8-1982

The relationship of feeder calf size and shape to rumen characteristics

Peggy J. Hamlett

To the Graduate Council:

I am submitting herewith a thesis written by Peggy J. Hamlett entitled "The relationship of feeder calf size and shape to rumen characteristics." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

J.B. McLaren, Major Professor

We have read this thesis and recommend its acceptance:

D.O Richardson, R.N. Heitmann

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

RELATIONSHIP OF FEEDER CALF SIZE AND SHAPE TO RUMEN CHARACTERISTICS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Peggy J. Hamlett

August 1982

ACKNOWLEDGMENTS

The author wishes to express her sincere gratitude and appreciation to the following who have made the completion of her graduate study and manuscript possible:

Her major professor, Dr. J. B. McLaren, for his knowledge in the related fields and assistance in the collection and statistical analysis of the data, for his encouragement and support throughout the program of study, and for giving his time for her personal guidance as well as her academic guidance;

Dr. D. O. Richardson, for serving as a member of the graduate committee and reviewing the manuscript, for his advice, enthusiasm, encouragement, and friendship;

Dr. R. N. Heitmann, for serving as a member of the graduate committee, reviewing the manuscript, and professional encouragement;

The University of Tennessee Computer Center for the use of that facility for analysis of these data;

The lab personnel and the secretaries for their assistance in the sample analyses and preparing the data;

V. L. Fulgoni III, W. S. Damron, M. C. Crider, W. R. Abner, K. K. Hawkins, G. R. Wehner and other graduate students for their assistance in the data collection and their continued friendship throughout the program of study;

Helen Scott for her supportive faith;

Her mother, father, brother, and sister, to whom she dedicates this thesis, for without their patient, understanding love, and encouraging support, this project would not have been possible; they are certainly responsible for any success she may achieve.

ABSTRACT

Thirty days before they were marketed, feeder calves were measured, sampled and allotted to preconditioning or market-management systems at the farms of Tennessee and Kentucky feeder-calf producers during each fall marketing season (1977-1978). Body measurements were weight (WT), height (HT), length (LEN), depth (DP), width (WD) and fat thickness over the 12th rib (BF). Rumen samples were taken by the tube method from intact steers and volatile fatty acids (VFA), protozoa concentrations and pH were determined. Rumen liquid volume and in vitro gas producing potential of the fluid (GPP) were estimated. Principal component indices describing general calf size (SIZE) and calf shape (SHAPE) were calculated. Calves from two farms were used to study the relationship of SIZE and SHAPE to rumen function at FO before weaning. Rumen volume was correlated with WT, WD, HT, DP and SIZE. Acetate was related ($P<.01$) to WT and BF. Depth and HT were the only individual body measurements that explained a large portion of the variation in protozoal concentration. Acetate and total VFA increased linearly ($P<.10$) as SIZE increased. Similar trends were observed for acetate, butyrate and higher VFA. The relationship of acetate and total VFA to SHAPE was curvilinear. Similar curvilinear trends were observed in the relationship of Spirotricha and total protozoal concentrations with SHAPE.

At FO the calves were randomly assigned to one of the three following market-management systems: 1) weaning and feeding a concentrate diet during the last 30 days before marketing and feeding hay at the orderbuyer barn (PW) and 2) allowing the calves to graze pasture with their dams during this period and feeding hay (NI) or a 50% concentrate diet at the orderbuyer barn (HE).

Rumen characteristics were measured at the beginning and end of the market phase. In general, calf size was related to changes in the total rumen protozoal concentration and to changes in protozoa subclass and genera populations. Calf shape was generally related to changes in volatile fatty acid concentrations. The changes in VFA concentrations were generally smallest in PW calves and the relationship of these changes to shape was greatest in HE calves. The relationship of protozoal changes to shape was more varied among the three groups (NI, HE, and PW calves) and were more difficult to explain than the relationship with size. Significant relationships of calf size and shape to change in rumen characteristics of weanling calves and changes in rumen characteristics during market were observed. This relationship was affected by market-management or preconditioning system to which the calves were subjected. In general, VFA concentrations and market changes were related to calf size and protozoal concentrations and market changes were related to calf shape.

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CHAPTER I

INTRODUCTION

Approximately 800,000 feeder calves are shipped annually from Tennessee to western and(or) cornbelt feedlots or wheat pastures (Tennessee Crop Reporting Service, 1979). Norman (1974) estimated that 5 to 10% of these calves die during market, transport and feedlot adaptation. According to Greathouse et al. (1973), bovine respiratory disease (BRD) or shipping fever is responsible for 80% of the deaths associated with relocation of feeder cattle. It was suggested by King et al. (1958), MacLean (1972), Norman (1974), Orr (1979) and Damron (1982), that during market-transit rumen characteristics are altered by stress. Quin (1943), Meiske et al. (1958), Warner (1962), and Damron (1982) reported that fasting of calves for periods similar in duration to these observed occurring at auction barns resulted in rapid decreases in microbial activity and that 10 days or longer was required for rumen microbial activity to return to pre-fasted status. They also stated that gas producing potential (GPP) of the rumen required a longer recovery period following fasting than other rumen characteristics. Galyean et al. (1981) reported GPP was reduced about 60% during the total market-transit phase.

Billingsley et al. (1981a) reported a relationship between calf size and shape and animal health and feedlot adaptation. Therefore, calf size and shape may be related to rumen function.

Since calf size and shape are related to animal performance and stress conditions similar to those encountered during marketing and transporting of feeder calves affected rumen function, it is possible that stress has a differential effect on the rumen functions of calves of different sizes and shapes. Another possibility is that if such a relationship between calf size and shape and the changes in rumen function during market-transit stress does exist, it may be indirect and due to differential preshipment rumen functions associated with calves of different sizes and shapes.

These hypotheses suggest that it is important to determine whether or not calf size and(or) shape are correlated to estimates of rumen microbial population size. If such a relationship exists, it would be important to determine whether or not there is a differential ability among calves of different sizes and(or) shapes to withstand stress during market and transport. Therefore, the objectives of this study were: 1) to determine the relationship of calf size and shape to rumen characteristics in non-weaned feeder steers and 2) to evaluate the influence of shipment, preconditioning regimes, farm of origin, and calf size and shape on rumen characteristics and their changes in market-transit stressed feeder steers.

CHAPTER II

REVIEW OF LITERATURE

During transportation, stress is the term used when referring to the combined effects of thirst, overcrowding, weather exposure, temperature extremes, fear, fatigue, and anxiety in feeder cattle (King et al., 1958 and Jensen and Mackey, 1979). Sinha and Abinanti (1962) suggested that stress was an important etiological factor making cattle susceptible to respiratory disease and influencing the development of viral infections. It is possible that stress interferes with the ciliated and mucus secreting cells of the respiratory epithelium thereby interfering with the removal of pathogens from the respiratory tract (Phillip, 1972). Stress is the major predisposing factor of the bovine respiratory disease (BRD) complex commonly referred to as shipping fever. Shipping fever is an acute respiratory infection of young cattle (Wills, 1980). Jensen et al. (1976) stated that the BRD complex affects feeder calves within 45 days after entering the market-transit phase which ends in the feedlot. Economic losses result from death, shrinkage, medical expenses, decreased feed efficiency and marketing delays. This problem was estimated to be a one-half billion dollar economic loss by Fleming (1975).

A. PRECONDITIONING AT FARM OF ORIGIN

Herrick (1969) defined preconditioning as factors necessary to get the animal from the site of production to the feedlot with the least amount of stress and to facilitate favorable feedlot adaptation. Preconditioning practices (PC) have been recommended (Greathouse et al., 1969; Norman, 1974) at the farm of origin (FO) in an attempt to assist the calf in making the transition to the feedlot (FL) with a minimum of stress. Koers et al. (1975) suggested that feeding a high-energy, antibiotic-fortified ration to calves, before they were shipped, gave them a significant increase in shipping fever resistance. Studies by Greathouse et al. (1969) showed that early-weaned calves gained faster than calves left with their dams during the last 30 days at FO (late-weaned). However, this gain was primarily due to fill, since early-weaned calves shrunk more during shipping than late-weaned calves. There was extreme variability in other trials and no overall advantage in pre-weaning was observed. Moody (1976) found that gain during the first few weeks in the feedlot was higher, death loss was lower and the incidence of clinical respiratory disease was lower in the calves fed a concentrate ration either at the FO or in the order buyer barn than in calves fed pasture or hay. Fleming (1975) reported that Cope and others observed higher feed consumption, higher gain, reduced sickness and lower death loss during feedlot adaptation in calves that were fed a high-energy ration during the marketing process than calves fed hay.

Self and Gay (1972) reported that direct shipment of feeder calves from the ranch or other grazing facility to feedlots or wheat pastures in Texas or Oklahoma resulted in lower weight losses than that observed in calves subject to some type of sale facility or those preconditioned for 30 days prior to shipment. Moody (1976), Cole et al. (1979), Billingsley (1979), Wills (1980), Abner (1981), and Damron (1982) discussed the causes, etiology, and results of shipping fever in stressed feeder calves.

B. RUMEN MICROBIAL ACTIVITIES

Results from numerous experiments have shown that diet composition and frequency of feeding can influence rumen microbial activity. McNaught et al. (1954) and Oxford (1955) suggested that rumen protozoa was a possible factor in the efficiency of nitrogen utilization. Pilgrim et al. (1970) and Weller and Pilgrim (1974) reported that protozoa contributed to the dietary need of the ruminant. According to El-Shazly and Hungate (1965), when food was in excess and conditions were constantly favorable, fermentation was maximum, and they described the fermentation rate as a positive linear function of microbial population size. The rate of rumen fluid change over time (1 h) in the fermentation of a substrate was suggested by El-Shazly and Hungate (1965, 1966) and El-Din and El-Shazly (1969) to be an accurate measure of change in important microorganisms in the rumen. Rate of gas production was related to rate of volatile fatty acid (VFA) production as indicated by Hungate (1965) and El-Din and El-Shazly (1969). Orr (1979), Su (1980) and Damron (1982) presented a detailed discussion of rumen microbial activity.

Volatile Fatty Acid

Under normal conditions the lower volatile fatty acids (VFA) are practically the only organic acids affecting pH of the rumen contents. Lactic acid is an intermediate product which is often observed in small amounts during the production of VFA when the diet is suitable for its accumulation (Phillipson 1942; Balch and Rowland, 1957). The nutrient supply of the rumen microorganisms affects their life activities and concurrently the rate of acid production and their nutrient supply is dependent on the diet of the host animal. Dougherty et al. (1965) and Warner (1964) reported the 70 to 80% of the total energy utilized by the ruminant was accounted for by VFA production in the rumen. The VFA normally found in the rumen are formic, acetic, propionic, butyric, isobutyric, valeric, isovaleric, caproic and heptanoic acids (Church, 1976). He grouped all VFA other than acetic, propionic, and butyric into a single classification and referenced them as "higher VFA." Annison and Lewis (1962) and Wheaton et al. (1970) reported several factors that influence the concentration of individual or total ruminal VFA. These factors were: 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.

Protozoa

Under favorable conditions the ciliated protozoa in the rumen may contribute as much as 20% of the host animals total nutritional requirements (Oxford, 1955; Gutierrez, 1958). The number, weight, and species distribution of protozoa varies greatly with diet, environmental conditions, and even varies among different animals of the same age and breed which are fed the same ration (Damron, 1982). Benefits of ciliated rumen protozoa enumerated by Eadie and Mann (1970) and Hinkson et al. (1976) include higher VFA production and a reduction in the ratio of acetic acid concentration to propionic acid concentration. Nakamura and Kanegasaki (1969) indicated animals fed combination of hay and concentrate were observed to have higher rumen protozoal numbers than those fed hay or concentrates alone. Christiansen et al. (1964) showed that when the diet contained large feed particles there was a slower rate of passage of ingesta and that a large protozoal population existed. A decrease in particle size coincided with a decrease in rumen protozoa. They also found increased protozoal populations result from increased frequency of feeding. A detailed review of methods of estimating protozoan populations, factors affecting population size, and the effects of protozoa population size on the host animals was presented by Damron (1982).

Rumen Liquid Volume

Purser and Moir (1966) thought rumen volume to have a double influence on rumen microbes by additionally influencing the microbial substrate relationships within the rumen. Animals with different rumen volumes that are fed at the same level of feed intake were the basis for this idea. Also, an animal with a small rumen would eat over a longer peiod of time and the microbial growth period would be extended. An animal with a large rumen would eat more quickly and have a shorter microbial growth period. Unpublished data collected by McLaren et al. suggested that calf size and shape have an effect on rumen liquid volume or fill. Therefore, it is possible that calf size and shape have an effect on rumen function.

A practical problem is the "lag" time associated with slow recovery of rumen protozoa concentration and the more rapid recovery of bacterial population size during marketing and shipping. During this time the calves remain weak and susceptible to disease. Su (1980) discussed the implications of various rumen liquid volumes and the recognized methods of estimating rumen volume in cattle.

C. SIZE AND SHAPE

Body measurements of dairy cows were utilized in a multivariate procedure, factor analysis by Tanner and Burt (1954). Numerous studies can be found in the literature (McCurley 1977; Eller, 1972; Hammack, 1973) pertaining to the relationship of size and shape, as defined by principal-component analysis, to growth and production in cattle. However, no reports of studies are available which relate size and shape to rumen characteristics and rumen changes associated with stress and(or) shipping fever.

Jolicoeur and Mosimann (1960) used the painted turtle to relate principal components with the concepts of size and shape. The variables used to calculate the size and shape components were length, width, and height of the shell. An increase or decrease of these variables correspond simultaneously to the equation of the major axis. Therefore, the loadings for the first component were used to combine the variables into a single component which was considered as an interpretation of growth trends or a generalized size variable. This component accounted for most of the variability in the independent structure. The direction cosines of the second axis with different signs corresponded to an increase in one measurement and a decrease in the other measurements. Therefore, the second component represented a trend in shape which generally contrasted the length and width measurements.

Eller (1972) used principal component procedures to analyze three data sets containing weight, fat thickness, and skeletal size scores of yearling bulls. The interpretation of the first two principal components were similar in all three data sets. The first component contrasted bulls of different sizes and accounted for 48 to 68% of the total variation. The second component contrasted bulls of different body shape and accounted for an additional 23 to 36% of the total explainable variation. In general, the shape component represented a range in shape from fat, wide, small-framed bulls to thin, narrow, large-framed bulls. Carpenter (1971) performed a principal component analysis on chest depth, hook width, body length, and weight measures of 38 Hereford cows. Ninety percent of the total variance was explained by the first two principal components (size and shape). The first component defined size and accounted for 80% of the variation. The size loading coefficients ranging from 0.42 to 0.54. The second principal component defined shape and the coefficients were both positive and negative. Brown et al. (1973a, 1973b) used records from 267 Hereford and 283 Angus bulls in an in-depth study which was analyzed by principal component procedures. The variables included nine skeletal measurements and body weight. Size was also defined by the first component in this study. The second component consisted of all positive loadings and those for weight, height, depth, length and heart girth (size traits) were larger than those for width. The second component consisted of large positive loadings for shoulder and hip width, and smaller loadings for height and length. Since the first component defined size, these positive measures indicated this component was positively correlated with preweaning gain. The second component was negatively related to all postweaning performance traits. A similar relationship could exist between the second component and preweaning gain since animals with high valves for the second component were wide, low and short-bodied.

D. SUMMARY

It has been established that rumen function is influenced by fasting and stress, and that size and shape influence the incidence of clinical respiratory disease and the rate of feedlot adaptation in transit-stressed feeder calves. Little information is available regarding normal rumen characteristics in feeder calves entering the marketing process or the effect of calf size and shape on these concentrations.

CHAPTER III

EXPERIMENTAL PROCEDURES

A. INDUSTRY MARKETING PROCEDURES

An intensive survey was conducted (McLaren, 1978; Billingsley, 1979; Damron, 1982) to determine the predominant marketing procedures of the Southeastern feeder-calf industry. This survey indicated that most Tennessee cow herds were small and averaged 28 cows. Most of the calves were transported to an auction barn (AB) direct after weaning. The calves arrived in a frightened and confused state and spent an average of 24 h at the AB without feed or water. They were provided .65 to 0.75 m^2 of pen space per steer. At the auction barn, orderbuyers purchased the emotionally and physically stressed calves and commingled them with similarly stressed calves from other farms. The calves were transported to an orderbuyer barn (OBB) which was another temporary stop in the market chain. The calves spent an average of 72 h in the OBB where they were allowed 1.42 to 2.80 m^2 of pen space per calf and had access to hay and water. Following the 3-day period in the OBB, the calves were loaded onto trucks and transported to a Western and(or) Cornbelt feedlot or Western wheat pastures. Transit time ranged from 18 to 42 h and the average transit time was 27 h.

B. CALF SOURCE AND MANAGEMENT

Seven groups (shipments) of weanling feeder steer calves weighing 137 to 296 kg were purchased from several Tennessee and

Kentucky feeder-calf producers (FO) for a large cooperative shipping fever study. For the study reported herein, a smaller group of calves were randomly selected from each of the larger groups and were used to evaluate the relationship of size, shape, and rumen characteristics. The 360 calves selected for this study were weighed, measured, and rumen fluid and serum samples were taken at the farm of origin 30 days before they were scheduled to be marketed. At this time they were randomly allotted to pre-shipment treatment groups on a farm-within-shipment basis.

The pre-shipment treatments and management procedures were as follows: 1) during the last 30 days at FO this group of calves were allowed to graze pasture with their dams without supplemental feed. During the OBB phase they were fed hay. This treatment simulated normal-industry, market-transit management systems observed in the survey (NI); 2) these calves were managed identical to the NI calves during the last 30 days at FO. But, they were fed a high-energy, high-antibiotic (55%) concentrate diet (Table 1) during the OBB phase (HE); and 3) the calves in this group were weaned and fed a concentrate (65%) diet (Table 1) at the FO for 30 days before they were marketed and they were fed hay during the orderbuyer barn phase (PW). The NI and HE calves were weaned on the day that all calves were shipped to a commercial auction barn at Algood, Tennessee. Auction barn environment was simulated for 24 h and OBB environment was simulated for 72 h. At the end of the OBB phase, the calves were transported to feedlots at the Highland Rim Experiment Station, Springfield, TN or at the Southwest

TABLE 1. COMPOSITION OF PRETRANSIT RATIONS[a]

Ingredient	IRN[b]	Ration[c] PW	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	--
NcCl, trace mineralized	6-04-152	0.5	0.5
Limestone, grnd (nm) 33 Ca	6-02-632	0.3	0.7
Calcium phosphate dibasic, commerical	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.

Great Plans Research Center, Bushland, TX or to wheat pastures at the Southwestern Livestock and Forage Research Station, El Reno, OK.

C. DATA COLLECTED

The calves were weighed and rectal temperatures, rumen samples, and body measurements were taken at FO 30 days before they moved into the market phase. They were weighed and sampled upon arrival at the auction barn (AAB), arrival at the orderbuyer barn (AOBB), departure from the orderbuyer barn (DOBB), and arrival at the feedlot (AFL).

Gas producing (Cellular digestion) potential was determined by the method described by El-Din and El-Shazly (1969) and pH of the rumen fluid was determined immediately upon collection with a Fisher portable pH meter (Su,1980). Rumen fluid samples were preserved with formaldehyde (Purser and Moir, 1959) for protozoa counts and frozen for later volatile fatty acid (VFA) determinations (Damron 1982). The VFA concentrations were determined with a Bendix gas chromatograph and protozoa counts were estimated by procedures used by Hungate et al. (1955). Polyethylene glycol or lithium sulfate were used as markers according to procedures outlined by Hyden (1955), Emmel et al. (1977), Ulyatt (1964) and Su (1980) to estimate the rumen fluid volume of each calf.

In order to calculate size and shape indices, the following measurements were taken: 1) body length from the anterior end of the first thoracic vertebra to the posterior prominence of the pin bone (LEN), 2) height at the withers (HT), 3) width at the points of the shoulders (WD), 4) depth of the body at the fore chest (DP), 5) fat thickness over the loin between the 12th and 13th rib (BF) and 6) body weight (WT).

D. STATISTICAL ANALYSIS

In an attempt to integrate body weight and body measurements into more descriptive and more easily evaluated terms, a multivariate procedure, generally known as principal-component analysis, was used to generate orthogonal size and shape indices. The loadings from the first component were used in a prediction-type equation to estimate size and loadings from the second component were used to develop individual shape indices. The use of this technique was reported by Jolicoeur and Mossimann (1960), Carpenter et al. (1971), Eller (1972), Brown et al. (1973a), Hammack (1973) and McCurley and McLaren (1981). The purpose of this analysis was to simultaneously study the relationship and effect of all body measurements on rumen characteristics and changes in rumen function during market-transit rather than examining the effects of individual measurements. The estimates of weight, height, and length are correlated indicators of body size (Brown et al., 1973a, 1973b). These correlations indicated that a linear combination of all measurements such as the first principal-component index would be appropriate. The individual estimates of fat cover, width, and depth are correlated indicators of body shape. It is desirable, also, for shape to be expressed as a single linear combination of these variables such as the second principal-component index. The PC technique involves linear combinations of the correlated measurements into factors, or components and according to Brown et al. (1973a) and McCurley and McLaren (1981) each component explained a portion of the variation in the total dependence structure.

In this study only the first two principal components (size and shape) were included in the regression analysis because 1) other components had little biological meaning and 2) the first two components explained approximately 75% of the total variation in the dependence structure of body measurements. Brown et al. (1973a) limited their analysis to these two components for similar reasons. The first component (size) accounted for 50 to 60% of the total variation in body measurements and the second component (shape) accounted for an additional 15 to 25% of the total variation.

For each animal two index values (size and shape) were calculated using the coefficient for the respective component. This involved multiplying each factor coefficient by the respective individual standard deviate of that variable and summing the products across variables on a within animal basis.

Analysis of variance was done to assess the effects of the independent variables (shipment, farm of origin, and preconditioning treatment) on the dependent variables (rumen characteristics at various points and their changes during marketing and transporting). Size and shape indices and their squares and cubes were included as covariates to access their relationship to the dependent variables.

CHAPTER IV

RELATIONSHIP OF FEEDER CALF SIZE AND SHAPE TO RUMEN CHARACTERISTICS

A. SUMMARY

Thirty days before they were marketed, 54 feeder-calves were measured and sampled at the farms of two cooperating feed-calf producers during each fall marketing season (1976 and 1977). Body measurements were weight (WT), height (HT), length (LEN), depth (DP), width (WD), and fat thickness over the 12th rib (BF). Rumen samples were taken by the tube method, and volatile fatty acids (VFA), protozoal concentrations, and pH were determined. Rumen liquid volume and in vitro gas producing potential of the fluid were estimated. Principal component indices describing general calf size (SIZE) and calf shape (SHAPE) were calculated. Rumen volume was coorelated with WT (P<.001), WD (P<.05), HT (P<.01), DP (P<.01), and SIZE (P<.05). Acetate was related (P<.01) to WT, BF, and the WT x BF interaction. Depth and HT were the only measurement variable that explained a large portion of the variation in protozoal concentrations. Acetate and total VFA increased linearly (P<.10) as SIZE increased. Similar trends were observed in the relationship of Spriotricha and total protozoal concentrations with SHAPE. In general, VFA concentrations were related to SIZE and protozoal concentrations were related to SHAPE.

B. INTRODUCTION

Most Southeastern feeder calves are weaned and immediately subjected to the crowding, starvation, and dehydration associated with marketing and transporting (MacLean, 1972; Billingsley et al. 1981a; Camp et al. 1981). The calves arrive in a frightened, fatigued, and often morbid condition (Greathouse et al., 1973; Norman, 1974; Billingsley et al. 1981a). Recovery of weight loss requires two weeks or more after feedlot arrival (Pierson, 1968; Self and Gay, 1972; Greathouse et al. 1973). Nutritional stress is particularly evident since intermittent periods of starvation during marketing and transporting result in conditions which are favorable to the major factors influencing rumen dysfuction discussed by Quin (1943), Meiske et al. (1958), Warner (1962), and Su (1980).

Eller (1972), Brown et al. (1973a), and McCurley and McLaren (1981) studied the relationship of calf size and shape to growth and performance. Self (1969) and Norman (1974) related body weight to morbidity and mortality and Billingsley et al. (1981a) reported that size and shape was related to the incidence of sickness in feeder calves. In addition, Self (1969) suggested that heavier calves tended to be fatter and tended to shrink less.

Since calf size and shape influenced the response to market-transit stressors, it is possible that the results with respect to these relationships could have been indirect and due to differential preshipment rumen functions associated with calves of different sizes and shapes. If rumen functions of small, young feed calves have not fully developed or if rumen dysfunction exist in older, larger calves, then a differential response to market-transit stresses could result.

The objective of this study was to determine the relationship of body measurements and size and(or) shape indexes to rumen parameters in non-weaned feed calves.

C. EXPERIMENTAL PROCEDURE

Fifty-four Angus and Hereford feeder steer calves weighing 163 to 250 kg were measured and sampled at the farms of two cooperating feeder-calf producers during two fall marketing seasons (1977 and 1978). This sample appeared to be representative of southeastern feeder calves based on similarity of this body weight distribution and the weight distribution of calves sold in southeastern feeder-calf sales, and visual evaluation by feeder-calf producers and orderbuyers. Also, feeder-calf quality grades assigned calves in this study by official Tennessee Department of Agriculture graders were similar to those assigned calves at Tennessee and Kentucky Feeder Calf Sales (Billingsley et al., 1981b).

Thirty days before marketing, the calves at each farm were gathered, separated from their dams, weighed and measured, and rumen samples collected. Fat thickness over the loin between the 12th and 13th rib was estimated. The body measurements taken with either steel graduated calipers or a steel tape, were: 1) body length from the anterior[1] end of the first thoracic vertebra to the posterior prominence

[1]Bronson Sonaray, Model 12.

of the pin bone (LEN), 2) height at the withers (HT), 3) width at the points of the shoulders (WD), and 4) depth of body at the forechest (DP).

Rumen parameters. Prior to measuring and sampling, the calves at both farms were pastured with their dams on combinations of tall fescue (*Festuca arundinacea* Schreb.), ladino clover (*Trifolium repens* L.), and lespedeza (*Lespedeza stipulacea*). Samples of rumen fluid were taken by orally inserting a stainless steel strainer attached to tygon tubing into the reticulo-rumen of the intact steers. Suction was applied with a 60 ml syringe. Approximately 60 ml of rumen fluid was drawn and discarded before collecting 120 ml for experimental use. Samples that were thick and serous were considered contaminated with 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.

Duplicate determinations of in vitro gas producing potential of the rumen fluid (GPP) were made immediately after collection. A modification (El-Din and El-Shazly, 1969) of methods described by Hungate et al. (1955), which included a 50% concentrate feedlot receiving diet as the substrate, was used. The remaining fluid was frozen for volatile fatty acid (VFA) analyses[2] or diluted with formaldehyde for differential protozoal counts (Purser and Moir, 1959).

[2]Bendix gas chromatograph 2600.

Rumen fluid liquid volume of each calf was estimated using polyethylene glycol (Hyden, 1955) as a marker.

Statistical analyses. Preliminary analyses of variance were conducted to determine the effect of the independent variables (year, farm of origin (FO) and their interaction) on rumen characteristics (volatile fatty acids, pH, protozoal concentrations, and GPP). In general, significant effects of year and FO on most rumen parameters were observed. In evaluation of certain characteristics, significant year x FO interactions were observed. However, due to difference in year and FO means, all subsequent analyses were done on a within FO-year basis.

Body measurement. In order to evaluate the relationship of weight (WT), individual body measurement, and backfat thickness (BF) to the rumen characteristics, these measurements and their squares and cubes were sequentially added as terms to a model containing year and FO. Terms which were not significant were deleted from the model and appropriate models were used to generate intercepts and partial regression coefficients.

Simple indexes. Simple indexes describing calf size and shape were developed as linear combinations of weight, body measurements and fat thickness. The simple indexes were: 1) weight/height ratio (WHR) = WT ÷ HT, 2) body volume (BVOL) = LEN x DP x WD and, 3) body density (DENS) = WT ÷ BVOL. Evaluation of the relationship of these simple indexes to rumen parameters was made in a similar manner to those used to evaluate the effects of individual body measurements. In this case, the value, square, and cube of each of the indexes were sequentially added to the model containing year and farm of origin, and nonsignificant terms were deleted from the final model. When significant effects of a simple index were found, predicted values for each dependent variable were calculated across the range of the independent index.

Principal component indexes. A multrivariate procedure, principal-component analysis, was used to generate orthogonal indices which describe general calf size and shape. Brown et al. (1973a), McCurley and McLaren (1981) and Billingsley et al. (1981a) used this procedure to evaluate the effect of calf size and shape on growth parameters, market-transit shrink, incidence of respiratory disease, and feedlot adaptation time in stressed feeder calves. In this study, size and shape index values were calculated as the sum of the products of individual principal-component loading values (Table 2) and standard deviates of the respective measurements of each calf. The effect of the size and shape indexes on the rumen parameters were evaluated in a manner similar to that used with the individual measurement and for the simple indexes.

D. RESULTS AND DISCUSSION

Description of calves. Mean of weights and body measurements (Table 3) were similar to those reported by Billingsley et al. (1981a) for 6- to 10-month-old calves just prior to weaning.

Acetic acid constituted 67.6% of the total rumen VFA concentration. The remaining VFA concentration was 17.2% propionic, 10.0% butyric, and 5.1% higher VFA. The acetate concentration was similar to the 63% reported by Pfander and Phillipson (1953) for cattle in the steady rumen state. However, the concentrations of propionate and butyrate were lower

TABLE 2. SCORE COEFFICIENTS OF PRINCIPAL COMPONENTS OBTAINED FROM BODY MEASUREMENTS OF STEERS

Measurement	Coefficients for principal component number 1	2	Principal Component	Description of steers with large positive indexes
---Steers evaluated in 1977---				
Weight	.24803	-.16317	1	Large-framed and heavy
Height	.22072	.39084		
Length	.23100	.18122		
Depth	.21293	.24641	2	Tall,thin, and narrow
Width	.20889	-.25681		
Fat	.11441	-.75589		
---Steers evaluated in 1978---				
Weight	.23837	-.17057		
Height	.22060	.34043	1	Large-framed and heavy
Length	.22557	.32897		
Depth	.23815	.25533		
Width	.14323	-.64817	2	Tall, thin and narrow
Fat	.19218	-.39863		

TABLE 3. UNADJUSTED MEANS OF WEIGHT, BODY MEASUREMENTS, FAT THICKNESS, RUMEN CHARACTERISTICS

Item	Mean	SE
Body measurements		
Weight, kg	215.0	2.93
Height, cm	95.6	.38
Length, cm	100.8	.47
Depth, cm	48.9	.31
Width, cm	33.5	.22
Fat, cm	1.6	.08
Rumen parameters		
Volatile fatty acids, mmol/l		
Acetic acid	33.0	1.02
Propionic acid	8.4	.32
Butyric acid	4.9	.20
Higher VFA	2.5	.08
Total VFA	48.8	1.47
Acetic to propionic acid ratio[a]	4.4	.10
Protozoal concentration/ml rumen fluid ($\times 10^5$)		
Spirotrichs	3.8	.30
Holotrichs	.1	.03
Total	3.9	.30
Total rumen protozoal populations[a] ($\times 10^9$)		
Spirotrichs	10.7	.98
Holotrichs	.4	.95
Total	11.1	1.38
Other parameters		
pH	7.0	.02
Gas producing potential, cm^3	6.7	.26
Rumen liquid volume, l	25.4	.68

[a]Calculation of ratios and products were made on an individual animal basis and the means reported are overall means of the individual values and, hence, are not equal to the ratio of the means of the individual parameters.

and that of the higher VFA was greater than values they reported. The mean of individual acetate to propionate ratios (A/P) was 4.4. Protozoal concentration (TPROT) was $3.9 \times 10^5 \pm 3.0 \times 10^4$ per ml of fluid, and this concentration was composed of 96.3% spirotrichs (SPIRO) and 3.7% holotrichs (HO). The mean individual total rumen protozoa populations (TTP) were $1.1 \times 10^{10} \pm 1.4 \times 10^9$ per ml. These concentrations were similar to those reported by Orr (1979). Mean values for rumen fluid pH, GPP, and rumen liquid volume (V) were 7.0 ± .02, 6.7 ± .26 cm^3, and 25.4 ± .68 l, respectively. These results are in agreement with rumen pH values reported by Phillipson (1955), gas producing potentials reported by Orr (1979) and Su (1980), and rumen volume of a larger group of calves reported by Su (1980).

<u>Correlation of body measurements and rumen parameters</u>. In order to evaluate the association of body measurements and rumen parameters, simple and residual correlations were calculated. Residual correlations were calculated from residual sums of squares and products resulting from a model containing terms for year, farm, and year x farm interaction. Coefficients of both simple and residual correlation (Table 4) among body measurements were all significant ($P<.10$). In general, coefficients of residual correlation were higher than coefficients of simple correlation.

Rumen liquid volume was correlated with WT ($P<.001$), WD ($P<.05$), HT ($P<.01$), DP ($P<.01$), the general size index ($P<.05$), and WHR ($P<.01$). Acetate (A), propionate (P), butyrate (B), and total VFA (TVFA) concentrations were correlated ($P<.05$) and the coefficients of correlations

TABLE 4. COEFFICIENTS OF CORRELATION AMONG BODY MEASUREMENTS AND INDEXES[a,b]

	Variables											
	Weight	Length	Height	Depth	Width	Fat	Size	Shape	WHR[c]	BVOL[c]	DENS[c]	Rumen Volume
Weight	--	.710	.657	.657	.690	.578	.895	.012	.964	.855	.149	.301
Length	.751	--	.738	.721	.430	.325	.843	.059	.583	.843	-.347	.152
Height	.705	.722	--	.735	.401	.241	.812	-.023	.436	.749	-.245	.101
Depth	.758	.718	.736	--	.323	.369	.842	.017	.528	.824	-.417	.119
Width	.674	.494	.468	.441	--	.472	.641	-.205	.685	.759	-.210	.207
Fat	.541	.341	.246	.436	.423	--	.569	.150	.608	.500	.073	.080
Size	.927	.267	.245	.320	.192	.247	--	0	.785	.953	-.223	.232
Shape	-.087	.858	.833	.869	.702	.583	-.074	--	.030	-.065	.152	-.144
WHR	.965	.657	.496	.658	.654	.573	.829	.053	--	.761	.263	.321
BVOL	.875	.871	.757	.860	.792	.491	.966	-.111	.793	--	-.376	.204
DENS	.043	-.354	-.249	-.387	-.379	-.017	-.276	-.071	.144	-.437	--	.136
Rumen Volume	.389	.303	.289	.263	.177	.100	.329	.041	.371	.288	.119	--

[a]Coefficients of correlation greater than .254 are significant (P<.01) and values greater than .194 are significant (P<.05).

[b]Values above the diagonal are coefficients of simple correlations. Those below the diagonal are coefficients of residual correlation calculated from residual sums of squares and products from models including shipment, farm of origin, and shipment x farm interaction.

[c]WHR = weight/ height ratio, BVOL = Body volume, DENS = density.

of these acid concentrations with A/P (Table 5) were negative and significant. Rumen pH was negatively correlated (P .01) with VFA concentrations, and was not related ($P<.10$) to either protozoal concentrations of rumen volume within the pH range observed in this study. Spirotricha and total protozoa concentrations were associated with P ($P<.001$), B ($P<.01$) and TVFA ($P<.01$) concentrations. The size and shape indexes were not correlated ($r \approx 0$), but the size index, WHR, and BVOL were positively correlated with each other and with most measurement variables.

Coefficients of correlation of body measurements and indexes reflecting general size (SIZE) and general shape (SHAPE) with rumen characteristics are presented in Table 6. Propionic acid was the only individual VFA significantly correlated with individual body measurements or the indexes. It was associated only with WT ($P<.05$), DP ($P<.01$), BF ($P<.05$), SIZE ($P<.05$), WHR ($P<.05$) and RV ($P<.10$). Total VFA concentration was correlated with WHR ($P<.05$). Coefficients of correlation of A/P with body measurements and indexes were small ($P>.1$) and negative. The associations of total rumen protozoal concentration and spirotricha concentration, which comprised 97.3% of the total, with body measurements and indexes were similar. They were correlated with WT ($P<.01$) and DP ($P<.05$). Total rumen protozoa populations and total rumen spirotricha (TRS) populations (total number in the entire rumen) were correlated ($P<.01$) with WT. LEN, DP, SIZE, WHR, BVOL and RV. Rumen volume was correlated ($P<.001$) with WT, LEN, SIZE, and WHR. Also, HT was correlated ($P<.01$) with RV.

TABLE 5. COEFFICIENTS OF CORRELATION AMONG RUMEN CHARACTERISTICS[a,b]

	Rumen Characteristics										
					Acetic/ Propionic	Protozoa			Gas Pro-		Rumen
	Acetic (A)	Propionic (P)	Butyric (B)	Total (TVFA)	Ratio (A/P)	Spirotricha (SPIRO)	Holotricha (HO)	Total (TPROT)	duction (GPP)	pH	Volume (V)
A	--	.732	.781	.971	-.252	.173	-.019	.173	.131	-.427	.091
P	.719	--	.639	.848	-.745	.394	-.131	.387	.332	-.470	.239
B	.786	.630	--	.856	-.238	.234	.051	.240	.205	-.562	-.010
TVFA	.974	.838	.846	--	-.405	.265	-.040	.264	.218	-.505	.111
A/P	-.228	-.724	-.259	-.384	--	-.373	.218	-.360	-.404	.222	-.219
SPIRO	.115	.227	.239	.178	-.113	--	-.149	.998	.546	-.164	.314
HO	-.046	-.111	-.033	-.069	.137	-.015	--	-.078	-.102	.037	.025
TPROT	.111	.217	.235	.172	-.101	.996	.071	--	.543	-.163	.319
GPP	.123	.192	.345	.299	-.178	.296	.037	.299	--	-.004	.270
pH	-.285	-.347	-.199	-.305	.176	.004	.129	.016	.072	--	-.040
V	.137	.194	.123	.152	-.060	.139	.141	.151	-.066	-.227	--

[a]Coefficients of correlation greater than .254 are significant (P<.01) and values greater than .194 are significant (P<.05).

[b]Values above the diagonal are coefficients of simple correlations. Those below the diagonal are coefficients of partial correlation calculated from the residual sums of squares and products from the model including shipment, farm of origin, and shipment x farm interaction.

TABLE 6. COEFFICIENTS OF RESIDUAL CORRELATION OF BODY MEASUREMENTS AND INDEXES WITH RUMEN CHARACTERISTICS[a,b].

Body Measurements and Indexes[c]	Rumen Characteristics[c]																	
	VFA, mmol/l				A/P	VFA, Moles/100 Moles			Protozoa/ml			Total Protozoa in rumen					Rumen Volume	GPP Total Rumen
	A	P	B	TVFA	Ratio	A	P	B	SPIRO	HO	TPROT	SPIRO	HO	TTP	GPP	pH	(V)	TRGPP
Weight	.141	.287	.154	.189	-.149	-.168	.210	.077	.252	.110	.261	.374	.112	.382	.125	-.037	.389	.371
Length	.061	.117	.063	.078	-.052	-.046	.076	.038	.187	.078	.194	.260	.096	.267	.077	-.069	.303	.256
Height	.006	.108	.029	.029	-.061	-.133	.088	.089	.173	.089	.180	.238	.092	.245	.083	-.103	.290	.246
Depth	-.004	.175	.055	.050	-.093	-.161	.158	.067	.222	.012	.222	.320	.008	.320	-.033	-.151	.263	.187
Width	.067	.112	.088	.084	-.071	-.099	.089	.148	.115	.170	.130	.180	.153	.192	.144	.095	.177	.244
Fat	.085	.212	.117	.128	-.118	-.163	.176	.088	.175	.087	.181	.246	.058	.246	.052	.093	.100	.146
Size	.071	.215	.107	.117	-.119	-.166	.171	.101	.237	.112	.246	.340	.109	.348	.101	-.056	.329	.309
Shape	-.051	-.011	-.081	.044	-.059	.011	.007	-.136	.024	-.034	.021	.028	.005	.029	-.130	-.163	.041	-.084
WHR	.169	.306	.174	.215	-.158	-.157	.223	.063	-.243	.103	.251	.367	.104	.375	.119	-.011	.371	.360
BVOL	.051	.171	.090	.089	-.095	-.138	.139	.109	.224	.104	.233	.317	.100	.325	.102	-.049	.288	.285
DENS	.108	.139	.073	.119	-.082	-.039	.099	-.082	.016	-.008	.016	.038	.001	.038	.060	.022	.119	.128
Rumen Volume	.137	.194	.123	.152	-.060	-.012	.136	-.020	.139	.141	.151	.358	.239	.377	-.066	-.277	1.000	.482

[a]Coefficients of correlations greater than .254 are significant (P<.01) and values greater than .194 are significant (P<.05).

[b]Coefficients of residual correlation calculated from residual sum of squares and cross products from models containing shipment, farm and shipment x farm interaction.

[c]Abbreviations are given in Table 3 and 4.

Relationship of body measurements and rumen parameters. In order to further evaluate the relationship of body measurements and rumen characteristics, a preliminary statistical model containing year, FO, and the linear, quadratic, and cubic terms for all measurement variables (WT, LEN, HT, DP, WD, and BF) was fitted for each rumen characteristic. In general, the increase in the coefficient of determination (R^2) due to adding the cubic terms to the model was small ($P>.05$) and, in the final analysis, all terms which were not significant were deleted in subsequent analyses and an interaction between significant covariates was added.

Both the linear and quadratic term of WT and the linear term of BF explained a significant portion ($P<.01$) of the variation in A and the WT x BF interaction effect was significant also. In calves with smaller BF (0 to 3 mm) A increased as WT increased (Figure 1). Similar but less pronounced trends were observed in calves with 3 to 4.5 mm of BF. In calves with more than 4.5 mm of BF, A was higher in the heavier (>300 kg) and lighter (<240 kg) calves than in calves with weights between 240 and 300 kg.

Inverse trends were observed with respect to the effect of WT and BF in explaining variation in B, and WT was the only body measurement that explained a large ($P<.001$) portion of the variation in P. The linear and quadratic terms of WT ($P<.05$), the linear term of BF and the WT x BF interaction explained a large fraction ($P<.01$) of the variation in higher VFA concentration (HVFA). Trends observed with respect to the association of HVFA with WT and BF were similar to, but less pronounced, than those observed with respect to A. As

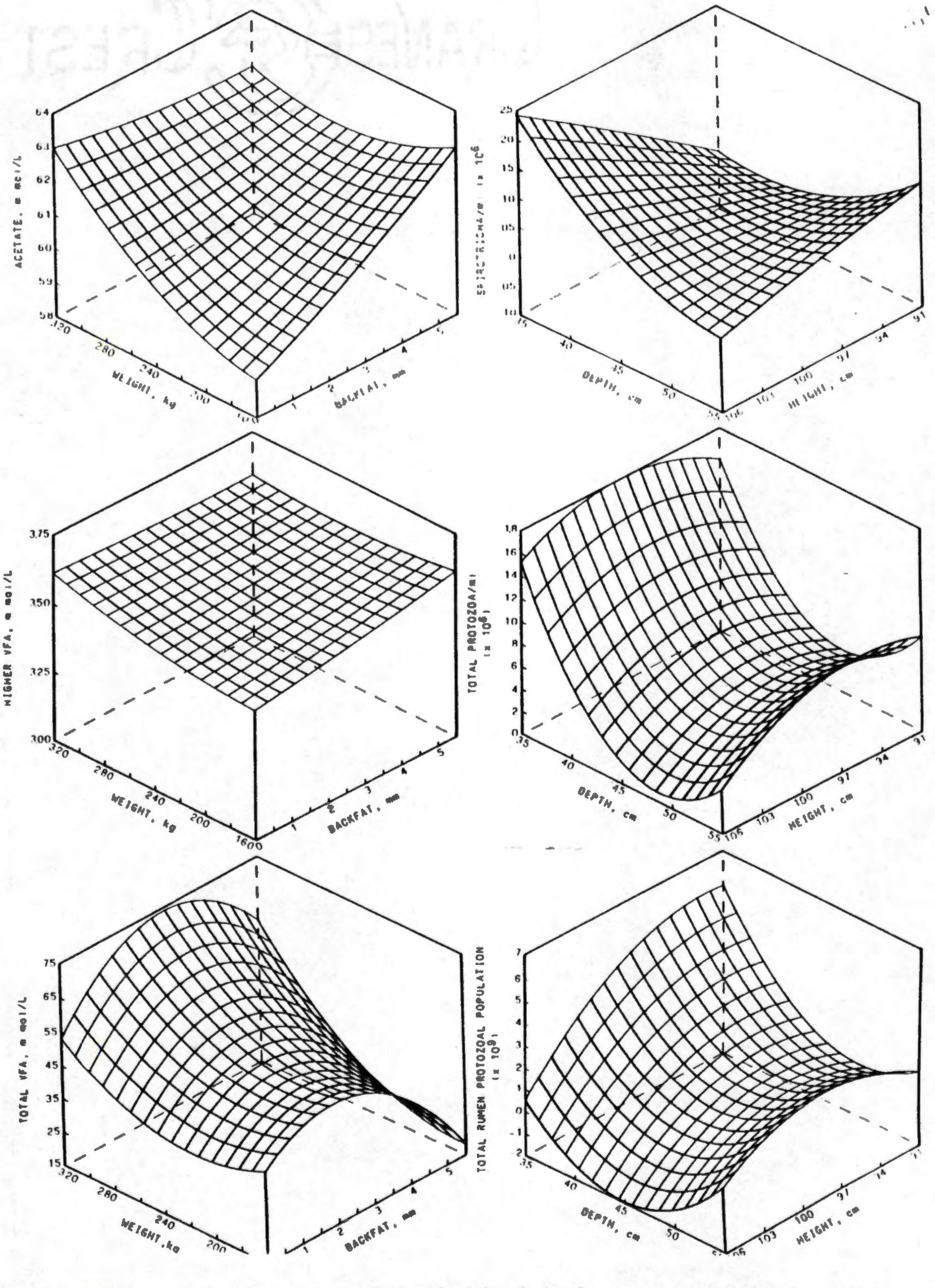

FIGURE 1. Relationship of individual body measurements to rumen parameters.

backfat increased in light weight calves, HVFA increased; but this trend was not observed in heavy (>280 kg) calves. Concentration of TVFA in the rumen was associated ($P<.10$) with WT and BF and the WT x BF interaction (Figure 1). The TVFA concentration increased as WT increased, but the increase in TVFA, associated with increasing WT, was more rapid in fat calves (4 to 5 mm) than in less fat calves (0 to 2 mm). The highest TVFA were observed in heavy calves with intermediate BF.

Depth and HT were the only measurement variables that explained a large ($P<.01$) portion of the variation in protozoal concentrations. Spirotricha concentration decreased as DP increased in calves with less HT (91 to 94 cm), but SPIRO decreased as DP increased in taller (HT>95 cm) calves. Rumen protozoal concentration decreased as DP increased, and similar trends were observed with respect to the relationship of DP and HT to TTP.

The observed relationship of VFA concentration to BF in lighter calves and the absence of such an association in other calves may be due to calf age. It has been established that calf age and WT are significantly and positively correlated. It is possible that some of the lighter calves were young and that, hence, a significant amount of their diet was milk. Some of the heavier calves may have been partially weaned by their dam and their diet was probably largely roughage.

Relationship of simple indexes and rumen parameters. The relationship of GPP to WHR (Figure 2) was curvilinear ($P<.05$). Gas producing potential decreased as WHR increased from 1.6 to 2. As WHR increased from 2 to 3.2, the increase in GPP was more rapid than in the lower

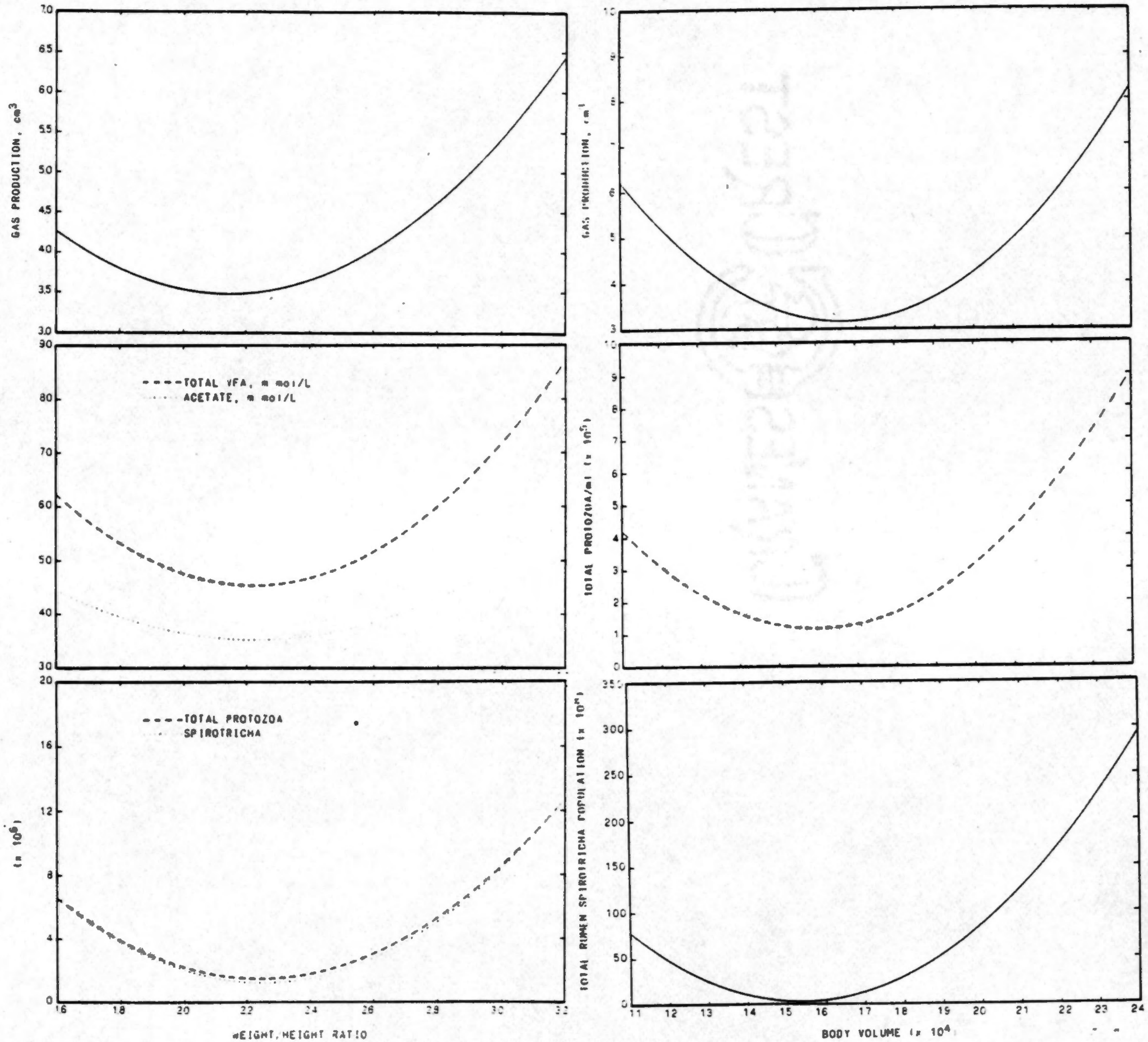

FIGURE 2. Relationship of simple indexes to rumen parameters.

segment of the WHR range. Rumen acetate, TVFA, TPROT, and SPIRO Figure 2 b,c) responses to changes in WHR also were curvilinear and similar to those observed with respect to GPP. Changes in WHR were not associated (P>.10) with changes in V, B, A/P, rumen pH and HO.

The relationship of SPIRO, GPP, HVFA, TPROT and TRS to BVOL (Figure 2) were curvilinear (P<.01). BVOL was not related (P>.10) to A, B, P, TVFA or HO or to A/P, pH, and V.

Relationship of orthogonal size and shape indexes to rumen parameters. The advantage of the principal-component procedure is that the independent, separate effect of all body measurements on rumen characteristics are considered simultaneously rather than separately after the effects of the other independent variables were held constant. The latter was the case in the previous discussion in which within-farm-year multiple-regression was examined. In this study, only the first two principal components (size and shape) were included in regression analysis because other components had little biological meaning and because the first two components explained 78 to 82% of the total variation in the dependence structure of the six measurement parameters (WT, LEN, HT, DP, WD, BF). Eller (1972) and Brown et al. (1973a) suggested these same two reasons for using only these two components to classify animals according to body size and shape. Definition of the two principal components in this study was similar to those reported by Brown et al. (1973a), Eller (1972), and McCurley and McLaren (1981). Calves with smaller size index values (SIZE) were described as small-framed, light weight animals and those with larger SIZE values were described as large-framed, heavy weight calves (Table 2, page 23). Calves with low shape index values (SHAPE) were described as short-bodied, with relatively low wither height values, and with a large amount of fat cover over the 12th rib. Calves with high SHAPE values were described as tall-framed, thin calves with relatively narrow bodies. It should be noted that this interpretation of the shape index results in the two extremes in calf shape being located at the upper and lower limits of the scale. Calves that are most desirable to feeder-calf purchasers, feedlot operators, and feeder calf graders tend to be intermediate with respect to SHAPE.

SIZE. In small-framed, light weight calves, GPP tended to decrease as SIZE increased, but GPP tended to increase in large-framed, heavy calves. However, this curvilinear relationship between calf SIZE and GPP was not significant. Changes in rumen pH were not related ($P<.10$) as SIZE increased from small to intermediate but decreased with further increases in SIZE (Figure 1a, page 31). No biological explanation for this relationship is obvious.

Acetate and TVFA (Figure 3) increased linearly ($P<.10$) as SIZE increased. Similar trends were observed with P, B, and the HVFA; however, these trends were not statistically significant. These results support the conclusion that the relationship between individual body measurement and simple indexes involving linear combinations are, in general, not correlated ($P<.10$) with rumen VFA concentrations. However, since V was highly correlated with WT, LEN, DP, SIZE, WHR and BVOL, it follows that the total VFA in the entire rumen is associated with measures of overall

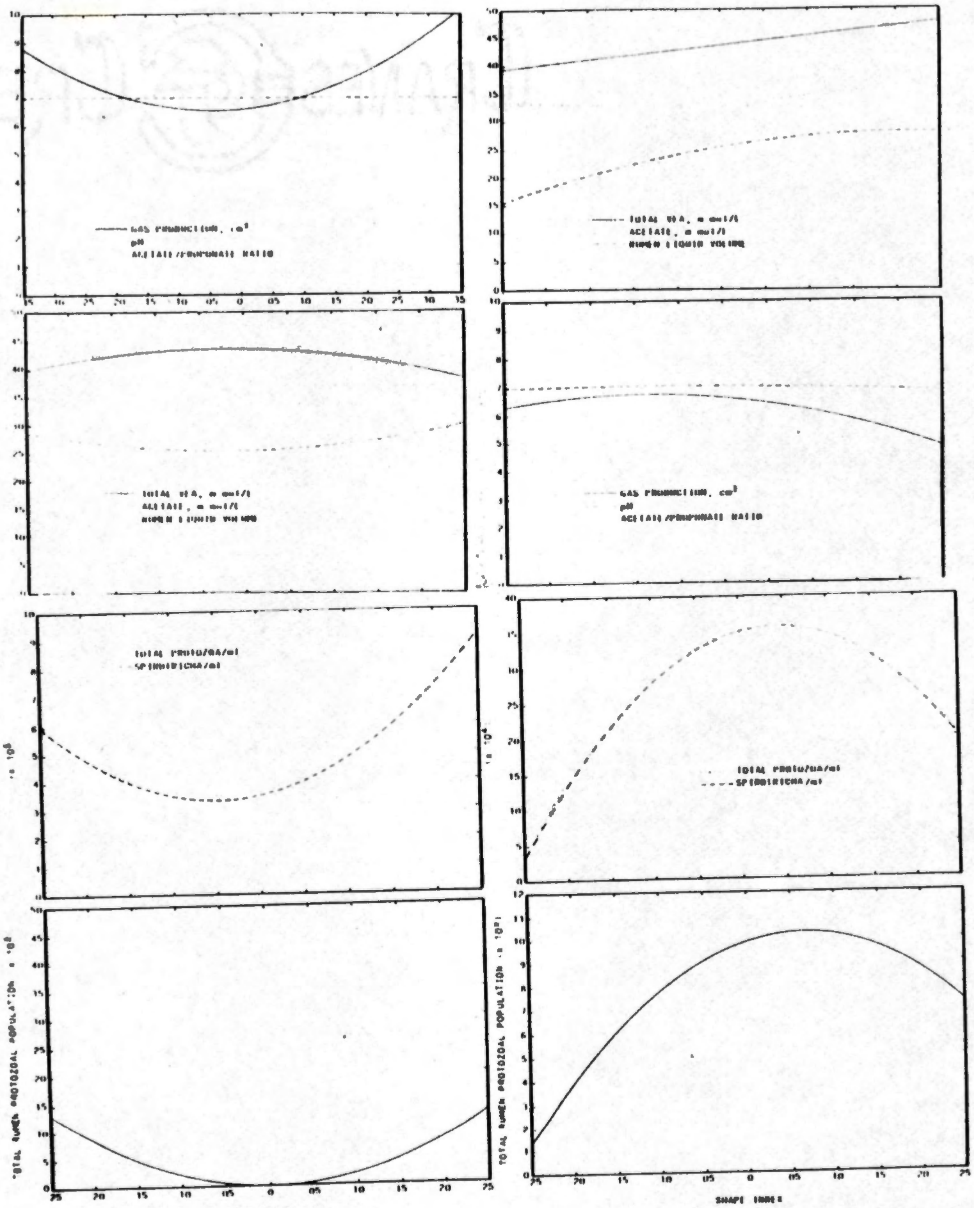

FIGURE 3. Relationship of size and shape indexes to rumen function.

body size. This could be one reason larger calves are more resistant to market-transit stressors than are small calves.

The curvilinear relationships of TPROT and SPIRO with calf size is shown in Figure 3. In small-framed, light calves which are associated with lower SIZE values, predicted TPROT concentration approached 750,000/ml but it decreased ($P<.10$) as SIZE increased from the low to intermediate values. In contrast, increases in SIZE above the mean value were accomplanied by increases ($P<.10$) in TPROT concentration. Since spirotricha comprised 96.3% of TPROT, it is logical that changes in SPIRO associated with changes in SIZE paralleled those observed for TPROT. The relationship of TTP to SIZE followed trends similar to those observed in the relationship of TPROT to SIZE, but the decrease in TTP was slower as SIZE increased from the lower to mean values and the increase in TPP as SIZE increased above the mean value was more rapid.

<u>SHAPE</u>. Calf SHAPE was not related ($P>.10$) to rumen pH values. Rumen GPP was lower ($P<.10$) in short, fat, deep-bodied calves (SHAPE -2) and in long, thin, narrow calves (SHAPE > 2) than in calves with intermediate SHAPE values (choice and prime feeder calves).

The A/P value increased as SHAPE increased from low (short, fat, deep-bodied calves) to intermediate (most desirable, calves with higher feeder-calf grades) values. The A/P value decreased, as SHAPE increased from intermediate to higher values (long, thin, narrow calves). This relationship between SHAPE and A/P may be due to differences in physiological maturity of calves with low and intermediate SHAPE or to differences in overall physiological condition and general health in calves with intermediate and high SHAPE values. Calves with extremely high SHAPE values were probably calves with subclinical disease or calves that were thin because of low nutrient intake or low metabolic efficiency.

The relationships of A and TVFA to SHAPE were curvilinear ($P<.10$), with HVFA values associated with more desirable confirmation and intermediate SHAPE values (Figure 3, page 36). The relationship of V to SHAPE only tended ($P>.10$) to be curvilinear with the lower rumen volume associated with intermediate SHAPE values.

Similar trends were observed in the relationships of SPIRO, TPROT, and TTP with SHAPE. Rumen protozoal concentrations were lower ($P<.05$) in short, fat, thick calves and in long, thin, narrow calves than in calves with intermediate SHAPE. In contrast, the relationships of TPROT, SPIRO, and TTP to SHAPE were just the opposite to their relationships to SIZE. In calves with extremely low SHAPE values (<-1.0), protozoal concentrations were low. They increased as SHAPE increased (-2.5 to 0) to intermediate values (-2.5 to 0) and decreased with further increased in SHAPE values (0 to 2.5). This curvilinear relationship of SHAPE to protozoal concentrations was probably due to effects of physiological maturity, health status, and nutrition status of the calves on SHAPE.

CHAPTER V

FEEDER CALF SIZE AND SHAPE AND RUMEN CHARACTERISTICS CHANGES DURING MARKETING

A. SUMMARY

Feeder calves (360) subjected to one of three market-management systems were used to evaluate the relationship of calf size and shape to change in rumen characteristics resulting from the stresses of marketing. The management systems included: 1) weaning and feeding a concentrate diet during the last 30 days before marketing and feeding hay at the orderbuyer barn (PW), 2) allowing the calves to graze pasture with their dams during this period and feeding hay (NI) or a 50% concentrate diet at the orderbuyer barn (HE).

In general, calf size was related to changes in the total rumen protozoal concentration and to changes in protozoa subclass and general populations. Calf shape was generally related to changes in volatile fatty acid concentration. The changes in volatile fatty acid concentration were generally the smallest in PW calves and the relationship of these changes to shape was greatest in HE calves. The relationships of protozoal changes to calf shape was more varied among the three groups (NI, HE and PW calves) and were more difficult to explain than the relationship with size. Significant relationships of calf size and shape to change in rumen characteristics during market were observed and this relationship was affected by the market-management or preconditioning system to which the calves were subjected.

B. INTRODUCTION

Stress, a major contributing factor in the shipping fever complex during relocation of feeder calves was studied by King et al. (1958), Sinka et al. (1962), Church (1967), Self (1969), McLean (1972), Billingsley et al. (1981a), Camp et al. (1982). During the marketing phase of the feeder calf industry, calves are subjected to a multitude of environmental, nutritional and managerial stressors. Billingsley (1980) reported calf size and shape was related to the incidence and severity of shipping fever in transported calves. In Chapter IV, the significant relationships between individual body measurements and individual rumen characteristics in unweaned, 8- to 10-month-old feeder calves, were discussed. In addition, functional relationships between generalized size and(or) shape indexes and rumen characteristics were established. In calves exhibiting the extreme shape index values, (e.i. short, fat, thick calves with large negative values and long, thin, narrow calves with large positive values), rumen protozoal and volatile fatty acid concentrations were lower than in calves with intermediate shape indexes. In general rumen protozoal concentrations were related to size and volatile fatty acid concentrations were related to calf shape.

Very little work had been reported concerning the relationship of calf size and(or) shape to rumen characteristics in stressed feeder calves. Knowledge of the effects of size and shape on changes in rumen characteristics during market-transit stress and the effect of various market management systems on this relationship would be valuable in establishing more desirable marketing systems. Therefore, the objective of this study was to evaluate the influences of shipment, preconditioning, farm of origin and calf size and shape on rumen characteristics and their changes in market-transit stressed feeder calves.

C. EXPERIMENTAL PROCEDURES

Weanling feeder steers weighing 137 to 296 kg were randomly selected from seven shipments (groups) of feeder calves purchased from several Tennessee and Kentucky feeder calf producers for a large cooperative shipping fever study. The purpose of this study was to evaluate the relationship of size and shape to changes in rumen characteristics during the marketing phase. A total of 360 calves were weighed, body measurements, rumen samples and rectal temperatures were taken at the farm of origin (FO) 30 days before being transported to an auction barn (AB). The body measurements were length (LEN), height (HT), depth (DP), width (WD) and backfat thickness (BF). The methods used to determine the measurements were described in Chapter IV. At the time of selection, the calves were randomly assigned to preconditioning treatment groups on a farm within shipment basis. These groups consisted of: 1) calves allowed to graze pasture with their dams, without supplemental feed during the last 30 days at FO and during the orderbuyer barn (OBB) phase they had access to hay. The treatment was designed to simulate the normal-industry market-transit procedures (NI) observed in the southeastern feeder calf market systems (Billingsley, 1979; Damron

1980); 2) calves managed identically to the NI calves during the last 30 days at the FO, but fed a high-energy, high antibiotic (55%) concentrate diet during the OBB phase (HE); and 3) calves weaned and fed a concentrate (65%) diet at FO for 30 days prior to marketing (PW). These PW calves were fed hay during the OBB phase. All calves were transported from the OBB phase to either feedlots at the Highland Rim Experimental Station, Springfield, Tennessee or Southwest Great Plains Research Center, Bushland, Texas or to wheat pastures at the Southeastern Livestock and Forage Research Station, El Reno, Oklahoma.

Data Collected

In addition to the body measurements obtained at the FO, the calves were weighed and sampled when they arrived at the auction barn (AAB), arrived at the orderbuyer barn (AOBB), and departed the orderbuyer barn (DOBB). Rumen characteristics and(or) determinations included rumen liquid volume (V), volatile fatty acids (VFA), differential protozoal counts, pH and gas producing potential (GPP) of the rumen fluid. Methods of sampling, sample preservation and laboratory procedures related to rumen characteristics are also discussed in Chapter IV. Orthogonal size and shape indices were generated from the body weight and measurements. A multivariate procedure, principal-component analysis (described in detail in Chapter IV) was used to generate the indices. Changes in rumen characteristics during market was calculated as the DOBB value for the respective traits minus the AAB value for that trait.

Statistical Analyses

The orthogonal indices were used to evaluate the relationship of feeder calf general size (SIZE) and body shape (SHAPE) to rumen characteristic changes during market-transit. Preliminary analyses of variance were performed to evaluate the effects of the independent variables (shipment, farm of origin, farm of origin within shipment, preconditioning, SIZE, SHAPE and the quadratic and cubic terms of SIZE and SHAPE) on the dependent variables (rumen characteristic changes during marketing). In the final analyses the term representing preconditioning treatments was deleted from the analysis and data of calves subjected to preconditioning were evaluated separately.

D. RESULTS AND DISCUSSION

The overall preliminary analyses and subsequent analyses on a within shipment basis indicated that there were only small differences among shipments with respect to changes in rumen characteristics during marketing but there were large differences in market rumen changes among calves subject to the different preconditioning treatments. Therefore, the final analyses were performed on a within treatment basis and only the results of the final analyses will be discussed.

Mean SIZE and SHAPE of calves subjected to the three preconditioning treatments were similar. In addition, the range of the SIZE and SHAPE values observed for the three PC group included similar index values (Table 7).

TABLE 7. MEAN BODY WEIGHT AND MEASUREMENTS OF THE CALVES[a]

Body Measurement	Preshipment Treatment			
	NI	HE	PW	SE
Weight, kg	206.4 (124.7-303.9)	196.3 (126-306)	198.8 (117.9-292.5)	1.97
Length, cm	98.0 (79.8-113)[b]	95.6 (71.1-113)	97.4 (86.9-112)	.37
Height, cm	94.0 (53.5-109)	92.8 (79 -108)	93.3 (87 -100)	.28
Depth, cm	48.2 (37.6- 58.0)	47.5 (38.7- 55)	48.4 (40 - 57)	.19
Width, cm	32.9 (24.0- 39)	31.9 (25.8- 40)	32.2 (26.9- 38)	.15
Fat, mm	1.64(0 - 3)	1.37(0 - 4)	1.10(0 - 3)	.05
Size index	.07(-2.0- 3)	-.08(-2.3- 3)	-.1 (-1.8- 2)	.05
Shape index	-.01(-2.3- 3)	.02(2.4- 3)	-.1 (-2.1- 2)	.05

[a]Preshipment treatments are defined on page 39.

[b]Values in parentheses are the maximum and minimum values observed in each treatment group.

In all groups, calf size ranged from light, small-framed (SIZE = -2.0) to heavy, large-framed (SIZE = 3.0). Shape ranged from short, fat, wide calves (SHAPE = -2.3) to thin, narrow and long calves (SHAPE = 2.5). But, mean SIZE and SHAPE were similar across the preshipment treatments (Table 7).

At AAB, all rumen characteristics except the rumen subclass protozoa, Holotricha (HO), were higher in the PW calves than in the NI or HE calves. The HO concentration was highest in HE calves and lowest in PW calves (Table 8). This would be expected since the concentration of the protozoal subclass HO has been shown to be high in the rumen fluid of calves fed a forage diet than in fluid of calves fed concentrates. The NI and HE calves were with their dams on pasture until they left the farm. During marketing, there were significant changes in rumen characteristics. In general, the largest changes were observed in PW calves, but the greatest change in acetic acid, rumen liquid volume and HO was in HE calves (Table 9).

In the final analyses, a relationship between calf size and rumen concentration of the protozoal subclass HO was observed ($P<.05$) in NI and PW calves (Table 10). The change in HO in PW calves during the market phase ranged from 10,000/ml in light, small-framed animals to -5,000/ml in the intermediate size animal (Figure 4). Only slight changes were observed in heavy large framed animals. The PW calves had higher HO concentrations at AAB than the NI or HE calves. The relationship of HO change in the PW calves to SIZE was opposite of that relationship in NI and HE calves.

TABLE 8. MEAN VALUES OF RUMEN CHARACTERISTICS UPON ARRIVAL AT THE AUCTION BARN

	Preshipment Treatment[a]			
	NI	HE	PW	SE
Volatile fatty acid, um/ml				
Acetic acid	38.8[b]	43.0[b]	50.0[c]	2.0
Propionic acid	10.1[b]	8.0[b]	16.8[c]	1.1
Butyric acid	5.7[b]	6.1[b]	9.0[c]	.78
Higher acid	2.4[b]	2.3[b]	3.0[c]	.02
Total	57.0[b]	62.0[b]	78.6[c]	3.9
Acetic/propionic ratio	4.4[b]	4.9[b]	4.0[c]	.01
Gas producing potential, cc	7.4[b]	6.8[b]	9.4[c]	.26
Rumen liquid volume	29.5[b]	25.1[b]	28.5[c]	.65
Total rumen protozoa x 10[a]	8.1[b]	6.4	13.3[c]	.1
Rumen protozoa concentration x 105/ml				
Total	2.8[b]	2.7[b]	4.0[c]	.3
Spirotricha	2.5[b]	2.4[b]	3.9[c]	.4
Holotricha	.3[b]	.4[b]	.6[c]	.09

[a]Preshipment treatments are explained on page 39.

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

TABLE 9. MEAN CHANGE IN RUMEN CHARACTERISTICS DURING MARKET[a]

	Preshipment Treatments[b]			
	NI	HE	PW	SE
Volatile fatty acids, um/ml				
Acetic acid	-10.21[c]	-.67[d]	-7.8[e]	4.7
Propionic acid	-2.19[c]	-1.64[d]	-6.2[e]	1.4
Butyric acid	1.06[c]	-3.71[d]	-3.6[d]	2.3
Higher acids	1.07[c]	.61[d]	-1.0[d]	.27
Total	-10.32[c]	-6.4[c]	-18.6[d]	4.2
Gas producting potential, cc	-3.60[c]	-2.01[d]	-5.0[c]	.84
Rumen liquid volume	2.5	-.66	1.7	1.33
Total rumen protozoa x 10^9/m	-6.0[c]	-1.90[c]	-12.00[e]	10.9
Rumen protozoal concentration, x 10^5/ml				
Total	-2.34[c]	.18[d]	-3.46[e]	1.48
Spirotricha	-2.04[c]	.52[d]	-3.41[e]	1.53
Holotricha	-.30[c]	-.31[c]	-.05[d]	.09

[a]Calculated as the difference between the value of a trait at arrival auction barn and departure orderbuyer barn.

[b]Preshipment treatments were described on page 39.

[c,d]Means in the same line superscripted with different letter are significantly different (P<.05).

[e]Mean of individual A/P ratios.

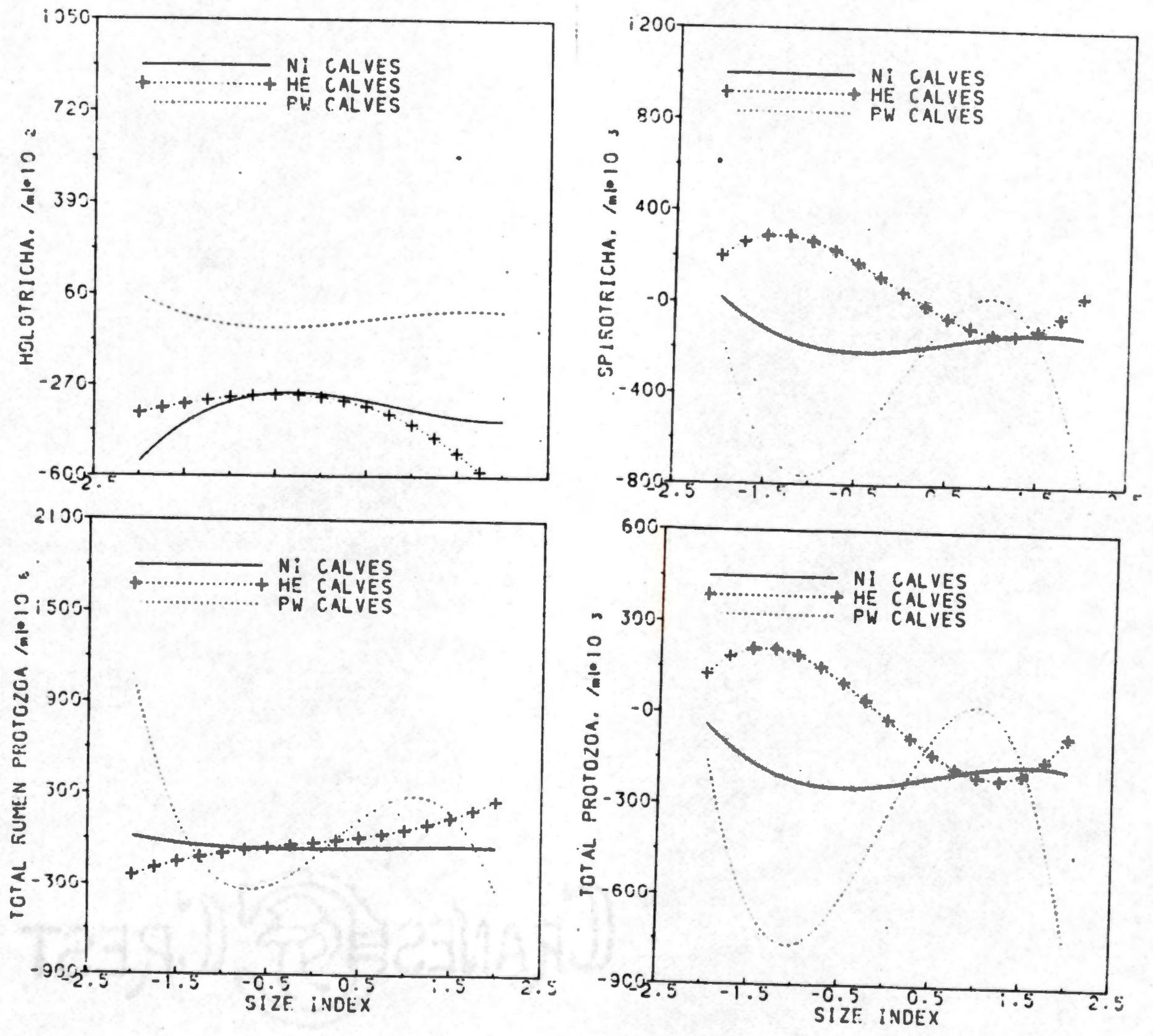

FIGURE 4. The relation of calf size to changes in rumen protozoa concentration during marketing.

As SIZE increased to intermediate values in the NI and HE calves, the change in HO concentration was smaller and the change was greatest in calves at each extreme of the size scale. In NI, calves, changes in total protozoa (Figure 4) were only slight for all calf sizes. Total protozoa (TPROT) concentration in light-small framed HE calves increased (SIZE = -2.5 to -.5) during marketing and the concentration decreased in heavy-large framed HE calves. In PW calves, the change in TPROT was extremely diverse for different size calves. In light-small-framed calves, TPROT concentration decreased approximately 1000,000/ml and the decrease was extreme (-800,000) in intermediate and large size calves. This relationship is difficult to explain, but it must be noted that the AAB protozoal population of PW calves differed from the AAB population of NI and HE calves. This difference was the result of the concentrate diet at FO and probably altered rumen development and influenced the size-rumen relationship. Changes in SPIRO were similar to trends in total protozoa observed in calves of various sizes. Changes in the total rumen protozoa in PW calves were similar to the trends in SPIRO and TPROT in preweaned calves. Changes in total rumen protozoa NI and HE calves were only slight regardless of size.

Rumen volatile fatty acid concentration was related to calf shape (Table 10). However, the relationship was significant (P<.10) with propionate (P), butyrate (B) and the group of long chain acids referred to as higher VFA (HVFA). This relationship

TABLE 10. RESULTS OF ANALYSES OF VARIANCE OF CHANGES IN RUMEN CHARACTERISTICS DURING MARKETING[a]

	Degree of Pooling of Data								
	Separate Analyses								Overall analyses
	NI		HE		PW				Probability of difference among treatment means
	SIZE	SHAPE	SIZE	SHAPE	SIZE	SHAPE	SIZE	SHAPE	
	Volatile Fatty Acids								
Acetic	-[b]	-	-	-	-	-	-	-	.0008
Propionic	-	.09[b]	-	.02	.05	-	-	.108	.0087
Butyric	-	.03	-	-	-	-	-	-	.0001
Higher	-	-	-	.02	-	.02	-	-	.0201
Total	-	-	-	-	-	-	-	.09	.1010
	Rumen Protozoa Concentration								
Spirotricha	.10	-	.10	-	.03	-	-	-	.0001
Holotricha	.05	-	.08	-	.03	-	-	-	.0009
Total	.10	-	.10	-	.01	-	-	-	.0001
	Other Rumen Characteristics								
Liquid volume	-	-	.08	.02	-	-	-	-	
Gas producing potential	.1	-	-	-	.06	-	-	.04	
Total rumen protozoa	.07	-	-	-	.06	-	-	-	.0052

[a]The statistical model included the independent variables shipment, farm or origin within year, preshipment management treatments, size and shape and the term treatment was deleted in the analyses of individual treatments.

[b]A "-" indicates that the relationship was not significant ($P>.1$) and the numerical values are the calculated probability levels.

was different in calves subjected to the different preshipment and market management systems. This was probably to differential fasting and energy density in the diets of NI, HE, and PW.

In NI calves the relationship of market change and calf shape (Figure 5) was small (P>.1) and the changes were small regardless of calf shape. In HE calves, the change in P concentration ranged (P<.02) from an increase of 10 mmol per ℓ in short-fat-wide calves, to a small increase in calves of intermediate shape. In long-thin-narrow calves the increase in P concentration was intermediate. In PW calves, market change in P was greatest (P<.05) in short-fat-wide calves and tended to be less as calf shape change for that extreme to the long-thin-narrow calves.

Change in rumen B concentrate during market in NI calves was small and ranged from a decrease of 2.5 mmol in calves with the extreme shape indices to an extremely small value in calves of intermediate shape (P<.03). In HE calves, B increased 7.5 mmol/ℓ in short-fat calves. The amount of increase was about 4 to 5 mmol/ℓ in intermediate shaped calves. The relationship of change in B concentration and calf shape was greatest in PW calves (P<.02). In short-fat and narrow-thin calves the concentration increased, but in calves of intermediate shape it decreased significantly (3 to 5 mmol/ℓ). Higher VFA concentration changes in NI, HE and PW calves with SHAPE values between -2.5 and 1 were similar and small. In HE and PW calves with values between 1 and 2, HVFA concentration increased from 1 to 5.5 mmol/l but there was on small changes in NI calves with that range in shape. Part of this association of

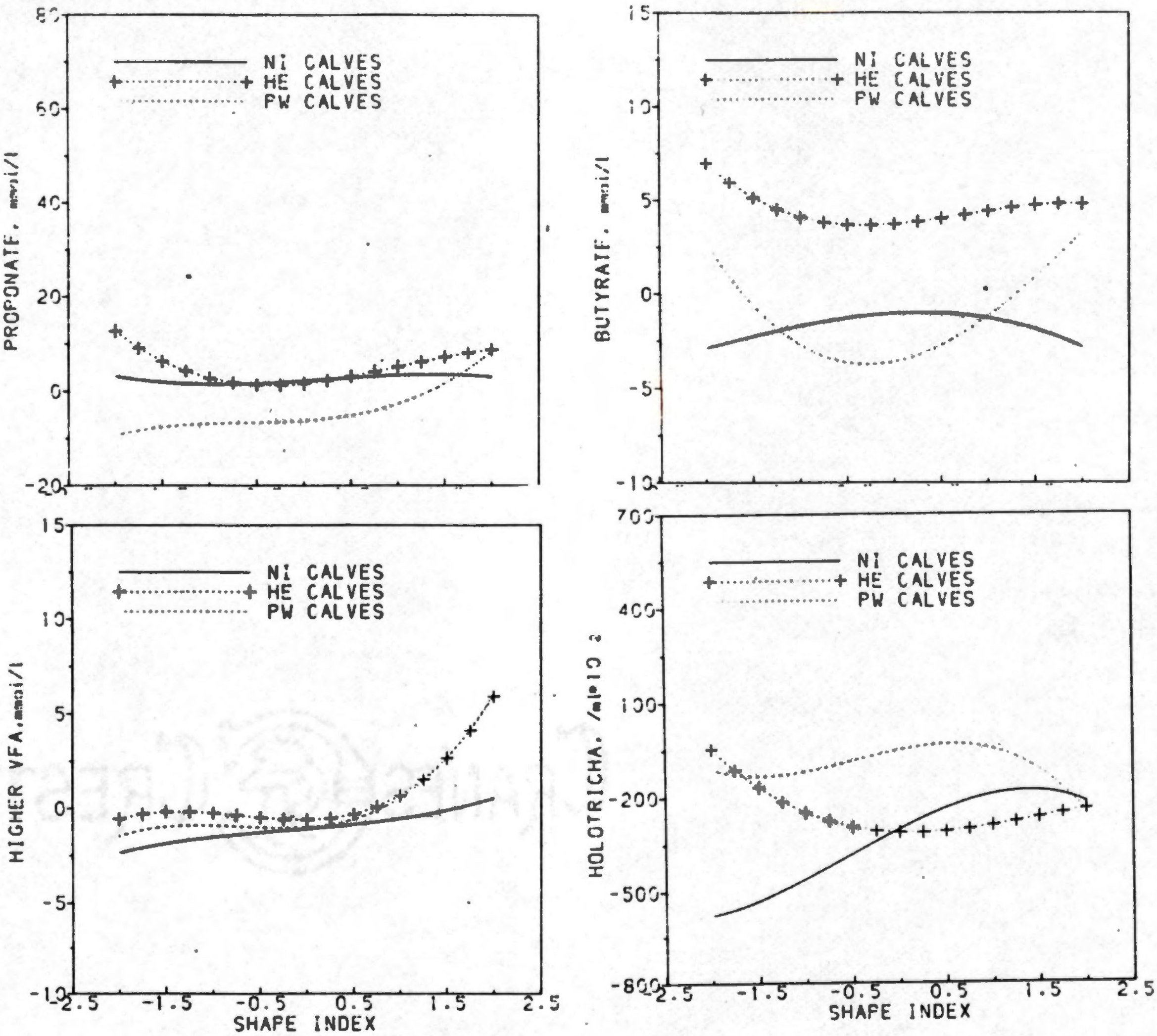

FIGURE 5. Relationship of calf shape to changes in rumen volatile fatty acid and protozoa concentrations during marketing.

VFA concentration and SHAPE could be due to differential absorption and(or) passage from the rumen in calves of different shapes.

Change in HO concentration was related to calf shape also. The variation in HO change across the range of calf shape values was smaller in PW calves than in HE or NI calves. In HE calves the decrease in rumen HO concentration during market was greater as calf shape progressed from fat-short calves to calves of intermediate shaped calves. As shape increased from intermediate to long-tall-thin calves, there was little difference in the change was observed in the long-tall-thin calves.

The difference in the relationship between calf shape and change in GPP (Figure 6) observed in NI, HE and PW calves is difficult to explain. Except that the largest differences were observed between the HE calves that were fed the concentrate ration which contained a high antibiotic level during the OBB phase and the NI and PW calves that were fed hay during that period. It has been shown that diets containing high antibiotic levels suppressed GPP. In general, GPP of the rumen fluid of HE calves decreased as calf shape changed from short-fat calves to long-tall-thin calves. Perhaps this is related to fatness and to the fact that long-tall-thin calves were so classified due to preshipment mismanagement of subclinical disease.

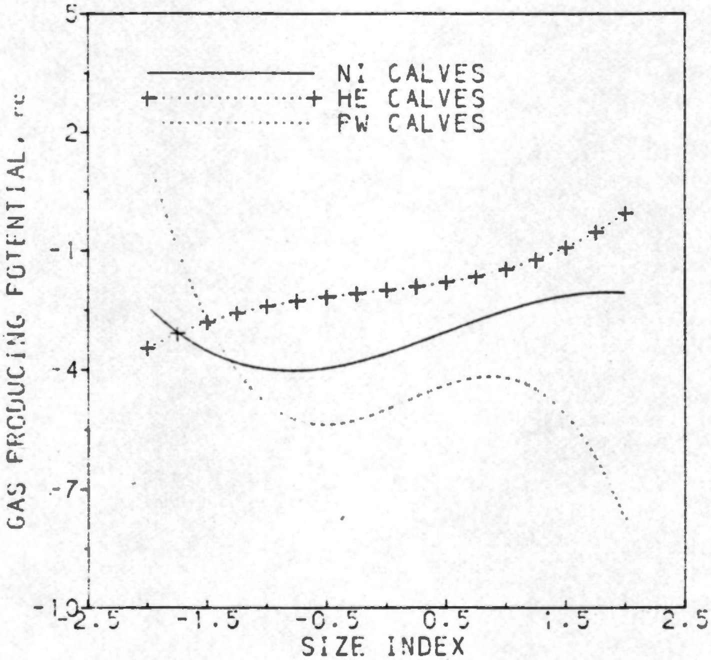

FIGURE 6. Relationship of calf size to changes in rumen gas producing potential during marketing.

CHAPTER IV

SUMMARY

Thirty days before they were marketed, feeder calves were measured, sampled and allotted to preconditioning or market-management systems at the farms of Tennessee and Kentucky feeder-calf producers during each fall marketing season (1977-1978). Body measurements were weight (WT), height (HT), length (LEN), depth (DP), width (WD) and fat thickness over the 12th rib (BF). Rumen samples were taken by the tube method from intact steers and volatile fatty acids (VFA), protozoa concentrations and pH were determined. Rumen liquid volume and in vitro gas producing potential of the fluid (GPP) were estimated. Principal component indices describing general calf size (SIZE) and calf shape (SHAPE) were calculated. Calves from two farms were used to study the relationship of SIZE and SHAPE to rumen function at FO before weaning. Rumen volume was correlated with WT, WD, HT, DP and SIZE. Acetate was related (P<.01) to WT and BF. Depth and HT were the only individual body measurements that explained a large portion of the variation in protozoal concentration. Acetate and total VFA increased linearly (P<.10) as SIZE increased. Similar trends were observed for acetate, butyrate and higher VFA. The relationship of acetate and total VFA to SHAPE was curvilinear. Similar curvilinear trends were observed in the relationship of Spirotricha and total protozoal concentrations with SHAPE.

At FO the calves were randomly assigned to one of the three following market-management systems: 1) weaning and feeding a concentrate diet during the last 30 days before marketing and feeding hay at the orderbuyer barn (PW) and 2) allowing the calves to graze pasture with their dams during this period and feeding hay (NI) or a 50% concentrate diet at the orderbuyer barn (HE).

Rumen characteristics were measured at the beginning and end of the market phase. In general, calf size was related to changes in the total rumen protozoal concentration and to changes in protozoa subclass and genera populations. Calf shape was generally related to changes in volatile fatty acid concentrations. The changes in VPA concentrations were generally smallest in PW calves and the relationship of these changes to shape was greatest in HE calves. The relationship of protozoal changes to shape was more varied among the three groups (NI, HE, and PW calves) and were more difficult to explain than the relationship with size. Significant relationships of calf size and shape to change in rumen characteristics of weanling calves and changes in rumen characteristics during market were observed. This relationship was affected by market-management or preconditioning system to which the calves were subjected. In general, VFA concentrations and market changes were related to calf size and protozoal concentrations and market changes were related to calf shape.

LITERATURE CITED

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Abner, W. R. 1981. Effects of Ralgro on performance of market-transit stressed feeder steers. M.S. Thesis. Univ. of Tennessee, Knoxville.

Annison, E. F. and D. Lewis. 1962. Metabolism in the Rumen. Wiley, New York.

Balch, D. A. and S. G. Rowland. 1957. Volatile fatty acids and lactic acid in the rumen of dairy cows receiving a variety of diets. Brit. J. Nutr. 11:288.

Billingsley, R. D. 1979. Market-transit shrink and post-transit feedlot performance of weanling steers. Ph.D. Dissertation. Univ. of Tennessee, Knoxville.

Billingsley, R. D., J. B. McLaren, N. A. Cole, D. P. Hutcheson, J. R. McCurley, E. L. Moody and W. S. Damron. 1981a. Factors affecting market-transit shrink and post-transit feedyard performance of weanling feeder steers. J. Anim. Sci. (in press).

Billingsley, R. D., J. B. McLaren, J. R. McCurley, E. L. Moody and R. D. Wills. 1981b. A description of Tennessee feeder-calf grades by body measurements and size and shape indexes. Tenn. Farm and Home Sci. 119:4.

Brown, J. E., C. J. Brown and W. T. Butts. 1973a. Evaluating relationships among immature measures of size, shape and performance of beef bulls. I. Principal components as measures of size and shape in young Hereford and Angus bulls. J. Anim. Sci. 36: 1010.

Brown, C. J., J. E. Brown and W. T. Butts. 1973b. Evaluating relationships among immature measures of size, shape, and performance of beef bulls. II. The relationships between immature measures of size, shape, and feedlot traits in young beef bulls. J. Anim. Sci. 36:1021.

Camp, T. H., D. G. Stevens, R. A. Sterner and J. P. Anthony. 1981. Transit factors affecting shrink, shipping fever and subsequent performance of feeder calves. J. Anim. Sci. 52:1219.

Carpenter, J. A., Jr., H. A. Fitzhugh, Jr., T. C. Cartwright, A. A. Melton and R. C. Thomas. 1971. Principal components for size of Hereford cows. J. Anim. Sci. 33:197 (Abstr).

Carpenter, J. A., Jr., H. A. Fitzhugh, T. C. Cartwright, R. C. Thomas, and A. A. Melton. 1978. Principal components for cow size and shape. J. Anim. Sci. 46:370.

Christiansen, W. C., W. Woods and W. Burroughs. 1964. Ration characteristics influencing rumen protozoal populations. J. Anim. Sci. 23:984.

Church, D. C. 1976. Digestive Physiology and Nutrition of Ruminants. Vol. 1. D. C. Church, Pub., Portland, Oregon.

Cole, N. A., J. B. McLaren, and M. R. Irwin. 1979. Influence on pretransit feeding and post-transit B vitamin supplementation on stressed feeder steers. J. Anim. Sci. 49:310.

Damron, W. S. 1982. Ruminal Characteristics of Feeder Calves. Ph.D. Dissertation. Univ. of Tennessee, Knoxville.

Dougherty, R. W., R. S. Allen, W. Burroughs, N. L. Jacobson and A. D. McGilliard. 1965. Physiology of Digestion in the Ruminant. Buttersworth, Washington.

Eadie, J. M. and S. O. Mann. 1970. Development of the ruminal microbial population: high starch diets and instability. In A. T. Phillipson (Ed.). Physiology of Digestion and Metabolism in the Ruminant. Oriel Press, Newcastle.

El-Din, M. Z. and K. El-Shazly. 1969. Some factors affecting fermentation capacity and net growth of rumen microorganisms. Appl. Microbiol. 18:313.

Eller, A. L., Jr. 1972. The utility of measures of fatness and skeletal size in explaining weight and size differences in yearling Angus and Hereford bulls. Ph.D. Dissertation. Univ. of Tennessee, Knoxville.

El-Shazly, K. and R. E. Hungate. 1965. Fermentation capacity as a measure of net growth of rumen micro-organisms. Appl. Microbiol. 13:62.

Emmel, R. H., J. J. Sotera and R. L. Stux. 1977. Atomic Absorption Methods Manual. Instrumental Laboratory Inc., Analytical Instrument Division, Jorspia Road, Wilmington, MA 01887.

Fleming, W. D. 1975. Feed those calves before they're shipped. Beef. June.

Galyean, M. L., R. W. Lee and M. E. Hubbert. 1981. Influence of fasting and transit on ruminal and blood metabolites in beef steers. J. Anim. Sci. 53:7.

Greathouse, T. R., D. A. Morrow, H. E. Henderson and W. T. Magee. 1969. Effect of pre- and post-weaning treatments on performance of feeder calves. Mich. State Univ. Res. Rep. 90.

Greathouse, T. R., D. A. Morrow, H. E. Henderson and W. T. Magee. 1973. Effect of pre- and post-weaning treatments on performance of feeder calves. Mich. State Univ. Res. Rep. 90, p. 7.

Gutierrez, J. 1958. Observations on bacterial feeding by the rumen ciliate Isotricha proxtoma. J. Protozoal. 5:122.

Hammack, S. P. 1973. Calfhood weights, body measurements and estimates of body composition vs. criteria of overall size and shape for predicting yearling performance in beef cattle. Ph.D. Dissertation. Univ. of Tennessee, Knoxville.

Herrick, John B. 1969. Preconditioning, its national status. J. Amer. Vet. Med. Assoc.154:1163.

Hinkson, R. S., M. D. Stern and H. G. Gray. 1976. Ruminal population of protozoa and bacteria and ruminal acid synthesis of steers fed all-concentrate, hay-concentrate and all-hay diets. Sci. Biol. 2:1.

Hungate, R. E., D. W. Fletcher, R. W. Dougherty and B. F. Barrentine. 1955. Microbial activity in the bovine rumen. Its measurement and relationship to bloat. Appl. Microbiol. 3:161.

Hungate, R. E. 1965. Quantitative aspects of the rumen fermentation, p. 311-321. In R. W. Dougherty (Ed). Physiology of Digestion in the Ruminant. Buttersworth, Washington.

Hyden, S. 1955. A turbidimetric method for the determination of higher polyethelene glycols in biological materials. Kgl. Lantbruks-Hogskol Ann. 22:139.

Jensen, R., R. E. Pierson, P. M. Braddy, D. A. Saari, L. H. Lauermann, J. J. England, H. Keyvanfer, J. R. Collier, D. P. Horton, A. E. McChesney, A. Benitz and R. M. Christie. 1976. Shipping fever pneumonia in yearling feedlot cattle. J. Amer. Vet. Med. Assoc. 169:500.

Jensen, R. and D. R. Mackey. 1979. Diseases of Feedlot Cattle (3rd Ed.). Lea and Febiger, Philadelphia.

Jolicoeur, P. and J. E. Mossimann. 1960. Size and shape variation in the painted turtle: A principal component analysis. Growth 24: 339.

King, N. B., C. Gale, H. R. Smith, A. H. Hamdy, V. L. Sanger, W. D. Pounden and E. W. Klosterman. 1958. Stress factors in shipping fever. Vet. Med. 53:67.

Koers, W. C., J. C. Parrott, L. B. Sherrod, R. H. Klett and G. E. Cope. 1975. Pre-shipment feeding of heavily stressed calves. J. Anim. Sci. 41:408 (Abstr.).

MacLean, G. J. 1972. Is it really "shipping fever"? The Practicing Nutritionist 6:21.

McLaren, J. B. 1978. Preliminary report on feeder calf transportation studies. Proc. of 62 Annual Meeting of the Livestock Conservation Institute, p. 118.

McCurley, J. R. 1977. Relationship of body measurements, weight, age and fatness to size and performance in beef cattle. Ph.D. Dissertation. Univ. of Tennessee, Knoxville.

McCurley, J. R. and J. B. McLaren. 1981. Relationship of body measurements, weight, age, and fatness to size and performance in beef cattle. J. Anim. Sci. 52:493.

Meiske, J. C., R. L. Salsbury, J. A. Hoefer and R. W. Lueake. 1958. The effect of starvation and subsequent refeeding on some activities of rumen microorganisms in vitro. J. Anim. Sci. 17:774.

Moody, E. L. 1976. Preliminary studies in preconditioning beef feeder calves. M.S. Thesis. Univ. of Tennessee, Knoxville.

Nakamura, K. and S. Kanegasaki. 1969. Densities of ruminal protozoa of sheep established under different dietary conditions. J. Dairy Sci. 52:250.

Norman, B. B. 1974. Health practices for auction cattle. Anim. Nutr. and Health 25:7.

Orr, C. L. 1979. Sodium bicarbonate buffered diets for marketing and transportation stressed feeder calves. M.S. Thesis. Univ. of Tennessee, Knoxville.

Oxford, A. E. 1955. The rumen ciliate protozoa: Their chemical composition, metabolism, requirements for maintenance and culture and physiological significance for the host. Exp. Parasitol. 4:569.

Pfander, W. H. and A. T. Phillipson. 1953. The rates of absorption of acetic, propionic and n-butyric acids. J. Physiol. 122:102.

Phillips, J. I. H. 1972. Bovine respiratory disease: Is control possible? Vet. Rec. 90:552.

Phillipson, A. T. 1942. The fluctuation of pH and organic acids in the rumen of the sheep. J. Exp. Biol. 19:186.

Phillipson, A. T. 1955. Rumen Dysfunction. In C. A. Brandley and E. L. Jungherr (Ed.), Advances in Veterinary Science, Vol. II, pp. 212-261, Academic Press, New York.

Pierson, R. E. 1968. Control and management of respiratory disease in beef cattle. J. Amer. Vet. Med. Assoc. 152:920.

Pilgrim, A. F., F. V. Gray, R. A. Weller and G. B. Belling. 1970. Synthesis of microbial protein from ammonia in the sheep's rumen and the proportion of dietary nitrogen converted into microbial nitrogen. Brit. J. Nutr. 24:589.

Purser, D. B. and R. J. Moir. 1959. Ruminal studies in the sheep. IX. The effect of pH on ciliated population of the rumen in vivo. Australian J. Agr. Res. 10:555.

Quin, J. I. 1943. Studies on the alimentary tract of merino sheep in South Africa. VIII. Fermentation in the forestomach of sheep. Onderstepoort J. Vet. Sci. and Anim. Ind. 18:91.

Self, H. L. 1969. Environmental stresses associated with cattle feeding. J. Anim. Sci. 35:148.

Self, H. L. and N. Gay. 1972. Shrink during shipment of feeder cattle. J. Anim. Sci. 35:489.

Sinha, S. K. and F. R. Abinanti. 1962. Shipping fever of cattle. In C. A. Brandy and E. L. Jungherr (Eds.), Advances in Veterinary Science. Academic Press, New York and London.

Su, P. K. 1980. Cellulose digestion potential, liquid volume and other rumen parameters of market-transit stressed steers. M.S. Thesis. Univ. of Tennessee, Knoxville.

Tanner, J. M. and A. W. A. Burt. 1954. Physique in the infra-human mammalia: A factor analysis of body measurement of dairy cows. J. Genetics 52:36.

Tennessee Crop Reporting Service. 1979.

Ulyatt, M. J. 1964. The use of polyethylene glycol as a marker for measuring rumen water volume and the rate of flow of water from the rumen of grazing sheep. New Zealand J. Agr. Res. 7:713.

Warner, A. C. 1962. Some factors influencing the rumen microbial population. J. Gen. Microbiol. 28:129.

Warner, A. C. 1964. Factors influencing numbers and kinds of microorganisms in the rumen. In R. W. Dougherty (Ed.). Physiology of Digestion in the Ruminant. Buttersworth, Washington.

Weller, R. A. and A. F. Pilgrim. 1974. Passage of protozoa and volatile fatty acids from the rumen of the sheep and from a continuous in vitro fermentation system. Brit. J. Nutr. 32: 341.

Wheaton, N. H., N. W. Bradley, G. E. Mitchell, Jr., C. O. Little and J. A. Boling. 1970. Distribution of VFA's in rumen ingesta of steers fed concentrate and roughage diets. J. Anim. Sci. 30:601.

Wills, R. W. 1980. Pasteurella Hemolytica: A bacteriological and serological study of its role in bovine respiratory disease in market stressed feeder steers. M.S. Thesis. Univ. of Tennessee, Knoxville.

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