

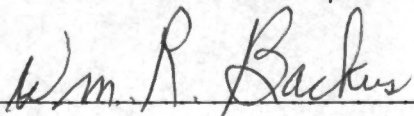
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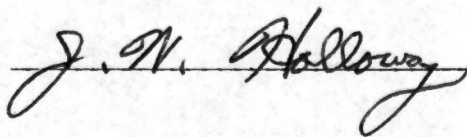
I am submitting herewith a thesis written by Jerry V. Wilhite entitled "Performance of and Ruminant Parameters in Beef Steers Fed Whole Shelled Corn Rations with Sodium Diacetate and/or Rumensin." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.



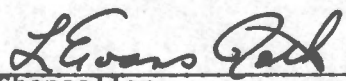
Ronald R. Johnson, Major Professor

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PERFORMANCE OF AND RUMINAL PARAMETERS
IN BEEF STEERS FED WHOLE CORN RATIONS
WITH SODIUM DIACETATE AND/OR RUMENSIN

A Thesis

Presented for the

Master of Science

Degree

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Jerry V. Wilhite

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ABSTRACT

The objectives of this study were to determine the influence of sodium diacetate added to whole shelled corn rations fed with and without rumensin to heavy yearling steers. Changes in pH, volatile fatty acid (VFA), and ciliate protozoa concentrations in the rumen, as well as animal performances and carcass characteristics were observed.

Experimental treatments (tmts) were (1) whole shelled corn + supplement(B), (2) B + 5gm Nadiac per day, (3) B + 25gm Nadiac per day, (4) B + 165mg Rumensin(R), per day, (5) B + R + 5gm Nadiac, and (6) B + R + 25gm Nadiac.

Three trials were conducted in which 54 and 60 Angus steers or 84 Hereford steers, were adapted to and finished with these rations for 84, 97 and 112 day periods, respectively.

Performance variables for treatments were not different ($P > .05$) in any of the trials, although, feed efficiency and average daily gain tended to decrease and increase, respectively, with addition of rumensin but showed some significant affects. Carcass variables were inconsistent between trials and considered of minor importance.

Ruminal parameters were pooled for trials one and two. The effects of day (time on feed) on rumen variables observed within each trial are presented at a 5% level of significance, and the pH and molar percent acetate decreased, (6.94-6.13) and (73.6-51.1), respectively, through day 33. Also total VFA and propionate increased, (78.7-156.3) and (15.2-31.6), respectively. Molar percent propionate increased with rumensin in the ration 27.8 compared to 35.3. The effects of treatment on total VFA were not significant. Although values

tended to increase with Nadiac in the rations. In trial 3, total VFA concentration tended to increase (90.8-128.1) through day thirty and leveled off (131.4) by day 63. Molar percent acetate decreased (72.5-44.1) and molar percent propionate increased (16.5-41.0) while molar percent butyrate remained somewhat stable through the finishing period. Changes in protozoa concentration were not significant. Protozoa concentrations, composed primarily of Entodinium, showed a slight decrease ($2.04-1.45 \times 10^5/\text{ml}$) on day 63 of the finishing period.

There were no significant differences between treatments in trial 3 but molar percent propionate tended to be higher for treatments containing rumensin on day 16, 30 and 63. Total VFA concentrations on day 30 tended to have higher values for treatments containing Nadiac.

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CHAPTER I

INTRODUCTION

Whole shelled corn rations have proven to be very useful for finishing heavy yearling beef cattle utilizing a relatively short feeding period. Although this system requires a somewhat different management input, it is suitable for the small feeder in Tennessee who wishes to finish his own or small group of purchased cattle at home. Because of the ever increasing cost of grain processing, it would be advantageous to use whole shelled corn rather than processed corn in many feedlot rations. Recently, researchers at The University of Tennessee (Godfrey et al., 1977; Lyle et al., 1979; Fain et al., 1979 and Wright et al., 1980) have shown that heavy yearling beef cattle could be safely and economically finished on grain rations utilizing whole corn and whole wheat rations.

Many feed additives have been developed to improve efficiency in order to offset the rising costs of finishing cattle. One of these additives, Rumensin, modified the rumen microbial fermentation in such a way as to improve feed efficiency on finishing rations. Recently, sodium diacetate was developed for use as a mold preventative in turkey rations and as a preservative in hay crops, high moisture corn and silages (Crop Cure^R). This additive with treated feeds is believed to have more crude protein available for digestion, is more palatable and improves feed value. Recent studies have suggested Crop Cure also improves performance of beef cattle fed finishing rations and lactating dairy cows (Rebhan et al., 1976).

Previous research indicated that high-grain rations supported lower ruminal pH levels, higher total VFA concentrations and higher

proportions of propionate relative to acetate and butyrate in sheep and cattle than did high-forage rations (Reid et al., 1957; Annison and Lewis, 1962; Raun et al., 1962a; Blaxter, 1962; Hungate, 1966; Hinkson et al., 1976). In ruminants consuming rations containing high levels of starch and little or no forage, the number of rumen ciliate protozoa may be sharply depressed (Annison and Lewis, 1962; Slyter et al., 1965; Hungate, 1966; Mackie et al., 1978). This could be contributed to a low rumen pH.

The objectives of this experiment were to study the effects of additions of Sodium Diacetate and/or Rumensin to whole shelled corn rations fed to beef steers. Changes occurring in pH, volatile fatty acid and ciliate protozoa concentrations, animal performances and carcass characteristics were observed.

CHAPTER II

LITERATURE REVIEW

Effect of Roughage in the Diet

The idea of feeding rations that contain no roughage to ruminants has stimulated interest for some time. A review of various researcher's findings show why this is true. As early as 1897, Davenport attempted to raise calves on a diet of milk and grain. He observed that normal rumination did not occur. Early attempts to rear calves on roughage free diets were unsuccessful according to Wise (1968). Later research has shown all-concentrate rations based upon corn (Gordon and Erwin, 1960; Wise et al., 1961; Davis et al., 1963; Oltjen et al., 1965), milo (Durham et al., 1963; McCartor et al., 1964) and barley (Geurin et al., 1959; Nicholson and Cunningham, 1961; Preston, 1963) have been successfully fed to beef cattle.

Variable results were reported from trials comparing all concentrate rations with rations containing added fiber or roughage. A number of reports indicated that small amounts of added roughage improved rate of gain (Anthony, et al., 1961; Brethour and Duitsman, 1963b; Roberts, 1963; Thomas and Myers, 1961. Wise et al., (1968) noted low levels of roughage served to reduce the incidence of liver abscesses, reduce acidosis and increase feed intake and daily gains.

Morrison (1956) reported that in roughage-containing rations, wheat-fed cattle made gains nearly as rapidly as those fed corn. Other reports show little or no advantage from adding roughage (Brethour and Duitsman, 1963a; Bucy and Bennion, 1962; Davis et al., 1963; Ellis et al., 1965; Gordon and Erwin, 1960; Pope et al., 1963;

Roberts, 1963; Wise et al., 1961; Woods et al., 1962). Cole et al (1976a) showed that roughage addition to whole shelled corn rations had no significant effect on rumen pH, total VFA concentration or molar percentages of acetic acid. However, the molar percentage of propionic acid was higher for the ration containing no roughage.

In comparing performance on rations containing roughage or no roughage, the general pattern of results indicated that rate of gain was essentially equal; however, feed consumption was markedly lower on all-concentrate rations. Also, lesser amounts of feed per pound of gain were required if roughage was excluded. Carcass characteristics were similar on both types of rations.

Essig et al. (1973) showed steers fed whole shelled corn rations required less feed to produce a kg. of gain than steers fed Johnsongrass hay. Results reported by Davis et al. (1963) showed cattle consumed more corn and cob ration than cattle receiving a ground shell corn ration. They also noted the daily gains, feed efficiency and carcass data were not different.

Use of Protein

The concentration of protein necessary to meet the requirements of ruminants finished on high-concentrate, low-fiber regimes has not been extensively investigated. Haskin's et al. (1967) work with cattle and Preston and Burroughs' work (1958) with sheep demonstrated that animal performance may be improved by feeding protein levels higher than currently recommended when high-concentrate diets are fed. A study conducted by Braman et al. (1973) suggested that dietary protein concentration had little apparent effect upon carcass parameters.

They also showed the greatest response to increased dietary protein concentration occurred early in the finishing period with little advantage to supplemental protein observed in the later phase. McDonald (1954) noted that corn protein is slowly degraded in the rumen.

Use of Nadiac or Crop Cure

Crop Cure is a dry granulated powder that combines with nutrients in silage to increase the level of acetic acid, which helps prevent growth of harmful bacteria, butyric acid formation and molds. Crop Cure is approximately 50% Nadiac. Nadiac, the active material in Crop Cure is defined as Sodium acid acetate. Sodium acid acetate is described as a "bound" compound of sodium acid and acetic acid. Current uses of Crop Cure include: mold inhibitor in breads, silage enhancer, hay preservative, stored grain preservative, high moisture grain preservative and as a feed additive. Justification for its use as a feed additive includes:

- a. In all feed Crop Cure will keep molds from growing and producing aflatoxins that will be detrimental to the poultry or livestock.
- b. In dairy feeds, Crop Cure will also aid in increasing butterfat percentage of the milk as well as aiding in the maintenance of milk production.
- c. In turkey feeds, the use of Crop Cure inhibits mold growth and will result in an increase in the number of Grade A turkeys produced.
- d. In beef feeds, Crop Cure aids in increasing the rate of growth and feed efficiency.

The major uses of Crop Cure are treating hay silage, high moisture ground corn, corn silage or high moisture and silage products. Because Crop Cure works during fermentation, harmful bacteria and molds can grow causing heating. This can reduce available protein and total feed value. High moisture grain research has demonstrated lower mold growth, higher yeast growth, and reduced spoilage and heating with ground or rolled corn treated at 2-3 lbs. Crop Cure per ton. In a 180 day test with 124 steers, those fed rations treated with Crop Cure showed an average daily gain of 2.91 lbs. Steers fed identical untreated rations showed a lower average daily gain of 2.74 lbs. (Rebhan et al., 1976).

Effects of Monensin

Monensin is a polyether antibiotic compound produced by a strain of Streptomyces cinnamomensis. Monensin inhibits gram positive organisms, thereby altering the population of bacteria normally found in the rumen (Haney and Hoehn, 1967). This compound alters rumen fermentation, improves feed efficiency of cattle fed high roughage (Potter et al., 1976a; Utley et al., 1976; Dinius et al., 1978) and concentrate diets (Gill et al., 1977; Perry et al., 1976; Potter et al., 1976b; Raun et al., 1976; Boling et al., 1977). Average daily gains of Rumensin-treated cattle may be equal to or greater than those of non-treated cattle. Feed intake may be decreased when monensin is added to concentrate diets (Gill et al., 1977; Raun et al., 1976; Perry et al., 1976; Potter et al., 1976ab; Boling et al., 1977; Dinius and Baile, 1977; Steen et al., 1978), but may not be affected when monensin is added to roughage diets (Potter et al., 1976b;

Utley et al., 1976; Dinius et al., 1978). Since cattle fed concentrate diets and monensin usually gain the same as those fed roughage diets, net energy available to the animal for growth per day is apparently similar in spite of decreased intake (Potter et al., 1974; Richardson et al., 1974; Dinius et al., 1978; Perry et al., 1977; Potter et al., 1976a; Raun et al., 1976; Boling et al., 1977). However, increased metabolizable energy per kilogram of feed due to increased molar proportions of propionic acid produced in the rumen by monensin (Hungate, 1966; Orskov et al., 1968) may not account for all energetic advantages obtained (Richardson et al., 1976). Further energetic advantages could be accounted for by the decreased heat increment associated with propionate metabolism (Blaxter, 1962). Dinius et al., (1978) reported total ruminal VFA concentration was not affected by feeding monensin blended with forage diet, but the molar proportion of acetic acid decreased from 66.7 to 61.3% and that of propionic acid increased from 20.1 to 26.1%. No other VFA's were affected. Raun et al. (1976) with cattle consuming a feedlot ration with monensin showed a decrease in molar proportions of acetate, butyrate, and valerate and an increase in molar proportions of propionate and isovalerate. The numbers of protozoa in ruminal fluid were not affected by feeding up to 33 ppm dietary monensin with a forage ration, Dinius et al. (1978).

The efficiency of ruminal fermentation may be limited by the inefficiency of the acetic acid and butyric acid producing fermentations (Van Nevel et al., 1969; Shaw et al., 1960). Propionic acid producing fermentations theoretically reduce the large loss of methane associated with the production of acetic and butyric acids (Wolin, 1960; Hungate, 1966). The efficiency of utilization of propionic acid in the ruminant

tissue may be higher than that of acetic acid (Blaxter, 1962). Propionic acid may also be a better energy source for protein synthesis (Church et al., 1976). Potter et al. (1976b) suggested that feeding monensin has minimal, if any, effects on carcass measurements. Since cattle fed monensin consumed less feed, the percentage of dietary energy and protein retained in the carcass was increased. Carcass characteristics were not affected by monensin treatment (Brown et al., 1974; Embry and Swan, 1974; Farlin et al., 1975; Raun et al., 1974).

Use of Corn in Finishing Rations

In previous feeding trials at Tennessee, whole shelled corn basal rations supplemented with protein (Godfrey et al., 1977) and/or different levels of wheat (Lyle et al., 1979; Fain et al., 1979 and Wright et al., 1980) have supported excellent average daily gains, feed conversions and carcass characteristics in heavy yearling finishing steers and heifers. Lyle et al. (1979) showed a decrease in pH as the amount of corn in the ration replaced roughage.

Cole et al. (1976a) suggested efficiency of utilization of cereal grains in high concentrate finishing rations had been greatly improved through the use of grain processing techniques. Galyean (1976) reported that processing corn by either high moisture grinding and ensiling or steam flaking resulted in more total in vivo starch digestion than did dry rolling or treating high moisture whole shelled corn with propionic acid. These results were due to increased ruminal starch fermentation. Galyean et al. (1979) suggested that rumen pH was not greatly influenced in relation to the particle size of corn, but that it did tend to increase. He also noted reduced digestion of higher levels of starch

because starch was not rapidly hydrolyzed in the intestine. The percentage of total dietary starch digested in the rumen of steers was greater with whole shelled corn rations than with flaked corn rations (91% vs 77%, respectively, as reported by McCullough and Matsushima, 1973). This difference was attributed to an alteration in the rate of rumen turnover.

Martin et al. (1971) and Weichenthal et al. (1972) in comparing the feedlot performance of steers receiving basal rations of either whole shelled corn, ground corn or rolled corn, indicated that the physical form of corn did not affect rate of gain or feed efficiency. The steers fed the whole shelled corn rations produced the most economical gains as a result of the absence of grain processing costs. Wagner and Aimone (1976) reported that feed efficiency, feed intake, average daily gain and carcass characteristics were not different with steers consuming whole shelled corn or rolled corn rations.

Comparison of steam rolled versus dry rolled grains have revealed no consistent advantages for either method of processing (Hayer, 1961; Nicholson, 1962). Davis et al. (1963) found reduced feed consumption but little difference in gain or conversion on pelleted corn rations.

Factors Affecting Ruminal pH

The rumen, although well buffered by bicarbonate, phosphate, protein and volatile fatty acids, can range in pH from 8 to less than 5 under different dietary conditions. Correlations between pH and concentrations of VFA within the rumen have also been noted. Changes in VFA pattern could be caused from a shift of biochemical pathways within the microbes present. Although many microbes are restricted in

their metabolic pathways and end products, it is likely that the types of microbes present change within the animal. Thus being partially responsible for the VFA shifts and subsequent pH levels (Allison, 1976; Slyter et al., 1966). In an early report, Phillipson and McAnally (1942) theorized that the pH of rumen contents is probably, to a large extent, a function of VFA concentration.

Since the relative amounts of ruminal acetate and propionate may influence the caloric efficiency of fattening (Blaxter, 1962) or alter milk composition (Rook and Balch, 1961), pH control of the rumen fermentation could be used to influence animal productivity.

Elsdale et al. (1972) reported an increase in acetate:propionate ratio from 1.1 to 2.8 when ruminal pH was raised from 5.5 to 6.2. They also suggested that changes in VFA production could take place in response to low pH conditions without necessarily changing the rumen microbial population.

Rumen pH has been observed to vary depending on the nature of the diet and on the time that it is measured after ingestion (Phillipson, 1970). Fulton et al. (1979) suggested that steers fed a wheat based diet experienced wider fluctuations in rumen pH values than steers fed a corn diet (4.60-6.25) vs (5.27-5.97). Lower pH values were observed for steers fed wheat at all levels.

Feed intake was depressed when the rumen fluid pH fell below 5.5 (Fulton et al., 1979) and rumen stasis has resulted (Dirksen, 1970). Feeding can also influence rumen fluid pH and ruminal pH can influence microbial fermentation and its end products (Hungate, 1966). Rumen pH value will generally decrease 2-6 hrs. after feeding, depending on the rapidity with which a meal is consumed (Briggs et al., 1957;

Reid et al., 1957). Allison et al. (1972) used sheep to study the effects of rumen overload on pH. The study showed ruminal pH was ≤ 5 within 48 hours after first rumen overload.

Several workers have reported considerable differences in pH in different parts of the rumen itself (Bryant, 1964; Lampila, 1964). Wheaton et al. (1970) reported pH was the highest in stomach tube samples. The pH was lowest near the surface of the rumen fluid in steers fed a roughage diet and lowest on the ventral floor of the rumen in those fed a concentrate diet.

Earlier work by Gordon (1958) showed that mastication and rumination was decreased on a high-concentrate diet, thereby reducing salivary flow to the rumen. Wheeler et al. (1977) suggested that high energy diets, plus a buffer to increase pH value, decreased the amount of starch in the feces. Usually high energy diets support lower ruminal pH values and show an increase in the amount of starch lost in the feces. Johnson et al. (1974) reported that rumen pH of steers fed whole shelled corn rations was higher than in those fed ground or heat processed corn.

These previous studies seem to suggest fluctuations in rumen pH reflect the changes in the quantities of organic acids that accumulate in the rumen and in the amount of saliva that is produced (Church et al., 1976).

Factors Effecting Rumen Protozoa

Protozoa in the rumen are primarily ciliated species. Although a few protozoa with flagella are found in young ruminants, these occur before ciliates become established or in animals who have lost their

ciliate population for one reason or another (Eadie, 1962a). These obligate anaerobic organisms are divided into two main orders based on substrate specificity and morphological features: (1) Oligotrichs, which are generally ciliated in a single oral zone and utilize more complex polysaccharides such as starch and cellulose and (2) Holotrichs, which are ciliated over their entire body surface and utilize readily available carbohydrates, such as sugars (Hungate, 1966; Barnett, 1961).

Protozoal species found in the rumen of domestic ruminants are known to vary according to diet, season of the year (partially diet) and geographical location (Church, 1976). Establishment of rumen ciliate populations in the young ruminant requires contact with older animals with a protozoal population (Pounden and Hibbs, 1950; Bryant et al., 1958; Eadie, 1962a; Ziolecki and Briggs, 1962; Borhami et al., 1967). Pounden and Hibbs (1950) reported development of calves raised without protozoa. They found their hair coats were much rougher in appearance. Also, their abdomens seemed deeper and more "pot-bellied" than those calves raised with an inoculation. A study by Dehority and Purser (1970) indicated that holotrich numbers were completely unrelated to water intake, percent dry matter of rumen contents and pH. In contrast the dilution effect of feed and H_2O intake, as well as rate of feed consumption, will influence holotrich numbers shortly after feeding (Dehority and Males, 1974). Russel et al. (1979) suggested that pH can be a significant factor determining competition among microbes in the rumen. Numbers of protozoa should be at or near maximum just prior to feeding, and day to day variation should be minimal (Dehority and Males, 1974). Christiansen, Woods and Burroughs (1964) observed higher

numbers of total protozoa with reduced feed intake and subsequent slower rate of passage.

Digestive disturbances associated with adaptation of feedlot ruminants to high concentrate diets are mainly a function of changes or adjustments in the rumen microbial population (Huntington and Britton, 1979). If an abrupt increase in concentrate intake occurs, there may be concomitant, rapid changes in the microbial profile characterized by loss of protozoa and an explosive increase in lactobacilli (Krogh, 1959; Hungate, 1966).

Diet has a major impact upon ruminal microbes. Factors related to nutrient quality include the nature of the microbial growth substrates and inhibitors as well as physical factors such as solubility, buffering capacity, particle size, etc. Nutrient quantity and rate and frequency of feeding may also have an effect on the microbial population (Allison, 1976). With animals fed once daily, a marked diurnal cycle has been observed for the holotrich protozoa (Purser, 1961; Clarke, 1965; Warner, 1964a; Dehority and Purser, 1970). Intermicrobial factors involved in control of the population include: competition, inhibition, predation, and symbioses.

Factors Effecting VFA Concentration

Volatile fatty acids in the rumen that are classified as such, include: acetic, propionic and butyric with lesser amounts of isobutyric, valeric and isovaleric. The concentration of any acid in the rumen at any given time is influenced by several factors, such as: (1) rate of absorption, (2) rate of production, (3) rate of passage of ingesta, (4) dilution with saliva, and (5) rate of utilization by microbes and

interconversion of acids or conversion of acids to other rumen metabolites (Annison and Lewis, 1962; and Wheaton et al., 1970). In addition, rumen fermentation may be influenced by the physical form of the diet, the level and frequency of feeding, feed processing methods, chemical additives and other factors (Thomas and Clapperton, 1972). Knox and Ward (1961) suggest that feeding frequency influenced the total concentration of VFA, the percent of VFA, and the ratios of VFA. The increase in total VFA concentration was significant when feeding frequency was increased from two to eight times per day. Acetic acid as a percentage of the total concentration was higher when they were fed two times daily than when fed eight times daily. The opposite was found with propionic acid, which showed a higher percentage on the eight-times-daily feeding.

Smith et al. (1955) recorded samples taken at different sites within the rumen. These were observed between top and bottom samples and showed VFA's and other variables to be significantly different due to location. There was a stratification of particles which was different between grains and roughages.

Erwin et al. (1961) suggested the relative concentrations of acetic acid has been related to efficient energy utilization and milk fat production in dairy cattle. Tyrell et al. (1979) have shown that partial efficiency of acetate utilization for body tissue deposition in mature cattle is low, being of the order of 30%, on high forage rations. Armstrong and Blaxter (1957) have confirmed (using sheep) that the efficiency of acetate utilization is relatively high, of the order of 60 to 70%, on high concentrate rations.

Increased propionate levels at the expense of acetate are generally associated with high concentrate fattening rations. Excessive lactic acid accumulations can occur on high concentrate diets (Hungate et al., 1952). Lactic acid in low quantities is widely considered to be a precursor of propionate. (Waldo and Schultz, 1956). It appears that propionate function in the ruminant tissues is mainly glucogenic. Reid (1950) stated that propionate was the principle source of blood glucose for sheep and McClymont (1951) and Leng et al. (1957) indicated that all ruminants maintained their blood sugar level by gluconeogenesis from propionate.

Correlation was shown between ruminal butyric acid levels and carcass grade (Raun et al., 1962). Theurer and Hale (1968) suggested that the role of propionate in regulating intake of a high-concentrate ration was not related to the energy content of this acid when infused.

The quantity of VFA present in the reticulo-rumen fluids is a reflection of microbial activity and of absorption or passage out of the rumen. Following the ingestion of readily fermentable feed, microbial activity increases rapidly, resulting in an increase in VFA concentration (Church et al., 1976).

In an early report, Raun et al. (1962) with sheep fed an 80% concentrate diet and had a TVFA value of 70 mm/ml and 52, 26.2 and 18.7 mm/ml for acetate, propionate and butyrate, respectively. Franks et al. (1972) reported that steers consuming a corn ration had a total VFA value of 121 μ M/ml and molar percents acetate, propionate and butyrate was 45%, 41% and 14%, respectively. Lyle et al. (1979) compared steers on pasture to steers consuming a whole corn ration and showed a decrease in molar percent acetate and butyrate occurred

(73.8-41.0 and 8.3-7.3, respectively). However, total VFA's and molar percent propionate increased (70.6-225.0 $\mu\text{M}/\text{ml}$ and 15.4-47.4, respectively) and the isoacids showed no change. Wilhite et al. (1979) reported steers consuming whole grain rations had TVFA levels of 163.4 $\mu\text{M}/\text{ml}$ and values for molar percent acetate, propionate and butyrate were 44.4, 46.2 and 5.4, respectively. Also rumen fluid pH decreased to 5.89.

High-energy finishing rations usually support higher total acid concentrations and higher proportions of propionate relative to acetate and butyrate than do low-energy, forage rations (Reid et al., 1957; Annison and Lewis, 1962; Raun et al., 1962a; Blaxter, 1962; Hungate, 1966; Hinkson et al., 1976).

CHAPTER III

EXPERIMENTAL PROCEDURE

Feeding Trials

Trial 1. Fifty-four Angus steers (averaging 358 kg) were taken off pasture. The cattle were ear tagged, treated for parasites, implatned with 36 mg of Ralgro^R and given intramuscular injections of 1,000,000 units of vitamin A prior to allotment. They were randomly allotted by weight to six treatments with nine animals per pen but only one pen per treatment. One steer was removed from the trial for reasons not relating to treatment. The steers were fed the treatments shown in Table 1 for 84 days. All steers were gradually changed over to the whole shelled corn rations. Supplements were weighed daily and mixed into the corn that was fed to each pen. All supplements were prominently labeled (number or color code) to avoid confusion in feeding. On the first day, rations were fed at a level of 2.0 kg of whole shelled corn topdressed with .5 kg of protein supplement per head. Hay was also fed ad libitum.

Initial weights were an average of two weights taken on two consecutive days, prior to the onset of grain feeding, with intermediate weights taken at 28-day intervals. All weights were taken with no withdrawal of feed or water. Daily feed records were kept for each pen. Upon termination (84 days) of the trial, the steers were transported approximately 90 miles from Ames Plantation to Bryan Brothers Packing facilities in West Point, Mississippi, for slaughter and collection of carcass data.

TABLE 1
EXPERIMENTAL RATIONS

Treatment	Rations
1	Whole shelled corn + .5 kg Tend-R-Leen ^A /animal/day - Basal Ration (BR)
2	BR + 5 gm Sodium diacetate ^B /animal/ day
3	BR + 25 gm Sodium diacetate/animal/ day
4	BR + 165 mg Rumensin ^C /animal/day
5	BR + 5 gm Sodium diacetate/animal/day + 165 mg Rumensin/animal/day
6	BR + 25 gm Sodium diacetate/animal/ day + 165 mg Rumensin/animal/day

^ATend-R-Leen^R is a commercial protein mineral beef finisher concentrate franchised by Domain Industries, New Richmond, Wisconsin. Minimum C.P. 36%.

^BSodium diacetate - 5 or 25 grams per head per day.

^CRumensin^R is the trade name for monensin, a product of Eli Lilly and Company.

As the 14-day adaptation phase progressed, the amount of whole shelled corn given was increased by .45 kg per head per day, with the supplement remaining constant for each pen. Furthermore, the amount of hay fed per head was reduced by .5 kg per day. By day 15 all animals were consuming a forage-free ration of whole shelled corn plus supplement.

Rumen fluid samples were taken from four steers, randomly selected from each pen, prior to the onset of the trial. These same steers were sampled again on day 33. Samples were taken by stomach tube as described by Raun and Burroughs (1962b). A stainless steel strainer attached to one end of a small, flexible tygon tube (.5 cm. i.d.) was passed through a speculum down the esophagus until the strainer entered the reticulo-rumen. An 80-100 ml sample of rumen fluid was aspirated with a 60 ml catheter tip syringe.

Trial 2. Sixty Angus steers averaging 325 kg were taken off pasture and randomly assigned by weight to 12 pens, five animals in each pen. Pens were randomly assigned to the treatments described in Table 1. Procedures for conduct of the trial were identical to those described for Trial 1 except the steers were on feed for 112 days.

Trial 3. Eighty-four heavy yearling steers (predominantly Hereford) were taken off pasture and randomly assigned by weight to 12 pens. Pens were randomly assigned to the 6 treatments in Table 1. Procedures for conduct of the trial were similar to those described for Trial 1. Rumen fluid samples were taken via stomach tube from four steers in each pen on day 0, 16, 30 and 63. Sufficient sample was obtained to determine rumen protozoa numbers in this trial.

Trial 3 concluded on day 97 when it was estimated that at least 75% had attained choice grade. Animals were transported from PES to East Tennessee Packing Company located in Knoxville, Tennessee for slaughter and collection of carcass data.

Procedures

Rumen fluid samples were processed in the same manner for all trials. The pH of the fluid was determined immediately after sampling. For protozoa counts, in Trial 3, a 10 ml aliquot of each rumen sample was preserved by diluting with 10 ml of 40% formalin, sealed in a test tube, agitated slightly and stored at room temperature until protozoa counts were made. For all samples, a 70 ml aliquot of rumen fluid was sealed in a plastic bag and frozen until a volatile fatty acid (VFA) analysis could be performed.

The VFA analyses were performed in duplicate using a procedure similar to that described by Erwin et al. (1961). Each frozen rumen sample was thawed and approximately 40-45 ml were transferred into a 50 ml tube and centrifuged under refrigeration at 10,000 g for 5 minutes. From this sample, two 10 ml aliquots of the supernate were taken and each was acidified with 2 ml of a 15% metaphosphoric acid solution which contained 2-ethyl butyric acid as an internal standard. The acidified sample was refrigerated for at least 30 minutes, and centrifuged again under refrigeration at 10,000 for 10 minutes. The supernate was then decanted and frozen to further coagulate any protein not precipitated by the acidifying process. These frozen samples were thawed and those which had coagulated protein that was visible were

centrifuged at 1500 g for 5-10 minutes. Quantitation of volatile fatty acids was performed by gas-liquid chromatography¹. A 5.0 microliter syringe² was used to inject a .5 μ l aliquot of the supernate into a 1.8 meter glass column (2.0 mm i.d.) packed with 10% SP-12001 percent H_3PO_4 on 80/100 mesh chromosorb W AW³ for separation of volatile fatty acids. Peak areas of individual volatile fatty acids were quantitated to volume using the 2-ethyl butyric acid factor and compared to similar areas from standard acid solutions.

The procedures used to stain, dilute and count protozoa for Trial 3 were similar to those described by Purser and Moir (1959). A 1 ml aliquot of the formalized rumen fluid (1:2 dilution) was pipetted into a 16 x 150 mm tube. Two drops of brilliant green dye were added and the contents were mixed and allowed to stand at room temperature for at least four hours. Nine ml of 30% glycerol were added to the stained samples, giving a 1:20 dilution. A 1 ml aliquot of the final dilution was pipetted into a Sedgwick-Rafter counting chamber and differential protozoa counts were performed in duplicate at 100X. The average of two counts was used to calculate the number of protozoa per ml of rumen fluid.

Other data resulting from the feeding trials consisted of carcass and performance data. Carcass data included carcass weight, carcass fat,

¹A Bendix 2500 gas-liquid chromatograph equipped with an Infotronics CRS-309 digital integrator was used.

²Hamilton Company, Reno, Nevada.

³Supelio Incorporated, Bellefonte, Pennsylvania.

percent kidney fat, marbling, rib-eye area, quality grade and yield grade. The performance aspects included initial weight, final weight, daily feed consumption, average daily gain and feed efficiency. The coding systems for marbling and quality grade can be found in Table 2.

Statistical Analysis

Data obtained from VFA and protozoa analyses was statistically analyzed as a split plot in time (Harvey, 1964) due to the successive observations made on the same whole unit over a period of time. Programs prepared by Barr et al. (1979) were used to conduct analyses of variance to determine if the rumen variables. The model used was:

$$Y_{ijk} = \mu + t_i + (a_j t_i) + d_k + t_i * d_k + e_{ijk}.$$

where Y_{ijk} = dependent variables (ruminal parameters).

μ = theoretical population mean.

t_i = effect of treatment, $i = 1-6$.

$(a_j t_i)$ = effect of animal within treatment, $j = 1-24$
(Trial 1), $j = 1-48$ (Trial 2,3).

d_k = effect of day, $k = 1-2$ (Trials 1,2), $k = 1-4$
(Trial 3).

e_{ijk} = random error.

If significant differences were determined among levels of the independent variables by F tests, means separation was accomplished by the Student-Neuman-Keuls test (Sokal and Rohlf, 1969).

Analysis of variance was conducted on the performance and carcass data, and fitted to the following model:

$$Y_{ij} = \mu + t_i + p_j(t_i) + e_{ij}.$$

TABLE 2

MARBLING AND CARCASS QUALITY GRADE CODING SYSTEMS

Code	Marbling	Code	Carcass quality grade
100	- Abundant	17	- Prime (+)
97	- Abundant (-)	16	- Prime
93	- Moderately abundant (+)	15	- Prime (-)
90	- Moderately abundant	14	- Choice (+)
87	- Moderately abundant (-)	13	- Choice
83	- Slightly abundant (+)	12	- Choice (-)
80	- Slightly abundant	11	- Good (+)
77	- Slightly abundant (-)	10	- Good
73	- Moderate (+)	9	- Good (-)
70	- Moderate	8	- Standard (+)
67	- Moderate (-)	7	- Standard
63	- Modest (+)	6	- Standard (-)
60	- Modest		
57	- Modest (-)		
53	- Small (+)		
50	- Small		
47	- Small (-)		
43	- Slight (+)		
40	- Slight		
37	- Slight (-)		
33	- Traces (+)		
30	- Traces		
27	- Traces (-)		
23	- Practically devoid (+)		
20	- Practically devoid		
17	- Practically devoid (-)		
13	- Devoid (+)		
10	- Devoid		

where Y = dependent variables (weight change and carcass traits).

μ = theoretical population mean.

t_i = effect of treatment, $i = 1-6$.

$p_j(t_i)$ = effect of pen within treatment.

e_{ij} = random error.

To determine the effects of initial weight on the dependent variables, analysis of variance was performed with initial weight as a co-variate. This type of analysis seemed appropriate because the animals were stratified by weight and the animals within each weight level were randomly assigned to pens. Thus, the variance within pen was maximized and the variance among pens treated alike was a more appropriate error term for testing treatment effect. The model used was:

$$Y_{ij} = \mu + t_i + w_j * t_i + e_{ij}.$$

where

Y_{ij} = dependent variables (ruminal parameters, weight change and carcass traits).

μ = theoretical population mean.

t_i = effect of treatment, $i = 1-6$.

w_j = effect of initial weight, of the ij^{th} animal.

$t_i w_j$ = effect of initial weight within treatment.

e_{ij} = random error.

In the preliminary analysis treatments were composed of combinations of various levels of Nadiac and Rumensin. When treatment effects on the independent variables were observed to be significant,

these treatment effects were partitioned into effects attributed to rumensin level, Nadiac and interactions between these factors. The two models used were:

$$(1) Y_{ij} = \mu + n_i + k_j + n_i * r_j + e_{ij}.$$

$$(2) Y_{ijk} = \mu + n_i + r_j + d_k + n_i * r_j + n_i * d_k + r_j * d_k + n_i * r_j * d_k + e_{ijk}.$$

where in models 1 and 2:

Y_{ijk} = dependent variables.

μ = theoretical population mean.

n_i = effect of Nadiac, $i = 1-3$.

r_j = effect of Rumensin, $j = 1-2$.

$n_i * r_j$ = effect of Nadiac + Rumensin interaction.

in model 1:

e_{ij} = random error.

and in model 2:

d_k = effect of day, $k = 1-2$ (Trial 1,2) $k = 1-4$ (Trial 3).

$n_i * d_k$ = effect of Nadiac within day.

$r_j * d_k$ = effect of Rumensin within day.

$n_i * r_j * d_k$ = effect of interaction between Nadiac and Rumensin within day (Error A).

e_{ijk} = random error (Error B).

CHAPTER IV

RESULTS AND DISCUSSION

Trial 1

Performance aspects. There were significant differences ($p > .05$) found between treatments for final weight, daily feed consumption, average daily gain or feed efficiency (Table 3). One might note, however, the highest rates of gain, heavy final weights and low feed efficiencies were for treatments (tmt) 4 and 6, which were basal (B) plus rumensin (tmt 4) and basal plus rumensin plus 25 gms Nadiac (tmt 6). This agrees with previous reports that rumensin improved feed efficiency (Gill *et al.*, 1977; Perry *et al.*, 1976; Potter *et al.*, 1976b; Raun *et al.*, 1976; Boling *et al.*, 1977). Average daily gain ranged from 1.63 kg per day for tmt 5 (B + 5 gm Nadiac + rumensin) to 1.91 kg per day for tmt 6 (B + 25 gm Nadiac + rumensin). Steers in this trial started on feed at a heavier weight and thus finished heavier than in Trials 2 and 3.

Carcass aspects. Carcass weight and fat were not significantly affected due to treatment (Table 4). However, there was a significant difference ($p < .05$) in percent kidney fat, ranging from 2.9 in tmts 1 and 5 to a value of 3.3 in tmts 2 and 4. One might expect carcass fat and kidney fat to be different between treatments since these two variables are a function of time and rate of gain. Marbling was similar in all groups with highly acceptable values. Rib-eye area values were also highly acceptable. Quality grade, which is based mainly on marbling, was relatively unaffected by treatment. Yield

TABLE 3
MEANS BY TREATMENT FOR PERFORMANCE VARIABLES, TRIAL 1

Variable ^a	Treatment					
	1	2	3	4	5	6
No. of animals	9	9	9	9	9	8
Initial weight (kg)	359	357	365	360	358	350
Final weight (kg)	503	508	511	518	495	505
Daily feed consumption (kg)	10.73	10.91	11.97	11.24	12.19	11.27
Average daily gain (kg/day)	1.71	1.80	1.72	1.88	1.63	1.91
Feed efficiency	6.26	6.05	6.94	5.98	7.49	5.90

^aNo differences were noted among variables between treatments, $P>0.05$.

TABLE 4
MEANS BY TREATMENT FOR CARCASS VARIABLES, TRIAL 1

Variable	Treatment					
	1	2	3	4	5	6
Carcass weight (kg)	283	293	293	294	282	291
Carcass fat (mm)	11.3	12.8	14.9	12.0	12.1	15.0
Percent kidney fat	2.9 ^a	3.3 ^c	3.1 ^b	3.3 ^c	2.9 ^a	3.2 ^c
Marbling	52	52	53	49	51	59
Rib-eye area (cm ²)	73.5	77.0	68.0	73.8	77.0	71.8
Quality grade	12.2	12.2	12.1	12.0	12.0	12.8
Yield grade	2.4 ^a	2.5 ^a	3.1 ^b	2.5 ^a	2.3 ^a	2.9 ^b

a,b,c Means within a row with differing superscripts are significantly different, $p < .05$.

Marbling: 47 = small minus; 50 = small; 53 = small plus; 57 = modest minus; 60 = modest.

Quality grade: 11.0 = high good (G+); 12.0 = low choice (C-); 13.0 = choice (C⁰).

grade was significantly higher ($p < .05$) for treatments 3 and 6 which contained increased levels (25 gms) of Nadiac in the ration. These data should be interpreted carefully because there was only one replication per treatment.

Trial 2

Performance aspects. Again, in trial 2, no significant differences ($p > .05$) between treatments were observed (Table 5). The poorest feed efficiency value was for treatment 3 (8.93) and the best values were for treatments 2 and 5, which were 7.23 and 7.21, respectively. This might suggest an improved efficiency when 5 gms of Nadiac were added to the ration.

This study disagrees with Rebhen et al. (1976) who reported that Nadiac improved rate of gain by 10%. Average daily gain (ADG) was the lowest for rations containing 25 gms of Nadiac which tends to show an inverse relationship for ADG as level of Nadiac increased from 5 to 25 gms but, one should be reminded there was no significance.

Carcass aspects. As shown in Table 6 there were no differences between treatments for carcass weight, carcass fat, marbling, quality grade and yield grade ($p > .05$). Percent kidney fat was significantly higher ($p < .05$) for treatment one (3.4) which was unexplainable. Values tended to be lower for the treatments containing rumensin, with exception of tmt 3. In addition rib-eye areas tended to be lower for the tmts with rumensin plus Nadiac and tmts 5 and 6 were significantly lower ($p < .05$).

TABLE 5
MEANS BY TREATMENT FOR PERFORMANCE VARIABLES, TRIAL 2

Variable ^a	Treatment					
	1	2	3	4	5	6
Number of animals	10	10	10	10	10	10
Initial weight (kg)	335	335	330	320	310	318
Final weight (kg)	488	479	453	464	457	457
Daily feed consumption (kg)	10.11	9.79	9.80	9.49	9.52	9.74
Average daily gain (kg/day)	1.36	1.29	1.10	1.29	1.32	1.28
Feed efficiency	7.56	7.23	8.93	7.37	7.21	7.62

^aNo differences were noted among variables between treatments, $p > 0.05$.

TABLE 6

MEANS BY TREATMENT FOR CARCASS VARIABLES, TRIAL 2

Variable ^a	Treatment					
	1	2	3	4	5	6
Carcass weight (kg)	297 ^a	292 ^a	277 ^b	280 ^b	270 ^b	274 ^b
Carcass fat (mm)	13.9	14.6	12.9	13.0	11.4	13.1
Percent kidney fat	3.4 ^a	3.1 ^b	2.9 ^c	2.9 ^c	3.0 ^{b,c}	2.9 ^c
Marbling	49	52	58	53	51	50
Rib-eye area (cm ²)	77.0 ^a	73.7 ^b	76.0 ^a	74.7 ^{a,b}	71.0 ^c	70.6 ^c
Quality grade	11.8	11.8	12.6	12.2	12.1	11.8
Yield grade	2.6	2.8	2.4	2.5	2.4	2.6

^{a,b,c}Means within a row with differing superscripts are significantly different, $P < .05$.

Marbling: 47 = small minus; 50 = small; 53 = small plus; 57 = modest minus; 60 = modest.

Quality grade: 11.0 = high good (G+); 12.0 = low choice (C-); 13.0 = choice (C⁰).

Trial 1 and 2

Rumen parameters. There were no differences between ruminal parameters for trials 1 and 2, therefore, the data were pooled. Rumen fluid pH and volatile fatty acid concentrations measured during these feeding trials are presented in Table 7. All values were significantly ($p < .05$) different between days 0 and 33. Steers on day 0 were just off pasture while steers on day 33 were receiving the whole shelled corn rations (Table 1, p. 18). Rumen fluid pH initially averaged 6.94 on day zero and decreased to 6.13 on day 33. This agrees with (Hungate et al., 1952; Reid et al., 1957; Krogh, 1961; Raun et al., 1962a; Lyle et al., 1979) who have reported ruminal pH decreased as level of starch in the diet increased. These pH findings are also supported by other researchers (McDougall, 1948; Clark and Weiss, 1952; Bailey, 1961), who reported ruminal pH was influenced by the physical character of the ration, whereas rations requiring much mastication and rumination supported a high ruminal pH by maintaining a copious flow of saliva to the rumen.

Total volatile fatty acid (TVFA) concentration, molar percent propionate, and butyrate showed an increase, whereas molar percent acetate and AC:PR Ratio decreased ($p < .05$). These changes occurred from day zero when steers were consuming all forage to day 33 when the diet consisted of a whole shelled corn ration (Table 1, p. 18). This is in agreement to reports of Raun et al. (1962a), Wise et al. (1968) and Mackie et al. (1978), which indicated that total VFA concentration increased and acetate proportions decreased as levels of starch in the diet increased. The increase in molar percent propionate agrees with

TABLE 7
MEANS BY DAY FOR RUMINAL pH AND
VFA LEVELS, TRIAL 1-2

Variable	Day	
	0	33
pH	6.94 ^a	6.13 ^b
Total VFA ($\mu\text{m}/\text{ml}$)	78.7 ^a	156.3 ^b
Acetate, %	73.6 ^a	51.1 ^b
Propionate, %	15.2 ^a	31.6 ^b
Isobutyrate, %	1.4 ^a	1.2 ^b
Butyrate, %	8.6 ^a	10.3 ^b
Isovalerate, %	0.8 ^a	2.8 ^b
Valerate, %	0.6 ^a	3.1 ^b
AC:PR Ratio	6.51 ^a	1.86 ^b

^{a,b} Means within a row with differing superscripts are significantly different, $P < .05$.

Annison and Lewis (1962), Raun et al. (1962a), Blaxter (1962), Lyle et al. (1979) and Hungate (1966), who indicated ruminal propionate levels were higher in animals consuming no forage rations. Increased levels of butyrate agree with reports by Allison et al. (1964) with sheep fed grain and Eadie and Mann's (1970) work with sheep fed barley ad libitum. In contrast Reid et al. (1957) reported levels of butyrate in the rumen of sheep decreased as levels of dietary starch increased; however, this observation was made after ruminal conditions had stabilized.

Means by treatment on day 33 for ruminal pH and VFA levels are given in Table 8. Treatment exerted no affect ($p > .05$) on ruminal pH, molar percent acetate, isobutyrate, butyrate, isovalerate or valerate. However, differences in treatment values for TVFA approached significance ($p < .08$). Molar percent propionate tended to be lower for the two basal rations plus Nadiac (tmt 2 and 3). Higher values for molar percent propionate were seen with rumensin treatments which agrees with Raun et al. (1976), Dinius et al. (1978), Perry et al. (1976), Richardson et al. (1976), Boling et al. (1977) and Mowat et al. (1977) who reported that rumensin supported an increase in the molar proportions of propionate and a decrease in the molar proportions of acetate and butyrate in the rumens of cattle consuming forage or mixed grain and forage rations. Acetate:Propionate ratio was significantly ($p < .05$) lower for ration 6 which contained rumensin and 25 gms of Nadiac.

Statistical analysis seemed to suggest a Nadiac X rumensin interaction, so Nadiac and rumensin plus the interaction were partitioned from treatment effect in analysis of variance. The Nadiac effect

TABLE 8

MEANS BY TREATMENT ON DAY 33 FOR RUMINAL pH AND VFA LEVELS, TRIAL 1-2

Variable	Treatment					
	1	2	3	4	5	6
pH	6.11	6.18	5.92	6.13	6.18	6.28
Total VFA ($\mu\text{m}/\text{ml}$)	136.8	169.5	148.1	158.8	179.5	145.1
Acetate, %	53.2	55.7	50.6	50.7	49.5	46.9
Propionate, %	30.0 ^{a,b}	26.0 ^a	27.5 ^a	33.6 ^{a,b}	33.6 ^{a,b}	38.7 ^b
Isobutyrate, %	1.0	1.1	1.2	1.1	1.1	1.4
Butyrate, %	11.0	11.0	12.6	9.0	9.6	8.7
Isovalerate, %	2.0	2.7	4.6	2.7	3.0	1.9
Valerate, %	2.9	3.6	3.6	2.9	3.2	2.4
AC:PR Ratio	1.97 ^{a,b}	2.3 ^a	2.3 ^a	1.8 ^{a,b}	1.56 ^{a,b}	1.31 ^b

^{a,b}Means within a row with differing superscripts are significantly different, $P < 0.05$.

consisted of 3 levels: 0 for tmts 1 and 4, 5 gms for tmts 2 and 5, and 25 gms for tmts 3 and 6. The Rumensin effect contained 2 levels, 0 for tmts 1, 2 and 3 and 165 mg/day for tmts 4, 5, and 6. There were no significant effects ($p>.05$) due to the interaction between Nadiac and rumensin for all variables. However, TVFA was significantly affected by Nadiac treatment. These results suggested that a higher TVFA concentration existed when 5 gms of Nadiac were added to the ration (175 $\mu\text{m}/\text{ml}$) compared to 148 and 146 $\mu\text{m}/\text{ml}$ for levels 0 and 25 gms, respectively. The addition of rumensin had significant effects ($p<.05$) on molar percent acetate, propionate and butyrate, agreeing with previous work mentioned earlier. Percent propionate increased (27.8 to 35.3) and percent acetate and butyrate decreased (53.2 to 49.0 and 11.5 to 9.1, respectively) with addition of rumensin. In addition, acetate:propionate ratio decreased significantly (2.17 to 1.56) with rumensin in the ration.

Analysis of variance was also conducted to determine if an interaction existed between days on feed and rumensin or Nadiac. Results of this analysis indicated there was a significant interaction ($p<.05$) between days on feed and rumensin for percent acetate, propionate and TVFA whereas the interactions for percent isobutyrate and isovalerate approached significance ($p>.05$).

Trial 3

Performance aspects. Means by treatment for trial 3 are shown in Table 9. There were no significant ($p>.05$) differences between treatments. These animals were on trial for 97 days. Feed efficiencies were low and very acceptable for all treatments, with tmts 1, 5 and 6 below 6.00.

TABLE 9
MEANS BY TREATMENT FOR PERFORMANCE VARIABLES, TRIAL 3

Variables ^a	Treatment					
	1	2	3	4	5	6
Number of animals	14	14	14	14	14	13
Initial weight (kg)	298	301	303	301	310	306
Final weight (kg)	440	426	429	434	456	452
Daily feed consumption (kg)	8.60	8.79	8.63	8.67	9.02	8.90
Average daily gain (kg/day)	1.46	1.30	1.30	1.38	1.51	1.51
Feed efficiency	5.88	6.78	6.63	5.35	5.99	5.88

^aNo differences were noted among variables between treatments, $P > 0.05$.

Carcass aspects. Means by treatment for trial 3 are listed in Table 10. Carcass fat was significantly ($p < .05$) different between treatments, the values showed an increase in fat with Nadiac in the diet. These values were inconsistent when compared to treatments containing rumensin. Yield grade values agreed with those in trial 1 in which values increased with Nadiac in the ration. However, there was no consistent affect for the increased level of Nadiac noticed. There were no differences ($p > .05$) for carcass weight, percent kidney fat, marbling, rib-eye area or quality grade.

VFA Parameters. As shown in Table 11, rumen fluid pH decreased significantly from the initial 6.9 to 6.1 on day 30 and increased slightly to 6.3 on day 63. Beeson (1969) indicated that whole shelled grains may serve as a source of roughage in the rumen. This may be true, thus increasing the processes of rumination and mastication which subsequently helped to maintain a higher pH. Total ruminal VFA concentration initially averaged 90.8 on day 0 and increased significantly ($p < .05$) to 131.4 $\mu\text{m}/\text{ml}$ on day 63.

This increase in total VFA concentration may be attributed to an increased rate of VFA production as well as some increased feed intake. However, one must assume that the rate of VFA removal from the rumen remained constant during the trial.

This study is in contrast to Lyle et al. (1979) who reported steers adapting from forage to an all grain ration, were virtually defaunated by day 14. Lyle concludes the absence of ruminal protozoa was not believed to be a result of low pH, which averaged 5.67 and 5.84. It is believed that the higher pH values (≈ 6.1) found in this

TABLE 10
MEANS BY TREATMENT FOR CARCASS VARIABLES, TRIAL 3

Variable	Treatment					
	1	2	3	4	5	6
Carcass weight (kg)	252	244	244	249	263	260
Carcass fat (mm)	8.0 ^a	8.7 ^a	9.9 ^b	6.3 ^c	10.5 ^b	8.3 ^a
Percent kidney fat	2.3	2.3	2.2	2.3	2.6	2.4
Marbling	54	50	53	54	50	52
Rib-eye area (cm ²)	72.4	64.5	66.5	68.9	68.4	69.9
Quality grade	12.4	11.7	12.3	12.1	12.0	12.2
Yield grade	1.8 ^a	2.2 ^{b,c}	2.3 ^{b,c}	1.8 ^a	2.4 ^c	2.1 ^b

a,b,c Means within a row with differing superscripts are significantly different, $P < 0.05$.

Marbling: 50 = small; 53 = small plus; 57 = modest minus.

Quality grade: 11.0 = high good (G+); 12.0 = low choice (C-); 13.0 = choice (C⁰).

TABLE 11
MEANS BY DAY FOR RUMINAL pH AND VFA LEVELS, TRIAL 3

Variable	Day of trial			
	0	16	30	63
pH	6.9 ^a	6.3 ^b	6.1 ^c	6.3 ^b
Total VFA ($\mu\text{m/ml}$)	90.8 ^a	110.2 ^b	128.1 ^c	131.4 ^c
Acetate, %	72.5 ^a	48.5 ^b	50.7 ^c	44.1 ^d
Propionate, %	16.5 ^a	35.8 ^b	35.5 ^b	41.0 ^c
Isobutyrate, %	1.5 ^a	1.5 ^a	1.4 ^a	1.0 ^b
Butyrate, %	8.0	8.7	8.1	9.2
Isovalerate, %	0.9 ^b	1.8 ^a	1.1 ^b	1.0 ^b
Valerate, %	0.7 ^a	3.4 ^b	3.3 ^b	3.4 ^b
AC:PR Ratio	4.5 ^a	1.5 ^b	1.5 ^b	1.2 ^c

a,b,c Means within a row with differing superscripts are significantly different, $P < .05$.

study may be responsible for the increased ciliate protozoa concentration. Molar percent acetate decreased from 72.5 on day 0 to 44.0 on day 63 while percent propionate increased from 16.5 to 41.0. Acetate:propionate ratio decreased from 4.5 to 1.2 which agrees with Lyle et al. (1979) in which rations were approximately equal molar proportions (44 to 46 percent) by day 21. Percent isobutyrate also decreased from 1.5 to 1.0. Molar percent isovalerate and valerate increased during this time and, in contrast to trial 1 and 2, percent butyrate did not change

Ruminal pH and protozoa concentrations measured on rumen samples taken during this feeding trial are presented in Table 11. As shown in Table 12, total protozoa concentrations averaged 2.04×10^5 per ml of rumen fluid as steers were consuming all forage rations (day 0). Total protozoa concentrations decreased on day 16 to 1.75×10^5 and further on day 30 to 1.45×10^5 , before increasing to 3.35×10^5 on day 63. However, the changes that occurred in total protozoa concentrations were not significant ($p > .05$).

Warner (1964a) indicated that when sheep were fed increasing amounts of starch, ruminal protozoa concentrations initially increased. However, he noted that the numbers of protozoa decreased as the amount of dietary starch was further increased, presumably as a result of the low ruminal pH associated with high levels of dietary starch. Other researchers (Hungate et al., 1952; Reid et al., 1957; Krogh, 1961; Raun et al., 1962a) have reported that ruminal pH decreased as the level of starch in the diet increased.

In this study, it should be noted that protozoa numbers decreased (although not significantly) as rumen fluid pH decreased (Table 12), and numbers then increased as pH increased slightly on day 63. This is

TABLE 12
MEANS BY DAY FOR RUMINAL pH AND PROTOZOA
CONCENTRATION, TRIAL 3

Variable	Day of trial			
	0	16	30	63
pH	6.93 ^a	6.33 ^b	6.14 ^c	6.33 ^b
Total protozoa	2.04	1.75	1.45	3.35
Epidinium	.035 ^a	.021 ^{a,b}	.001 ^b	.000 ^b
Entodinium	1.25	1.70	1.42	3.34
Piplodinium	.21 ^a	.01 ^b	.02 ^b	.00 ^b
Dasytrich	.46 ^a	.02 ^b	.01 ^b	.00 ^b
Isotrich	.055 ^a	.005 ^b	.002 ^b	.000 ^b
Charon	.03 ^a	.00 ^b	.00 ^b	.00 ^b

All protozoa values expressed as number $\times 10^{-5}$ /ml rumen fluid.

a,b,c Means within a row with differing superscripts are significantly different, $P < .05$.

in contrast to Lyle et al. (1979) who reported steers adapting from all forage to an all grain ration, were virtually defaunated by day 14. The absence of ruminal protozoa was not believed to be a result of low pH, which averaged 5.67 and 5.84. Reports by Oxford (1955) and Purser and Moir (1959) indicated that ciliate protozoa could not survive when ruminal pH was below 6.0. Krogh (1959), Eadie and Mann (1970) and Abe et al. (1973) reported that when ruminal pH dropped below 5.5, a marked decrease in protozoa numbers occurred.

Differential protozoa counts (Table 12) revealed that concentrations of Epidinium, Diplodinium, Dasytrich, Isotrich and Charon genera were initially low and remained so throughout day 30. After day 30, steers were virtually devoid of these genera. However, the numbers of Entodinium were initially high ($1.25 \times 10^5/\text{ml}$) which agreed with Lyle et al. (1979) and Wilhite et al. (1979) in adaptation trials with steers fed whole shelled corn (WSC) and WSC plus whole wheat. Entodinium species then increased further to ($3.34 \times 10^5/\text{ml}$) on day 63. Oxford (1955) found that in animals consuming rations high in starch, Entodinium were virtually the only genus of protozoa present in the rumen. Results of this study support Oxford's findings. Eadie and Mann (1970) found viable populations of Entodina species when the ruminal pH of sheep was 5.5 or slightly lower.

Means by treatment for trial 3 on day 16 are presented in Table 13. As shown in this table, there were no significant differences ($p > .05$). However, differences in molar percent propionate and butyrate were approaching significance ($p < .06$ and $p < .08$, respectively) for treatment effect. Therefore, Nadiac and Rumensin as in trial 1 and 2

TABLE 13

MEANS BY TREATMENT ON DAY 16 FOR RUMINAL pH AND VFA LEVELS, TRIAL 3

Variable ^a	Treatment					
	1	2	3	4	5	6
pH	6.43	6.55	6.24	6.25	6.19	6.30
Total VFA ($\mu\text{m}/\text{ml}$)	109.1	116.4	115.5	109.9	109.8	100.3
Acetate, %	52.3	49.6	46.4	50.1	44.0	48.7
Propionate, %	30.4	32.6	36.0	35.2	43.2	37.1
Isobutyrate, %	1.5	1.5	1.3	1.5	1.6	1.8
Butyrate, %	10.5	10.9	9.5	7.7	6.6	6.9
Isovalerate, %	1.2	1.5	1.6	1.9	1.6	3.1
Valerate, %	3.9	4.0	3.4	3.6	3.2	2.5
AC:PR Ratio	1.84	1.60	1.41	1.55	1.05	1.45

^aNo differences were noted among variables between treatments, $P > .05$.

were partitioned from treatment. This analysis showed that treatments with rumensin produced significantly higher molar percent propionate than those without. However, molar percent butyrate was significantly lower ($p < .05$) for the rumensin treatments. These results agree with Raun et al. (1976) with cattle consuming a feedlot ration.

Means by treatment for ruminal pH and VFA levels on day 30 are given in Table 14. There were no significant differences observed, even when treatment effects were partitioned into Nadiac and Rumensin. It should be noted that molar percent propionate and butyrate approached significance ($p < .06$).

Means by treatment on day 63 for ruminal pH and VFA levels are shown in Table 15. Molar percent valerate was significantly lower in tmt 6. The effect of Nadiac levels on percent valerate approached significance ($p > .05$) which suggested an increased level of valerate with 5 gms Nadiac but decreased with the 25 gm level.

These data indicated that ruminal pH decreased, total volatile fatty acid concentration increased, molar percent acetate decreased, molar percent propionate increased and total protozoa concentration did not change as steers were adapted to and finished on all-grain rations. The results of this study also indicate that the effects of rumensin on ruminal acetate and propionate levels in steers consuming all-grain rations of whole shelled corn are as marked as that reported in steers consuming forage or grain and forage mixed rations. Feed efficiency and average daily gain tended to decrease and increase, respectively, with addition of rumensin. Finally, data indicated that Nadiac fed with whole shelled corn with and without rumensin tended to increase total VFA concentration

TABLE 14
MEANS BY TREATMENT ON DAY 30 FOR RUMINAL pH AND VFA LEVELS, TRIAL 3

Variable ^a	Treatments					
	1	2	3	4	5	6
pH	6.06	6.20	6.34	6.18	5.86	6.28
Total VFA (μm/ml)	120.9	130.9	149.7	112.4	140.5	117.1
Acetate, %	53.1	52.7	48.6	49.5	51.6	49.0
Propionate, %	32.7	33.4	33.6	37.7	34.9	38.7
Isobutyrate, %	1.8	1.2	1.7	1.3	1.3	1.2
Butyrate, %	8.2	8.7	10.9	7.6	7.7	6.6
Isovalerate, %	.7	.7	1.4	1.1	1.5	1.2
Valerate, %	3.5	3.3	3.8	3.0	3.1	3.3
AC:PR Ratio	1.7	1.7	1.5	1.4	1.7	1.3

^aNo differences were noted among variables between treatments, $P > .05$.

TABLE 15

MEANS BY TREATMENT ON DAY 63 FOR RUMINAL pH AND VFA LEVELS, TRIAL 3

Variable	Treatments					
	1	2	3	4	5	6
pH	6.15	6.30	6.45	6.20	6.51	6.36
Total VFA ($\mu\text{m}/\text{ml}$)	132.7	144.9	146.1	129.7	109.7	125.5
Acetate, %	42.4	47.1	45.1	42.5	42.3	45.1
Propionate, %	43.0	37.5	38.8	41.2	44.0	42.0
Isobutyrate, %	1.4	.9	.8	.9	.8	1.2
Butyrate, %	7.5	10.0	10.9	9.8	7.7	8.8
Isovalerate, %	.5	.9	.9	2.1	.8	.9
Valerate, %	3.0 ^a	3.7 ^a	3.5 ^a	3.8 ^a	4.4 ^a	2.02 ^b
AC:PR Ratio	1.02	1.33	1.30	1.13	1.00	1.19

^{a,b} Means within a row with differing superscripts are significantly different, $P \leq .05$.

with no consistent effects on other VFA's or carcass or performance characteristics. In addition, ruminal pH and ciliate protozoa concentrations were not affected by Nadiac in the diet.

CHAPTER V

SUMMARY

This study was conducted to observe changes in pH, volatile fatty acid (VFA) and ciliate protozoa concentrations in the rumen, and animal performances and carcass characteristics as steers were consuming whole shelled corn rations with additions of Sodium diacetate (Nadiac) and/or Rumensin. Treatments (tmt) were (1) whole shelled corn + supplement (B), (2) B + 5 gm Nadiac per day, (3) B + 25 gm Nadiac per day, (4) B + 165 mg Rumensin (R) per day, (5) B + R + 5 gm Nadiac and (6) B + R + 25 gm Nadiac. In trials 1, 2 and 3, fifty-four, sixty and eighty-four steers were adapted to and finished with these rations for 84, 97 and 112 day periods, respectively. Ruminal fluid samples were taken on days 0 and 33 for trials one and two, whereas in trial 3 samples were taken on days 0, 16, 30 and 63.

Performance variables for treatments were not different ($p > .05$) in any of the trials. Carcass variables were inconsistent between trials. In trial 1, percent kidney fat was higher ($p < .05$) in treatments 2, 4 and 6. Yield grade values were poorest in treatments 3 and 6. During trial 2 carcass weight was higher ($p < .05$) for treatments 1 and 2. Percent kidney fat was highest ($p < .05$) for tmt 1 (3.4%), and rib-eye area decreased ($p < .05$) with additions of Nadiac and rumensin. During trial 3 carcass fat was higher for treatments 3 and 5 and yield grade tended to be poorest for treatments containing both levels of Nadiac.

In trials 1 and 2 data for ruminal parameters were pooled. Total VFA concentration, molar percent propionate, butyrate, isovalerate and valerate increased significantly ($p < .05$) by day 33, while ruminal pH, molar proportions acetate, isobutyrate and acetate:propionate ratio decreased significantly ($p < .05$). Molar percent propionate increased ($p < .05$) with rumensin in the ration. In trial 3 total VFA concentration tended to increase ($p < .05$) through day 30 and leveled off by day 63. Molar percent acetate and propionate decreased and increased, respectively, through day 63. Molar proportions of butyrate did not change ($p > .05$), while molar proportions of valerate increased ($p < .05$) through day 16 and remained stable. Isovalerate increased on day 16 and isobutyrate decreased by day 63. Ruminal pH ($p < .05$) and protozoa numbers decreased through day 30 and increased by day 63. There were no differences ($p < .05$) between treatments.

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APPENDIX

TABLE A1
COMPOSITION OF TEND-R-LEEN^R BEEF FINISHER
CONCENTRATE PROTEIN SUPPLEMENT

Active Drug Ingredient	
Chlortetracycline.	133.4 g/Ton
Guaranteed Analysis	
Crude Protein (min.)	36.00 %
This includes not more than 12 percent equivalent crude protein from non-protein nitrogen.	
Crude Fat (min.)	1.25 %
Crude Fiber (max.)	12.00 %
Calcium (Ca) (min.)	2.75 %
(Ca) (max.)	3.50 %
Phosphorus (P) (min.)	1.00 %
Iodine (I) (min.)	.00006 %
Salt (NaCl) (min.)	2.00 %
(max.)	3.00 %
Vitamin A (min.)	30,000 USP units/lb.
Vitamin D-3 (min.)	6,000 USP units/lb.

Ingredients

Linseed Meal, Sunflower Seed Meal, Soybean Meal, Cottonseed Meal, Meat and Bone Meal, Dehydrated Alfalfa Meal, Cane Molasses, Wheat Middlings, Brewers Dried Grains, Urea, DiCalcium Phosphate, Salt, Defluorinated Phosphate, Calcium Carbonate, Manganous Sulfate, Iron Sulfate, Copper Oxide, Calcium Iodate, Cobalt Carbonate, Zinc Oxide, Vitamin A Palmitate, D-Activated Animal Sterol, Vitamin E Supplement, Vitamin B-12 Supplement, Riboflavin Supplement, Choline Chloride, Calcium Pantothenate, Folic Acid, Menadione Sodium Bisulfite, Biotin, Pyrodoxine, Thiamine, Niacin, Dried Extracted Streptomyces Meal, Dried Fermentation Solubles, Dried Whey Products, Dried Fermented Corn Extractive, Ethoxyquin (a preservative).

TABLE A2
INGREDIENTS OF CROP CURE

Sodium Diacetate, Dried Whey, Sodium Chloride, Sodium Bentonite, Mineral Oil, Ferrous Sulphate, Manganous Oxide, Cobalt Carbonate, Copper Oxide, Zinc Oxide, Iron Oxide.

Basic Active Material

Sodium Diacetate, Sodium acid acetate; CH_3COONa , CH_3COOH .
White powder, soluble in water, liberating 42.25% available acetic acid.

VITA

Jerry V. Wilhite was born in Bolivar, Tennessee on April 4, 1956. He attended elementary and junior high in that city, and was graduated from Bolivar Central High School in 1974. He then entered the University of Tennessee at Martin, and in August 1978 he received the Bachelor of Science degree in Agriculture. While at Martin, he met and later married Carla Latham of Middleton, Tennessee. In September 1978 he began graduate studies in the Department of Animal Science at the University of Tennessee at Knoxville as a graduate research assistant. In December 1980 he received the Master of Science degree in Animal Science.