AN ABSTRACT OF THE THESIS OF

WESTLEY RALPH PATTON for the Ph. D.
(Name) (Degree)

in ANIMAL SCIENCE presented on Sept 4, 1969
(Major) (Date)

Title: RUMINANT AND MICROBIAL PHYSIO-CHEMICAL RESPONSE TO ABRUPT RATION CHANGES AS INFLUENCED BY CHEMICAL AND/OR BIOLOGICAL MEANS

Abstract approved: Redacted for Privacy
A. T. Ralston

Three trials with wethers and four trials with steers were conducted to determine some of the effects of sodium bicarbonate, calcium hydroxide and/or transfer of ruminal contents on ruminant adjustment to abrupt changes to concentrate rations.

Lambs fed a basal concentrate diet plus sodium bicarbonate had the highest average feed intake, the highest pH and lowest lactic acid level for the first ten days, but went off-feed after buffer removal (Trial I). The lambs receiving buffer plus rumen fluid had the highest overall average feed intake for the trial. Basal fed lambs went off-feed the second day of the trial at which time rumen and urine pH decreased and lactic acid levels increased. Lambs given rumen fluid developed diarrhea, went off-feed, had low rumen pH and total VFA values and elevated lactic acid levels in the rumen. Significant correlations occurred between rumen pH and acetic to propionic acid

($P < .05$) and acetic to butyric ($P < .10$) acid ratios. Also, lactic acid and feed intake were correlated ($P < .05$). A negative correlation ($P < .01$) between rumen pH and lactic acid levels also existed.

Lambs fed buffered rations had the highest average intake, ADG, rumen pH at the second collection and final total VFA levels (Trial II). Lambs given buffer plus rumen fluid and those fed basal rations performed similarly overall, but basal fed lambs went off-feed. A negative correlation ($P < .05$) was found between rumen pH and total VFA. Rumen pH and acetic to propionic acid ($P < .01$) and acetic to butyric ($P < .05$) acid ratios were correlated.

Calcium hydroxide added to the ration reduced feed intake and ADG in Trial III. Calcium hydroxide plus rumen fluid resulted in improved gains and feed efficiency. Average pH at the second collection was increased by this treatment. The sodium bicarbonate group had the highest overall feed intake but rumen pH decreased after buffer withdrawal. Correlations between rumen pH and acetic to propionic were the same as in Trial I.

Steers fed a buffered ration and given rumen fluid had lower rumen pH values, but higher feed intake and ADG than steers fed a buffered ration (Trial IV). Average pH was increased significantly ($P < .05$) in both groups, by the addition of sodium bicarbonate to the ration. The lactic acid level was higher in the buffer plus rumen fluid group. Negative correlations ($P < .05$) in this trial existed between rumen pH and lactic acid and rumen pH and total VFA levels.

There were no significant differences in average feed intake, ADG or average feed conversion in Trial V. Although rumen pH was increased by addition of buffers to the diet both groups went off-feed when the buffers were removed. There were negative correlations ($P < .01$) between rumen pH and total VFA levels and total VFA levels and lactic acid. Also, rumen pH and lactic acid were correlated ($P < .01$).

In Trial VI there were no significant differences in animal performance. Rumen pH in the buffer plus rumen fluid group was higher than that of the basal fed group. Average rumen pH, total VFA levels and acetic to propionic acid ratios were significantly ($P < .01$) lower at the end than at the beginning of the trial for both groups. Rumen pH and acetic to butyric acid ratios were correlated ($P < .01$). Rumen pH and total VFA were negatively correlated ($P < .05$).

The buffer fed group had a higher average intake than the basal fed group in Trial VII. One steer in the basal fed group developed acute indigestion on the second day of the trial. Rumen pH decreased and lactic acid level increased at that time. There were negative correlations ($P < .01$) between rumen pH and lactic acid, between rumen pH and acetic to propionic acid ratios and between lactic acid and total VFA levels.

Ruminant and Microbial Physio-Chemical Response to Abrupt Ration Changes as Influenced by Chemical and/or Biological Means

by

Westley Ralph Patton

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

June 1970

APPROVED:

Redacted for Privacy

Professor of Animal Science
in charge of major

Redacted for Privacy

Head of Department of Animal Science

Redacted for Privacy

Dean of Graduate School

Date thesis is presented September 4, 1969

Typed by Mary Jo Stratton for Westley Ralph Patton

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to the following persons involved in the completion of this project:

Dr. A. T. Ralston, my major professor, for his advice, assistance and guidance throughout this investigation.

Dr. D. C. Church who served on my graduate committee and allowed the use of his laboratory and equipment for necessary analysis.

Dr. P. H. Weswig, Dr. F. L. Hisaw, Jr. and Dr. J. E. Oldfield who capably served on my graduate committee.

My wife, Jane, for her help in sample collection, laboratory analysis, manuscript preparation and her endless encouragement during the course of this study.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	5
High-Energy Rations for Ruminants	5
Microbial Response to Ration Change	7
Acute Indigestion	9
Treatment of Acute Indigestion	12
Prevention of Acute Indigestion	13
Transfer of Ruminal Inoculum	18
EXPERIMENTAL	22
General	22
Trial I	24
Results and Discussion	25
Trial II	36
Results and Discussion	37
Trial III	43
Results and Discussion	44
Trial IV	51
Results and Discussion	52
Trial V	58
Results and Discussion	59
Trial VI	65
Results and Discussion	66
Trial VII	72
Results and Discussion	73
GENERAL RESULTS AND DISCUSSION	81
SUMMARY	85
BIBLIOGRAPHY	90
APPENDIX	97

Table		Page
12	Summary of average rumen pH (lambs).	107
13	Summary of average rumen pH (steers).	108
14	Summary of average total VFA (lambs).	109
15	Summary of average total VFA (steers).	110
16	Summary of average acetic to propionic acid ratios (lambs).	111
17	Summary of average acetic to propionic acid ratios (steers).	112
18	Summary of average acetic to butyric acid ratios (lambs).	113
19	Summary of average acetic to butyric acid ratios (steers).	114
20	Average lactic acid values (steers).	115

LIST OF TABLES

Table		Page
1	Effect of sodium bicarbonate and/or rumen fluid transfer on animal performance in Trial I.	26
2	Effect of sodium bicarbonate and/or rumen fluid transfer on rumen and urine pH in Trial I.	27
3	Effect of sodium bicarbonate and/or rumen fluid transfer on average lactic acid levels in Trial I.	30
4	Effect of sodium bicarbonate and/or rumen fluid transfers on average total VFA levels of rumen fluid in Trial I.	31
5	Effect of sodium bicarbonate and/or rumen fluid transfer on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial I.	34
6	Effect of sodium bicarbonate and/or rumen fluid transfer on animal performance in Trial II.	38
7	Effect of sodium bicarbonate and/or rumen fluid transfer on average rumen pH in Trial II.	39
8	Effect of sodium bicarbonate and/or transfer of rumen fluid on average total VFA levels of rumen fluid in Trial II.	40
9	Ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial II.	42
10	Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfer on animal performance in Trial III.	45

Table		Page
11	Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on average rumen pH in Trial III.	47
12	Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on the average total VFA levels of rumen fluid in Trial III.	49
13	Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial III.	50
14	Effect of sodium bicarbonate and sodium bicarbonate plus transfers of rumen fluid on steer performance in Trial IV.	53
15	Effect of sodium bicarbonate and sodium bicarbonate plus transfers of rumen fluid on average rumen pH in Trial IV.	55
16	Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average lactic acid levels in Trial IV.	55
17	Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average total VFA levels of rumen fluid in Trial IV.	56
18	Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on ratios of acetic to propionic and acetic to butyric acids in Trial IV.	57
19	Effect of sodium bicarbonate and sodium bicarbonate plus transfers of rumen fluid on steer performance in Trial V.	60
20	Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on average rumen pH in Trial V.	61

Table		Page
21	Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on average lactic acid levels in Trial V.	62
22	Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average total VFA levels of rumen fluid in Trial V.	63
23	Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial V.	64
24	Effect of sodium bicarbonate plus rumen fluid on steer performance in Trial VI.	67
25	Effect of sodium bicarbonate plus transfers of rumen fluid on average rumen pH in Trial VI.	68
26	Effect of sodium bicarbonate plus transfers of rumen fluid on average lactic acid values in Trial VI.	69
27	Effect of sodium bicarbonate plus transfers of rumen fluid on average total VFA levels of rumen fluid in Trial VI.	70
28	Effect of sodium bicarbonate plus transfers of rumen fluid on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial VI.	71
29	Effect of sodium bicarbonate on steer performance in Trial VII.	74
30	Effect of sodium bicarbonate on average rumen pH in Trial VII.	75
31	Effect of sodium bicarbonate on average rumen lactic acid levels in Trial VII.	75
32	Effect of sodium bicarbonate on average total VFA levels of rumen fluid in Trial VII.	78

Table		Page
33	Effect of sodium bicarbonate on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial VII.	79

LIST OF APPENDIX TABLES

Table		Page
1	Average daily feed intake in lbs. (lambs).	97
1a	Average daily feed intake in lbs. (steers).	98
2	Effect of sodium bicarbonate and/or rumen fluid transfer on average molar percentages of VFA of rumen fluid in Trial I.	99
3	Effect of sodium bicarbonate and/or transfer of rumen fluid on average molar percentages of VFA of rumen fluid in Trial II.	100
4	Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on the average molar percentages of VFA of rumen fluid in Trial III.	101
5	Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average molar percentages of VFA in rumen fluid in Trial IV.	102
6	Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average molar percentages of VFA in rumen fluid in Trial V.	102
7	Effect of sodium bicarbonate plus transfers of rumen fluid on average molar percentages of VFA in rumen fluid in Trial VI.	103
8	Effect of sodium bicarbonate on average molar percentages of VFA in rumen fluid in Trial VII.	103
9	Correlation coefficients (Trials I - VII).	104
10	Summary of average feed intake in lbs. (lambs).	105
11	Summary of average feed intake in lbs. (steers).	106

RUMINANT AND MICROBIAL PHYSIO-CHEMICAL RESPONSE TO ABRUPT RATION CHANGES AS INFLUENCED BY CHEMICAL AND/OR BIOLOGICAL MEANS

INTRODUCTION

High levels of readily fermentable carbohydrates are generally necessary in the diet to meet the energy requirements for maximum gains in beef cattle and sheep (Tremere, Merrill and Loosli, 1968). Early attempts at feeding all-concentrate rations to ruminants failed (Davenport, 1897; McCandlish, 1923; Huffman, 1928 (as reported by Wise, 1961)). However, more recently the feasibility of feeding all-concentrate rations to steers (Geurin et al., 1959) and lambs (Matrone, Ramsey and Wise, 1957) has been demonstrated. Uhart and Carroll (1967) point out that in practical fattening operations cattle are adapted to a high-energy diet as quickly as possible without forcing them "off-feed." A problem arises in that ruminants (Fraser, 1959) and micro-organisms (Walker, 1968) are slow to adapt to ration changes. If the ration is changed from hay to concentrate too rapidly, acute indigestion (acidosis) develops, concurrent with the animals going "off-feed." Conditions of acidosis reviewed by Hungate (1966) and Church (1969), which could possibly hinder rapid animal and microbial adaptation include: increased rumen lactic acid production, increased rumen acidity, accumulation of the D(-) enantiomorph of lactic acid, histamines and tryamine production and the presence of unidentified toxic factors isolated from rumen microorganisms. Attempts have been made to speed up the adjustment of animals and microorganisms to sudden ration changes. However, the problem still exists and the prescribed method of preventing acute indigestion is to limit the amount of readily available carbohydrate in the ration or to gradually adapt animals to high-energy rations (Church, 1969).

The use of sodium bicarbonate in concentrate diets to prevent acidosis has been reported for steers (Nicholson and Cunningham, 1961), dairy cows (Miller et al., 1965) and lambs (Woolfitt, Howell and Bell, 1964). However, in each of these cases the animals were adjusted to the concentrate ration gradually and the buffer treatment was continued to prevent acidosis as the feeding period advanced. Only limited work (Shelton, Huston and Calhoun, 1969) has been reported using buffers initially to prevent acute indigestion during abrupt ration changes. Results of this work with lambs were inconsistent.

Limited use of calcium hydroxide has shown it to be less palatable to cows than sodium bicarbonate (Thomas and Emery, 1969). The use of various other buffers in ruminant rations has been reported. In addition, supplemental saliva has been added to the rumen of dairy cattle during a 14-day period (Hawkins and Little, 1968). The alkaline buffering capacity of rumen fluid itself has been investigated (Bloomfield et al., 1966).

Transfer of ruminal material from mature animals to young calves has been shown to be beneficial in establishing adult-type micro-organisms in the rumen of calves (Pounden and Hibbs, 1948; Conrad, Hibbs and Frank, 1958; Borhami et al., 1967). Allison, Bucklin and Dougherty (1964) prevented lambs fed wheat via rumen fistulas from getting sick by transferring large quantities of ruminal contents to them from lambs already adapted to wheat. Durham (1967) used small quantities of "sharp frozen" rumen fluid from a fast gaining steer for transfer material, but the procedure used and the preparation technique have been questioned (Thomas, 1968). Commercially prepared cultures lyophilized and embedded in gelatin (Thomas, 1968) have been promoted. However, Hungate (1966) states that, "Even when rumen bacteria are lyophilized under conditions most conducive to survival, a large number of the cells are killed by the process."

Considering the limited amount of work done with buffers at the time of abrupt ration change, and the inconsistency of the results, further work in this area seems feasible. Furthermore, the techniques for transfer of ruminal contents in an attempt to establish a new microbiota have been questioned. Information on the use of buffers in addition to the transfer of ruminal contents is totally absent in the literature. The lack of information in these areas, along with the inconsistent results mentioned above, initiated interest in this investigation.

The objectives of this study were to determine some of the effects of sodium bicarbonate, calcium hydroxide and/or transfer of ruminal contents on ruminant adjustment to concentrate rations, when no period of adaptation was used. Animal performance, rumen pH, urine pH, rumen lactic acid production, volatile fatty acid (VFA) production and VFA ratio changes were studied.

REVIEW OF LITERATURE

A thorough review of the literature on the physio-chemical response of the ruminant and its microorganisms to abrupt ration changes is not available in the literature. Nor has the work concerning biological and chemical alterations of this response been summarized. Therefore, areas pertinent to this investigation will be reviewed here.

High-Energy Rations for Ruminants

High-energy, high-concentrate and all-concentrate are very inclusive terms when used in respect to ruminant rations. The ingredients used and the combinations in which they are used in these kinds of rations are numerous. However, certain characteristics are common. The fiber content of these feedstuffs is low (generally below 12%), the energy, density and palatability are generally high (Morrison, 1954). For example, an all-concentrate ration (90% milo and 10% cottonseed meal) used by Durham (1962) would have contained about 3% crude fiber and 79% total digestible nutrients.

Roughage diets naturally consumed by ruminants differ markedly from the all-concentrate ration mentioned above. On a dry matter basis, roughages are generally higher in fiber and bulk and lower in energy content than concentrates (Morrison, 1954). Attempts to feed high-energy rations have not always been successful. Wise *et al.*

(1967) has reviewed the early but unsuccessful attempts to feed all-concentrate rations. Some of these will be reviewed here. Davenport 1897) fed calves a diet of milk and corn, oats, or bran. These calves did not ruminate, they exhibited insatiable appetites for a short period of time and then showed enlargement and stiffening of the joints, dizziness, impaired locomotion and anorexia. Feeding hay restored normal appetites in the sick calves. Whole milk diets were used by McCandlish (1923) and Huffman (1928) in attempts to raise calves with no roughage. After initial failure the latter worker postulated an acid-base disturbance which he tried to overcome by supplementing the diet with bases. More recently, Geurin (1959) fed rolled barley, adequately supplemented with protein, to steers. Gains were significantly ($P < .05$) greater than when a ground ear corn-based ration was fed. Furthermore, feed efficiency was improved in steers on the barley ration. Wise et al. (1961) and Wise et al. (1965) have demonstrated the feasibility of an all-concentrate diet based on ground shelled corn and urea or soybean oil meal. These workers report average daily gain of about 2.7 pounds per head for several steer finishing trials. In other work, all-concentrate rations based on 74% steam rolled milo resulted in faster gains and increased feed efficiency in steers when compared to a conventional fattening ration based on 50% milo and 24% cottonseed hulls (Pope et al., 1963).

Matrone, Ramsey and Wise (1957) reported greater growth rates in lambs fed a purified diet of glucose and salts of acetic, propionic and butyric acids than in lambs receiving mixtures of either glucose and starch or glucose, starch, and cellulose.

Ralston, Kennick and Davidson (1964) have recommended that high-energy rations be formulated with the fiber content between 5 and 10% for best results for yearlings. Additional information on the effect of all-concentrate rations on finishing beef cattle has been reviewed by Wise *et al*. (1967).

Microbial Response to Ration Change

Investigators have reported various microbial responses to ration changes. Time required for this adjustment has also varied from study to study. Pounden and Hibbs (1948) fed various ratios of good quality alfalfa hay and a grain mixture (four parts of corn, three of oats, one of bran, and one of soybean oil meal) to young calves. Two main groups and four subgroups of bacteria were identified in rumen ingesta. One main group and its subgroups were associated with ingestion of hay and the other with ingestion of grain. The number of protozoa and microflora of the hay varieties were moderate when hay was fed. Massive numbers of protozoa, limited numbers of bacteria of the hay groups, and numerous bacteria of the grain groups were associated with ingestion of equal quantities of hay and grain. Samples from calves fed only grain rations generally contained no protozoa or organisms of the hay groups, but contained massive numbers of grain group organisms.

Maki and Foster (1957) fed dairy cows either a high-roughage diet or no roughage and made microscopic and cultural counts of rumen bacteria. Predominant organisms in cultures were isolated, morphologically characterized and end products were determined on a substrate of glucose. Plate counts from the roughage groups were only 3 to 12% of the microscopic counts, while the concentrate group plate counts were 57 to 73% of microscopic counts. This indicated that the roughage organisms did not grow well on the readily fermentable glucose substrate used, or the substrate lacked other growth requirements.

There was a marked increase in Holotricha sp. and flagellate protozoa in a sheep changed from a hay diet to one of hay plus concentrates (Warner, 1962). The total bacteria count was increased markedly and, in this case, stable levels were reached within ten days after the ration change.

Nilson, Owen and Georgi (1967) made microbial counts on rumen samples from cows fed a) corn silage, b) alfalfa hay, and c) a grain-concentrate mixture. The total number of microorganisms was similar for the three rations fed. Numbers fluctuated in a similar manner with time in the case of all three rations. Presumably, fluctuation in numbers of microorganisms was due to ration changes at the beginning of the trial. Numbers declined from 10^{10} per ml. on day 1 to 10^6 to 10^7 per ml. on day 5, then numbers increased until day 21 when they were near levels of the first day. The authors suggested that the microbial population of the rumen required in excess of three weeks to complete adjustment to abrupt ration changes.

Acute Indigestion

Acute indigestion, resulting in animals going "off-feed" sometimes complicates and prolongs the adjustment of ruminants to sudden ration changes (Reid, Hogan and Briggs, 1957). Hungate *et al*. (1952), Briggs, Hogan and Reid (1957), and Ryan (1964) reported increased lactic acid production and increased acidity in the rumen during acute indigestion. Uhart and Carroll (1967) reported a rumen lactic acid content of 0.10 mM/L. and a pH of 6.98 while steers were fed an alfalfa diet. After sudden change to a concentrate diet lactic levels were 99.96 mM/L. and rumen pH was 4.81. The acid buildup has been attributed to rapid changes in the rumen flora by Fraser (1959) who reported a vast increase in the number of lactic acid producers (*Streptoccocus bovis*) during acute indigestion. As the acidity in the rumen increases *Lactobacilli* sp. multiply and dominate the rumen population (Hungate, 1966). The production of volatile fatty acids also varies during the rumen adjustment. Uhart and Carroll (1967) reported 149 mM/L. of rumen VFA production prior to diet change, 107 mM/L. during the "off-feed" period, and 83 mM/L. after adjustment. Tremere, Merrill and Loosli (1968) and Ryan (1964) reported similar trends.

Acetic to propionic acid ratios widened because of increased acetic and decreased propionic acid concentrations after "off-feed" in dairy heifers fed a ration based on wheat (Tremere, Merrill and Loosli, 1968). Uhart and Carroll (1967) abruptly changed steers to a ration of 45% barley, 45% milo and 10% alfalfa hay and they went "off-feed." In this case the acetic to propionic ratio became narrower after "off-feed." Conversely, when rations were abruptly changed to glucose or ground shelled corn and fed via a rumen fistula to lambs, no differences were found in the rumen molar ratios of VFA (Huber, Mitchell and Little, 1962). Experimentally over-fed ruminants have been shown to have elevated blood lactate and increased acidity (Annison, Lewis and Lindsay, 1959; Dunlop and Hammond, 1965). Fraser (1959), in a review, reported hemoconcentration and a reduction in the alkali reserves of the blood during acute indigestion. This worker also reported dullness and anorexia when rumen pH was 4.5 to 5.0; below a pH of 4.5 there was dullness, anorexia, salivation, and occasional grunting and teeth grinding. Rumen motility ceased, urine pH fell as low as 5.0 and diarrhea contributed to the dehydration of these animals. Development of clinical symptoms may take only 2 to 3 hours or up to 2 to 3 days, while death losses may occur after 6 hours or after several days (Church, 1969).

Factors predisposing acidosis may include less saliva production (Balch, 1959) and failure in some animals to ruminate when fed concentrate rations (Cullison, Campbell and Walker, 1960). The latter workers suggest that failure to ruminate may curtail the recycling of mineral cations in the saliva which, in turn would impair the buffering capacity of the rumen and the activity of the rumen microbes. Saliva aids in maintaining rumen pH within limits that are favorable to normal rumen function (Hawkins and Little, 1968). Turner and Hoggetts (1955) found the buffering capacity of ovine parotid saliva to be maximal at pH 6.8. The buffering capacity of saliva was poor at the pH (8.12) collected and below pH 5. These characteristics may partially explain the slow adaptation of ruminants to concentrate rations while rumen pH is low.

The specific causes of acute indigestion and "off-feed" have not been identified. Dunlop and Hammond (1965), Bond (1959), Ryan (1964), and Turner and Hodgetts (1959) have reported that the slowly metabolized D(-) enantiomorph of lactic acid accumulates in the rumen and plays an important role in causing acute indigestion. Dain, Neal and Dougherty (1955) produced acute indigestion in sheep by feeding wheat or cracked corn via a fistula. Histamine and tryamine were found to be toxic substances in the rumen ingesta. The severity of the sheep's condition was found to be directly correlated with the level of histamine in the ingesta. The histamine level was inversely related to rumen pH, and reached a level of 70 mcg. per ml. below pH 4.5. Sanford (1963) reported elevated histamine levels in experimentally overfed sheep 24 hours after rumen pH decreased to 4.0 to 4.5. He suggested that this time lag might result from a change in ruminal flora brought about by the altered environment.

Mullenax, Keller and Allison (1966) extracted toxins from gram-negative rumen bacteria and injected them into cattle and sheep. This injection resulted in leukopenia, hyperglycemia followed by hypoglycemia, respiratory rate changes, decreased rumen motility, and decreased eructation efficiency. They proposed that endotoxins of the gram-negative rumen bacteria may be absorbed and play a role in certain diet induced diseases.

Allison, Bucklin and Dougherty (1964) found a large accumulation of ethanol and a drop in rumen pH following grain engorgement. Based on previous studies, Hungate (1966) does not feel that the accumulation of alcohol alone would result in the symptoms reported.

Treatment of Acute Indigestion

Jensen and Mackey (1965) suggested that evacuation of the rumen, followed by administration of mineral oil and antiferments may be helpful in the treatment of acute indigestion in early stages of the disease. These workers also advise that restoration of acid base balance can be aided by oral or intravenous administration of sodium bicarbonate. Fraser (1959), a veterinarian, reports that antihistamines may be effective in preventing laminitis if given early, but are useless in acute cases. Furthermore, penicillin or aureomycin given orally at the time of rumen overload inhibited growth of gram-positive organisms and the rumen pH did not drop below 6.2. He proposes that although administration of magnesium hydroxide or sodium bicarbonate solutions may be helpful, a complete electrolyte solution would be more desirable. In contrast with these recommendations Krogh (1960) found that oral administration of sodium bicarbonate solutions worsened the indigestion symptoms in lambs.

Prevention of Acute Indigestion

Church (1969) states that, "prevention of acute indigestion is best accomplished by 1) limiting the amount of readily fermentable carbohydrates in the ration of ruminants or 2) by gradual adaptation to diets containing large amounts of such carbohydrates." Approximately 3 to 4 weeks are required to adapt cattle to high-concentrate rations (Uhart and Carroll, 1967; Tremere, Merrill and Loosli, 1968; Blood and Henderson, 1963) without causing an "off-feed" condition. Only limited work has been done using buffers in high-energy rations in an attempt to shorten or eliminate the adaptation period normally required.

Shelton, Huston and Calhoun (1969) fed lambs a basal ration containing 77% milo supplemented with 1) mixtures of aluminum, magnesium and calcium hydroxides; 2) mixtures of sodium and potassium bicarbonate; 3) calcium hydroxide; or 4) calcium hydroxide for 14 days followed by the basal ration. In a second trial supplementation with sodium bicarbonate alone was used. Only the mixture of bicarbonates (treatment 2) in the first trial improved dry lot performance of lambs in this study.

The addition of buffers to high-energy rations to prevent acute indigestion when a more extensive adaptation period was used has been more thoroughly investigated. Under these conditions, the addition of sodium bicarbonate alone, or in mixtures with other buffers to concentrate rations has given favorable results. Nicholson and Cunningham (1961) added sodium propionate and mixtures of sodium bicarbonate, potassium and calcium carbonates to high-concentrate steer rations at the rate of 2 to 9 pounds per 100 pounds of feed. These buffers partially prevented decreases in gain and feed consumption reported in the control group when hay was removed from the diet. This supported earlier work by Nicholson, Loosli and Warner (1960) who found improved feed consumption and growth in calves on a ration of corn cobs, corn starch, soybean oil meal and urea supplemented with carbonate and bicarbonate salts of calcium, magnesium, sodium, and potassium.

The addition of three percent sodium bicarbonate to barley-based steer rations resulted in a significant ($P < .05$) increase in feed intake (Nicholson, Cunningham and Friend, 1963). Slight but non-significant advantages in average daily gain and dressing percents resulted in significantly ($P < .05$) heavier carcass weight. They also found a slight decrease in total VFA concentration due to the addition of buffers. Acetic acid production was proportionally higher on the control ration than on buffered rations. There was no change in propionic acid concentration, but the acetic to butyric acid ratio was higher in the control group (6.41:1) than in the sodium bicarbonate group (5.64:1). Also, the pH was lower in the rumen of the control animals (6.24 vs 6.70).

A 14 day transition period was used by Wise et al. (1965) to adjust steers and heifers to a ground shelled corn-based concentrate ration with added buffers. Three percent potassium bicarbonate and 2% sodium bicarbonate or 5% sodium bicarbonate replaced 5% of the corn in this ration. Addition of these buffers resulted in a slight increase in feed intake and rate of gain. Another corn ration using different buffers (2.1% potassium carbonate; 2.0% calcium carbonate and 0.5% magnesium sulfate) was used in steer finishing trials by Oltjen and Davis (1963). In contrast to the previously reviewed work, the buffer groups gained less than the controls. Furthermore, cattle consuming buffered rations had significantly ($P < .05$) lower carcass grades and significantly less fat over the rib eye than the cattle on non-buffered rations.

Lassiter, Hamdy and Buranamanas (1963) added 0.5% sodium bicarbonate to the drinking water of steers for the first 21 days of a feeding trial. Steers were fed a pelleted ration of hay and grain. Those receiving sodium bicarbonate almost doubled their intake (8.64 vs 4.66 lbs.) and the anaerobic, aerobic and certain facultative micro-organisms increased rapidly. VFA production increased in the rumen of the steers fed the buffered ration, but declined after removal of the buffer. Rumen pH and the aerobic flora of the genera Bacillus, Micrococcus and Ramibacterium were unaffected by the addition of buffers to the water.

The addition of 1.0 lb. potassium bicarbonate, 0.84 lbs. sodium bicarbonate, or 0.42 lbs. magnesium carbonate to the high-concentrate diet of dairy cows prevented the decline of milk fat which normally occurs when cows are fed grain rations (Miller et al., 1965). These cows fed buffered rations had significantly ($P < .05$) higher molar percentages of acetic acid and significantly ($P < .05$) lower percentages of propionic and valeric acids. However, buffers had no effect on rumen pH. Emery and Brown (1961) also found absence of milk fat depression when sodium or potassium bicarbonates were added to concentrate dairy rations. Nevertheless, in this case, the molar proportions of VFA were not altered, but the rumen pH was elevated by the inclusion of buffers.

Matrone, Ramsey and Wise (1959) added sodium and potassium bicarbonate to purified diets consumed by lambs and reported performance equal to those on control diets. Conversely, purified diets which did not contain bicarbonates of potassium and sodium would not support lamb growth. Five percent sodium bicarbonate in concentrate rations for lambs resulted in increased gains and increased feed efficiency, while carcass quality was unchanged in work reported by Woolfitt, Howell and Bell (1964).

Substitution of a solution of sodium bicarbonate for saliva resulted in weight gains, VFA production and rumen pH of steers similar to that of controls (Hawkins and Little, 1968). The addition of supplemental saliva resulted in similar gains, but decreased VFA concentration and increased rumen pH.

Only limited work has been done with the addition of calcium hydroxide to high-energy rations. Thomas and Emery (1969) reported that calcium hydroxide was not as effective in maintaining milk fat as magnesium oxide when fed in high concentrate rations to dairy cows. Furthermore, calcium hydroxide inhibited voluntary feed intake to a greater extent than did magnesium oxide. Investigations previously mentioned in this review showed no advantage in adding calcium hydroxide to lamb fattening rations (Shelton, Huston and Calhoun, 1969).

Transfer of Ruminal Inoculum

A general review of work in this area has been done by Hungate (1966). Pounden and Hibbs (1948) transferred cud material from mature cattle to the rumens of small calves in an attempt to establish certain microorganisms. Milk intake was limited to encourage the calves to eat hay and grain. Calves were given portions of cud four times between the fifth and twenty-first day of age. In this study, ruminal material helped establish rumen protozoa in calves eating hay alone or both hay and grain. Establishment of some microflora associated with hay ingestion were assisted by transfer of cud material, but those associated with grain ingestion were inhibited. Diarrhea was present in a large number of the calves except those that received hay and milk alone. Later work at the same station by Conrad, Hibbs and Frank (1958) showed that transferring cud material resulted in establishment of rumen protozoa, while untreated calves remained free of protozoa until 16 weeks of age. Treatment also increased in vitro cellulose digestion by rumen microorganisms, increased levels of butyric acid, decreased ruminal propionic acid and increased rumen pH during the first few weeks. More recently, Borhami et al. (1967), working with water buffalo calves, substantiated the effectiveness of transferring rumen contents in establishing rumen protozoa. Calves treated with 100 ml. of rumen fluid from an adult had a thriving mixed population of rumen protozoa within six days while untreated calves took two to four months to develop a similar microfauna. In addition, treated calves had about 0.18 lbs. per day advantage in growth rate, particularly on low planes of nutrition. Rumen VFA and rumen ammonia-N concentrations tended to be higher in the treated calves, but there was no difference in blood urea or blood reducing sugar levels.

Ewan, Hatfield and Garrigus (1958) reported a significantly ($P < .05$) higher nitrogen balance in lambs fed a biuret supplemented ration and receiving 50 to 100 ml. of rumen contents from a sheep previously established on a similar ration. However, no other effects of the transfer of rumen contents were noted.

Allison, Bucklin and Dougherty (1964) fed lambs each 700 gm. of cracked wheat and 1200 gm. of alfalfa pellets through rumen fistulas. Transfer of 1800 to 2000 gm. of ruminal contents from a sheep well adapted to hay plus wheat rations prevented sheep from developing acute indigestion, while untreated sheep developed typical symptoms of this condition. In addition, predominating gram-negative bacteria gave way to a large proportion of gram-positive rods and Streptococci. Proportions of VFA in control and treated sheep remained unchanged while in the sick animal the acetic acid proportion markedly increased. In addition, the sick sheep had ruminal ethanol concentrations that were measurably higher than the control or treated animals.

The use of smaller amounts of rumen contents in transfer work has been reported by Durham, Lopez and Martin (1967) and Durham (1968). In three different trials they placed 600 lb. yearling steers, 450 lb. heifers or old thin cows on a milo-based all-concentrate ration in a six day period. On day one cattle received 1.5% of their body weight in all-concentrate ration. The rate was increased one pound per day until day six when they were fed ad libitum. On day six, half of the cattle in each trial were given 60 gm. of rumen fluid that had been taken from a fast gaining steer adapted to the all-concentrate ration. The rumen fluid had been collected, put in sausage casings, sharp frozen at -10° F, and stored until time of use. There was a significant increase in weight gains and feed efficiency in treated cattle during the first 50 days. No digestive disturbances were reported in any group of cattle, nor were any data reported on physio-chemical changes within the rumen.

The above approach has been criticized by microbiologists such as Thomas (1968) who suggests that freezing kills all of many types of organisms that are necessary for fermentation of concentrate rations. Furthermore, he stated that by waiting until the sixth day to give the rumen fluid boluses the critical period was passed and the animal was probably on its way to recovery. Thomas (1968) obtained rumen culture from steers that had been on high-concentrate feed and cultured certain of these microorganisms in the laboratory. The microbes were then lyophilized, gelatin-coated, and added to 50 to 70% concentrate feeds.

Upon arrival in the feedlot cattle were given 240 grains of aspirin, one and one half grams of Neomycin, and were fed four or five pounds of concentrate feed containing his commercial cultured product, Rumen Life, at the rate of one lb. per 40 head per day. The Rumen Life was discontinued after three days. A seven to nine lb. advantage in treated calves was reported at the end of one week. No comparative feed data, microbial counts, or rumen physio-chemical response was reported.

This review has summarized studies which show conflicting data concerning the effect of buffers on ruminant response to concentrate rations. Varying degrees of success have also been reported when transfer of ruminal contents was used to speed adaptation of ruminants to high concentrate diets. Due to the conflicting data of trials and the lack of information in certain areas it is evident that further investigation is necessary.

EXPERIMENTAL

General

This section will describe transfer, collection, and laboratory procedures used in some or all of the subsequent trials with wethers and steers. In addition, statistical analysis methods will be given.

Rumen fluid that was to be transferred was collected from fistulated donor animals of the same species, except in Trial I, when steer rumen fluid was given to lambs. Donor animals were well adapted to concentrate rations prior to the time of collection of ruminal material for transfer. Rumen fluid was strained through two layers of cheesecloth and transferred to recipient animals immediately after collection. Designated lambs received 100 ml. and steers were given 800 ml. of rumen fluid daily for the first three days after the abrupt change to concentrate diets. The rumen fluid was administered with a dosing syringe.

Rumen fluid samples were collected from treated animals with a stomach tube. A one-quarter inch soft rubber tube was fitted with a brass collection filter and passed through a section of five-eights inch nylon fiber reinforced rubber tubing. The larger tube protected the smaller tube from the animal's teeth. The operator held the lambs between his legs when passing the tube down the animal's throat, while calves were restrained in a squeeze chute during collection.

Suction was applied to the tubing with a stockman's dosing syringe or a 100 cc. syringe.

Approximately 60 to 80 ml. of rumen fluid were collected from each animal at every collection with this apparatus. The fluid was placed in 200 ml. glass containers and the pH was determined within one minute of collection with a Beckman Expanded Scale pH Meter equipped with a glass electrode. A saturated solution of mercuric chloride (0.6 ml. per 30 ml. of rumen fluid) was added to the samples to stop microbial activity.

In the laboratory, the rumen fluid samples were centrifuged in a Serval Enclosed Superspeed centrifuge for ten minutes at 12,500 r.p.m. to separate the large solid material. Five milliliter aliquots of the supernatant were pipetted into test tubes, frozen and stored for lactic acid analysis. Lactic acid levels were determined colorimetrically by the procedure of Umbreit, Burris and Stauffer (1957). Preparation of rumen fluid for VFA analysis was done in the manner described by Erwin, Marco and Emery (1961). The procedure of Kutches, Church and Duryee (1969) was used for VFA analysis.

Statistical analysis of data consisted of analysis of variance of variables using the design for factorial experiments, or that for completely randomized experiments (Ostle, 1956). Treatment means were compared using Duncan's New Multiple Range Test and correlation coefficients were determined for certain of the variables measured

(Li, 1965).

Trial I

The objectives of this trial were twofold. The effects of sodium bicarbonate and/or the transfer of ruminal contents from adjusted animals, on the adaptation of lambs to abrupt ration changes were studied.

Twelve crossbred wether lambs averaging 84 lbs. each were fed pelleted alfalfa hay for seven days, moved to individual metabolism stalls and fed the same diet for an additional 14 days. At the end of this period all groups were immediately changed to a basal diet of 85% barley, 12% alfalfa, 3% molasses, and supplemental limestone. They were alloted to one of the four treatment groups as follows: Group I, basal ration; Group II, 3% sodium bicarbonate; Group III, 100 ml. of rumen fluid daily for three days from a donor animal; Group IV, 3% sodium bicarbonate plus rumen fluid. The trial lasted for 21 days after the abrupt change to the concentrate ration. On the tenth day the buffers were deleted from the diets and all groups were continued on the basal concentrate ration. Rumen pH and urine pH were determined before the ration change (Collection 1), eight hours after ration change (Collection 2), 27 hours after ration change (Collection 3), day nine (Collection 4), day eleven (Collection 5) and at the end of the trial (Collection 6). Urine pH was not measured at

Collection 2. The rumen fluid samples were handled and analyzed according to the procedure described in the previous section. Urine was collected under mineral oil in one gallon glass containers placed under the metabolism stall urinals. The pH was determined soon after collection with the pH meter described previously for determining rumen fluid pH.

Lambs were fed individually and feed was weighed back daily. Water was available to lambs at all times. At the end of the trial all lambs were removed from the metabolism stalls and weighed.

Results and Discussion

Performance data of lambs in this trial is summarized in Table 1 and Appendix Table 1. Average daily feed intake per animal was highest in Group IV (2.26 lbs.), intermediate in Groups I (2.02 lbs.) and II (2.01 lbs.), and lowest in Group III (1.26 lbs.). Animals in the non-treated group (I) consumed approximately 3.3 lbs. of feed per head daily for the first two days of the trial and decreased their intake to about one pound per head on the third day. Two lambs in this group consumed no feed on the fourth day. In addition, all lambs in this group developed diarrhea. Beginning on the fifth day feed intake increased but in an undulating manner. The average weight gain per animal for Group I was 3.3 lbs. for the trial compared to -1.33, -4.00 and 2.67 for Groups II, III and IV, respectively. In Group II

Table I. Effect of sodium bicarbonate and/or rumen fluid transfer on animal performance in Trial I.

Average feed intake for first ten days (lbs. /hd. /day)	Average overall feed intake (lbs. /hd. /day)	Average weight change during trial (lbs.)
	Group I - basal	
1.96	2.02	+3.33
	Group II - $NaHCO_3$	
2.56	2.01	-1.33
	Group III - rumen fluid	
.64	1.26	-4.00
	Group IV - $NaHCO_3$ + rumen fluid	
2.49	2.26	+2.67

(sodium bicarbonate) lambs consumed large quantities of feed without developing acute indigestion until the buffer was removed. The day following the removal of sodium bicarbonate one lamb went off-feed and consumed no more feed during the remainder of the trial. The other lambs in this group decreased their feed intake for two days and then increased daily consumption. This response would indicate that abrupt deletion of sodium bicarbonate resulted in some marked changes in the physio-chemical environment of the rumen as reflected in decreased pH values (Table 2). The lamb that refused feed lost 13.0 lbs. during the trial, causing the average loss in weight for Group II mentioned above. Lambs in Group III (basal plus rumen fluid) were most adversely affected by the rapid change in diet. After an intake of 2.5 to 4.0 lbs. of feed on the first day, the average intake declined to

Table 2. Effect of sodium bicarbonate and/or rumen fluid transfer on rumen and urine pH in Trial I.

Collection 1 (before ration change)		Collection 2 (8 hr after change)	Collection 3 (27 hr after change)		Collection 4 (day 9)		Collection 5 (day 11)		Collection 6 (end of trial)	
Rumen pH	Urine pH	Rumen pH	Rumen pH	Urine pH	Rumen pH	Urine pH	Rumen pH	Urine pH	Rumen pH	Urine pH
				Group I (basal)						
6.31	8.15	6.52	6.00	8.19	6.26	7.13	6.39	7.99	5.79	6.93
				Group II ($NaHCO_3$)						
6.66	8.15	5.97	6.19	8.38	5.60	8.24	5.65	8.15	6.61	5.69
				Group III (rumen fluid)						
6.56	7.93	6.22	5.21	6.83	6.35	7.56	6.17	8.27	6.30	6.34
				Group IV ($NaHCO_3$ + rumen fluid)						
6.24	7.95	6.11	5.96	8.17	5.51	7.70	5.73	8.67	5.86	6.58
				Average						
	8.05[a,b]			7.89[b,c]		7.66[b,c]		8.27[a,b]		6.39[c]

a, b, c, Means in the same bearing a common superscript letter are significantly ($P < .01$) different.

0 to .5 lbs. per head the third day. One lamb refused feed from the fourth day to the end of the trial, while the others in the group slowly resumed eating moderate amounts of feed. The result was a comparatively low average feed intake to ten days (.63 lbs.) and for the trial (1.26 lbs. per head). Furthermore, this group had an average weight loss of 4.0 lbs. during the trial. The weight loss was contributed to by diarrhea which started the second day and lasted for three to four days in most lambs in Group III. A similar condition was reported by Pounden and Hibbs (1948) in calves given cuds from adult cattle.

Group IV lambs, receiving both sodium bicarbonate and rumen fluid consumed a relatively constant amount of feed (2.26 lbs. per head daily) and gained an average of 2.67 lbs. per head during the feeding period. They developed mild diarrhea early in the trial, but apparently were not affected by this condition as shown by their performance. Furthermore, removal of sodium bicarbonate from the ration had no adverse effect.

Lambs that went off-feed during the trial exhibited symptoms typical of acute indigestion reported by Fraser (1959). In addition to anorexia and diarrhea, the sick lambs were lethargic, droopy eared and visibly weak.

Due to individual variations no significant differences in rumen pH were found to result from collection time or type of treatment. However, definite trends can be seen in these data (Table 2). On the day following the ration change rumen pH decreased for all groups. At the third collection average rumen pH was highest (6.19) for lambs receiving the buffered ration and lowest (5.21) for those receiving the transfer of rumen fluid. A low pH of 4.48 was recorded in one extremely sick lamb in Group III. It is noted from Table 2 that the average rumen pH of groups receiving buffer was lower at Collections IV and V than that of the non-buffered groups. This was most likely due to higher consumption by the buffered groups at these periods.

The low average rumen pH in Group III at Collection 3 was accompanied by a low (6.83) average urine pH (Table 2). Average urine pH in all groups on Collection 6 was significantly lower than at Collections 1 and 5 ($P < .01$) and 3 and 4 ($P < .05$).

Lactic acid levels were quite variable within groups, being extremely high in lambs that were off-feed at the time of collection and very low in those that had not become sick. In Table 3 certain trends can be noted for lactic acid levels within treatment groups. The high average lactic acid level (3070 μgm/ml.) for Group I at Collection 3 corresponds to a period when lambs became visibly ill. The low level (8.2 μgm/ml.) at Collection 5 represents a time when the lambs had stabilized their intake and appeared to be doing well. Near the end of the trial the level rose to 2560 μgm/ml. when feed consumption increased.

Group II had a low level of lactic acid until Collection 5, which

Table 3. Effect of sodium bicarbonate and/or rumen fluid transfer on average lactic acid levels in Trial I (in μgm. /ml.)

Collection 1 (before ration change)	Collection 3 (27 hr. after change)	Collection 5 (day 11)	Collection 6 (end of trial)
	Group I - basal		
3.4	3070	8.2	2560
	Group II - $NaHCO_3$		
3.3	9.1	1860	1009
	Group III - rumen fluid		
2.9	2340	10.4	966
	Group IV - $NaHCO_3$ + rumen fluid		
2.6	1040	336	139

was one day following removal of sodium bicarbonate from the ration. At this time the rumen fluid contained an average of 1860 μgm/ml. of lactic acid. Average lactic acid levels for Group III were high (2340 μgm/ml.) at Collection 3 and low (10.4 μgm/ml.) during a low feed intake period at Collection 5. In Group IV the increase in lactic acid level was not so marked at Collection 3 as in Group I and III. None of the lambs in this group went off-feed which would indicate that the chemical and biological treatments may have had an influence on the adjustment of the lambs to the change to concentrate feed.

Average total VFA levels are summarized in Table 4. In Groups I and III the average total VFA level decreased from Collection 1 to Collection 4, increased at Collection 5 and then decreased again at Collection 6. The groups (II and IV) receiving sodium bicarbonate

Table 4. Effect of sodium bicarbonate and/or rumen fluid transfers on average total VFA levels of rumen fluid in Trial I (in μM/ml.).

VFA	Collection 1 (before ration change)	Collection 2 (8 hr. after change)	Collection 3 (27 hr. after change)	Collection 4 (day 9)	Collection 5 (day 11)	Collection 6 (end of trial)
			Group I - basal			
acetic	78.85	49.01	47.71	29.47	44.25	23.00
propionic	21.76	24.81	16.50	21.09	25.65	9.58
butyric	8.10	12.47	12.47	7.48	7.54	4.47
other	1.25	.95	3.24	1.95	1.11	1.90
total	109.95	87.24	77.63	59.99	78.55	38.95
			Group II - $NaHCO_3$			
acetic	65.92	70.28	42.63	48.46	77.16	24.18
propionic	13.55	35.51	18.73	34.53	28.89	7.78
butyric	6.09	16.93	10.31	13.49	13.09	3.18
other	.77	.32	2.59	.82	1.52	1.89
total	86.13	123.04	74.26	97.30	120.66	42.03
			Group III - rumen fluid			
acetic	85.53	44.15	36.13	40.86	64.42	25.19
propionic	19.70	21.18	24.14	19.48	17.92	8.43
butyric	8.57	7.43	7.01	5.93	6.12	6.21
other	1.30	.10	3.59	.54	2.39	3.92
total	115.10	72.86	71.14	66.87	90.85	43.75

Table 4. (continued).

VFA	Collection 1 (before ration change)	Collection 2 (8 hr. after change)	Collection 3 (27 hr. after change)	Collection 4 (day 9)	Collection 5 (day 11)	Collection 6 (end of trial)
			Group IV - $NaHCO_3$ + rumen fluid			
acetic	82.11	76.88	37.32	39.87	53.98	33.58
propionic	18.76	38.19	11.85	5.36	27.90	13.08
butyric	7.41	11.53	8.37	8.88	11.05	10.95
other	1.02	.98	2.10	.87	2.09	3.85
total	108.30	127.58	59.64	54.98	95.02	61.46
			Average total VFA			
	$104.9^{a,b,}$	$102.7^{a,b,}$	$70.7^{b,c,d,e}$	$69.8^{b,c,d,e}$	$96.3^{b,c,d}$	$46.6^{c,e}$

[a, b, c] Means in the same line not bearing a common superscript are significantly ($P < .01$) different.

[d, e] Means in the same line not bearing a common superscript are significantly ($P < .05$) different.

showed an increase at the second collection, a decrease and then an increase before the final low at the last collection. Total VFA levels were significantly lower for all groups at Collection 6 than at Collections 1 and 2 ($P < .01$) and Collection 5 ($P < .05$). This decline in total VFA level cannot be fully explained by the decrease in total VFA reported (Church, 1969) in ruminants changed from roughage to concentrate diets.

Ratios of acetic to propionic and acetic to butyric acids and the molar percentages of VFA appear in Table 5 and Appendix Table 2, respectively. Because of individual variation and small animal numbers no significant changes in VFA ratios or VFA molar percentages could be attributed to chemical treatment or collection time. However, the trend for all groups was a decrease in acetic acid, an increase in propionic and butyric acids and an increase in the sum of valeric, iso-butyric and iso-valeric acids. The ratio of acetic to propionic acid changed from an average for all groups of 4.30:1 at Collection 1 to 2.2:1 at Collection 2 and to 3.48:1 by the end of the trial. The ratios at intermediate collections were quite variable as can be noted in Table 5. Due to extremely low levels of propionic and butyric acids in one animal in Group IV during Collection 4, the average ratios for the group appear large in the tables. Furthermore, the proportion of butyric acid was higher than that of propionic acid resulting in a lower acetic to butyric acid ratio. Acetic to butyric acid

Table 5. Effect of sodium bicarbonate and/or rumen fluid transfer on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial I.

Collection I (before ration change)		Collection 2 (8 hr after change)		Collection 3 (27 hr after change)		Collection 4 (day 9)		Collection 5 (day 11)		Collection 6 (end of trial)	
Acetic/ Propionic	Acetic/ Butyric	Acetic/ Propionic	Acetic/ Butyric	Acetic/ Propionic	Acetic/ Butyric	Acetic/ Propionic	Acetic/ Butyric	Acetic/ Propionic	Acetic/ Butyric	Acetic/ Propionic	Acetic/ Butyric
Group I (basal)											
3.70	10.30	1.88	6.00	3.00	4.97	1.30	3.85	2.25	9.94	2.62	4.42
Group II ($NaHCO_3$)											
4.87	10.68	2.31	6.91	2.94	5.60	1.40	4.65	2.82	6.08	4.04	7.97
Group III (rumen fluid)											
4.15	10.35	2.31	26.00	1.63	5.72	2.09	8.61	3.36	9.80	3.55	6.47
Group IV ($NaHCO_3$ + rumen fluid)											
4.49	11.12	2.30	7.50	3.38	3.97	10.19	6.51	2.93	6.66	3.72	4.00
Average											
4.30	10.60	2.20	11.60	2.74	5.07	3.75	5.91	2.84	8.12	3.48	5.72

ratios changed from an average of 10.60:1 for all groups at the beginning to an average of 5.72:1 at the end of the trial, with fluctuations during the intermediate period. These changes in VFA ratios and molar percentages would tend to indicate that adaptation of the animals and/or the microbial populations to the abrupt ration change had not been completed by the end of the trial.

Appendix Table 9 consists of correlations of variables in this trial. There was a significant ($P < .01$) negative correlation ($r = .74$) between rumen pH and lactic acid level. As the rumen pH decreased the lactic acid level increased. This is in accord with the findings of Allison, Bucklin and Dougherty (1963), who worked with overfed sheep. Rumen pH and acetic to propionic acid ratios were significantly ($P < .05$) negatively correlated ($r = .21$), while the correlation between rumen pH and acetic to butyric acid ratio was significant ($P < .10$) and positive ($r = .20$). These relationships can be explained because the rumen pH decreased when lambs were overfed the concentrate ration and the relative proportion of propionic acid was less than it was in lambs that did not over-eat. Conversely with decreases in rumen pH there was an increase in the relative proportions of butyric acid.

The correlations between lactic acid and total VFA, or urine pH were not statistically significant. There was a significant ($P < .05$) positive correlation ($r = .38$) between lactic acid level and feed intake as would be expected. The regression of lactic acid on total VFA level for Groups I, II, III, and IV, separately, or combined, was not significant.

Trial II

Trial II was designed to reevaluate some treatments used in Trial I under group feeding conditions. In addition, the effect of a higher buffer level was studied in this investigation.

The 12 wether lambs used in Trial I were readjusted to a pelleted alfalfa hay diet for a 30-day period prior to the trial. Lambs were weighed and randomly alloted to four equal treatment groups. All treatment groups were changed with no adaptation period to the basal concentrate ration used in Trial I. Group I received the basal ration only. In addition, Group II received 3% sodium bicarbonate and 100 ml. of rumen fluid given daily for the first three days from a lamb previously adapted to a concentrate ration. Group III received 6% sodium bicarbonate, and Group IV received 3% sodium bicarbonate. The buffers were gradually removed from the rations over a four day period beginning on the eighth day of concentrate feeding. Samples of rumen fluid were collected the day prior to the initial ration change (Collection 1), 27 hours after ration change (Collection 2), and at the end of the trial (Collection 3). Rumen fluid VFA levels and rumen fluid pH were determined on all samples as per the procedure described in the General Experimental Section. Group feed consumption was noted daily and lambs were weighed at the end of the trial.

Results and Discussion

The average daily feed intake, average daily gain (ADG) and group feed conversion (FC) data for this trial appear in Table 6 and Appendix Table 1. Although results of performance characteristics were not significantly different for treatment groups, certain patterns of performance occurred. Lambs receiving 6% sodium bicarbonate in the concentrate ration (Group III) had an average daily intake of 3.31 lbs. for the first ten days and an overall average of 3.30 lbs. per head per day. This group had a slight advantage over all other groups in ADG (0.54 lbs.) and FC (6.13 lbs. of feed per pound of gain). Lambs in Group IV, receiving 3% sodium bicarbonate had the highest feed intake to ten days (3.56 lbs. per head per day), the highest overall average feed intake (3.52 lbs. per head per day), the second highest ADG (.51 lbs.), but were the least efficient (6.90 lbs. of feed per lb. of gain). Groups I (basal) and II (buffer plus rumen fluid) had respective average overall feed intake values of 3.14 and 3.28 lbs., ADG's of 0.48 and 0.48 lbs. and FC figures of 6.54 and 6.83 lbs. of feed per lb. of gain. Average feed intake for the first ten days for Group I was 3.20 lbs. per head per day and for Group II 3.40 lbs. per head per day.

On the day after the ration change lambs in all groups had

Table 6. Effect of sodium bicarbonate and/or rumen fluid transfer on animal performance in Trial II.

Average feed intake for first ten days (lbs. /hd. /day)	Average overall feed intake (lbs. /hd. /day)	ADG (lbs. /hd.)	FC (lbs. feed/lb. gain)
	Group I - basal		
3.20	3.14	.48	6.54
	Group II - 3% $NaHCO_3$ + rumen fluid		
3.40	3.28	.48	6.83
	Group III - 6% $NaHCO_3$		
3.30	3.31	.54	6.13
	Group IV - 3% $NaHCO_3$		
3.65	3.52	.51	6.90

diarrhea. Lambs given 3 and 6% sodium bicarbonate rations had recovered from this condition by the evening of the second day. Individual lambs in the other two groups did not recover for three to five days. Group I decreased their voluntary feed intake on the fourth and fifth days and went off-feed on days six and seven. Additional outward symptoms of acute indigestion including lethargy, drooping ears and visible weakness were evident in sick lambs at this time. However, these lambs recovered rapidly and performed well during the remainder of the trial.

Rumen pH was very similar for all groups while lambs were on an alfalfa pellet diet (Collection 1) (Table 7). At Collection 2 (27 hours after the ration change)lambs receiving 3 or 6% sodium bicarbonate tended to have higher average rumen pH values (6.18 and 6.33, respectively) than Group I fed the basal ration (6.06) or Group II given rumen fluid (5.96).

Table 7. Effect of sodium bicarbonate and/or rumen fluid transfer on average rumen pH in Trial II.

Collection 1 (before ration change)	Collection 2 (27 hr. after change)	Collection 3 (end of trial)
	Group I - basal	
6.61	6.06	6.10
	Group II - 3% $NaHCO_3$ + rumen fluid	
6.62	5.96	6.44
	Group III - 6% $NaHCO_3$	
6.60	6.33	5.93
	Group IV - 3% $NaHCO_3$	
6.76	6.18	5.80

After the buffer was removed from the diet (Collection 3) the rumen pH was 6.10, 6.44, 5.93, and 5.80 for Groups I, II, III, and IV, respectively. Although rumen pH decreased in Group III lambs following the removal of sodium bicarbonate from the ration, the lambs did not go off-feed as in the preceding trial. This was possibly due to the gradual removal of the buffer over a four-day period as opposed to the abrupt change-over in Trial I. It is interesting to note that Group II went from the lowest average rumen pH at Collection 2 (5.96) to the highest at Collection 3 (6.44).

Average total VFA levels in rumen fluid are summarized by group and collection in Table 8. Average total VFA tended to be lower

Table 8. Effect of sodium bicarbonate and/or transfer of rumen fluid on average total VFA levels of rumen fluid in Trial II (in μM/ml.).

VFA	Collection 1 (before ration change)	Collection 2 (27 hr. after change)	Collection 3 (end of trial)
	Group I - basal		
acetic	55.77	52.96	59.73
propionic	22.15	35.22	21.39
butyric	5.10	7.02	12.26
other	1.31	3.07	1.83
total	84.33	98.27	95.21
	Group II - 3% $NaHCO_3$ + rumen fluid		
acetic	57.42	44.06	29.50
propionic	17.72	29.84	21.59
butyric	5.76	7.48	5.52
other	.91	2.19	2.36
total	81.81	83.57	58.97
	Group III - 6% $NaHCO_3$		
acetic	60.80	58.40	64.17
propionic	14.68	34.18	23.06
butyric	7.33	8.18	10.03
other	.59	3.12	5.49
total	83.40	103.88	102.75
	Group IV - 3% $NaHCO_3$		
acetic	67.95	47.48	72.22
propionic	15.22	26.36	40.20
butyric	5.67	5.96	10.98
other	1.56	3.11	5.02
total	90.40	82.91	128.42

at Collection 1 than at Collections 2 and 3 for lambs receiving the basal ration (Group I) and those fed the ration containing 6% sodium bicarbonate (Group III). In lambs receiving both sodium bicarbonate and rumen fluid (Group II) the average total VFA level remained nearly the same until the last collection at which time it decreased to 59.0 μM/ml. of rumen fluid. Total VFA for Group IV was 90.4, 82.9, and 128.4 μM/ml. for Collections 1, 2, and 3, respectively.

The average ratio of acetic to propionic acid tended to decrease in all groups from Collection 1 (3.66:1) to Collection 2 (1.65:1) (Table 9). The average acetic to butyric acid ratio was significantly ($P < .10$) larger at Collection 1 (10.50:1) than at Collection 3 (6.60:1). The general decrease in acetic acid and the increase in propionic and butyric acids can also be observed in the relative changes in molar percentages (Appendix Table 3). Furthermore, there appears to have been an increase in the sum of valeric, iso-butyric and iso-valeric acids (Others) after the lambs were changed to the concentrate ration.

Correlations between certain variables in this trial can be found in Appendix Table 9. The correlation between rumen pH and total VFA level was significant ($P < .05$) and negative ($r = .40$). This is converse to the positive correlation between these two variables found in Trial I. This is explained by the fact that in Trial I the total VFA tended to decrease, increase, and then decrease, while in this trial, with one exception, the level remained relatively constant or

Table 9. Ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial II.

Collection 1 (before ration change)		Collection 2 (27 hr. after change)		Collection 3 (end of trial)	
Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric
		Group I - basal			
3.25	11.63	1.64	8.10	2.97	5.09
		Group II - 3% $NaHCO_3$ + rumen fluid			
3.26	10.09	1.51	6.61	1.41	6.05
		Group III - 6% $NaHCO_3$			
4.20	8.79	1.91	8.76	2.82	6.66
		Group IV - 3% $NaHCO_3$			
3.91	11.48	1.54	10.11	1.94	8.60
		Average of ratios			
3.66	10.05[a]	1.65	8.42[a, b]	2.29	6.60[b]

[a, b]Acetic to butyric acid ratios in the same line not bearing a common superscript letter are significantly ($P < .10$) different.

increased. Furthermore, in Trial I the decrease in rumen pH was associated with the off-feed condition, while in Trial II, with the exception of Group I, it was associated with increased feed consumption and higher total VFA levels. The significant ($P < .01$) correlation ($r = .49$) between rumen pH and acetic to propionic acid ratio is due to the relatively higher proportion of acetic acid produced on the alfalfa diet; a time when the rumen pH was also the highest. The same explanation can be given for the significant ($P < .05$) correlation ($r = .39$) between rumen pH and acetic to butyric acid ratios.

Trial III

Trial III was designed to compare the effect of calcium hydroxide to that of sodium bicarbonate on ruminant adjustment to sudden ration change. Comparisons of these two buffers were to be made separately and in combination with transfer of ruminal material from adapted donor lambs.

Wether lambs used in the previous two trials were readjusted to alfalfa pellets during a 21-day period, weighed, and then randomly alloted to four groups of three animals each. All groups were immediately changed to the basal ration. In addition Group I received 6% sodium bicarbonate, Group II received 6% sodium bicarbonate plus 100 ml. of rumen fluid daily for the first three days of the trial, Group III received 3% calcium hydroxide, and Group IV received 3% calcium hydroxide plus the transfer of rumen fluid. Feed was withheld from all lambs for 28 hours prior to the sudden ration change. Eight hours after the feed was withdrawn the lambs to be given rumen fluid were drenched with 250 ml. of mineral oil to help evacuate the rumen. Eight hours later these lambs were drenched with 60 cc (50 mg. per cc) of Liquamycin to reduce the microbial population in the rumen. At the end of the 28 hour period lambs in all groups were offered their respective rations. Buffers were removed from the rations over a four day period beginning the eighth day of concentrate feeding which lasted a total of 16 days. Rumen fluid samples were collected 36 hours after the ration change (Collection 1), prior to the removal of the buffers (Collection 2), and at the end of the trial (Collection 3). Lambs were weighed at the end of the trial.

Results and Discussion

A summary of animal performance data for Trial III is presented in Table 10 and Appendix Table 1. Group I (6% sodium bicarbonate) had an average daily intake of 2.38 lbs. per head per day for the trial, having consumed an average of 2.00 lbs. per head on each of the first three days of the trial, and an average of 2.40 lbs. for the first ten days. Overall average daily gain was .34 lbs. and feed conversion was 6.26 lbs. of feed per lb. of gain. These lambs began eating well and showed no incidence of off-feed during the feeding

Table 10. Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfer on animal performance in Trial III.

Feed intake day one (lbs./hd.)	Feed intake day two (lbs./hd.)	Feed intake to day ten (lbs./hd.)	Overall feed intake (lbs./hd./day)	ADG (lbs./hd.)	FC (lbs. gain/lb. feed)
		Group I - 6% $NaHCO_3$			
2.00	2.00	2.40	2.38	.34	6.26
		Group II - 6% $NaHCO_3$ + rumen fluid			
2.00	2.00	—*	—*	—*	—*
		Group III - 3% $Ca(OH)_2$			
2.00	0	2.00	2.13	.27	7.89
		Group IV - 3% $Ca(OH)_2$ + rumen fluid			
2.00	0	1.80	2.04	.50	4.08

*All animals in group died.

trial. All lambs in this group developed a mild case of diarrhea which lasted only one day. All lambs in Group II died from pneumonia within three days of the administration of mineral oil. Apparently, some mineral oil entered the lungs during dosing which, in turn, predisposed the disease. Consequently, data on lambs receiving 6% sodium bicarbonate plus transfers of rumen fluid will be missing from this trial. In Group III (calcium hydroxide) lambs did not eat the concentrate feed readily, as they consumed an average of two lbs. per head the first day, but none on the second day, and an average of 2.00 lbs. for the first ten days. This lack of acceptance of feed containing calcium hydroxide agrees with the findings of Thomas and Emery (1969) for dairy cattle. Group III lambs gained less (.27 lbs. per head per day) than the other groups and were the least efficient (7.89 lbs. of feed per lb. of gain). Lambs of Group IV, receiving calcium hydroxide plus transfers of rumen fluid, consumed the same amounts of feed on day one and two as Group III, but only an average of 1.80 lbs. for the first ten days. However, these lambs had an overall ADG of .50 lbs. per head on an average of 2.04 lbs. of feed, which resulted in the most efficient gain (4.08 lbs. of feed per lb. of gain) of the three groups. Although two lambs in this group developed diarrhea the second day of the trial there were no occurrences of acute indigestion.

As in the previous trial lambs receiving sodium bicarbonate (Group I) maintained the highest average rumen pH until after the removal of the buffer from the diet (Table 11). Although the lambs did not develop acute indigestion after the gradual four day deletion of sodium bicarbonate the average rumen pH decreased to 5.10. In the calcium hydroxide group (Group III) the rumen pH decreased from 6.58 at Collection 1 to 5.75 at Collection 2 and finally to 5.39 at the end of the trial. Group IV (calcium hydroxide plus rumen fluid) average rumen pH values were 5.62, 5.83, and 5.42 for Collections 1, 2, and 3, respectively. Even though these pH values are the lowest for any group at each of the collections, the performance of this group was superior (Table 10). It is unfortunate that the lambs in Group II were lost, for a comparison of the two buffers combined with the transfer of rumen fluid would perhaps have been informative.

Table 11. Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on average rumen pH in Trial III.

Collection 1 (36 hr. after ration change)	Collection 2 (day 7)	Collection 3 (end of trial)
	Group I - 6% $NaHCO_3$	
6.47	6.39	5.10
	Group II - 6% $NaHCO_3$ + rumen fluid	
6.56	__*	__*
	Group III - 3% $Ca(OH)_2$	
6.58	5.75	5.39
	Group IV - 3% $Ca(OH)_2$ + rumen fluid	
5.62	5.83	5.42

* All animals in group died.

Average total VFA in rumen fluid is shown in Table 12 for the trial. Group III (calcium hydroxide) had a significantly higher total VFA level than Groups I ($P < .05$) at Collections 1, 2, and 3 and IV ($P < .10$) at Collections 1 and 3. There were no significant differences between total VFA levels of the other two groups, but that of the sodium bicarbonate group tended to be lower throughout the trial. In this trial, as in the preceding study, the total VFA level tended to increase with time in the sodium bicarbonate group. Table 13 and Appendix Table 4 contain acetic to propionic and butyric acid ratios and VFA molar percentages. Unlike the results of Trial II, the average molar percent of acetic acid increased following the removal of sodium bicarbonate from the ration. This was due to an extremely high ratio of acetic to propionic acid in one lamb in the group. The average ratios of acetic to propionic acid were similar for Groups III and IV. They became smaller during the intermediate period than they were at the beginning or the end of the trial. The average acetic to butyric acid ratios for these two groups varied, but tended to increase at the end of the feeding period. The average acetic to butyric acid ratio was significantly ($P < .05$) larger at Collection 3 than at either Collection 1 or 2. Perhaps the removal of the buffers from all three rations following Collection 2 had an influence on this ratio.

Table 12. Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on the average total VFA levels of rumen fluid in Trial III (in μM/ml.).

VFA	Collection 1 (36 hr. after ration change)	Collection 2 (day 7)	Collection 3 (end of trial)
	Group I - 6% $NaHCO_3$		
acetic	34.60	35.89	50.45
propionic	23.98	24.75	21.56
butyric	5.18	6.36	2.41
other	1.84	.93	.58
total	65.60[b]	67.93[b]	75.00[b]
	Group II - 6% $NaHCO_3$ + rumen fluid		
acetic	64.16	—	—
propionic	23.05	—	—
butyric	10.03	—	—
other	1.84	—	—
total	99.08[a, b, c, d]	—	—
	Group III - 3% $Ca(OH)_2$		
acetic	76.73	55.53	59.24
propionic	31.37	32.18	39.38
butyric	12.65	4.22	7.87
other	4.01	3.17	3.18
total	124.76[a, c]	94.90[a]	106.67[a]
	Group IV - 3% $Ca(OH)_2$ + rumen fluid		
acetic	49.76	43.76	34.57
propionic	27.87	40.71	19.84
butyric	10.94	9.22	3.63
other	3.50	3.96	2.17
total	92.02[a, b, d]	97.65[a]	60.21[b]

[a, b]Means in the same column not bearing a common superscript letter are significantly ($P < .05$) different.

[c, d]Means in the same column not bearing a common superscript letter are significantly ($P < .10$) different

Table 13. Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial III.

Collection 1 (36 hr. after ration change)		Collection 2 (day 7)		Collection 3 (end of trial)	
Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric
		Group I - 6% $NaHCO_3$			
1.49	6.98	1.57	5.63	8.44	37.29
		Group II - 6% $NaHCO_3$ + rumen fluid			
2.49	6.66	—	—	—	—
		Group III - 3% $Ca(OH)_2$			
2.71	6.53	1.80	12.07	2.95	14.12
		Group IV - 3% $Ca(OH)_2$ + rumen fluid			
2.23	4.76	1.03	4.79	2.35	10.45
		Average ratio			
2.23	6.23[b]	1.47	5.87[b]	3.44	15.47[a]

[a, b]Acetic to butyric acid ratios in the same line not bearing the same superscript letters are significantly ($P < .05$) different.

In Appendix Table 9 correlation coefficients for certain variables of this trial are listed. There was a significant ($P < .05$) negative correlation ($r = .35$) between rumen pH and acetic to propionic acid ratio as there was in Trial I. Again, this was due to the increase in proportion of acetic acid to propionic acid at the lowest pH recordings. In addition, one lamb in the buffer group had an extremely high ratio of acetic to propionic acids after the removal of the buffer. There was also a significant ($P < .01$) negative correlation ($r = .62$) between rumen pH and acetic to butyric acid ratio, which follows from the above explanation.

Trial IV

Trial IV was conducted to determine the effects of two of the treatments used in the previous lamb studies on the adjustment of beef steers to immediate ration changes.

Eight beef steers averaging 603 lbs. were randomly divided into two groups of four. Both groups were adapted to a pelleted mixture of two-thirds alfalfa hay and one-third grass hay for a three week period prior to the trial. Both groups were then changed to a basal concentrate ration (85% steam rolled barley, 12% alfalfa hay, and 3% molasses) with 6% sodium bicarbonate added. In addition, Group I was drenched with 800 ml. of rumen fluid daily for three days from a steer previously adjusted to a concentrate ration. The buffer was removed from the concentrate ration over a four-day period beginning on the eighth day of the 18-day feeding trial. Steers were group fed twice daily at 7:00 A.M. and 4:00 P.M. Excess feed was weighed back at 10:00 A.M. and 7:00 P.M.

Collection 1 was made the day before the rapid ration change; Collection 2, 36 hours after the change, and Collection 3 at the end of the trial. Samples were collected and analyzed for pH, lactic acid and VFA in the manner described in the General Experimental Section. Steer weight changes were recorded on the last day of the trial.

Results and Discussion

Table 14 and Appendix Table 1a summarize the performance data on each treatment group for Trial IV. Calves in Groups I (buffer plus rumen fluid) and II (buffer) each consumed an average of 8.0 lbs. of concentrate feed the first day of the trial. The second day, Group I consumed a total of 10.5 lbs. and by the third day only 5.5 lbs. were eaten. Calves became inactive and gaunt at this time. Meanwhile, Group II only decreased feed intake slightly from day one to day two (6.87 lbs.) but diarrhea occurred in three of the calves. Feed consumption increased only slightly to 8.5 lbs. per head in this group on the eighth day. Conversely, feed intake of Group I increased very rapidly to 16.25 lbs. per head on day ten. Average feed intake for Group II decreased to 6.06 lbs. per head on the second day of the

Table 14. Effect of sodium bicarbonate and sodium bicarbonate plus transfers of rumen fluid on steer performance in Trial IV.

Feed intake day one (lbs. /hd.)	Feed intake day two (lbs. /hd.)	Feed intake day 9 (lbs. /hd.)	Feed intake day 11 (lbs. /hd.)	Overall feed intake (lbs. /hd. /day)	ADG (lbs. /hd.)	FC (lbs. gain/lb. feed)
Group I - 6% $NaHCO_3$ + rumen fluid						
8.00	2.62	15.63	9.62	10.97	3.02	3.64
Group II - 6% $NaHCO_3$						
8.00	6.87	6.06	10.00	8.44	2.20	3.85

gradual removal of sodium bicarbonate. From this point, feed intake increased rapidly to a high of 16.62 lbs. per head on day 15. Group I's average feed intake decreased to 9.62 lbs. per head on day 11 and then increased to 18.67 lbs. on day 15. On day 16 there was another period of decreased feed consumption for Groups I (13.60 lbs.per head) and II (6.0 lbs. per head). Feed intake was on the increase by the end of the trial for both groups. For the trial, Groups I and II had respective average daily feed intake values of 10.97 and 8.44 lbs., ADG figures of 3.02 and 2.20 lbs., and average feed conversions of 3.64 and 3.85 lbs. of feed per lb. of gain.

Average rumen pH in Group I increased from 6.76 at Collection 1 to 6.95 at the second collection (Table 15). There was a slight decrease at Collection 3 (pH 6.83), but this was still higher than the initial pH. In Group II the pH increased from 6.82 to 7.27 soon after the ration change (Collection 2) and declined to 6.36 after removal of the buffer. The average rumen pH for both groups at Collection 2 was significantly ($P < .05$) higher than at Collections 1 and 3.

The average lactic acid level in Group I increased from 3.8 μgm/ml. of rumen fluid before the ration change to 1030 μgm/ml. at Collection 2 and 28.8 μgm/ml. at Collection 3 (Table 16). The average lactic acid level for Group II was similar (3.6 and 3.7 μgm/ml.) at the first two collections and increased (554 μgm/ml.) after the buffer was removed from the ration.

Table 15. Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on average rumen pH in Trial IV.

Collection 1 (before ration change)	Collection 2 (36 hr. after change)	Collection 3 (end of trial)
	Group I - 6% $NaHCO_3$ + rumen fluid	
6.76	6.95	6.83
	Group II - 6% $NaHCO_3$	
6.82	7.27	6.36
	Average	
6.79^b	7.11^a	6.60^b

[a, b]Means in the same line not bearing a common superscript are significantly ($P < .05$) different.

Table 16. Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average lactic acid levels in Trial IV (in μgm. /ml.).

Collection 1 (before ration change)	Collection 2 (36 hr. after change)	Collection 3 (end of trial)
	Group I - 6% $NaHCO_3$ + rumen fluid	
3.8	1030	28.8
	Group II - 6% $NaHCO_3$	
3.6	3.7	554

A summary of average total VFA levels appears in Table 17. The average total VFA for Group I increased from 49.8 μM/ml. (Collection 1) to 64.0 μM/ml. (Collection 2) and then to 84.6 μM/ml. (Collection 3). In Group II average total VFA for Collections 1, 2 and 3 were 98.6 μM/ml., 44.8 μM/ml., and 107.3 μM/ml., respectively.

Table 17. Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average total VFA levels of rumen fluid in Trial IV (in μM/ml.).

VFA	Collection 1 (before ration change)	Collection 2 (36 hr. after change)	Collection 3 (end of trial)
	Group I - 6% $NaHCO_3$ + rumen fluid		
acetic	32.98	39.14	44.51
propionic	8.82	11.94	20.98
butyric	7.12	11.20	13.84
other	.92	1.70	5.31
total	49.84	63.98	84.64
	Group II - 6% $NaHCO_3$		
acetic	70.46	25.45	61.13
propionic	17.78	10.34	22.67
butyric	8.73	5.82	17.44
others	1.62	3.23	6.01
total	98.59	44.84	107.25

From data in Table 18 (VFA ratios) and Appendix Table 5 (molar percent) it can be seen that there was very little change in the proportions of the VFA in Group I from Collections 1 to 2. By the third collection the proportion of acetic acid had decreased, while the proportions of other VFA increased. There was a greater decrease in acetic acid and a greater increase in other VFA for Group II than

Table 18. Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on ratios of acetic to propionic and acetic to butyric acids in Trial IV.

Collection 1 (before ration change)		Collection 2 (36 hr after change)		Collection 3 (end of trial)	
Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric
Group I - 6% $NaHCO_3$ + rumen fluid					
3.78	4.96	3.97	4.93	2.18	3.34
Group II - 6% $NaHCO_3$					
4.18	20.47	2.89	5.07	3.38	3.53

for Group I at Collection 2.

Correlation coefficients appear in Appendix Table 9 for certain variables in this trial. There was a significant ($P < .05$) negative correlation ($r = .43$) between rumen pH and lactic acid as there had been for Trial I with lambs. In contrast to findings in Trial I, there was a significant ($P < .01$) negative correlation ($r = .68$) between rumen pH and total VFA levels in this trial. The pH levels did not decrease to extremely low levels as some did in Trial I. Rather, in this trial, the decline in levels was associated with intake of the concentrate ration and not with the off-feed condition as it was with the lambs.

Trial V

Trial V was carried out in the same manner as Trial IV, except that the treatments and Groups were reversed. Also, a different basal concentrate ration was used and feed was limited for the first three days of the trial. This provided a means for determining the effectiveness of a brief period of feed restriction in preventing the initial decrease in feed intake noted in Trial IV.

Both groups were reestablished on the pelleted hay mixture described in the preceding trial during a 21-day period. Then both groups were changed immediately to a basal concentrate ration (73% steam rolled barley, 10% beet pulp, 7% alfalfa hay, and 3% cottonseed oil meal) plus 6% sodium bicarbonate. In addition, Group I received three daily doses of 800 ml. of rumen fluid. Initial feed intake was limited to 8, 10, and 12 lbs. per head per day, respectively, for days one, two, and three of the concentrate feeding period. During the remainder of the trial the ration was fed in excess and weighed back twice daily as in Trial IV.

Sodium bicarbonate was withdrawn from the ration over a four-day period beginning on the eighth day of the trial. Rumen fluid was collected one day before the trial (Collection 1), on day two (Collection 2), on day seven (Collection 3), and on day 17 (Collection 4). Rumen fluid pH, lactic acid level and VFA level were determined as described in the General Experimental Section.

Results and Discussion

Average daily feed intake for Groups I (buffer plus rumen fluid) and II (buffer) was 6.00 lbs. for days one and two which was less than the alloted amount. Then both groups gradually increased their intake to 12.50 lbs. per head and 12.16 lbs. per head, respectively, on day nine (Table 19 and Appendix Table 1a). Both groups refused feed on days 10, 11, and 12. Many of the calves developed diarrhea, became lethargic, droopy eared and very gaunt. An average of 6.00 lbs. per head of feed was consumed for calves in both groups on day 13 and then average feed intake increased to 14.00 lbs. per head by the end of the

Table 19. Effect of sodium bicarbonate and sodium bicarbonate plus transfers of rumen fluid on steer performance in Trial V.

Feed intake day one (lbs. /hd.)	Feed intake day two (lbs. /hd.)	Average feed intake to day nine (lbs. /hd. /day)	Overall feed intake (lbs. /hd. /day)	ADG (lbs. /hd.)	FC (lbs. gain/lb. feed)
		Group I - 6% HCO_3 + rumen fluid			
6.00	6.00	12.50	9.74	2.03	5.09
		Group II - 6% $NaHCO_3$			
6.00	6.00	12.16	9.59	2.10	4.87

trial. Due to the off-feed period overall average daily feed consumption was low for both Groups I (9.74 lbs.) and II (9.59 lbs.). Average daily gain and average feed conversion were 2.03 lbs. and 5.09 lbs., and 2.10 lbs. and 4.87 lbs. for Groups I and II, respectively.

Average rumen pH values are given by treatment and collection period in Table 20. The average pH of rumen fluid was significantly ($P < .01$) higher in Collection 2 (7.30) than for any of the other collection periods. Rumen pH values at Collection 1 for Group I were significantly lower than at Collections 2 ($P < .01$) and 3 ($P < .05$). Rumen pH of Group 2 at Collection 2 was significantly higher than values for Group I, Collection 2, and Group II, Collection 3 ($P < .05$), and also higher than for all other groups ($P < .01$). Final average rumen pH values for Groups I and II were 6.72 and 6.58, respectively.

Table 20. Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on average rumen pH in Trial V.

Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (day 17)
	Group I - 6% $NaHCO_3$ + rumen fluid		
$6.39^{b,d}$	$7.07^{a,c}$	$6.87^{b,c}$	$6.72^{b,c,d}$
	Group II - 6% $NaHCO_3$		
6.71^{b}	$7.52^{a,c}$	$7.05^{a,b}$	6.58^{b}
	Average		
6.55^{c}	7.30^{a}	6.96^{b}	6.65^{b}

a, b Means in the same line not bearing a common superscript are significantly ($P < .01$) different.

c, d Means in the same line not bearing a common superscript are significantly ($P < .05$) different.

There were no significant differences in lactic acid levels between the two treatment groups (Table 21). However, Group II levels tended to be higher during the concentrate feeding period than levels in Group I.

Table 21. Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on average lactic acid levels in Trial V (in μ gm. /ml.).

Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (day 17)
	Group I - 6% $NaHCO_3$ + rumen fluid		
16.3	7.0	14.8	3.7
	Group II - 6% $NaHCO_3$		
9.0	17.8	20.6	4.5

Average total VFA levels for both treatment groups were significantly ($P < .01$) greater at Collections 1, 3, and 4 than at Collection 2 (Table 22). The low level (33.3 μM/ml.) recorded for Group II at Collection 2 was due to the extremely low total VFA level of one animal.

The average ratio of acetic to propionic acid in Group I (buffer plus rumen fluid) remained about the same (4.12:1 and 4.10:1) at the first two collection periods and tended to decline at Collections 3 (3.32:1) and 4 (3.18:1) (Table 23 and Appendix Table 6). In Group II the ratio decreased to 2.91:1 at Collection 2, increased to 5.00:1 at the third collection and decreased to 2.41:1 at the end of the trial.

Table 22. Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average total VFA levels of rumen fluid in Trial V (in µM/ml.).

VFA	Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (day 17)
	Group I - 6% $NaHCO_3$ + rumen fluid			
acetic	75.11	30.22	60.62	73.79
propionic	18.40	7.36	15.87	19.89
butyric	10.56	14.02	11.14	12.28
other	1.44	2.18	4.16	3.51
total	105.51	53.78	81.79	109.77
	Group II - 6% $NaHCO_3$			
acetic	69.72	20.49	58.82	53.99
propionic	16.08	7.21	23.69	22.58
butyric	8.16	4.29	14.30	8.24
other	1.21	1.32	5.06	4.21
total	95.17	33.31	101.87	89.02
	Average			
	100.3[a]	43.6[b]	91.8[a]	99.4[a]

[a, b]Means in the same line not bearing a common superscript are significantly ($P < .01$) different.

Table 23. Effect of sodium bicarbonate or sodium bicarbonate plus transfers of rumen fluid on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial V.

Collection 1		Collection 2		Collection 3		Collection 4	
Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric
			Group I - 6% $NaHCO_3$ + rumen fluid				
4.12	$7.23^{a,b,c}$	4.10	$2.98^{b,d}$	3.32	$5.48^{a,b,c}$	3.18	$5.09^{a,b,c,d}$
			Group II - 6% $NaHCO_3$				
4.34	8.73	2.91	4.89	5.00	5.07	2.41	6.78
			Average				
	7.98^{a}		3.94^{b}		5.28^{b}		$5.94^{a,b}$

^{a,b}Means in the same line not bearing a common superscript letter are significantly ($P < .01$) different.

^{c,d}Means in the same line not bearing a common superscript letter are significantly ($P < .05$) different.

The average acetic to butyric acid ratio for Collection 1 (7.98:1) was significantly larger ($P < .01$) than for Collections 2 (3.94:1) or 3 (5.28:1). The acetic to butyric acid ratio was significantly ($P < .01$) higher in Group I, Collection 1, than in Group I, Collection 2. The ratio in Group I, Collection 3 was significantly ($P < .05$) higher than Group I, Collection 2.

There was a significant ($P < .01$) negative correlation ($r = .63$) between rumen pH and average total VFA level in this trial as in Trial IV (Appendix Table 9). This was due to the decrease in average total VFA at Collection 2, a time when the rumen pH was elevated. Similarly, the lactic acid level was generally the highest during this period of high rumen pH resulting in a significant ($P < .01$) positive correlation ($r = .49$) between rumen pH and lactic acid. The significant ($P < .01$) negative correlation ($r = -.58$) between average total VFA and lactic acid level logically follows the above two relationships mentioned.

Trial VI

The two previously conducted trials were designed to compare physio-chemical responses of steers to two different treatments. The trial reported here was designed to compare the influence of one of these treatments with that of no treatment on the adjustment of ruminants to rapid ration changes.

The steers (Groups I and II) used in Trial V were fed a pelleted hay ration for a 17-day period prior to Trial VI. All steers were immediately changed to the basal concentrate ration. In addition, Group II received 6% sodium bicarbonate and 800 ml. of rumen fluid daily for three days. Feed intake was limited to 10 and 12 lbs. per head for the first two days of the 20 day feeding trial. Steers were group fed at 7:00 A.M. and 4:00 P.M. Feed remaining was weighed back at 10:00 A.M. and 7:00 P.M.

Collections of rumen fluid were made one day before the ration change (Collection 1), on day two (Collection 2), day seven (Collection 3), and at the end of the trial (Collection 4). The analyses of rumen pH, lactic acid, and VFA were carried out according to the procedures found in the General Experimental Section. Steers were individually weighed at the beginning and conclusion of the trial.

Results and Discussion

Each animal in Group I and II consumed 6.75 lbs. of feed on the first day (Table 24 and Appendix Table 1a). On day two Group I consumed an average of 9.50 lbs. of feed per head compared to 8.00 lbs. per head for Group II. One steer in Group II was injured while being stomach tubed at Collection 2 and was removed from the trial on day three. Steers in Group I consumed an average of 21.00 lbs. per head on day four and declined to 11.25 lbs. per head on day six after

Table 24. Effect of sodium bicarbonate plus rumen fluid on steer performance in Trial VI.

Feed intake day one (lb. /hd.)	Feed intake day two (lb. /hd.)	Feed intake day ten (lb. /hd.)	Overall feed intake (lb. /hd. /day)	ADG (lbs. /hd.)	FC (lbs. gain/lb. feed)
			Group I - basal		
6.75	9.50	23.00	18.72	2.86	6.55
			Group II - 6% $NaHCO_3$ + rumen fluid		
6.75	8.00	24.00	18.67	2.82	6.62

which there was a relatively steady increase in feed consumption to the end of the trial. No steers in this group went off-feed and the decrease in average rumen pH was no greater than in Group II (Table 25). Intake of steers in Group II increased steadily to day 13 (27.67 lbs. per head), but decreased to approximately 11.00 lbs. per head daily on days 14 and 15. From day 16 to the end of the trial Group II's feed intake rose.

Table 25. Effect of sodium bicarbonate plus transfers of rumen fluid on average rumen pH in Trial VI.

Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (end of trial)
	Group I - basal		
6.90	6.56	6.55	6.59
	Group II - 6% $NaHCO_3$ + rumen fluid		
6.93	7.07	6.65	6.54
	Average		
6.92^{a}	$6.82^{a,b}$	$6.60^{a,b}$	6.56^{b}

^{a,b}Means in the same line not bearing a common superscript letter are significantly ($P < .01$) different.

Average rumen pH decreased somewhat in Group I from Collection 1 (6.90) to Collection 2 (6.56). Values were relatively stable for the remainder of the trial (Table 25). In Group II, the average rumen pH increased from 6.93 for Collection 1 to 7.07 for Collection 2. Values were similar to those of Group I for the subsequent collections. Average rumen pH for Collection 1 was significantly ($P < .01$) higher than for Collection 4.

Although no extremely high levels of lactic acid were detected the average level for Group I, Collection 3, was significantly ($P < .05$) higher than for Group II, Collection 1, in this trial (Table 26). Furthermore, average lactic acid levels in the basal group (I) tended to be higher throughout the trial than were Group II levels.

Table 26. Effect of sodium bicarbonate plus transfers of rumen fluid on average lactic acid values in Trial VI (in µgm. /ml.).

Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (end of trial)
	Group I - basal		
$5.6^{a,b}$	$8.4^{a,b}$	9.9^{a}	11.5^{a}
	Group II - 6% $NaHCO_3$ + rumen fluid		
3.3^{b}	$5.0^{a,b}$	$5.4^{a,b}$	$7.5^{a,b}$

[a, b]Means in the same line not bearing a common superscript letter are significantly ($P < .05$) different.

The average total VFA level in this trial was significantly ($P < .01$) higher at Collection 1 than at Collections 2, 3, or 4 (Table 27). The trend for both groups was a decline at Collection 2, an increase in level at Collection 3, and a slight decrease at the end of the trial.

The average acetic to propionic acid ratio was significantly ($P < .01$) greater for Collection 1 than for all other collections (Table 28; Appendix Table 7). This is the expected situation when animals are

Table 27. Effect of sodium bicarbonate plus transfers of rumen fluid on average total VFA levels of rumen fluid in Trial VI (in μM/ml.).

VFA	Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (end of trial)
		Group I - basal		
acetic	75.84	46.27	45.69	45.16
propionic	18.49	17.17	20.86	21.93
butyric	9.85	9.87	13.04	9.82
other	1.58	1.53	3.80	5.05
total	105.76	74.84	83.39	81.96
		Group II - 6% $NaHCO_3$ + rumen fluid		
acetic	73.85	36.79	58.87	49.35
propionic	17.69	12.81	29.67	24.53
butyric	4.12	7.94	11.27	14.68
other	.99	.73	2.26	3.13
total	101.65	58.27	102.07	91.69
		Average		
	103.7[a]	66.6[b]	92.7[b]	86.8[b]

[a, b]Means in the same line not bearing a common superscript letter are significantly ($P < .01$) different.

Table 28. Effect of sodium bicarbonate plus transfers of rumen fluid on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial VI.

Collection 1 (before ration change)		Collection 2 (day 2)		Collection 3 (day 7)		Collection 4 (end of trial)	
Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric
Group I - basal							
4.25	7.81	2.71	4.89	2.21	4.12	2.62	4.96
Group II - 6% $NaHCO_3$ + rumen fluid							
4.29	8.69	2.84	4.64	2.05	5.13	2.01	4.19
Average ratios							
4.27[a]	8.25[c]	2.78[b]	4.77[d]	2.13[b]	4.63[d]	2.32[b]	4.58[d]

[a, b] Acetic to propionic acid ratio means in the same line not bearing a common superscript letter are significantly ($P < .01$) different.

[c, d] Acetic to butyric acid ratio means in the same line not bearing a common superscript letter are significantly ($P < .01$) different.

changed from a roughage to a concentrate ration. The average proportions of VFA changed in a similar manner for both treatment groups during the trial. The pattern for change in acetic to butyric acid ratio followed that of acetic to propionic acids, being significantly ($P < .01$) greater at Collection 1 than at Collections 2, 3, and 4.

There was a significant ($P < .01$) correlation ($r = .55$) between rumen pH and acetic to butyric acid ratios in this trial (Appendix Table 9). With the exception of Group II, Collection 2, the average rumen pH declined and the relative proportion of butyric acid increased with the change in feed. As the trial progressed the average rumen pH decreased and the average level of total VFA increased resulting in a significant ($P < .05$) negative correlation ($r = -.36$) between these two variables.

Trial VII

Trial VII, the counterpart of the previous trial, was designed to compare the influence of sodium bicarbonate with that of no treatment on ruminant adjustment to abrupt ration changes.

Six steers from Trial VI were fed alfalfa-grass hay pellets for 18 days prior to the trial, and then changed immediately to the basal concentrate ration used in the preceding trial. In addition, Group I received 6% sodium bicarbonate in the diet.

Feed intake was not initially limited as it had been in Trials V and VI. Animals were fed twice daily (7:00 A.M. and 4:00 P.M.) and feed was weighed back after three hours (10:00 A.M. and 7:00 P.M.). Rumen fluid was collected prior to the ration change (Collection 1), on day two (Collection 2), on day seven (Collection 3), and at the end of the 18-day trial (Collection 4). Analysis of rumen fluid samples for pH, VFA levels, and lactic levels was handled in the manner described in the General Experimental Section. Steers were weighed at the beginning and end of the feeding trial.

Results and Discussion

Feed intake varied between treatment groups in this trial (Table 29; Appendix Table 1a). Group I (buffer) consumed an average of 17.83 lbs. per head on day one compared to 24.33 lbs. per head for Group II (basal). On day two (Collection 2) steers in Group I consumed an average of 23.33 lbs. per head, but Group II steers only consumed a total of 5 lbs. Rumen pH decreased to 4.98 in one animal in this group at Collection 2 (Table 30), and the average lactic acid level increased (Table 31). All steers in Group II had diarrhea on the second day. This condition lasted for approximately four days. The steer with the low rumen pH, mentioned above, was lethargic, gaunt, droopy eared and unwilling to eat for about three days. Average feed intake for Group II increased gradually to 20.00 lbs. at day ten and was the same as that of Group I (26.67 lbs. per head daily) by the end of the

Table 29. Effect of sodium bicarbonate on steer performance in Trial VII.

Feed intake day one (lbs./hd.)	Feed intake day two (lbs./hd.)	Feed intake day ten (lbs./hd.)	Overall feed intake (lbs./hd./day)	ADG (lbs./hd.)	FC (lbs. gain / lb. feed)
			Group I - 6% $NaHCO_3$		
17.83	23.33	27.00	24.68	2.75	5.71
			Group II - basal		
24.33	1.67	20.00	20.24	2.45	5.26

Table 30. Effect of sodium bicarbonate on average rumen pH in Trial VII.

Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (end of trial)
	Group I - 6% $NaHCO_3$		
6.45	6.19	5.98	6.68
	Group II - basal		
6.82	6.09	5.89	6.63

Table 31. Effect of sodium bicarbonate on average rumen lactic acid levels in Trial VII (in µgm. /ml.).

Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (end of trial)
	Group I - 6% $NaHCO_3$		
5.4	4.2	10.5	6.0
	Group II - basal		
3.8	1320	23.1	8.0

trial. After a decrease of feed intake to 11.33 lbs. on day four, Group I increased consumption rapidly to 27.00 lbs. on day ten. There was only a slight decrease in feed intake when the buffer was removed from the ration. None of the calves in this group went off-feed or developed diarrhea either initially or when the buffer was withdrawn. Animals were not as adversely affected by buffer withdrawal when an eight day period was used as they had been in earlier trials when a shorter period was used. Average daily gain for the trial was 2.75 lbs. (Group I) and 2.45 lbs. (Group II). The steers fed the basal diet tended to be slightly more efficient (5.26 vs 5.71 lbs. of feed per lb. of gain) than those receiving buffer.

The average rumen pH of the sodium bicarbonate group for Collection 1 was 6.45; for Collection 2, 6.19; for Collection 3, 5.98; and for Collection 4, 6.68 (Table 30). In Group II the average rumen pH for Collection 2 was lower (6.09) than in Group I. At that time, two of the steers were off-feed. The pH values for the sick animals were 4.98 and 6.97. The latter sample was composed mostly of saliva which explains the high pH value. Average rumen pH values were significantly ($P < .05$) less at Collection 3 than at Collection 1 for both groups. Values tended to increase in each case at the final collection.

Although differences in average lactic acid levels were not significant, values tended to be higher in the basal fed group (II)

(Table 31). The level reached 1320 μgm/ml. of rumen fluid at the second collection.

Average total VFA levels of rumen fluid for this trial are given in Table 32. For Group I levels increased from 108.8 μM/ml. at Collection 1 to 114.4 μM/ml. at the second collection; by the end of the trial levels had decreased to 86.27 μM/ml. The basal group (II) responded somewhat differently during this trial. The average total VFA level decreased to 46.7 μM/ml. at Collection 2, increased to 99.5 μM/ml. at the third collection, and was 89.4 μM/ml. by the last day of the trial. The low level at the second collection for Group II agrees with the results found in Trial VI.

The average acetic to propionic acid ratio was significantly ($P < .05$) greater at Collection 1 than at Collections 2 and 4 (Table 33; Appendix Table 8). The same trend was demonstrated with respect to the average acetic to butyric acid ratios. It is interesting to note that the ratios did not decrease as much in Group II at Collection 2 as they did in Group I. This was also the trend in previous trials when animals were at low-intake or off-feed conditions.

Correlation coefficients of variables in this trial are in Appendix Table 9. In agreement with results of foregoing trials, there was a significant ($P < .01$) negative correlation ($r = \ .58$) between rumen pH and lactic acid. Again, in this trial, the low pH values on day two corresponded to elevated levels of lactic acid. As noted above, the

Table 32. Effect of sodium bicarbonate on average total VFA levels of rumen fluid in Trial VII (in μM/ml.).

VFA	Collection 1 (before ration change)	Collection 2 (day 2)	Collection 3 (day 7)	Collection 4 (end of trial)
		Group I - 6% $NaHCO_3$		
acetic	70.65	57.85	61.08	47.51
propionic	23.40	33.16	20.57	25.51
butyric	11.72	17.54	11.99	9.28
other	2.26	2.80	3.91	3.97
total	108.03	114.35	97.55	86.27
		Group II - basal		
acetic	38.53	26.88	58.99	51.53
propionic	13.28	11.14	23.11	22.06
butyric	5.84	6.44	13.73	12.25
other	.92	2.22	3.65	3.58
total	58.57	46.68	99.48	89.42

Table 33. Effect of sodium bicarbonate on ratios of acetic to propionic and acetic to butyric acids in rumen fluid in Trial VII.

Collection 1		Collection 2		Collection 3		Collection 4	
Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric	Acetic/ propionic	Acetic/ butyric
Group I - 6% $NaHCO_3$							
3.05	6.05	1.80	3.31	3.00	5.24	1.91	5.16
Group II - basal							
2.87	6.50	2.61	5.27	2.65	4.40	2.38	4.18
Average ratio							
2.96[a]	6.26	2.20[b]	4.29	2.83[a,b]	4.83	2.16[b]	4.67

[a,b] Acetic to propionic acid ratio means on the same line not bearing a common superscript letter are significantly ($P < .01$) different.

ratios of acetic to propionic acids decreased at Collections 2 and 4. There was a corresponding increase in pH levels at the final collection which resulted in a significant ($P < .01$) negative correlation ($r = .58$) between rumen pH and acetic to propionic acid ratios.

There was a significant ($P < .01$) negative correlation ($r = .57$) between average lactic acid level and average total VFA level. A similar relationship occurred in preceding trials and was attributed to the low average total VFA levels and high lactic acid values at the second collection, particularly in animals that were off-feed.

GENERAL RESULTS AND DISCUSSION

A comparative compilation of data for this investigation appears in Appendix Tables 10 through 20. Trends for all treatments for all groups for all trials appear there.

Abrupt change from roughage to concentrate diets caused some lambs (Trials I and II) and steers (Trial VII) to go off-feed for a period of three to five days. In addition to feed refusal, individuals developed diarrhea, became gaunt, lethargic, and droopy eared. This was accompanied by a decrease in rumen pH, increased lactic acid levels, and generally a decline in total VFA levels. Feed intake in basal fed groups was lower than in animals fed sodium bicarbonate supplemented rations for the first ten days of lamb and steer trials and for the entire trial with steers.

Rapid removal of sodium bicarbonate from the ration (Trials I, IV, and V) resulted in feed refusal or decreased feed intake, while longer periods of buffer withdrawal had no adverse effects on performance (Trials, II, III, VI, and VII). In each case, addition of buffers alone to basal rations resulted in a higher rumen pH at the second collection. Generally, the addition of buffers prevented the decrease in proportion of acetic acid in rumen fluid normally found when concentrates are fed. In trials comparing effects of buffered and non-buffered rations the lactic acid levels were lower in animals fed buffered rations. The exact mode of action of the buffers in this study is unknown, but the effects were measurable.

The transfer of ruminal fluid in Trial I resulted in diarrhea, off-feed, low rumen and urine pH, and poor performance, while groups in Trials I, II, III, and IV which were given rumen fluid in addition to buffers performed well. In most cases, the rumen pH, initial feed intake, and average total VFA levels were lower than in straight buffer groups, while lactic acid levels were higher. However, gain and overall feed intake were generally greater for those receiving both treatments.

The addition of calcium hydroxide alone to the basal ration in Trial III resulted in less feed consumption, lower ADG and less efficient feed utilization than when sodium bicarbonate was added to the feed. The combination of ruminal fluid transfer and calcium hydroxide resulted in quite favorable performance in lambs.

Animals used in these trials, which had been subjected to repeated stress, would have been expected to have performed poorly and produced low quality carcasses. However, the ADG in the final lamb trial (III) indicated the good performance of these animals. Although no carcass data were available on the lambs, the steer carcasses were trim, exhibited high degrees of marbling, and were generally of high quality.

Certain conditions arise in almost every investigation which are not anticipated at the onset. Explanation of these conditions sometimes aids future research in the area.

The times set for collection of rumen fluid in this study were the same for each animal in the trial. The decrease in rumen and urine pH and off-feed conditions undoubtedly did not occur at the same time for all individuals in a group. Consequently, the levels of substances (e.g. lactic acid) measured were quite variable within group at any given collection. Sampling at the time of off-feed in each individual animal was not possible in this study, but for future work an arrangement of this type is suggested.

The shortcomings of collecting rumen fluid by stomach tube have been reported (Turner and Hodgetts, 1955). The fact that saliva sometimes dilutes the sample and that the tube does not always reach the same area of the rumen was accepted at the onset. Fistulation of the number of animals used in this investigation was not feasible, but with smaller numbers this alternative would be preferred.

Analysis of rumen fluid samples for VFA was a very time consuming portion of the project. In future work, if large numbers of animals are used, perhaps reliance on lactic acid levels and rumen pH would be a sufficient measure of rumen conditions, leaving time for more extensive work in other areas.

A comparison of the effects of a gradual adaptation period on animal adjustment to those of the chemical and/or biological treatments was not done in this study because of limited animal numbers.

This type of comparison would readily lend itself to larger numbers of animals in a feedlot situation, where the economic value of each treatment could also be evaluated.

With the exception of work with blood the investigation, during acute indigestion, of portions of the animal body other than the rumen has not been thorough. The effects of products of rumen fermentation during such a period on the lower digestive tract have not been extensively studied. Future research in such an area may prove extremely fruitful.

Microbial response to chemical and/or biological treatments was not studied in this work. Subsequent progress in the area of rumen fluid transfer will most certainly include a more thorough understanding of microorganism adjustment to extrinsic factors.

SUMMARY

The objectives of this investigation were to determine the influence of sodium bicarbonate, calcium hydroxide, and/or the transfer of ruminal contents on ruminant adjustment to abrupt changes to concentrate rations. Animal performance, rumen and urine pH changes, rumen lactic acid production, VFA production, and VFA ratio changes were studied.

In Trial I, lambs fed the basal diet plus sodium bicarbonate had the highest average feed intake, the highest pH and lactic acid level for the first ten days, but went off-feed after buffer removal. The lambs receiving buffer plus rumen fluid had the highest overall average feed intake and the second highest overall gain for the trial. Lambs changed to the basal ration went off-feed on the second day of the trial, at which time rumen and urine pH decreased and lactic acid levels increased. Lambs given rumen fluid in addition to the basal concentrate ration developed diarrhea, went off-feed, had low rumen pH and average total VFA values, and had elevated levels of lactic acid in the rumen.

There was a significant ($P < .01$) negative correlation between rumen pH and lactic acid level in this trial. The correlation between rumen pH and acetic to propionic ratios was significant ($P < .05$) and positive. There was a significant ($P < .10$) positive correlation between rumen pH and acetic to butyric acid ratio. Lactic acid and feed intake were significantly ($P < .05$) positively correlated.

Lambs receiving buffered rations in Trial II had the highest overall average intake, ADG, rumen pH at the second collection and final average total VFA level. The buffer plus rumen fluid group had a greater average feed intake than the basal group, but the two groups were equal in ADG. Average rumen pH at the second collection was higher for the basal fed group than for the group receiving both buffer and rumen fluid. By the end of the trial the average pH for the latter mentioned group was higher than for any other. Basal fed lambs went off-feed and developed typical symptoms of acute indigestion on the sixth day.

There was a significant ($P < .05$) negative correlation between rumen pH and total VFA level during the trial. Rumen pH and acetic to propionic acid ratio were significantly ($P < .01$) correlated, as were rumen pH and acetic to butyric acid ratios ($P < .05$).

Calcium hydroxide added to the basal ration resulted in low overall feed intake and ADG (Trial III). Furthermore, the rumen pH of this group was higher at the second collection that that of other groups. Average total VFA levels for the first ($P < .05$) and last ($P < .10$) collections were significantly higher in the calcium hydroxide group than in others. Average feed consumption was the lowest, ADG the highest, and feed efficiency the greatest in the group which received calcium hydroxide and rumen fluid. Average rumen pH was lower at the first two collections and the final average total VFA level was lower in this group than in all others. The sodium bicarbonate group had the highest overall feed intake and the second highest ADG. The rumen pH decreased to the lowest level in this group after the buffer withdrawal.

There was a significant ($P < .05$) negative correlation between rumen pH and acetic to propionic acid ratio as there was in Trial I. The correlation between rumen pH and acetic to butyric acid ratio was significant ($P < .01$) and negative.

Steers fed a buffered basal ration and given rumen fluid decreased feed intake markedly on the second day of Trial IV and again on the eleventh day. Overall average feed intake, ADG, and feed efficiency were superior in this group when compared to the group receiving a buffered ration. Conversely, decrease in feed intake on the second day and at the time of buffer removal was less marked in the buffer group. Average rumen pH was significantly ($P < .05$) higher for both groups at the second collection than for any other collections. The average lactic acid level was elevated at the second collection for the buffer plus rumen fluid group and at the final collection for the buffer group.

There was a significant ($P < .05$) negative correlation between rumen pH and lactic acid as there had been in Trial I with lambs. In contrast to Trial I, there was a significant ($P < .05$) negative correlation between pH and total VFA levels in this trial.

There were no significant differences in average feed intake, ADG, or in feed conversion in Trial V. Both groups refused feed on days 10, 11, and 12, when the buffer was removed. Average rumen pH was significantly ($P < .01$) higher for both groups at the second collection than at any other collection. Average total VFA levels for both groups were significantly ($P < .01$) lower at the second collection than at any other collection. The ratios of acetic to butyric acid decreased significantly ($P < .01$) after the first collection.

There was a significant ($P < .01$) negative correlation between rumen pH and average total VFA level. Also, there was a significant ($P < .01$) negative correlation between total VFA and lactic acid. Rumen pH and lactic acid were significantly ($P < .01$) correlated.

In Trial VI there was no significant difference in animal performance. Rumen pH in the group receiving buffer and rumen fluid was higher at the second collection than that of the basal group. Average rumen pH for the first collection was significantly ($P < .01$) higher than for the last collection. Average total VFA levels and average acetic to propionic acid ratios were significantly ($P < .01$) higher at the first collection than for all other collections.

Rumen pH and acetic to butyric acid ratios were significantly ($P < .01$) correlated. Rumen pH and total VFA level were significantly ($P < .05$) negatively correlated.

The buffer fed steers consumed less feed the first day, but a substantially larger amount than the basal fed group on the second day (Trial VII). Also, feed intake on day ten and overall feed intake was higher for the buffer group. One steer in the basal fed group went off-feed and developed symptoms of acute indigestion on the second day of the trial. Rumen pH at the second collection was lowest and lactic acid was highest for the basal fed group. The average acetic to propionic acid ratio was significantly ($P < .05$) greater at the first collection than at the second and last collections.

The correlation between rumen pH and lactic acid was significant ($P < .01$) and negative. There was a significant ($P < .01$) negative correlation between rumen pH and acetic to propionic acid ratios. Also, there was a significant ($P < .01$) negative correlation between lactic acid and total VFA level.

BIBLIOGRAPHY

Allison, Milton J., J. A. Bucklin and R. W. Dougherty. 1964. Ruminal changes after over-feeding with wheat and the effect of intra-ruminal inoculation on adaptation to a ration containing wheat. Journal of Animal Science 23:1164-1171.

Annison, E. F., D. Lewis and D. B. Lindsay. 1959. The metabolic changes which occur in sheep transferred to lush spring grass. II. Changes in acid-base balance of whole animal. Journal of Agricultural Science 53:42-45.

Balch, C. C. 1959. Observations of the act of eating in cattle. British Journal of Nutrition 12:330-334.

Blood, D. L. and J. A. Henderson. 1963. Veterinary medicine. 8th ed. Baltimore, Williams and Wilkins. 436 p.

Bloomfield, R. A. et al. 1966. Alkaline buffering capacity of rumen fluid. (Abstract) Journal of Animal Science 25:1276.

Bond, H. E. 1959. A study on the pathogenesis of acute acid indigestion in the sheep. Ph. D. thesis. Ithaca, Cornell University. 143 numb. leaves.

Borhami, B. E. et al. 1967. Effect of early establishment of ciliate protozoa in the rumen on microbial activity and growth of early weaned buffalo calves. Journal of Dairy Science 50: 1654-1660.

Briggs, P. K., J. P. Hogan and R. L. Reid. 1957. The effect of VFA, lactic acid, and ammonia on rumen pH in sheep. Australian Journal of Agricultural Research 8:674-678.

Church, D. C. 1969. Digestive physiology and nutrition of ruminants. Vol. 1. Corvallis, Oregon, D. C. Church. 316 p.

Conrad, H. R., J. W. Hibbs and Norma Frank. 1958. High roughage system for raising calves based on early development of rumen function. IX. Effect of rumen inculations and cholortetracycline on rumen function of calves fed high roughage pellets. Journal of Dairy Science 41:1248-1261.

Cullison, A. E., B. M. Campbell and R. W. Walker. 1960. Effect of physical form of the ration on steer performance and certain rumen phenomena. Journal of Animal Science 19:1256-1260.

Dain, J. A., A. C. Neal and R. W. Dougherty. 1955. The occurrence of histamine and tyramine in rumen ingesta of experimentally overfed sheep. Journal of Animal Science 14:930-935.

Davenport, E. 1897. On the importance of the physiological requirements of the animal body; Results of an attempt to grow cattle without coarse feed. Urbana. p. 362-368. (Illinois. Agricultural Experiment Station. Bulletin 46) (Cited in Wise, Milton et al. Investigations on the feeding of all-concentrate rations to beef cattle. Journal of Animal Science 20:561-565.)

Dunlop, R. H. and P. B. Hammond. 1965. D-lactic acidosis of ruminants. Annals of the New York Academy of Sciences 119: 1109-1116.

Durham, Ralph. 1962. A technique for feeding all concentrate rations to cattle and sheep. Lubbock. n.p. (Texas. Technological College. Reports on Agricultural Industry. Vol. 3, no. 2)

__________ 1968. New horizons in nutrition may be opened by the technique of rumen inoculation, a Texas scientist feels. Feedstuffs 40(5):38-39.

Durham, Ralph, L. Lopez and R. C. Martin. 1967. Specific rumen inoculations in new feeder cattle being fed a specific all-concentrate ration. Journal of Animal Science 26:917-918.

Emery, R. S. and L. D. Brown. 1961. Effect of feeding sodium and potassium bicarbonate on milk fat, rumen pH, and volatile fatty acid production. Journal of Dairy Science 44:1899-1901.

Erwin, E. S., G. J. Marco and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. Journal of Dairy Science 44:1768-1772.

Ewan, R. C., E. E. Hatfield and U. S. Garrigus. 1958. The effect of certain inoculations on the utilization of urea or biuret by growing lambs. Journal of Animal Science 17:298-303.

Fraser, C. M. 1959. Rumen overload. Canadian Journal of Comparative Medicine 23:347-349.

Geurin, H. B. et al. 1959. Rolled common barley serves as both grain and roughage for fattening steers. (Abstract) Journal of Animal Science 18:1489.

Hawkins, G. E. and J. A. Little. 1968. Response of steers to two levels of saliva added intraruminally. Journal of Dairy Science 51:1817-1822.

Huber, T. L., G. E. Mitchell, Jr. and C. O. Littel. 1962. Acid-base status of sheep with acute indigestion. Journal of Animal Science 21:1025-1027.

Huffman, C. F. 1928. Hay is necessary in ration of dairy cattle; unknown factor present in hay needed to maintain health of dairy cattle. Michigan Experiment Station Quarterly Bulletin 11(1):3. (Cited in Wise, Milton B. et al. Investigations on the feeding of all-concentrate rations to beef cattle. Journal of Animal Science 20:561-565.

Hungate, R. E. 1966. The rumen and its microbes. New York, Academic. 533 p.

Hungate, R. E. et al. 1952. Microbiological and physiological changes associated with acute indigestion in sheep. Cornell Veterinarian 42:423-449.

Jensen, R. and D. R. Mackey. 1965. Diseases of feedlot cattle. Philadelphia, Lea and Febiger. 305 p.

Krogh, N. 1960. Studies on alterations in the rumen fluid of sheep, especially concerning the microbial composition, when readily available carbohydrates are added to the food. II. Lactose. Acta Veterinaria Scandinavica 1:383-385.

Kutches, A. J., D. C. Church and F. L. Duryee. 1969. Proceedings of the Western Section of the American Society of Animal Science 20:193-198.

Lassiter, J. W., M. K. Hamdy and Prasob Buranamanas. 1963. Effect of sodium bicarbonate on microbial activity in the rumen. Journal of Animal Science 22:335-340.

Li, J. C. R. 1965. Statistical inference. Rev. ed. Ann Arbor, Edwards Brothers. 685 p.

Maki, L. R. and E. M. Foster. 1957. Effect of roughage in the bovine ration on types of bacteria in the rumen. Journal of Dairy Science 40:905-913.

Matrone, G., H. A. Ramsey and G. H. Wise. 1957. Purified diets for ruminants. Proceedings of the Society for Experimental Biology and Medicine 95:731-733.

________________ 1959. Effect of volatile fatty acids, sodium and potassium bicarbonate in the purified diets for ruminants. Proceedings of the Society for Experimental Biology and Medicine 100:8-11.

McCandlish, A. C. 1923. Studies in the growth and nutrition of dairy calves. V. Milk as the sole ration for calves. Journal of Dairy Science 6:54-59.

Miller, R. W. et al. 1965. Effect of feeding buffers to dairy cows fed a high-concentrate, low-roughage ration. Journal of Dairy Science 48:1455-1458.

Morrison, Frank B. 1954. Feeds and feeding. 8th ed., abridged. Ithaca, Morrison. 630 p.

Mullenax, C. H., P. F. Keller and M. J. Allison. 1966. Physiological responses of ruminants to toxic factors extracted from rumen bacteria and rumen fluid. American Journal of Veterinary Research 27:857-868.

Nicholson, J. W. G. and H. M. Cunningham. 1961. The addition of buffers to ruminant rations. I. Effect on weight gains, efficiency of gains and consumption of rations with and without roughage. Canadian Journal of Animal Science 41:134-137.

Nicholson, J. W. G., H. M. Cunningham and D. W. Friend. 1963. Effect of adding buffers to all-concentrate rations on feedlot performance of steers, ration digestibility and intra-rumen environment. Journal of Animal Science 22:368-373.

Nicholson, J. W. G., J. K. Loosli and R. G. Warner. 1960. Influence of mineral supplements on the growth of calves, digestibility of the rations and intra-ruminal environment. Journal of Animal Science 19:1071-1080.

Nilson, K. M., F. G. Owen and C. E. Georgi. 1967. Effect of abrupt ration change on rumen microorganisms and the niacin and vitamin B_6 content of rumen fluid and milk. Journal of Dairy Science 50:1172-1176.

Oltjen, R. R. and R. E. Davis. 1963. Zinc, urea and buffers in all-concentrate steer rations. Journal of Animal Science 22:842-846.

Ostle, Bernard. 1956. Statistics in research. Ames, Iowa State College. 487 p.

Pope, L. S. et al. 1963. Fattening cattle on "all-concentrate" rations based on steam rolled milo. Stillwater. 124 p. (Oklahoma. Agricultural Experiment Station. Miscellaneous publication 70)

Pounden, W. D. and J. W. Hibbs. 1948. The influence of the ration and rumen inoculation on the establishment of certain micro-organisms in the rumens of young calves. Journal of Dairy Science 31:1041-1050.

Ralston, A. T., W. H. Kennick and R. P. Davidson. 1964. The effect of varying diluents upon a wheat finishing ration for beef steers. Proceedings of the Western Section of the American Society of Animal Science 15:XLIII-1XLIII-4.

Reid, R. L., J. P. Hogan and P. K. Briggs. 1957. The effect of diet on individual volatile fatty acids in the rumen of sheep, with particular reference to the effect of low rumen pH and adaption to high starch diets. Australian Journal of Agriculture Research 8:691-694.

Ryan, E. K. 1964. Concentrations of glucose and low-molecular-weight acids in the rumen of sheep changed gradually from a hay to a hay-plus-grain diet. American Journal of Veterinary Research 25:653-659.

Sanford, J. 1963. Formation of histamine in ruminal fluid. Nature 199:828-829.

Shelton, M., J. E. Huston and M. C. Calhoun. 1969. Buffers in high concentrate rations for lambs. (Abstract) Journal of Animal Science 28:147.

Thomas, D. 1968. New program for incoming cattle - the drowsy bug. Calf News 6(10):4ff.

Thomas, J. W. and R. S. Emery. 1969. Effects of sodium bicarbonate, magnesium hydroxide on milk fat secretion. Journal of Dairy Science 52:60-63.

Tremere, A. W., W. G. Merrill and J. K. Loosli. 1968. Adaptation to concentrate feeding as related to acidosis and digestive disturbances in dairy heifers. Journal of Dairy Science 51: 1065-1072.

Turner, A. W. and V. E. Hodgetts. 1955. Buffer systems in the rumen of the sheep. I. pH and bicarbonate concentration in relationship to pCO_2. Australian Journal of Agriculture Research 6:115-124.

________________ 1955. Buffer systems in the rumen of the sheep. II. Buffering properties in relationship to composition. Australian Journal of Agriculture Research 6:124-144.

________________ 1949 to 1959. Toxicity of large rations of wheat. First to the eleventh Annual Reports, Commonwealth of Australia. (Cited in Tremere, A. W., W. G. Merrill and J. K. Loosli. 1968. Adaptation to concentrate feeding as related to acidosis and digestive disturbances in dairy heifers. Journal of Dairy Science 51:1065)

Uhart, B. A. and F. D. Carroll. 1967. Acidosis in beef steers. Journal of Animal Science 26:1195-1198.

Umbreit, W. W., R. H. Burris and J. F. Stauffer. 1957. Manometric techniques. 3d ed. Minneapolis, Burgess. 305 p.

Walker, D. J. 1968. The position of lactic acid and its derivatives in the nutrition and metabolism of ruminants. Nutrition Abstracts and Reviews 38:1-11.

Warner, A. C. I. 1962. Some factors influencing the rumen microbial population. Journal of General Microbiology 28:129-135.

Wise, M. B. et al. 1961. Investigations on the feeding of all-concentrate rations to beef cattle. Journal of Animal Science 20:561-565.

________________ 1965. Influence of rumen buffering agents and hay on performance and carcass characteristics of steers fed all-concentrate rations. Journal of Animal Science 24:8388-8391.

Wise, M. B. *et al*. 1967. Unpublished research on finishing beef cattle on all-concentrate rations. Raleigh, North Carolina State University, Department of Animal Science.

Woolfitt, W. C., W. E. Howell and J. M. Bell. 1964. The effect of hormones, buffer salts and protein quality on the feeding of spring lambs. Canadian Journal of Animal Science 44:179-183.

APPENDIX

Appendix Table 1. Average daily feed intake in lbs. (lambs).

Day	Trial I Groups				Trial II Groups				Trial III Groups			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	3.42	2.71	3.13	2.92	4.0	4.0	4.0	4.0	2.0	2.0	2.0	2.0
2	2.82	3.76	1.84	2.47	4.0	4.0	4.0	4.0	2.0	2.0	0	0
3	1.00	3.22	.31	2.51	4.0	4.0	4.0	4.0	3.0	0	3.0	2.0
4	.68	2.41	.77	1.95	2.67	3.0	3.0	4.0	3.0	0	3.0	0
5	1.52	1.34	1.28	2.24	2.0	3.0	3.0	2.0	2.0	–	2.0	2.0
6	2.18	2.28	.94	1.72	2.0	2.0	3.0	3.0	2.0	–	2.0	2.0
7	1.66	2.86	1.43	2.97	0	2.0	4.0	3.0	2.0	–	0	2.0
8	2.22	2.34	.93	2.83	4.0	2.67	4.0	4.0	3.0	–	3.0	2.0
9	2.18	2.17	1.39	2.76	4.0	4.0	4.0	4.0	3.0	–	3.0	4.0
10	2.25	2.10	1.33	2.91	4.0	3.0	3.0	4.0	2.0	–	2.0	2.0
11	1.83	1.01	1.24	1.88	3.0	3.0	3.0	2.5	3.0	–	2.0	2.67
12	2.77	2.05	1.22	2.29	3.0	4.0	4.0	4.5	3.0	–	3.0	3.0
13	3.14	2.13	1.15	2.06	2.0	3.0	2.0	3.0	2.0	–	3.0	3.0
14	2.48	1.26	1.66	2.72	3.0	3.0	4.0	3.0	4.0	–	2.0	2.0
15	1.69	.56	.96	2.88	4.0	4.0	4.0	3.0	2.0	–	2.0	2.0
16					3.0	3.0	3.0	3.0	2.0	–	2.0	2.0
17					4.0	4.0	3.0	3.0				
18					3.0	3.0	4.0	3.0				
19					3.0	3.0	2.0	4.0				
20					4.0	4.0	1.0	4.5				
21					4.0	2.0	4.0	4.0				
22					3.0	3.0	4.0	3.0				
23					3.0	3.0	3.0	3.0				
24					3.0	4.0	3.0	4.0				
25					3.0	4.0	4.0	4.0				
26					2.0	4.0	4.0	4.0				
27					4.0	4.0	4.0	4.0				

Appendix Table 1a. Average daily feed intake in lbs. (steers).

Day	Trial IV Groups I	Trial IV Groups II	Trial V Groups I	Trial V Groups II	Trial VI Groups I	Trial VI Groups II	Trial VII Groups I	Trial VII Groups II
1	8.00	8.00	6.00	6.00	6.75	6.75	17.83	24.33
2	2.63	6.88	6.00	6.00	12.67	8.00	23.33	1.67
3	1.38	7.00	9.00	9.00	20.25	15.26	24.33	6.33
4	3.63	6.38	12.00	12.00	21.00	15.00	11.33	14.67
5	7.38	7.75	14.50	14.50	14.50	18.67	22.00	15.50
6	10.50	8.38	16.00	16.00	11.25	21.00	26.00	13.67
7	13.81	8.63	17.00	17.00	14.50	25.67	27.00	19.00
8	14.88	8.69	16.00	14.50	16.00	22.67	24.67	21.67
9	15.63	6.06	16.00	14.50	19.25	24.34	26.17	21.67
10	16.25	8.75	0	0	17.25	24.00	27.00	20.00
11	9.63	10.00	0	0	17.75	28.33	27.00	27.33
12	12.13	11.25	0	0	20.75	26.00	26.67	24.33
13	14.50	11.75	6.00	6.00	23.00	27.67	26.67	24.00
14	17.50	13.50	9.00	9.00	19.00	10.33	28.67	26.67
15	18.63	16.63	10.00	10.00	18.25	11.33	26.67	26.67
16	13.50	5.88	14.00	14.50	22.50	17.00	26.67	26.67
17	17.50	6.50	14.00	14.00	22.00	23.67	26.67	26.67
18					25.00	19.00	26.67	26.67
19					25.50	21.67		
20					22.00	22.00		

Appendix Table 2. Effect of sodium bicarbonate and/or rumen fluid transfer on average molar percentages of VFA of rumen fluid in Trial I (in M%).

VFA	Collection 1 (before ration change)	Collection 2 (8 hrs. after change)	Collection 3 (27 hrs. after change)	Collection 4 (day 9)	Collection 5 (day 11)	Collection 6 (end of trial)
			Group I - basal			
acetic	72.04	58.20	60.39	47.57	67.01	57.55
propionic	19.76	30.85	22.00	38.63	27.02	24.11
butyric	7.15	10.02	14.00	13.35	10.19	13.48
other	1.01	.90	3.58	1.27	1.24	4.81
			Group II - $NaHCO_3$			
acetic	76.14	57.83	59.59	49.51	61.77	65.54
propionic	15.78	29.23	25.37	35.34	24.36	19.71
butyric	7.17	11.96	12.32	14.24	19.82	9.95
other	.89	.98	2.69	.88	2.25	5.75
			Group III - rumen fluid			
acetic	74.38	61.04	49.87	59.64	67.65	62.05
propionic	17.05	22.29	33.76	30.22	22.08	17.83
butyric	7.05	12.11	10.28	9.14	7.70	11.17
other	1.09	.09	3.88	.68	2.39	8.94
			Group IV - $NaHCO_3$ + rumen fluid			
acetic	75.09	60.29	63.22	78.98	61.84	57.62
propionic	17.20	29.93	20.33	7.75	27.90	16.18
butyric	6.80	9.02	11.55	12.14	9.98	18.65
other	.90	.76	2.68	1.45	1.54	6.93

Appendix Table 3. Effect of sodium bicarbonate and/or transfer of rumen fluid on average molar percentages of VFA of rumen fluid in Trial II (M %)

VFA	Collection 1	Collection 2	Collection 3
	Group I - basal		
acetic	68.78	54.52	61.96
propionic	24.11	35.22	23.47
butyric	6.01	7.55	12.60
other	1.14	2.90	1.94
	Group II - 3% $NaHCO_3$ + rumen fluid		
acetic	68.74	53.13	50.11
propionic	21.20	35.32	36.48
butyric	6.86	8.91	9.32
other	3.17	2.47	4.48
	Group III - 6% $NaHCO_3$		
acetic	72.05	58.15	61.67
propionic	17.47	30.50	22.99
butyric	8.59	8.26	9.69
other	1.27	2.97	5.63
	Group IV - 3% $NaHCO_3$		
acetic	72.31	54.34	57.88
propionic	18.52	36.06	31.14
butyric	7.20	6.17	7.19
other	1.94	3.53	3.77

Appendix Table 4. Effect of sodium bicarbonate, calcium hydroxide and/or rumen fluid transfers on the average molar percentages of VFA of rumen fluid in Trial III.

VFA	Collection 1 (M%)	Collection 2 (M%)	Collection 3 (M%)
	Group I - 6% $NaHCO_3$		
acetic	52.74	52.01	68.99
propionic	36.68	37.00	27.25
butyric	7.78	9.21	2.46
other	2.78	1.76	.77
	Group II - 6% $NaHCO_3$ + rumen fluid		
acetic	61.68		
propionic	22.99		
butyric	10.28		
other	5.71		
	Group III - 3% $Ca(OH)_2$		
acetic	62.22	58.05	60.96
propionic	24.57	34.06	30.17
butyric	10.24	4.54	6.09
other	2.94	3.34	2.87
	Group IV - 3% $Ca(OH)_2$ + rumen fluid		
acetic	55.66	43.62	60.24
propionic	28.30	42.63	29.89
butyric	18.18	9.88	6.27
other	3.96	3.86	3.41

Appendix Table 5. Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average molar percentages of VFA in rumen fluid in Trial IV.

VFA	Collection 1 (M%)	Collection 2 (M%)	Collection 3 (M%)
	Group I - 6% $NaHCO_3$ + rumen fluid		
acetic	66.33	64.28	52.44
propionic	17.66	17.08	25.02
butyric	13.99	15.35	16.22
other	2.68	3.27	6.28
	Group II - 6% $NaHCO_3$		
acetic	71.56	58.49	60.01
propionic	18.00	22.05	18.87
butyric	8.78	11.95	16.12
other	2.31	7.35	4.98

Appendix Table 6. Effect of sodium bicarbonate or sodium bicarbonate plus rumen fluid on average molar percentages of VFA in ruman fluid in Trial V.

VFA	Collection 1 (M%)	Collection 2 (M%)	Collection 3 (M%)	Collection 4 (M%)
	Group I - 6% $NaHCO_3$ + rumen fluid			
acetic	71.20	61.67	61.31	63.57
propionic	17.38	15.05	19.05	20.21
butyric	10.04	20.82	14.19	12.61
other	1.36	2.12	4.69	3.61
	Group II - 6% $NaHCO_3$			
acetic	74.87	61.29	60.23	60.76
propionic	17.36	21.10	22.63	25.44
butyric	8.65	12.79	9.24	9.17
other	1.34	2.03	4.51	4.50

Appendix Table 7. Effect of sodium bicarbonate plus transfers of rumen fluid on average molar percentages of VFA in rumen fluid in Trial VI.

VFA	Collection 1 (M%)	Collection 2 (M%)	Collection 3 (M%)	Collection 4 (M%)
		Group I - basal		
acetic	71.90	61.48	53.17	57.31
propionic	17.36	23.20	24.41	24.04
butyric	11.77	12.96	14.62	12.11
other	1.44	2.00	4.43	6.26
		Group II - 6% $NaHCO_3$ + rumen fluid		
acetic	72.87	62.92	58.11	53.37
propionic	17.54	22.20	28.72	27.21
butyric	8.70	13.55	11.00	14.88
other	.85	1.31	1.61	3.21

Appendix Table 8. Effect of sodium bicarbonate on average molar percentages of VFA in rumen fluid in Trial VII.

	Collection 1 (M%)	Collection 2 (M%)	Collection 3 (M%)	Collection 4 (M%)
		Group I - 6% $NaHCO_3$		
acetic	65.45	42.11	62.31	55.17
propionic	21.57	29.46	21.59	29.39
butyric	10.91	15.91	12.10	10.77
other	2.05	2.50	4.00	4.62
		Group II - basal		
acetic	65.45	60.69	59.34	57.35
propionic	22.82	23.73	23.15	22.85
butyric	10.11	12.28	13.84	13.70
other	1.59	3.27	3.64	4.07

Appendix Table 9. Correlation coefficients (Trials I - VII).

Correlations	Trial I correlation coefficient (r)	Trial II correlation coefficient (r)	Trial III correlation coefficient (r)	Trial IV correlation coefficient (r)	Trial V correlation coefficient (r)	Trial VI correlation coefficient (r)	Trial VII correlation coefficient (r)
Rumen pH to urine pH	.13						
Rumen pH to lactic acid	-.74[a]			-.43[b]	.49[a]	-.12	-.58[a]
Rumen pH to total VFA	.50[a]	-.40[b]	.10	.68[a]	-.63[a]	-.36[b]	.12
Rumen pH to acetic to propionic acid ratio	-.23[b]	-.49[a]	-.35[b]	.06	.05	.21	-.58
Rumen pH to acetic to butyric acid ratio	.21[c]	.39[b]	-.62[a]	-.68	.01	.55[a]	.06
Lactic acid to total VFA	.20			.06	.58[a]	-.16	-.57[a]
Lactic to urine pH	.05						
Lactic acid to feed intake	.38[b]						

[a]Significant (P < .01)

[b]Significant (P < .05)

[c]Significant (P < .10)

Appendix Table 10. Summary of average feed intake in lbs. (lambs).

	Collections				
	Day 1 - eight hrs.	Day 2	Prior to buffer removal	After buffer removal	End of trial
		Trial I			
basal ration	3.42	2.82	2.18	1.83	1.69
3% $NaHCO_3$	2.71	3.76	2.17	1.01	.56
rumen fluid	3.13	1.84	1.39	1.24	.97
3% $NaHCO_3$ + rumen fluid	2.92	2.47	2.76	1.88	2.88
		Trial II			
basal ration	4.00				2.00
3% $NaHCO_3$ + rumen fluid	4.00				4.00
6% $NaHCO_3$	4.00				4.00
3% $NaHCO_3$	4.00				4.00
		Trial III			
6% $NaHCO_3$		2.00	2.00		2.00
rumen fluid		2.00	—		—
3% $Ca(OH)_2$		.00	.00		2.00
3% $Ca(OH)_2$ + rumen fluid		.00	2.00		2.00

Appendix Table 11. Summary of average feed intake in lbs. (steers).

	Day 2	Day 7	End of trial
		Trial IV	
6% $NaHCO_3$ + rumen fluid	2.63	13.81	17.50
6% $NaHCO_3$	6.88	8.67	16.50
		Trial V	
6% $NaHCO_3$	6.00	17.00	14.00
6% $NaHCO_3$ + rumen fluid	6.00	17.00	14.00
		Trial VI	
basal	12.67	14.50	22.00
6% $NaHCO_3$ + rumen fluid	8.00	25.67	22.00
		Trial VII	
6% $NaHCO_3$	23.33	27.00	26.67
basal	1.67	19.00	26.67

Appendix Table 12. Summary of average rumen pH (lambs).

	Collections					
	Prior to ration change	Day 1 - eight hrs.	Day 2	Prior to buffer removal	After buffer removal	End of trial
			Trial I			
basal ration	6.31	6.52	6.00	6.26	6.39	5.79
3% $NaHCO_3$	6.66	5.97	6.19	5.60	5.65	6.61
rumen fluid	6.56	6.22	5.21	6.35	6.17	6.30
3% $NaHCO_3$ + rumen fluid	6.24	6.11	5.96	5.51	5.73	5.86
			Trial II			
basal ration	6.61	6.06				6.10
3% $NaHCO_3$ + rumen fluid	6.62	5.96				6.44
6% $NaHCO_3$	6.60	6.33				5.93
3% $NaHCO_3$	6.76	6.18				5.80
			Trial III			
6% $NaHCO_3$			6.47	6.39		5.10
rumen fluid			6.56	—		—
3% $Ca(OH)_2$			6.58	6.75		5.39
3% $Ca(OH)_2$ + rumen fluid			5.62	5.83		5.42

Appendix Table 13. Summary of average rumen pH (steers).

	Collections			
	Prior to ration change	Day 2	Day 7	End of trial
		Trial IV		
6% $NaHCO_3$ + rumen fluid	6.76	6.95	—	6.83
6% $NaHCO_3$	6.82	7.27	—	6.36
		Trial V		
6% $NaHCO_3$	6.39	7.07	6.87	6.72
6% $NaHCO_3$ + rumen fluid	6.71	7.52	7.05	6.58
		Trial VI		
basal	6.90	6.56	6.55	6.59
6% $NaHCO_3$ + rumen fluid	6.93	7.07	6.66	6.54
		Trial VII		
6% $NaHCO_3$	6.45	6.19	5.98	6.68
basal	6.82	6.09	5.89	6.63

Appendix Table 14. Summary of average total VFA in μM/ml. (lambs).

	Collections					
	Prior to ration change	Day 1 - 8 hrs.	Day 2	Prior to buffer removal	After buffer removal	End of trial
			Trial I			
basal ration	109.95	87.24	77.63	59.99	78.55	38.95
3% $NaHCO_3$	86.13	123.04	74.26	97.30	120.66	42.03
rumen fluid	115.10	72.86	71.14	66.81	90.85	43.75
3% $NaHCO_3$ + rumen fluid	108.30	127.58	59.64	54.98	95.02	46.66
			Trial II			
basal ration	84.33	98.27				95.21
3% $NaHCO_3$ + rumen fluid	81.81	83.57				58.97
6% $NaHCO_3$	83.40	103.88				102.75
3% $NaHCO_3$	90.40	82.91				128.42
			Trial III			
6% $NaHCO_3$			65.60	67.93		75.00
rumen fluid			65.60	—		—
3% $Ca(OH)_2$			124.76	94.90		106.67
3% $Ca(OH)_2$ + rumen fluid			92.02	97.65		60.21

Appendix Table 15. Summary of average total VFA in µM/ml. (steers).

	Collections			
	Prior to ration change	Day 2	Day 7	End of trial
		Trial IV		
6% $NaHCO_3$ + rumen fluid	49.84	63.98	—	84.64
6% $NaHCO_3$	98.59	44.84	—	107.25
		Trial V		
6% $NaHCO_3$	105.51	53.78	81.79	109.77
6% $NaHCO_3$ + rumen fluid	95.17	33.31	101.87	89.02
		Trial VI		
basal	105.76	74.84	83.39	81.96
6% $NaHCO_3$ + rumen fluid	103.7	66.60	102.07	91.69
		Trial VII		
6% $NaHCO_3$	108.03	114.35	97.55	86.27
basal	58.56	45.68	99.48	89.42

Appendix Table 16. Summary of average acetic to propionic acid ratios (lambs).

	Collections					
	Prior to ration change[a]	Day 1- 8 hrs.[a]	Day 2[a]	Prior to buffer removal[a]	After buffer removal[a]	End of trial[a]
			Trial I			
basal ration	3.70	1.88	3.00	1.30	2.25	2.62
3% $NaHCO_3$	4.87	2.31	2.94	1.40	2.82	4.04
rumen fluid	4.15	2.31	1.63	2.09	3.36	3.55
3% $NaHCO_3$ + rumen fluid	4.49	2.30	3.38	10.19	2.93	3.72
			Trial II			
basal ration	3.25	1.64				2.97
3% $NaHCO_3$ + rumen fluid	3.26	1.51				1.41
6% $NaHCO_3$	4.20	1.91				2.82
3% $NaHCO_3$	3.91	1.54				1.94
			Trial III			
6% $NaHCO_3$			1.49	1.57		8.44
rumen fluid			2.49	—		—
3% $Ca(OH)_2$			2.71	1.80		2.95
3% $Ca(OH)_2$ + rumen fluid			2.23	1.03		2.35

[a]Ratios represent acetic to propionic ratio when propionic equals one.

Appendix Table 17. Summary of average acetic to propionic acid ratios (steers).

	Collections			
	Prior to ration change[a]	Day 2[a]	Day 7[a]	End of trial
		Trial IV		
6% $NaHCO_3$ + rumen fluid	3.78	3.97	—	2.18
6% $NaHCO_3$	4.18	2.89	—	3.38
		Trial V		
6% $NaHCO_3$	4.12	4.10	3.32	3.18
6% $NaHCO_3$ + rumen fluid	4.34	2.91	5.00	2.41
		Trial VI		
basal	4.25	2.71	2.21	2.62
6% $NaHCO_3$ + rumen fluid	4.29	2.84	2.05	2.01
		Trial VII		
6% $NaHCO_3$	3.05	1.80	3.00	1.91
basal	2.87	2.61	2.65	2.38

[a]Ratios represent acetic to propionic ratio when propionic equals one.

Appendix Table 18. Summary of average acetic to butyric acid ratios (lambs).

	Collections					
	Prior to ration change[a]	Day 1-8 hrs.[a]	Day 2[a]	Prior to buffer removal[a]	After buffer removal[a]	End of trial[a]
			Trial I			
basal ration	10.30	6.00	4.97	3.85	9.94	4.42
3% $NaHCO_3$	10.68	6.91	5.60	4.65	6.08	7.97
rumen fluid	10.35	26.00	5.72	3.36	9.80	7.47
3% $NaHCO_3$ + rumen fluid	11.12	7.50	3.97	2.93	6.66	4.00
			Trial II			
basal ration	11.63	8.10				5.09
3% $NaHCO_3$ + rumen fluid	10.09	6.61				6.05
6% $NaHCO_3$	8.79	8.67				6.66
3% $NaHCO_3$	11.48	10.11				8.60
			Trial III			
6% $NaHCO_3$			6.98	5.63		37.29
rumen fluid			6.66	—		—
3% $Ca(OH)_2$			6.53	13.07		14.12
3% $Ca(OH)_2$ + rumen fluid			4.76	4.79		10.45

[a]Ratios represent acetic to butyric ratio when butyric equals one.

Appendix Table 19. Summary of average acetic to butyric acid ratios (steers).

	Collections			
	Prior to ration change[a]	Day 2[a]	Day 7[a]	End of trial[a]
		Trial IV		
6% $NaHCO_3$ + rumen fluid	4.96	4.93	—	3.34
6% $NaHCO_3$	20.47	5.07	—	3.53
		Trial V		
6% $NaHCO_3$	7.23	2.98	5.48	5.09
6% $NaHCO_3$ + rumen fluid	8.73	4.89	5.07	6.78
		Trial VI		
basal ration	7.81	4.89	4.12	4.96
6% $NaHCO_3$ + rumen fluid	8.69	4.64	5.13	4.19
		Trial VII		
6% $NaHCO_3$	6.05	3.31	5.24	5.16
basal ration	6.50	5.27	4.40	4.18

[a]Ratios represent acetic to butyric ratio when butyric equals one.

Appendix Table 20. Average lactic acid values in μgm. /ml. (steers).

	Collections			
	Prior to ration change	Day 2	Day 7	End of trial
	Trial IV			
6% $NaHCO_3$ + rumen fluid	3.8	1030	—	28.8
6% $NaHCO_3$	3.6	3.7	—	550
	Trial V			
6% $NaHCO_3$	16.3	7.0	14.8	3.7
6% $NaHCO_3$ + rumen fluid	9.0	17.8	20.6	4.5
	Trial VI			
basal	5.6	8.4	9.9	11.5
6% $NaHCO_3$ + rumen fluid	3.3	5.0	5.4	7.5
	Trial VII			
6% $NaHCO_3$	5.4	4.2	10.5	6.0
basal	3.8	1310	23.1	8.0