" and not an estimate of rumen capacity. The overall

mean rumen volume was 25.9 ± 0.54 l (Table 5, p. 47) with a range of 5 to 85 l. Some of the small volumes possibly could be explained by the fact that the calves did not have access to water during the time they were awaiting sampling. However, the ratio of mean body weight (202 kg) to mean rumen weight (25.9 l) was 12.85. This is similar to the values obtained by similar marker techniques in adult sheep (Purser and Moir, 1966a) and in adult beef cows (Nutt et al., 1980). Significant differences among mean volumes of calves from various farms were observed (Table 7, p. 52); however, individual FO weight to volume ratios were generally between 10.0 and 15.5%. Year and FO within year explained 28.7% of the total variation in volume. When weight was included in the model, an additional 14.2% of the total variation was explained. The intrafarm correlation for volume was 0.22 and suggests that a large portion of the 28.7% total variation explained by FO within year was a true FO effect.

Gas Production

Mean one hour gas producing potential (GP) of rumen fluid samples was 6.3 ± 0.18 cm^3 (Table 5). The values ranged from 0 to 23 cm^3. Some of the zero values could possibly be explained by technique errors; however, evaluation of other rumen parameters indicated low rumen fermentation in some of the calves with low GP values, which, in other calves, only GP was low. Health records indicated that no clinical signs or other atypical conditions existed. The only aberrant parameter was body temperature. Elevated temperatures up to 42.2°C were observed in individual calves at some farms and in the entire group of calves at

other farms. The effect of elevated body temperature on GP has not been defined, but Camp et al. (1981) found that rumen temperature was highly correlated with rectal temperature. Hungate (1966) indicated that rumen protozoa could not tolerate temperatures above 40°C; therefore, there is reason to suspect that elevated body temperature of the animal at sampling would affect in vitro microbial activity.

Year did not affect GP ($P < 0.10$) but when FO within year was added to the model the R^2 value was increased 43.7% ($P < 0.001$). It appears that a significant portion of the FO within year component is due to true farm differences. Mean GP of calves from various farms varied from 1.9 to 12.6 cm^3.

Protozoa

Mean total ciliated protozoa concentration was 312,500 ± 17200 per ml of rumen fluid (Table 5, p. 47). The total protozoa concentration consisted of 90.8% Spirotricha and 9.2% Holotricha. The protozoal genera contributing to the total Spirotricha count were Entodinium (85.3%), Diplodinium (8.2%) and Epidinium (6.5%). The Holotricha consisted of Dasytricha (85.7%), Isotricha (8.0%), Paraisotricha (4.9%), and Charon (1.4%). Entodinium and Dasytricha comprised 86.6% of the total ciliated protozoa population.

Year did not significantly affect rumen concentration of total ciliated protozoa, protozoal subclasses, or individual genera (Table 7, p. 52). FO within year influenced all protozoal concentrations ($P < 0.001$) except that of the Epidinium and Charon genera. When weight was added to the model additional amounts of only 1.4% ($P < 0.05$), 0.2,

and 1.5% of the variation in Spirotricha, Holotricha, and total ciliated protozoa concentrations, respectively, were explained (Table 7, p. 52). In general, the increased R^2 resulting from adding weight was low and nonsignificant. Therefore, most protozoa genera and subclasses appear to be less affected by animal weight than were body measurements, VFA, GP, and rumen volume.

Zero values for all protozoal genera were observed in some individual calves. Total protozoa counts of zero were observed both in calves with low GP and in calves with high GP. Hungate et al. (1955a) and El-Din and El-Shazly (1969a) pointed out that in vitro GP reflects the status of both rumen bacteria and rumen protozoa. Several possible reasons can be suggested for the low protozoal concentration in rumen fluid of individual calves in this study. Milk consumption of some of the younger calves could have been high enough to effectively suppress the protozoal populations. Also, the technique used to count the protozoa was sensitive only to counts greater than 1600/cm^3 making it possible that very low concentrations were undetected. These factors would have a small effect on the bacterial population and GP production could be unaffected.

In calves with low values for both GP and protozoal counts, one must consider possible saliva contamination of the samples. However, the sampling technique tended to minimize contamination. For this reason and those considered for GP, it was concluded that contamination was not a major factor influencing estimates of protozoal concentration and the variation in protozoal counts observed was attributed to animal or FO variation. The percentage of a calf population in microbial upset

at any given time is not known. However, the values for both GP and protozoal counts indicate that a small percentage may be in a state of microbial dysfunction at any time.

Entodinium spp. was the only protozoal genus found at all farms (Table 9). Dipodinium spp. and Epidinium spp. were found at 95.5% of the farms. In contrast, the Spirotricha spp. Ophryoscolex were not found in any farm populations. Holotricha spp. Buetschlia was observed at only one farm. Paraisotricha minuta was observed at 5 farms (23% of the total). This genus was first observed in the horse by Hsiung (1930) and was later reported in contents from the stomach of the hippopotamus (B. A. Dehority, personal communication). The presence of Paraisotricha Minuta in the rumen of cattle in the study was verified by B. A. Dehority, Professor of Animal Science, Wooster, Ohio. Charon spp. were found in calves at 27% of the farms and Isotrichia and Dasytricha were each found at 91% of the farms.

Means of protozoal counts at various farms were more variable than were those of the other rumen parameters. An example of this is the mean Entodinium count for farms 3 and 12 in both 1977 (41.06×10^4 and 7.82×10^4, respectively) and 1978 (65.49×10^4 and 13.04×10^4, respectively). Another example is the mean total ciliated protozoa counts for farm 28 (46.63×10^4) and for farm 31 (7.74×10^4) in 1977. This large variation among farms emphasizes the sensitivity of protozoal populations to environmental and nutritional influences. The inability to control all factors influencing protozoal concentrations at all farms makes interpretation of data from field studies difficult. However, the influence of variation in preshipment nutrition and rumen function on

TABLE 9. OVERALL MEAN NUMBER OF RUMEN CILIATED PROTOZOA BY YEAR, SHIPMENT, AND FARM

		Rumen Ciliate Protozoa[a]								
		Spirotricha				Holotricha[b]				Total Ciliated Protozoa
	N	Entodinium	Diplodinium	Epidinium	Total	Paraisotricha	Charon	Isotricha	Dasytricha	Total	
		concentration/cm^3									
YEAR 1977	182	19.39	2.36	1.37	23.12	0.04	0.04	0.22	2.23	2.53	25.65
Shipment 4	45	18.29	3.42	1.56	23.28	0.00	0.00	0.23	2.58	2.82	26.10
Farm 19	7	23.66	5.76	2.17	31.59	0.00	0.00	0.09	2.22	2.31	33.90
Farm 20	10	24.59	3.60	2.35	30.50	0.00	0.00	0.19	3.50	3.70	34.24
Farm 21	3	20.11	5.65	2.82	28.59	0.00	0.00	4.64	4.64	4.64	33.23
Farm 22	13	17.44	2.04	0.20	19.68	0.00	0.00	0.43	2.88	3.31	22.99
Farm 25	12	10.39	2.84	1.72	14.95	0.00	0.00	0.20	1.20	6.95	21.89
Shipment 5	51	17.56	2.37	1.18	21.11	0.00	0.13	0.36	3.14	3.65	24.76
Farm 1	2	19.44	0.00	0.32	19.76	0.00	0.00	0.32	0.00	0.32	20.08
Farm 13	12	19.47	2.20	0.97	22.64	0.00	0.30	0.12	2.65	3.07	25.71
Farm 14	8	22.10	2.05	0.63	24.78	0.00	0.00	0.97	8.99	9.96	34.74
Farm 16	5	7.87	0.70	0.35	8.93	0.00	0.00	0.13	2.27	2.40	11.33
Farm 28	7	31.31	5.89	5.43	42.63	0.00	0.28	0.68	2.91	4.00	46.63
Farm 29	5	16.51	2.69	0.00	19.20	0.00	0.00	0.26	1.89	2.14	21.34
Farm 31	8	5.75	0.68	0.12	6.55	0.00	0.15	0.04	1.00	1.19	7.74
Farm 34	4	14.80	3.64	0.48	18.92	0.00	0.00	0.36	1.84	2.20	21.12
Shipment 6	32	14.96	1.50	0.97	17.43	0.17	0.00	0.22	2.07	2.48	19.90
Farm 3	4	41.32	2.12	3.08	46.52	0.00	0.00	0.08	0.00	0.80	46.60
Farm 4	8	18.96	1.12	0.30	20.38	0.50	0.00	0.00	1.48	1.98	22.36
Farm 12	7	6.51	2.10	1.81	10.42	0.00	0.00	0.69	3.75	4.55	14.97
Farm 30	8	8.22	0.84	0.30	9.36	0.08	0.00	0.14	1.58	1.80	11.16
Farm 32	5	10.05	1.82	0.26	12.13	0.13	0.00	0.13	3.10	3.36	15.49
Shipment 7	54	24.45	1.95	1.64	28.06	0.21	0.00	0.09	1.16	1.46	29.52
Farm 3	27	41.09	1.99	1.38	44.46	0.02	0.00	0.13	0.16	0.31	44.77
Farm 12	27	7.82	1.93	1.91	11.66	0.40	0.00	0.05	2.16	2.61	14.26
YEAR 1978	137	30.66	2.29	2.48	35.43	0.21	0.04	0.23	2.77	3.54	38.97
Shipment 10	20	22.98	2.10	1.30	26.38	1.10	0.01	0.17	2.77	4.04	30.42
Farm 13	10	22.80	2.61	1.97	27.38	0.00	0.00	0.27	2.02	2.29	29.66
Farm 30	10	23.17	1.58	0.64	25.39	2.19	0.02	0.06	3.52	5.79	31.18
Shipment 11	54	39.26	2.85	4.96	47.07	0.13	0.08	0.12	1.31	1.64	48.71
Farm 3	27	65.49	3.74	8.90	78.13	0.00	0.00	0.08	0.83	0.91	79.04
Farm 12	27	13.04	1.96	1.01	16.01	0.26	0.15	0.15	1.79	2.36	18.37
Shipment 12	63	25.73	1.88	0.72	28.33	0.00	0.02	0.35	4.03	5.01	33.35
Farm 41	18	30:51	1.56	0.48	32.54	0.00	0.00	0.28	3.88	4.55	37.09
Farm 42	16	5.06	1.13	0.15	6.34	0.00	0.00	0.11	1.91	2.02	8.36
Farm 43	14	22.59	1.99	1.14	25.72	0.00	0.08	0.24	5.11	7.48	33.20
Farm 44	15	44.99	2.97	1.22	49.18	0.00	0.00	0.79	5.46	6.46	55.64

[a]Actual values = table values x 10^4.

[b]Beutschilia were found in a few calves at farm 28.

animal performance and health during market and transit could be an important aspect of research designed to elucidate farm management and nutritional practices which could reduce the incidence of Bovine Respiratory Disease Complex.

CHAPTER V

RESPONSE OF RUMEN PARAMETERS TO MARKET-TRANSIT STRESS IN FEEDER CALVES

A. SUMMARY

One-hundred-eighty-four weanling steer calves were subjected to the stresses associated with industry procedures for marketing and transporting Southeastern feeder calves from the farms where they were raised to commercial backgrounding and/or finishing facilities. These stresses (Market-Transit) included a 24-h starvation period at a commercial auction barn (AB), a 72-h period at an orderbuyer barn (OBB) facility where the calves were fed grass hay and provided water free-choice, and a transit phase (T) of 12 to 30 h when the calves were transported by truck from the OBB to a feedlot.

Body weight decreased during AB, increased slightly during OBB, and decreased during T. Total market-transit weight loss was 13% of the arrival AB weight. Rumen liquid volume (RV), rumen gas producing potential (GPP), rumen total volatile fatty acid concentration (TVFA), and rumen protozoal concentration (TPROT) decreased significantly (25.6%, 71%, 25%, and 50%, respectively) during AB. During the AB starvation period, rumen pH increased. This was followed by a decrease during OBB. Weight and all other rumen parameters increased during OBB.

Total market-transit (M-T) decreases in GPP, TVFA, and TPROT were 19.4%, 57.5%, and 78.5%, respectively. Although M-T decreases in some rumen parameters were small, large changes, which could alter rumen

functions, were observed in one phase (AB or OBB) followed by large increases in the subsequent phase. The GPP, RV, and VFA parameters were more severely affected by the intermittent starvation-feeding and stress periods than were other parameters, and the recovery from the depressed values sustained at AB was more rapid in the case of all parameters other than rumen protozoal concentrations.

B. INTRODUCTION

During the process of marketing and transporting (Market-Transit), calves are subjected to a variety of stresses. These stresses often include weaning, crowding, starvation, dust, and drastic changes in temperature, precipitation, and humidity (Crenshaw, 1967; Pierson, 1968; MacLean, 1972; Wiseman, 1978; McKercher, 1978). Self (1972) suggested that animals may lose 10% or more of their body weight in the form of digestive tract content and tissue water losses during this phase, and Church (1967) found that two or more weeks were required to recover this market-transit weight loss. Nutritional stress is particularly evident since the calves are subjected to periods of intermittent starvation and refeeding during Market-Transit. Even when feed and water are available, pasture-reared calves may be reluctant to eat or drink from a trough or to consume hay. Further dietary alterations, in the form of diet changes, occur upon arrival at the feedlot. These factors imposed during Market-Transit alter rumen metabolism and delay feedlot adaptation (Baldwin, 1967; Koers et al., 1975; Orr, 1979; Cole et al., 1979).

Previous studies indicate that the health and performance of feeder calves can be improved by altering their diet before they are

marketed (Woods et al., 1973; McLaren, 1978; Cole et al., 1979), during Market-Transit (Koers et al., 1975), and after feedlot arrival (Lofgreen et al., 1975; Hutcheson et al., 1978). However, little emphasis has been placed on evaluating rumen changes in calves during Market-Transit, and no effort has been made to partition the effects due to specific segments of this stressful experience. The purpose of this study was to measure the changes in rumen parameters of feeder calves during Market-Transit (MT) stress and to partition these changes into components attributable to the auction barn (AB), orderbuyer barn (OBB), and transport (T) phases.

C. EXPERIMENTAL PROCEDURES

Animals

The 184 calves used in this study were from 22 farms and were a subsample of 2236 weanling (7- to 11-month-old) steer calves used in a larger stress and respiratory disease study. The larger group represented 50 different farm environments (FO) provided by Tennessee and Kentucky feeder calf producers. The steers were assembled and shipped in seven groups (shipments). Four of the shipments were made in the Fall of 1977 and three were made in the Fall of 1978. Calves within each farm were chosen at random. The calves were of predominantly beef breeding. All were castrated, dehorned males (steers) that had been vaccinated against blackleg and malignant edema and recovered from the surgical procedure.

Market-Transit Treatment

The calves were exposed to environmental conditions designed to duplicate the normal M-T conditions described in detail by Billingsley

(1979) and in Chapter III. The calves were weaned and transported to an AB the same day and were immediately exposed to the stresses of weighing, sorting, and a simulated sale. The market facility at Algood, Tennessee, which was provided for this study by the owners, was regularly used as an auction facility and as an intermediate OBB by three order-buyers. Calves from each FO were graded, weighed and co-mingled with other calves immediately after arrival at the AB. They were confined to 0.65 to 0.75 m^2 of pen space per calf, without feed or water, during the 24-h AB phase. During the next 72 hours, OBB environment was simulated by allowing 1.8 to 2.5 m^2 pen space per steer and free access to grass hay and water. At the end of the OBB phase, steers were loaded onto trucks and transported (483 to 1600 km) to feedlots at either Springfield, Tennessee, or Bushland, Texas, or to wheat pasture at El Reno, Oklahoma (Chapter III).

The calves were weighed immediately after arrival at the auction barn (AAB), at the end of the auction barn phase (arrival at OBB, AOBB), prior to loading onto the trucks (departure from OBB, DOBB), and immediately after unloading at the feedlot or wheat pasture (arrival at the feedlot, AFL). At these times, rumen fluid samples were collected by stomach tube according to procedures described by Raun and Burroughs (1962) and in Chapter IV. The pH of the rumen fluid was determined immediately, and methods described by Hungate et al. (1955a) and El Din and El-Shazly (1969a) were used for determination of in vitro gas producing potential (GPP) of the fluid. Rumen liquid volume (RV) was estimated by the polyethylene glycol technique used by Hyden (1955). Volatile fatty acid concentration (VFA) determinations were made by gas

chromatography, and differential protozoal counts were made according to procedures described by Purser and Moir (1959).

Analyses of variance were performed to evaluate the effects of the independent variables (year, shipment, farm of origin, and elapsed time in the market-transit sequence) on the dependent variables (rumen parameters). The effect of elapsed time in days was included as a covariate in the statistical model, and the effect on each parameter was partitioned into linear, quadratic, and cubic components. Coefficients of regression of individual rumen parameters on elapsed time were used to express sequential changes in the various parameters during M-T.

D. RESULTS AND DISCUSSION

Body Weight

Body weight (BW) of the calves was similar during the two years. However, shipment within year, farm within shipment-year, and the linear, quadratic and cubic components of elapsed time in the M-T chain were all important ($P < 0.001$) on BW changes (Table 10). The model containing these variables explained 51.77% of the variation in BW (Table 11). The most important factors contributing to variation in BW were shipment within year (18.31%) and farm within shipment-year (27.18%). Farm was shown to be the most important factor influencing variation in BW of feeder calves at FO, and the shipment effect appeared to be due in part to confounding with FO. However, the shipment effect observed in this study was probably a measure of significant climatic differences in shipments. During the 5-day M-T period the calves sustained an overall

TABLE 10. ANALYSIS OF VARIANCE OF THE EFFECT OF YEAR, SHIPMENT, FARM OF ORIGIN, AND ELAPSED TIME (DAYS) IN THE MARKET-TRANSIT SCHEME ON WEIGHT AND RUMEN CHARACTERISTICS

		Mean Squares							
Source	df	Weight	pH	Gas Production Potential	Rumen Fluid Volume	Total VFA	Total[a] Protozoa	OL[a]	HO[a]
Year	1	276	2.07***	271***	315	10042***	243	184	4
Shipment/year	5	3178***	.50***	102**	1459***	7640***	267	232	2†
Farm/shipment-year	21	1358***	.17***	58***	255***	843**	366***	283***	5***
Regression of Y on day									
Linear	1	17283***	4.83***	1492***	651***	18113***	447***	349***	6**
Quadratic	1	19436***	6.46***	1209***	982***	28306***	254*	208*	3†
Cubic	1	22119***	7.38***	1006***	1353***	37851***	156†	124†	2
Residual		759	.05	8.7	62	458	41	39	.8
Residual df		687	550	517	372	500	429	390	390

†P < 0.10; *P < 0.05; **P < 0.01; ***P < 0.001.

[a]Actual values = table values x 10^6, OL = oligotrichs; HO = holotrichs.

TABLE 11. FRACTION OF THE SUM OF SQUARES OF THE DEPENDENT VARIABLE THAT WAS EXPLAINED BY SEQUENTIALLY ADDING INDEPENDENT VARIABLES AND COVARIATES TO THE STATISTICAL MODEL

Independent Variables[a]						ΔR^2							
Year	Shipment	Farm of Origin	Day	Day^2	Day^3	Weight	pH	Gas Production Potential	Rumen Fluid Volume	Total VFA	Total Protozoa	OL[b]	HO[b]
X						.0217***	.0717***	.0000	.0388***	.0030	0	0	.0007
X	X					.1831***	.0923***	.0611***	.1935***	.0825***	.0840***	.0728***	.0450***
X	X	X				.2718***	.0694***	.1354***	.1344***	.0540***	.1932***	.2178***	.1946***
X	X	X	X			.0169***	.0411***	.1180***	.0037	.0022	.1065***	.0884***	.0772***
X	X	X	X	X		.0028*	.0163***	.0546***	.0225***	.0690***	.0245***	.0199***	.0207***
X	X	X	X	X	X	.0214***	.1441***	.1148***	.0338***	.1119***	.0052*	.0044†	.0033
Total R^2						.5177	.4349	.4839	.4267	.3226	.4134	.4033	.3415

†P < 0.10; *P < 0.05; ***P < 0.001.

[a]The independent variables were year, shipment/year, farm/shipment-year and linear, quadratic, and cubic effects of time in the market-transit scheme. Day 0 = arrival auction barn; Day 1 = arrival orderbuyer barn (24 h later); Day 4 = departure orderbuyer barn; and Day 5 = arrival feedlot.

[b]OL = oligotrichs; HO = holotrichs.

mean weight loss of 30 kg (Table 12). This represents an approximate overall loss of 13% of their AAB body weight during the 24-h stress and starvation period. This value was 1 and 2 percentage points greater than those reported by Camp et al. (1981) and Cole et al. (1979), respectively. However, this loss does not represent the total weight loss of the calves from FO to AFL since some shrink occurred during transit from FO to AB.

The intercept and coefficients of regression, shown in Table 13, were used to describe BW loss and gain patterns during the total M-T phase (Figure 1). The calves lost an average of 10.3% of their ABB weight during the 24-h AB phase. During the OBB phase, they regained part of the BW loss which occurred during the AB phase, and the cumulative loss from AAB to DOBB was 7.05%. This is greater than the 4.34% reported by Cole et al. (1979), and the 6% reported by Lynch (1968). During the 24-h transit period, the calves lost an additional 14 kg (6.9% of DOBB weight). This in-transit loss was less than the 8.2% reported by Camp et al. (1981) and the 11.9% transit shrink reported for adult steers not stressed prior to transport (Galyean et al., 1981). However, it is in agreement with the 6.79% shrink reported by Cole et al. (1979) for similarly treated calves.

pH

Rumen pH values (Figure 1) were affected ($P < 0.001$) by the stresses of the M-T chain (Table 11). The pH values at AAB (Table 10) were similar to those for rumen fluid samples at FO reported in Chapter IV. During the initial 24-h starvation period, rumen pH

TABLE 12. OVERALL MEANS AND THEIR STANDARD ERRORS FOR WEIGHT AND SELECTED RUMEN AND BLOOD PARAMETERS

	Arrival Auction Barn	Arrival Feedlot
Weight, kg	233 ± 2.95	203 ± 2.74
Rumen characteristics		
pH	7.04 ± .02	7.04 ± .02
Gas production potential, cm^3	7.39 ± .35	3.12 ± .16
Fluid volume, l	25.5 ± .86	26.9 ± .62
Total VFA, moles/100 moles	57.0 ± 1.97	45.8 ± .63
Acetic/propionic ratio	3.9 ±	4.2 ±
Total protozoa (1×10^3)	378.3 ± 36.9	81.26 ± 8.0
Ologitricha	350.4 ± 37.0	72.9 ± 7.47
Holotricha	27.9 ± .38	8.3 ± 1.19
Blood parameters		
Packed cell volume, %	38.5 ± .64	41.2 ± .46

TABLE 13. ESTIMATES TO INTERCEPT AND COEFFICIENTS FROM PARTIAL REGRESSION OF RUMEN CHARACTERISTICS ON ELAPSED TIME (DAYS) DURING THE MARKET-TRANSIT PHASE

		Coefficient of Regression of Y on Day		
	Intercept	Linear	Quadratic	Cubic
Weight	233.04	-13.15	6.56	-.87
pH	7.04	.21	-.12	.02
Gas Production, cm^3	7.39	-4.04	1.42	-1.42
Rumen Fluid Volume, l	29.52	-6.02	2.69	-.31
Total VFA, mmol/ml	56.96	-15.58	9.50	-1.33
Acetic Acid	38.79	-18.41	13.36	-1.99
Protionic Acid	10.06	-6.83	3.56	-.45
Butyric Acid	5.68	-5.34	2.61	-.33
Total Ciliated Protozoa/ml	350,000	-226723	57385	-4938
Spirotricha/ml	302,996	-210070	30683	-1304
Entodinium	256,250	-212735	64747	-6385
Epidinium	93330	-10165	2586	-237
Diplidinium	26200	-22256	6861	-682
Holotricha/ml	27,900	-3360	7508	-56
Dasytricha	30,000	-23936	6484	-578
Paraisotricha	900	-1057	400	-44
Charon	1625	=431	415	-77

Each dependent variable was adjusted for year, shipment and farm of origin by including these effects in the models from which to intercept and regression coefficients were estimated.

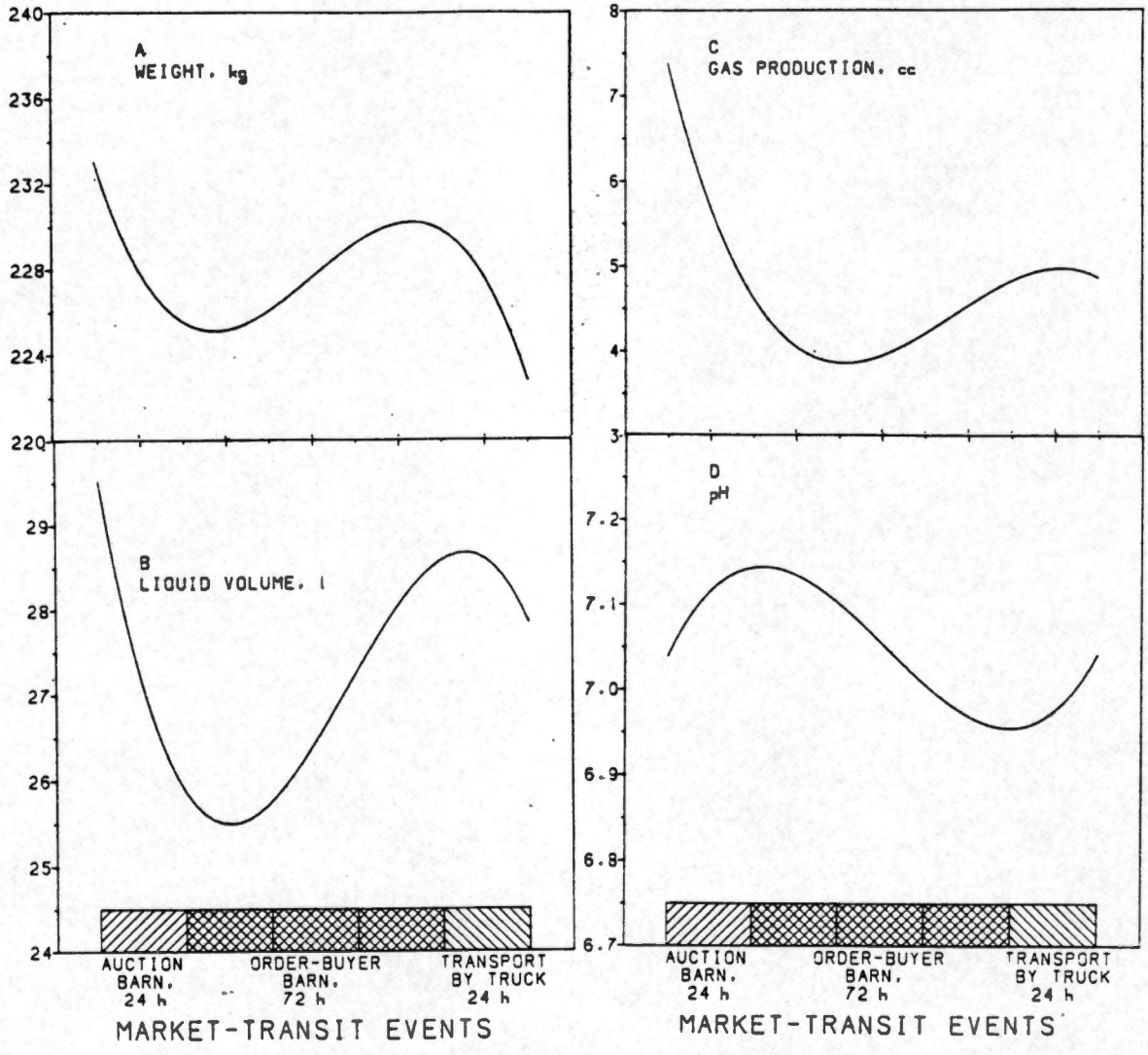


Figure 1. Market-Transfer Effects on Weight, Rumen Liquid Volume, Gas Producing Potential and Rumen pH.

increased by 0.23 units. During the 3-day OBB phase, the mean pH value decreased by 0.42 units to a value of 6.81 which was 0.23 units below the AAB mean value. During the transportation phase, ruminal pH increased to 7.04 which was equal to the AAB value. Meiske et al. (1958) reported that increased rumen pH accompanied starvation. This increase in pH is consistent with the other rumen parameters, since VFA concentrations decreased by 24% during the AB period. McAnally and Phillipson (1942), Reid et al. (1957), and El-Shazly et al. (1961) suggested that ruminal pH is a function of ruminal VFA concentration. Emmanuel et al. (1969), Rumsey et al. (1970), and Mullen (1973) also indicated that ruminal pH decreased as VFA concentrations increased. During the OBB phase, the decrease in pH was paralleled by an increase in VFA concentrations. An inverse relationship was observed during the transportation phase. One surprising observation was the fact that the pH values at DOBB were lower than AAB values. The calves had grazed fescue, ladino clover and lespedeza pastures at FO, but the diet change from pasture to grass hay, which was fed at OBB, would not appear to be sufficient to lower the rumen pH appreciably. In addition, lowered pH values are generally associated with concentrate feeding. The decrease could have been due to a decreased salivary flow, and, therefore, reduced buffering capacity. Reduced salivary flow is known to result in lower ruminal pH (McDougall, 1948). Rumen liquid volume at DOBB was 95% of the AAB values. It is of course possible that rumen volumes were maintained during the OBB phase by water consumption in the absence of normal salivary secretion. However, the calves were fed unground hay

during the OBB and roughage feeding is associated with increased salivary flow (Gordon, 1958; Bailey, 1961). However, this does not appear to be a plausible explanation of the depressed pH values. Also, when the profound and rapid decrease in both GPP and total ciliated protozoa (TPROT) during the AB phase is considered, the increased VFA values associated with reduced pH become difficult to explain. Either the VFA production would either have to increase or a decrease in absorption must occur if VFA concentratiions are increased. In light of the above findings the later is considered more likely.

Gas Producing Potential

Gas producing potential of the rumen fluid (GPP) was adversely affected ($P < 0.001$) by the stresses imposed during M-T (Figure 1). A severe reduction (63%) in GPP was observed during the AB phase. When these values are projected to total GPP of the entire rumen, the AAB value was 71% greater than the AOBB value. The GPP values increased only modestly during the OBB phase and then further decreased ($P < 0.001$) during transit. Quin (1943), Meiske et al. (1958), and Warner (1962) reported rapidly decreasing microbial activity during starvation, and a delay of up to 10 days before a return to pre-starvation levels occurred. Although some increase in GPP was observed during the 3-day post-starvation period (OBB), rumen GPP did not reach pre-starvation (AAB) levels. In adult steers stressed only by a 32-h shipment and starvation period, Galyean et al. (1981) reported decreased bacterial populations, similar to those reflected by low GPP in these steers. During the total M-T period, GPP was reduced about 60%.

Rumen Volume

Although the overall means of rumen liquid volume (RV) at AAB and AFL (Table 10, p. 73) were similar, pronounced intermediate changes in RV were observed during the marketing phase (Figure 1). Rumen volume decreased by 25.6% during the AB phase of the M-T chain. This was probably due both to decreased salivary production and a lack of feed and water intake. At DOBB, RV was similar to the AAB value. Additional decreases occurred during transit, but these decreases were smaller than those observed during the first starvation-stress period (AB). However, this is probably an artifact due to the influence of two shipments which were transported a shorter distance than were the other shipments.

VFA

VFA concentrations decreased ($P < 0.001$) during the AB phase (Table 11, p. 74). Total volatile fatty acid concentration (TVFA) decreased 25% (Figure 2). However, acetate concentration was less severely affected during the AB stress-starved period than were those of the other individual acids. The consistent acetate concentration tended to stabilize the TVFA concentration and prevented severe decreases in it. The acetate decreased only 18% during the AB phase, compared to 36% and 54% for propionate and butyrate, respectively. Therefore, some shifts in molar ratios were observed. The molar percent of acetate increased by 6 percentage points and was accompanied by corresponding decreases in concentrations of the other two primary VFA. TVFA concentration of rumen fluid increased during the OBB phase, and the TVFA value at DOBB was 121% of that observed in AAB.

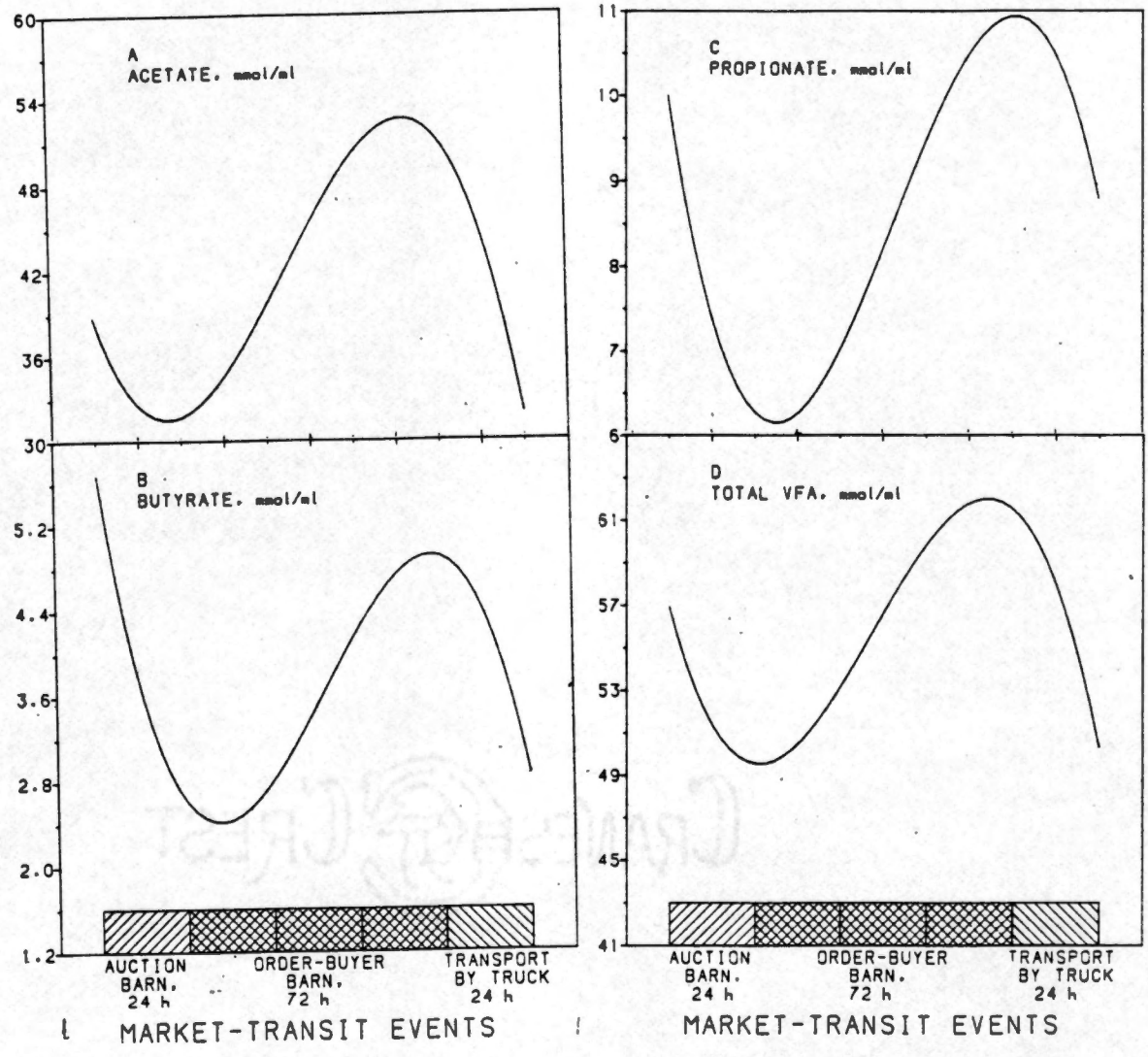


Figure 2. Market-Transit Effects on Volatile Fatty Acids.

During this period the increase in acetate was greater (13 mmol/l) than that of propionate and butyrate which had returned to their respective AAB levels. During transport, another decrease in all VFA levels occurred. Total VFA, acetate, propionate and butyrate decreased to values which were 81, 62, 82 and 57% of the DOBB values, respectively. The increases in VFA concentration during the OBB phase appear somewhat disproportionate to changes in GPP and protozoal concentration during that period. When metabolites of bacteria and protozoa are considered, the VFA changes should closely follow the pattern of changes in those two parameters. Therefore, the decreases in TPROT and modest increases in GPP would have suggested a concomitant decrease in TVFA concentration rather than the increase in VFA concentrations which was observed.

One possible explanation is that AAB values were somewhat smaller (as compared to FO values) due to the stress and short starvation (4 to 6 h) to which the calves had been subjected during gathering and penning at FO and during transport from FO to AB (20 to 75 km). However, the farm TVFA values reported in Chapter IV were similar to the AAB values (60.88 and 57.96, mmol/l, respectively). A concentration effect cannot be used as a basis for explanation due to the fact that the RV for AAB and DOBB were similar. The most plausible explanation is that decreased absorption of VFA occurred rather than an increased production.

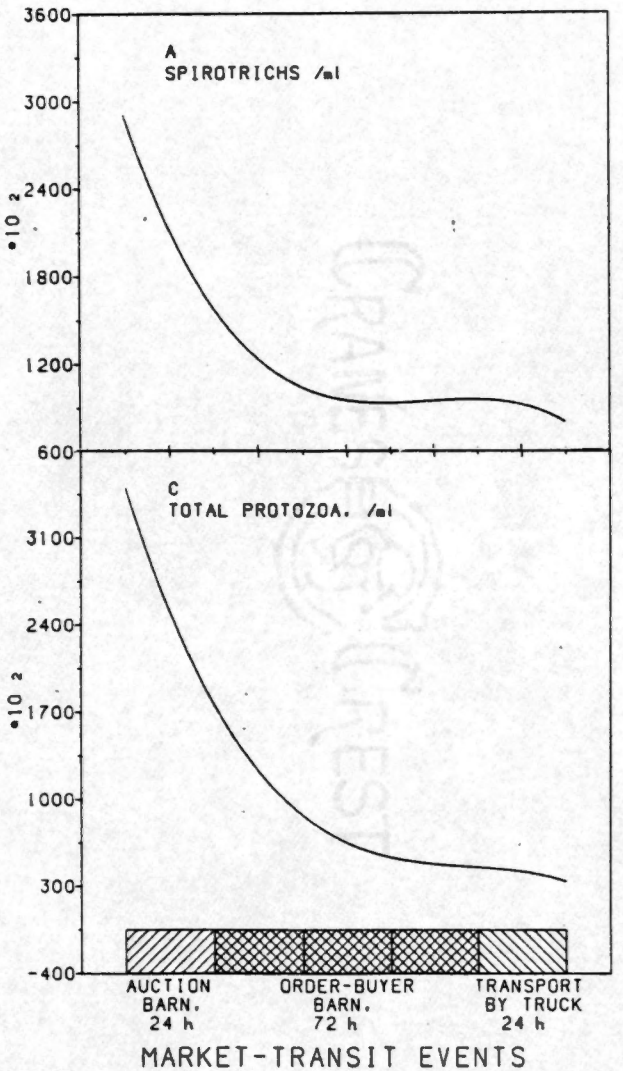
Protozoa

Total ciliated protozoa concentration (TPROT) responded to the stress and intermittent starvation in a manner similar to the GPP responses. Both parameters decreased drastically (50%) during the AB

phase (Figure 3). Since the AOBB values were total counts of protozoa which could include dead but not deteriorated protozoa, it is probable that the numbers of actual viable organisms at AOBB were much smaller than the recorded values indicate. Furthermore, when TPROT concentrations were converted to a total rumen basis by considering rumen volume, the total number of protozoa in the rumen actually decreased by 64%. Meiske et al. (1958), Hershberger and Cowan (1972) and Potter and Dehority (1973) observed similar decreases in protozoal numbers following fasting.

Although gradual increases in protozoal counts are generally associated with refeeding, the values for TPROT decreased further during the OBB phase. The TPROT value at DOBB was 73.0% less than the AOBB value and 86.7% less than the AAB value. When considered on a total rumen basis, these decreases are similar due to the fact that liquid volume nearly returned to AAB levels by DOBB.

Figures 4 and 5 reflect the effects of market-transit stress on individual genera counts. All genera counts, except two holotrichs (Charon and Paraisotricha), exhibited changes similar to TPROT. Charon and Paraisotricha concentrations increased during the OBB phase; however, the gains were small and could possibly be due to random error. It is possible also that these two genera respond differently to the effect of stress and/or starvation than do other genera. Several factors probably caused the decline in TPROT numbers. The calves were changed from a diet which was predominantly grass and milk to one of grass hay. The effects of ration change have been reported to cause changes in the protozoal populations. Lowered ruminal pH has been linked to the reduction or



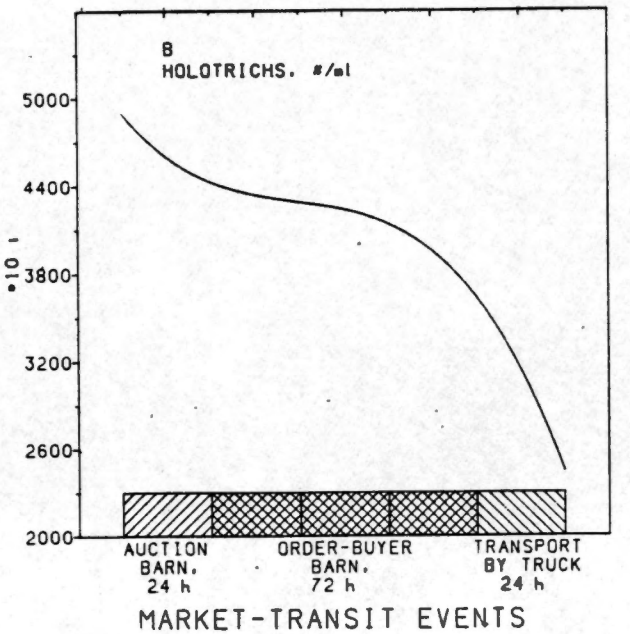


Figure 3. Market-Transit Effects on Rumen Ciliated Protozoa.

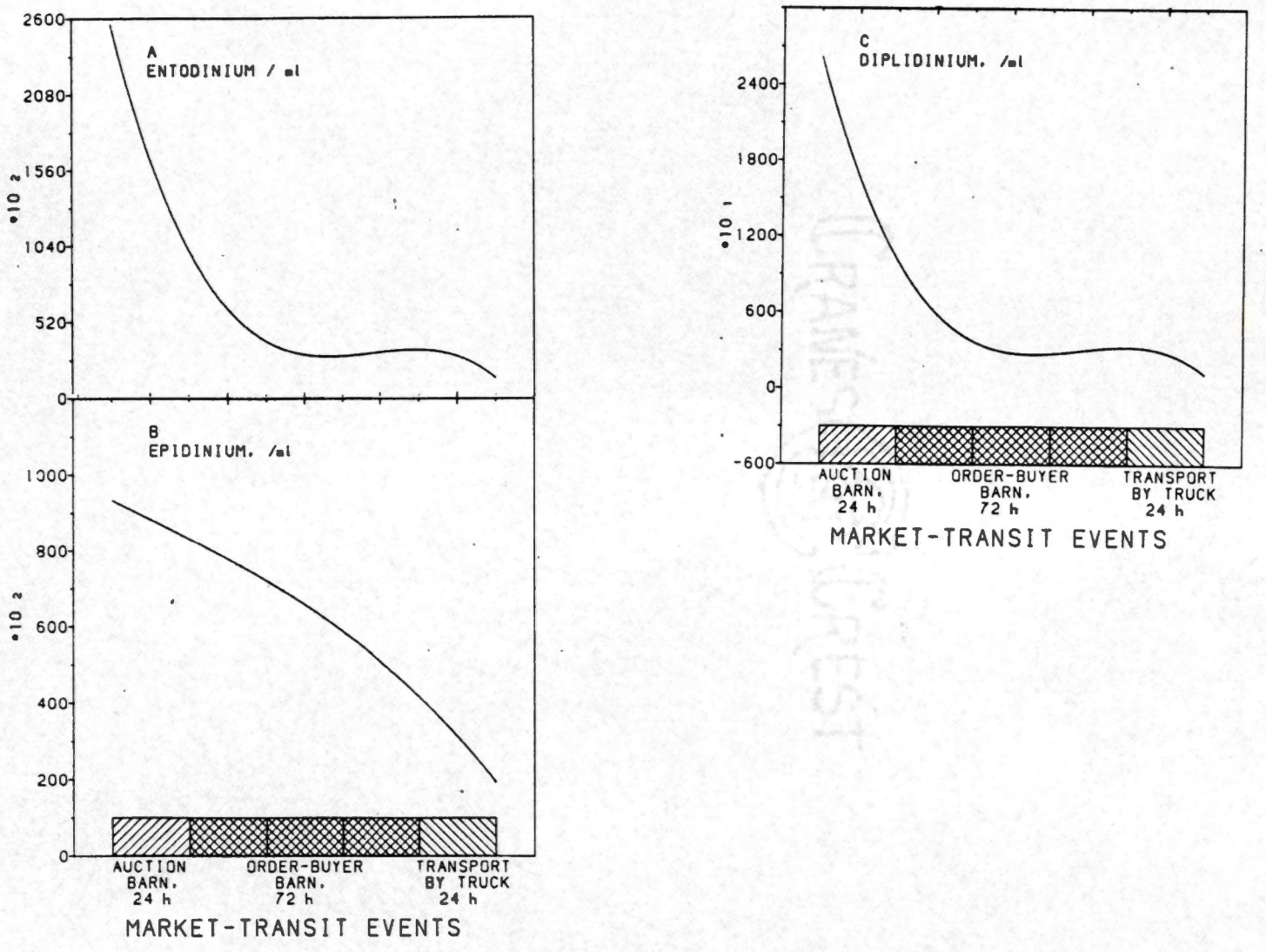
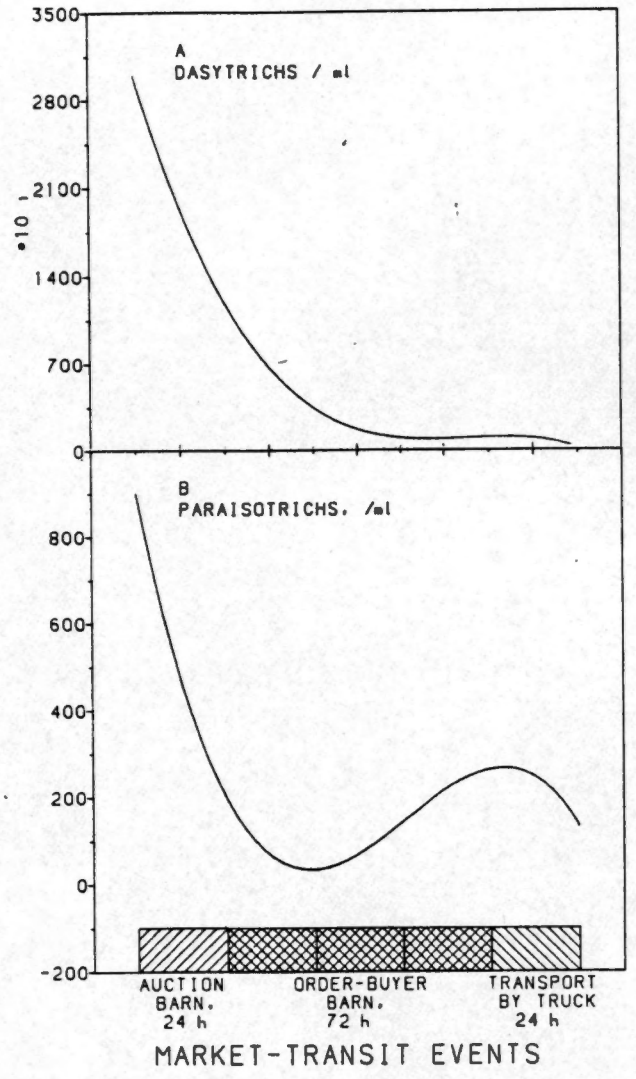


Figure 4. Market-Transit Effects on Spirotrich Genera.



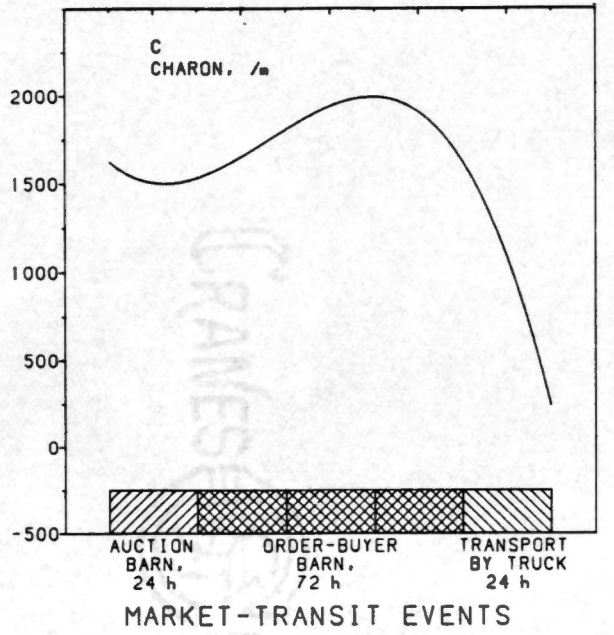


Figure 5. Market-Transit Effects on Holotrich Genera.

disappearance of the ciliated protozoa (Oxford, 1955; Hungate, 1966; Purser and Moir, 1959; Warner, 1964a; Eadie and Mann, 1970; Abe et al., 1973). In this study, ruminal pH was observed to decrease and could have exerted an influence on the protozoal populations. When the tremendous ingesta losses which constitute a large portion of market-transit BW loss is considered, it is logical to assume that ruminal rate of flow is altered during this stress period and could therefore cause a decrease in total rumen protozoal populations (Christiansen et al., 1964). Of all stress factors, starvation during the AB phase and the transportation phase probably exerted the greatest detrimental influence on the ruminal protozoal populations.

CHAPTER VI

SUMMARY

Most feeder calves marketed in the Southeast are subsequently exposed to the stresses of marketing and transporting which alter rumen metabolism and delay feedlot adaptation. A review of the literature established the need of a multidisciplinary approach in studying the nutritional aspects of animals subjected to these market-transit stresses.

Rumen samples were taken and weight, body measurements, and backfat thickness were determined for 360 unweaned, 6- to 10-month-old calves at 22 farms before the calves entered the market-chain during the Falls of 1977 and 1978. Mean weight, body length, height at the wither, body depth at the fore chest, width at the point of the shoulder, backfat at the 12th rib, rumen liquid volume, in vitro gas producing potential, total volatile fatty acids, ciliated protozoa (Spirotricha and Holotricha), and rumen pH were 202 ± 1.97 kg, 97 ± 0.37 cm, 93 ± 0.49 cm, 48.0 ± 0.19 cm, 32 ± 0.15 cm, 1.47 ± 0.05 mm, 26 ± 0.54 l, 6.3 ± 0.18 cm^3, 63.1 ± 1.29 mmol/l, 31.25 x 10^4 ± 1.72 x 10^4/ml (28.37 x 10^4 ± 1.71 x 10^4/ml and 2.87 x 10^4 ± 0.20 x 10^4/ml), and 7.0 ± 0.02, respectively.

One-hundred-eighty-four weanling steer calves were subjected to the stresses associated with the normal industry procedures for marketing and transporting Southeastern feeder calves from the farms where they were raised to commercial backgrounding and/or finishing facilities.

Body weight decreased during the auction barn phase, increased slightly during orderbuyer barn phase, and decreased during transit. Total market-transit weight loss was 13% of the arrival auction barn weight. Rumen liquid volume, rumen gas producing potential, rumen total VFA concentration, and rumen protozoal concentration decreased significantly (25.6%, 71%, 25%, and 50%, respectively) during the auction barn phase. During the auction barn starvation period, rumen pH increased. This was followed by a decrease in pH during the orderbuyer barn phase. Weight and all other rumen parameters increased during the orderbuyer barn phase.

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