MINERAL BUFFERS IN DAIRY COW RATIONS

By

JACK DEAN STOUT

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1955

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1966

MINERAL BUFFERS IN DAIRY COW RATIONS

Thesis Approved:

S. D. Musgrave

Thesis Adviser

L. J. Bush

J. H. Boggs

Dean of the Graduate College

ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to Dr. S. D. Musgrave, Head, Department of Dairy Science, for his counsel, guidance, suggestions, and personal interest throughout the course of study leading to the completion of this thesis.

Much appreciation is extended to Dr. Linville J. Bush for his assistance in planning of the research and his advice and encouragement in the writing of this thesis.

The author expresses gratitude to Dr. Robert Morrison and Robert Easterling for advice and help in the statistical analyses of the experimental data.

Sincere appreciation and gratitude are expressed to the author's wife, Jodelle, for her sacrifice, aid, and encouragement throughout this study program.

To the author's parents, Mr. and Mrs. R. M. Stout, special recognition is extended for their aid and encouragement to continue this study to completion.

The author is indebted to Harley Miller, Jerry Murray, and other employees at the OSU dairy barn for their assistance in feeding, milking, and caring for the experimental animals.

The author wishes to thank Mrs. Patty Johnson and Mrs. Ann Burk for their assistance with laboratory analyses and computing the production data. Mrs. Beverly Schrag is thanked for typing this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The production of milk with a milk fat content lower than breed average, and even lower than the U.S. Public Health Service definition, is causing concern among both producers and processors.

The producer problem is threefold: (a) lower economic returns from selling low fat test milk in a pricing situation based on milk fat content; (b) potential loss of fluid milk market if milk is consistently below 3.25% milk fat; and (c) the potential sale of breeding stock is reduced as a result of lower fat records.

The reduction of the price received for milk is not always accompanied by a corresponding drop in production costs. To the contrary, some of the factors that may have contributed to the depression of milk fat may have increased the total feed cost. Higher levels of concentrate feeding and the pelleting of rations are both cost increasing in nature and have been shown to be associated with a low milk fat test (12, 29). The trend in recent years has been toward higher levels of grain feeding. A recent study (34) of DHIA records showed that grain consumption per cow increased 1000 lb per lactation from 1960 to 1964, inclusive. Feeding guides, used to compute dairy cow rations, have been revised to allow more total digestible nutrients (TDN) per pound of milk produced with allowances made for decreasing efficiency of utilization as increments of grain increase (35).

Other dietary factors that affect milk fat percentage are physical form of forage, level and type of fiber, forage characteristics, alkaline salts, and the time of feeding ration components. The way these factors individually affect milk fat percentage is not fully understood and the situation may well be further complicated by some factors being cumulative in action.

Some of these factors may be related to the adoption of improved management technology in the overall dairy operation. Lower fiber roughages are being produced as a result of improved crop varieties, more efficient harvesting methods and equipment, and new types of storage facilities. Labor saving and automated equipment has forced dairymen to use pelleted grains and in some cases chopped or wafered forages. In this particular area, the utilization of wheat pasture reduces the total fiber intake.

The rumen fluid of animals on milk fat depressing diets has a higher acidity (5, 7, 8), with different percentages of volatile fatty acids (VFA) being produced by rumen digestion. Buffering materials, such as sodium bicarbonate and potassium bicarbonate, have been added to milk fat depressing rations with some degree of success in maintaining rumen pH levels. In most studies, the addition of mineral buffers has reduced the palatability of the ration (5, 7, 8, 14, 21).

The objectives of the research reported herein were to determine the effect of adding certain buffers, i.e., sodium plus potassium bicarbonates or magnesium oxide, on ration palatability and the characteristics of the rumen fluid of animals consuming these rations.

LITERATURE REVIEW

Effect of High Grain-Restricted Roughage Rations on Rumen Physiology

Dairy cows have been called "roughage burners" for many years because of their ability to utilize large amounts of forage for the production of human food. They can adapt to a wide variety of feeds and feeding programs. Changes in ration characteristics have brought about distinct physiological changes in the rumen; namely, lower pH and a change in the mole per cent of VFA. These changes resulted in depressed milk fat percentage.

Rumen pH

The rumen fluid pH of ruminating animals normally is slightly acid, 6.4 to 6.9. It has been theorized (2) that the rumen pH is controlled by the saliva output. Balch et al. (2), using dairy cattle, demonstrated that as the per cent of roughage in a diet was lowered, the saliva output was reduced and rumen pH dropped. Lower rumen pH was also noted by Nicholson et al. (28) in beef cattle fed all concentrate rations, and by Raun et al. (31) in fattening lambs fed only 20% roughage. Autrey (1) measured a 180% increase in saliva flow rate (ml/hr) in fistulated steers fed coastal Bermuda hay compared to succulent oat pasture. Feeding roughage in the form of pellets lowered rumen pH to 6.0, compared to 6.9, when the same amount of hay was fed in long form (11). Kesler and Spahr (16) have reported that rations for dairy cows should contain 13 to 14% total fiber to keep the rumen in proper physiological condition.

Rumen pH may be affected by the constituents of saliva as well as volume of output. Autrey (1) noted that the mean range of the dry matter content of salivas varied from 0.84 to 1.137% when different feeds were consumed.

Volatile Fatty Acid Production

As the estimated net energy level of the ration increased, due to narrowed concentrate:roughage ratios, there was a change in the mole per cent of VFA produced in the rumen. The higher acid media of the rumen fluid enhanced growth of microflora that favored propionic acid synthesis. Hinders and Owen (10) reported that as the per cent of concentrates in the ration increased, the relative amounts of acetic acid decreased and butyric acid increased. It was shown that concentration of VFA produced in the rumen was reduced as the proportion of concentrates in the ration increased (10). This was thought to be due to decreased rumen digestion caused by smaller particles passing through the rumen at a faster rate (10) or to a lower volume of rumen contents (27).

Volatile fatty acid percentages were altered by reducing the amounts of acetic acid produced, and milk fat was depressed when ground and pelleted alfalfa hay was substituted for long alfalfa hay in a California trial (29). Some benefit was gained by feeding the grain and alfalfa pellets at separate times and thus more evenly distributing the function of rumen fermentation overtime. Hinders and Owen (10) noted a change in VFA concentration and a depression of milk fat when cows were fed 70 and 90% of the ration as concentrates, with alfalfa hay, even though some ingredients of the concentrates were high fiber feeds.

Holstein cows, consuming 17 lb of grain and on high quality pearl millet pasture, had lower rumen fluid molar percentages of acetic, butyric, isovaleric acids, higher molar percentage of propionic acid and produced milk lower in fat than did cows on Sudan grass pasture (21). Raun et al. (31) noted narrowed acetate-propionate ratios, higher levels of butyric acid, lowered total VFA levels, and lowered rumen pH in fattening lambs fed rations containing 80:20 ratios of grain to roughage as compared to rations with a 50:50 ratio.

Several workers (2, 3, 4, 5, 7) noted that depressed milk fat resulted when the molar percentage of propionic acid increased at the expense of acetic acid. Balch et al. (2) postulated that propionic acid exerted an inhibitory effect on milk fat synthesis. This phenomenon is not clearly understood, but one explanation is that less acetate is available in the blood for fat synthesis by the mammary gland. Van Soest, in his review (37), suggested that a fundamental antagonism existed between metabolisms able to produce milk fat efficiently and those related to high body weight gains. His explanation was that milk fat and body fat were synthesized from two different groups of fatty-acid combinations. Acetate and beta-hydroxybutyric acid are used in milk fat formation, whereas propionic acid is a precursor to body fat. Evidence to substantiate this theory was produced by Emery et al. (7).

Addition of Mineral Buffers to High Grain-Restricted Roughage Rations

Mineral buffers have been added to high concentrate rations fed to ruminants with some degree of success in correcting pH and VFA changes brought about by such rations. It was theorized that alkaline salts incorporated into high grain rations would replace the buffering capacity lost by reduced saliva output (6).

Emery and Brown (6) added sodium and potassium bicarbonates to a concentrate ration, fed ad libitum, along with 3 lb of alfalfa hay. Both sodium and potassium bicarbonates were effective in maintaining milk fat percentage, although the potassium bicarbonate was somewhat less efficient on a per unit weight basis. In later work (5), equal parts of sodium bicarbonate and potassium bicarbonate were added at two levels, 1.5 and 3.0%, to a grain mixture fed free choice along with 5 lb of alfalfa hay. The 3.0% level of bicarbonates maintained milk fat at 3.54% compared to 1.74% for cows on the control ration. The 1.5% level of bicarbonate feeding showed a trend similar to the higher level, but milk fat test was not maintained at a normal level. Contrary to the earlier experiment (6), the molar percentage of propionic acid was decreased and acetic and butyric acids were increased by the buffered rations.

Schultz et al. (32), of Wisconsin, added sodium bicarbonate to a pelleted concentrate fed at a 3:1 ratio with alfalfa hay. Continuous feeding of the bicarbonate ration maintained milk fat at 80% of normal while the control ration dropped milk fat to 30% of normal. It was significant to note in this experiment that adding 3.0% sodium bicarbonate after milk fat was depressed returned it to 60% of normal, indicating that two weeks was not enough time to re-establish proper microflora.

A ration containing 80% concentrate and 20% roughage was supplemented with 1.5 and 3.0% calcium carbonate and sodium bicarbonate and fed to fattening lambs. There was no effect on the buffering capacity of rumen fluid or VFA levels (31). Canadian workers (28) found that a 3.0% level of sodium bicarbonate was equal to a more complex buffer, namely, three parts sodium bicarbonate, two parts ground limestone, and one part potassium bicarbonate fed at a 6.0% level, in maintaining the rumen pH of feedlot steers on an all concentrate ration.

Restricted roughage rations supplemented with 1.5% magnesium oxide (0.4 lb/day) were as efficient as 3.0% sodium bicarbonate (0.8 lb/day) in preventing milk fat depression (7). The two alkaline salts apparently affected milk fat synthesis by different mechanisms. Blood analyses indicated that magnesium oxide increased mammary uptake of plasma acetate and triglycerides. Sodium bicarbonate increased rumen pH, thus reducing propionic acid production. A daily intake of 0.42 lb of magnesium carbonate or 1.0 lb of potassium bicarbonate was not effective in raising fat test or altering VFA production in cows grazing lush, succulent pearl millet pasture (21).

Sodium bicarbonate (0.5%) was added to drinking water offered feedlot steers (17, 18, 19). There was no significant effect on feed intake, weight gain, or pH level of rumen fluid. Daily water intake increased by 60% and anaerobic bacteria decreased with no significant change in the predominant microflora.

The mineral buffers that were effective in alleviating milk fat depression caused by high grain-restricted roughage diets apparently acted by different mechanisms to control milk fat synthesis. Sodium and potassium bicarbonate exhibited their effect by controlling rumen pH and thus maintained microflora that favored acetic acid production (5, 7, 8). This resulted in higher levels of blood lipids and beta-hydroxybutyric acid being available for milk fat synthesis (32). Emery theorized that magnesium oxide acted in milk fat synthesis by causing increased mammary uptake of plasma acetate and triglycerides (7).

Conflicting results with the different alkaline salts indicated that more work was needed to reveal how they affect milk fat level.

Objections to Mineral Buffer Feeding

The most apparent objection to mineral buffers for dairy cows has been their effect on ration palatability. A dairy cow in high production must consume enough of the ration offered to maintain milk flow without losing body condition too rapidly. Brown Swiss cows refused to eat grain rations supplemented with 3.0% sodium bicarbonate but consumed acceptable amounts of a 1.5% sodium bicarbonate ration (5). Emery et al. (8) noted a 10 to 20% drop in grain consumption when 1.0 lb (approximately 3.0%) of sodium bicarbonate was added to the daily diet. Palatability was not specifically mentioned by other workers, but in analyzing their data, a 6 to 10% drop, in grain, or total dry matter consumption was found (7, 14, 15, 21). Contrary to the effect on palatability of dairy cow rations, 3.0% sodium bicarbonate and 6% mixed buffers added to an all concentrate ration increased feed intake of feedlot steers by 10% (28). Rations supplemented with 11% sodium and potassium bicarbonate reduced feed consumption and performance of feedlot steers (39). Nicholson et al. (24, 25) noted reduced consumption of grain by feedlot steers when mineral buffers were supplemented at levels of 7 to 9%.

Abnormally high daily intakes of mineral buffers may cause serious kidney damage to dairy cows. Steers slaughtered at the termination of feedlot trials designed to test all concentrate rations, supplemented with mineral buffers, showed high incidence (up to 90%) of kidney lesions (24, 25, 28). Emery et al. (8) reported that higher urine pH resulted from feeding sodium bicarbonate rations. Urinary block and acute digestive disturbances were reported by Shelton and Ellis (33) in lambs fed calcium carbonate and sodium bicarbonate at 1, 2, 3, and 4% levels.

The economics of feeding alkaline salts is to be considered. To be effective, 1.0 lb of bicarbonates or 0.5 lb of magnesium oxide must be consumed daily. In usual rations this represented 3 and 1.5%, respectively, of bicarbonate or magnesium oxide. While technical grade buffers cost approximately 40 cents per pound, the feed grade material would cost considerably less. However, a local source of the feed grade buffer would be hard to locate. The addition of buffers to rations is expensive and does not add to the energy value of the ration. Other compounds possessing nutritional qualities are available.

Feed Components Used to Alter Milk-fat Depressing Rations

A discussion of other feed components that would alter milk fat synthesis is beyond the scope of this thesis, but in view of the objections raised to mineral buffers, some of these components should be mentioned. As one might surmise from the literature already presented, maintaining a fiber level in the total diet above 14% would be the most logical precaution in preventing milk-fat depression. However, milk flow may not be maintained at as high a level. Warner (38), in his review, summarized several reports and postulated that a daily hay intake of 1.5 lb/cwt of body weight should preserve normal milk fat test. When certain conditions warranted the feeding of less hay, high fiber concentrates were used successfully. Whole gin-run cottonseed fed at a level of 22% of the concentrate mixture with alfalfa hay, 1 lb/cwt of body weight, increased milk production and maintained milk fat percentage over isocaloric rations of grain plus alfalfa hay ad libitum (23).

The addition of saturated fat to high concentrate rations was effective in raising low fat test, at least temporarily (40). Low fiber rations containing 6.0% prime tallow maintained milk fat levels equal to those produced on a control ration with the same estimated net energy and 61% higher crude fiber content (30). Unsaturated oils such as cod liver oil, cottonseed oil, or fish oil did not change milk fat percentage when added to milk fat depressing diets (3, 38).

Urea is widely used in dairy cow rations as a protein substitute. Wise et al. (39) investigated all-concentrate rations fed to beef cattle and noted that 1% urea in rations resulted in a higher buffering capacity of the rumen fluid. The NH_4 + cation from urea helped neutralize the VFA that were rapidly formed from the all-concentrate rations. Pelleted corn supplemented with 3% urea resulted in higher rumen pH and dry matter intake in an experiment conducted by Jorgensen and Schultz (14) with dairy cattle.

Dried whey, a by-product of the dairy industry, adds considerable nutritional value to the ration and has been proven effective in altering low fat tests produced on high grain diets. Huber (13) found that rations supplemented with 30% delactosed whey fed with alfalfa hay (1 lb/cwt of body weight) maintained milk fat at 96% of normal. The delactosed whey ration resulted in higher rumen pH with the relative percentage of acetic acid increased and the propionic acid decreased.

EXPERIMENTAL PROCEDURE

In order to meet the objectives of this study, two trials were conducted. The palatability of buffered rations was tested using lactating cows (Trial I), and the buffering capacity, pH, and VFA of rumen fluid of the rations was determined using fistulated steers (Trial II). Sodium bicarbonate ($NaHCO_3$),[1] potassium bicarbonate ($KHCO_3$),[2] and magnesium oxide (MgO)[3] were used as the buffering compounds.

TRIAL I

Selection of Animals and Assignment of Treatments

Twenty-four lactating cows, 18 Ayrshires and 6 Holsteins, were selected from the Oklahoma State University dairy herd. Twelve of the Ayrshire cows were in late lactation and the other 12 cows were in early lactation. The cows were grouped in blocks of six cows each on the basis of breed, age, stage of lactation, and level of milk production. They were assigned to treatments at random.

Three experimental rations were fed cafeteria style with only two of the rations being offered to each cow at a time (24). The

---

[1]USP grade sodium bicarbonate furnished by the Olin Chemicals Division, 745 Fifth Avenue, New York, New York.

[2]Technical grade (99% pure) potassium bicarbonate furnished by Allied Chemicals, 40 Rector Street, New York, New York.

[3]Feed grade (92.87% pure) magnesium oxide furnished by Basic Incorporated, Cleveland, Ohio.

combinations of rations A, B, and C were assigned according to a 3 x 3 Latin square design (24). Ration combinations of A-B, A-C, and B-C were considered as treatments in this design (Table I).

TABLE I

TREATMENT SEQUENCES FOR LATIN SQUARE--TRIAL 1

Period	Block I	Block II
1	A-B A-C B-C	A-B A-C B-C
2	A-C B-C A-B	B-C A-B A-C
3	B-C A-B A-C	A-C B-C A-B

An experimental period of 14 days was selected for each treatment sequence. A standardization period of 7 days was used to get the cows accustomed to the tie stalls and new milking order. The regular university dairy herd ration was fed during the standardization period.

Composition and Handling of Rations

Rations were mixed by the Stillwater Milling Company, Stillwater, Oklahoma under the supervision of the author. Two mixers were used to prevent cross-contamination of the rations. The control ration was mixed first when one mixer had to be used to mix two of the rations. Since sorghum grain constituted 40% of the rations, it was used as the clean-out material for the mixers, holding bins, and pelleting machine. The buffering compounds and dried molasses were forced through a double screen to insure against lumps and mixing time was standardized at 10 minutes. The feed was pelleted through a 0.1875-inch die and each ration was marked with a different colored tag.

The position of the two rations in the manger was changed each week to prevent the possibility of bias resulting from a cow's preference for a particular side of the manger. The measure of palatability was determined by the total consumption of each experimental ration.

TABLE II

COMPOSITION OF RATIONS

Ingredient	Na+$KHCO_3$	MgO	Control
	(lb/ton)		
Sorghum grain	800	800	800
Oats	100	100	100
Corn	440	470	500
Wheat shorts	200	200	200
Cottonseed meal, 41%	200	200	200
Molasses, dried	140	140	140
Vitamin-mineral premix	20	20	20
Salt	20	20	20
Defluorinated phosphate	20	20	20
Sodium bicarbonate	30	--	--
Potassium bicarbonate	30	--	--
Magnesium oxide	--	30	--

Care of Experimental Animals

The cows were kept in an exercise lot with access to a free-stall barn for shade and shelter. Good quality alfalfa hay was available in metal bunks which provided 32 inches of bunk space per cow. Fresh water was available at all times except during the period the cows were in their tie stalls for grain feeding.

The cows were chained in the tie stalls approximately 1.5 hr before each milking and offered the two rations. The portion of each ration refused by each cow was weighed back following each milking.

The health and general condition of the experimental animals were observed closely several times daily by the author and by various employees of the OSU Department of Dairy Science.

During the experimental period, the cows were in essence on a free-choice grain feeding program as a result of two rations being offered each cow at a time. The amount of each ration offered to each cow was determined to provide 70% of the requirements for milk production. It was assumed, in calculating the amounts of concentrates needed for animals in this trial, that the roughage portion of the ration would furnish the nutrients necessary for body maintenance. Nutrient requirements listed by Stone et al. (35) were used to calculate the theoretical amounts of concentrates needed per cow, using 4.0 and 3.5% milk fat test for Ayrshire and Holstein cows, respectively.

Analyses of Data

The measure of the palatability was determined by the total consumption of each ration. Statistical analyses were calculated by the Oklahoma State University Computing Center. In the analysis, the total consumption of each ration for week one and week two of each time period was analyzed separately, then added together and analyzed to check for carry-over effect.

Although this particular trial was not intended to measure production response, milk production data were recorded. Milk weights were recorded daily according to the regular procedure for all cows of the OSU dairy herd. Milk samples were collected at four consecutive milkings each week and later used to make a true composite sample in the laboratory. The percentage of milk fat was determined by the standard

Babcock method.

TRIAL II

Selection of Animals and Assignment of Treatments

Three fistulated steers, two Ayrshires and one Holstein, weighing approximately 650 lb each were selected. The steers were assigned at random to the feeding sequences determined by a 3 X 3 Latin square design. Experimental periods of 35 days each were used. Samples of rumen fluid were taken at the end of each period. The pH, buffering capacity, and mole percentage of VFA of the rumen fluid were used as the response criteria.

TABLE III

TREATMENT SEQUENCE FOR LATIN SQUARE

Periods	Treatment sequence		
1	A	B	C
2	B	C	A
3	C	A	B

Composition and Handling of Rations

Rations fed to the steers were A - 1.5% sodium bicarbonate plus 1.5% potassium bicarbonate, B - 1.5% magnesium oxide, and C - control. The composition of the rations was the same as those used in Trial I, Table I.

These rations were mixed at the Oklahoma State University dairy barn in a 300-lb capacity horizontal mixer. The ingredients were purchased in a finely ground state from the Stillwater Milling Company, Stillwater, Oklahoma so that they should have been comparable to the ingredients of the pelleted rations used for the lactating cows in Trial I. These rations were fed in loose form.

Care of Experimental Animals

The steers were kept in individual pens 10 X 60 ft with a galvanized metal building for shelter. Automatic watering cups provided water at all times. Good quality alfalfa hay and the concentrate mixture were fed so that a 60:40 grain to hay ratio was maintained. Feeding time was approximately 8 AM and 5 PM.

Due to the location of these pens, in relation to the other areas, the steers were observed several times daily by the author and others connected with the OSU Department of Dairy Science.

Collection of Rumen Fluid Samples

Samples of rumen fluid were collected during the last week of the comparison period. The collections were made approximately 3 hr following the morning feeding via the rumen fistula. The rumen fluid was strained through cheesecloth and divided into two portions for analysis. Saturated mercuric chloride solution (1 ml/100 ml rumen fluid) was added to stop microbial activity in the sample to be used for VFA analysis.

Determination of Rumen pH and Buffering Capacity

The pH was determined immediately using a Beckman Model N portable pH meter at the first sampling period and a Beckman Zeromatic at subsequent sampling periods.

Buffering capacity of the rumen fluid was measured by titration. A 100 ml sample of rumen fluid was adjusted to pH 7.0 with 1.0 N sodium hydroxide (NaOH), then titrated with 0.5 N hydrochloric acid (HCl) to pH 4.0. The number of milliequivalents of HCl necessary to reduce the pH from 7.0 to 4.0 in increments of 0.5 units was the criterion of buffering capacity.

Determination of VFA

A modification of the gas chromatograph method of Erwin et al. (9) was used for VFA analysis. The samples were prepared by adding 1 ml of metaphosphoric acid (25%) to 5 ml of rumen fluid and centrifuging at 3000 rpm for 10 min. The supernatant was frozen for later analysis.

The instrument used was an Aerograph Model A-600-C with a hydrogen flame ionization detector. Sensitivity range of 1 million was availalbe on the instrument through the use of an output attenuator and an input range control. A 36-inch, by 0.125-inch (OD) column, packed with neopentylglycol succinate (20% NPGS on 60/80 firebrick treated with 3% H_3PO_4) was used. The oven temperature was maintained at approximately 135 C. An Aerograph hydrogen generator model A-650 was used to produce hydrogen from water by the process of electrolysis. Filtered hydrogen (20 ml/min) and oxygen (60 ml/min) was necessary for the operation of the flame ionization detector.

A 5 µl sample of supernatant was injected into the injection block which was maintained at 250 C to provide rapid vaporization of the sample. The fatty acids of the rumen sample, and the standard solution, were eluted using nitrogen (30 ml/min) as a carrier gas. Symmetrical peaks were obtained in approximately 19 min, in order as follows:

acetic, propionic, butyric, isovaleric, and valeric. A Sargent Model SR recorder was used to record the eluted fatty acid peaks. Peak area was determined as the product of the height of the peak and the width of the peak at half-height in millimeters.

Preparation of VFA Standard

A standard solution of VFA containing known amounts of acetic, propionic, butyric, valeric, and isovaleric acids was prepared for use in the quantitative determination of the individual fatty acids.

TABLE IV

PREPARATION OF VFA STANDARD

Acid		g/1	µg/5µl	mole %
Acetic	C_2	4.3845	21.922	57.0
Propionic	C_3	2.2976	11.488	24.2
Butyric	C_4	1.7786	8.893	15.7
Valeric	C_5	0.1818	0.909	1.4
Isovaleric	iso-C_5	0.2220	1.110	1.7

The total concentration of VFA in the standard closely corresponded to the average reported level (15 mM/100 ml) for rumen fluid. The quantity of each acid needed in the standard was calculated by multiplying the mole percentage of acid usually found in rumen fluid times 15 and then times the millimolar weight of the individual acid (mole % of acid X 15 X mM wt of acid). To make a liter of solution, the calculated amount of each acid was multiplied by 10 and weighed on an analytical balance. Distilled water was used to rinse the weighing flask and to bring the volume up to one liter. The prepared solution was stored until needed.

Calculation of VFA

Five microliters of the prepared rumen sample were injected into the gas chromatograph and the quantity of each acid was calculated from the peaks obtained. The area of the respective peaks obtained for the rumen fluid sample was divided by the area of the peak for the same acid in the standard VFA solution. This value was then multiplied by the calculated number of micromoles of VFA per 5 μl of standard and the appropriate dilution factor to determine the quantity of each fatty acid in 100 ml of rumen fluid. It was assumed that the peaks obtained after injection of the standard represented the computed number of micromoles per 5 μl.

To minimize analytical error, several portions of the standard VFA solution were used and the results averaged to get the representative factors. Duplicate determinations were made on each rumen fluid sample, and the results were averaged in calculating the mole percentage of the acids.

RESULTS AND DISCUSSION

The cows used in this palatability study were of two production levels: Group I consisted of 12 late lactation Ayrshires and Group II of six Ayrshire and six Holstein cows in early lactation. The milk production of Group I cows averaged 32.3 lb/cow per day with a range of 21.5 to 40.5 lb. Group II cows ranged in production from 34.3 to 70.5 lb/cow per day with a mean of 52.1 lb. The low production of one cow in Group II was attributed to her nervous disposition and objection to the tie stall.

The trial started the latter part of August when afternoon temperatures reached 90 to 105 F. During the early part of the trial, Group I feed consumption was lower at the 2 PM feeding than at the 2 AM feeding. The temperature moderated during the third week of the trial and the difference in feed consumption between the two daily feedings narrowed. Two mild cases of bloat occurred and one cow was off feed for three days. The two cows that bloated, one in each production level, were both being offered the buffered rations in combination.

An analysis of variance was computed on the data for the first and for the second week of the feeding periods. The two weeks were then combined to indicate possible carry-over effects. There was a significant difference (Table VI) among rations for each week with essentially the same trends in consumption of the different rations for the two weeks. The number of cows that preferred each ration and the number that changed preference from week one to week two as given in Table V.

TABLE V

PREFERENCE OF LACTATING DAIRY COWS FOR RATIONS WITH MINERAL BUFFERS

Week during feeding periods	Ration preferred	Ration combination: $Na+KHCO_3$: MgO	$Na+KHCO_3$: Control	MgO: Control
		(No. of cows)		
1	$Na+KHCO_3$	12	5	--
	MgO	12	--	1
	Control	--	19	23
2	$Na+KHCO_3$	8	7	--
	MgO	16	--	4[a]
	Control	--	17	19[a]
1 + 2	$Na+KHCO_3$	10	8	--
	MgO	14	--	2
	Control	--	16	22
No. of cows changing preference from wk 1 to 2		6	4	5

[a]One cow showed no preference.

There was more tendency to switch rations from the first to the second week when the two buffered rations were fed in combination. All six cows that changed their preference while on the two buffered rations, in combination, switched in favor of the magnesium oxide ration. Three cows changed from the control ration to the magnesium oxide ration, whereas one cow changed from the control to the bicarbonate ration for the second week of the treatment periods. One cow showed a preference for both buffered rations over the control. (Ayrshire cow 421 preferred the magnesium oxide ration over the control by 21.3% and preferred the bicarbonate ration by 30.9%.) The most pronounced dislike for the buffered rations was exhibited by Holstein cow 375. This cow ate 91.7% more of the control than of the magnesium oxide ration and 98.5% more of the control than of the bicarbonate ration. When the two buffered grains were offered in the same treatment sequence, she preferred the magnesium oxide ration by 88.8%, but total feed consumption was down for that two-week period by 137.4 lb and 144.8 lb compared to MgO:control and Na+$KHCO_3$:control, respectively.

TABLE VI

CONSUMPTION OF RATIONS SUPPLEMENTED WITH DIFFERENT MINERAL BUFFERS BY LACTATING DAIRY COWS

Week during feeding periods	Ration	Ration combination: Na+$KHCO_3$: MgO	Na+$KHCO_3$: Control	MgO: Control	Avg.
		(lb/wk)			
1	Na+$KHCO_3$	50.6	43.0	----	46.8[a]
	MgO	62.0	----	38.4	50.2[a]
	Control	----	83.5	85.0	84.2[b]
2	Na+$KHCO_3$	43.1	49.8	----	46.5[a]
	MgO	69.0	----	49.6	59.3[a]
	Control	----	84.2	75.8	80.0[b]
1 + 2	Na+$KHCO_3$	46.8	46.4	----	46.6[a]
	MgO	65.5	----	44.0	54.7[a]
	Control	----	83.8	80.4	82.1[b]

[a]Significantly different from[b] ($P < .01$).

Weekly consumption of the rations is given in Table VI. The amount of each ration eaten averaged 82.1 lb for the control, 46.6 lb for the sodium plus potassium bicarbonate, and 54.7 lb for the magnesium oxide. Total consumption, by cows, for each ration in the treatment sequence is given in Table VII.

TABLE VII

CONSUMPTION OF RATIONS BY INDIVIDUAL COWS

Block	Cow number	Treatment sequence	A - B Na+$KHCO_3$:MgO		B - C MgO:Control		A - C Na+$KHCO_3$:Control	
1	420	3-2-1	134.0	131.2	38.8	104.9	115.1	146.9
1	409	2-1-3	76.6	141.3	75.4	131.9	118.7	154.8
1	358	1-3-2	26.5	101.1	80.9	171.3	35.3	175.1
2	425	3-1-2	140.6	124.2	66.3	154.1	116.0	113.1
2	423	2-3-1	166.9	88.2	109.8	169.1	156.2	128.2
2	421	1-2-3	26.8	156.4	127.8	105.3	164.6	125.7
3	491	2-1-3	145.3	62.2	75.3	145.0	145.4	134.5
3	505	3-2-1	156.7	115.2	75.5	151.5	162.0	143.2
3	506	1-3-2	112.4	87.2	103.7	117.1	73.7	123.7
4	598	3-1-2	99.6	173.7	123.8	137.3	101.8	175.2
4	596	2-3-1	25.6	114.3	126.5	134.9	46.4	133.6
4	595	1-2-3	44.7	139.4	73.7	141.7	123.1	148.4

TABLE VII (Continued)

Block	Cow number	Treatment sequence	A - B Na+$KHCO_3$:MgO		B - C MgO:Control		A - C Na+$KHCO_3$:Control	
5	375	1-3-2	17.2	141.0	22.1	256.3	6.1	279.7
5	215	2-1-3	10.9	278.7	99.9	299.6	19.3	304.0
5	214	3-2-1	121.9	117.9	61.1	225.2	43.0	252.3
6	377	3-1-2	103.8	166.5	122.2	165.3	125.6	121.2
6	285	2-3-1	47.6	160.8	106.5	114.9	149.1	133.3
6	370	1-2-3	162.5	136.9	81.2	189.4	121.3	148.5
7	366	1-3-2	198.3	97.9	73.2	212.1	46.0	256.8
7	349	2-1-3	64.2	102.4	96.1	190.5	39.1	215.6
7	401	3-2-1	118.5	138.5	144.6	129.9	41.7	226.2
8	561	3-1-2	154.4	111.7	117.4	170.8	89.1	171.4
8	564	2-3-1	33.1	137.8	87.7	132.0	93.7	172.1
8	550	1-2-3	61.5	110.5	30.1	106.6	95.4	40.0

There was not a significant difference between production level groups in their acceptance of the buffered rations. Each cow was offered 140% of her daily concentrate requirements as defined in the previous section, i.e., 70% from each ration of the treatment combination. As the amount of grain offered daily increased, there was a more marked preference for the control ration. The lower production cows (Group I) were offered an average of 11.9 lb of grain daily and consumed a total of 69.5% of it. The early lactation cows (Group II) consumed only 48.4% of the 18.9 lb of grain offered to them. The wide difference was a result of the refusal by the cows of the buffered rations at the higher production level. Group I cows consumed 62.4, 62.4, and 83.6% of the bicarbonate, magnesium oxide and control rations, respectively (Table VIII). Acceptance of each of the rations was considerably less by the higher producing group. They consumed 30.9% of the sodium and potassium bicarbonate grain, 44.2% of the magnesium oxide grain, and 71.1% of the control feed.

Effect of Buffered Rations on Milk Fat Production

This palatability trial was not intended to measure production response of the cows fed rations supplemented with mineral buffers. However, to get an indication of the effect of the buffered rations, the fat-corrected-milk (FCM) production was calculated for the second week of each treatment period. Cows of both production levels produced a greater quantity of FCM on the combination of two buffered rations than when the control was an alternative. There was no appreciable difference between FCM production of the sodium plus potassium bicarbonate and magnesium oxide rations fed in combination with the control grain. The

TABLE VIII

RATION CONSUMPTION BY EXPERIMENTAL ANIMALS

Ration	Offered	Consumed	Consumed
	lb	lb	%
Group I[a]			
Na+$KHCO_3$	4026.4	2514.0	62.4
MgO	4026.4	2511.9	62.4
Control	4026.4	3366.5	83.6
Total	12079.2	8392.4	69.5
Group II[b]			
Na+$KHCO_3$	6344.8	1963.3	30.9
MgO	6344.8	2742.7	44.2
Control	6344.8	4513.7	71.1
Total	19034.4	9219.7	48.4

[a]Late lactation group

[b]Early lactation group

difference in the conversion of feed to FCM was in favor of the buffered rations, but would have to be discounted in this trial since body weight gains were not recorded, and the roughage was fed on a free-choice basis.

Stage of lactation and level of milk production may also be factors to consider. Ten cows of the low production group and three of the lower producers of Group II showed a steady increase in milk fat percentage regardless of the ration sequence. This may have been due to a natural increase of milk fat as production drops during late lactation.

TRIAL II

Buffering Capacity of the Rumen Fluid of Animals Fed the Experimental Rations

The magnesium oxide ration exhibited the highest buffering capacity, requiring an average of 28.3 ml of 0.5 N HCl to change the pH of rumen fluid from 7.0 to 4.0. The sodium and potassium bicarbonate rations excelled the control ration in buffering capacity (25.1 ml vs 24.9 ml). The total buffering capacity for each animal is shown in Table IX. The buffering capacity in increments of 0.5 pH units revealed a similar pattern for the three rations (Figure 1).

The sheltered area of the steers' pens was bedded with wood shavings and changed as often as deemed necessary. When clean shavings were put into the stalls the steers would eat a portion of them. This could account for the lack of real differences in buffering capacity on the different rations.

One steer broke the rigid plastic fistula early in the trial and the replacement did not fit as snugly as the first. Several times

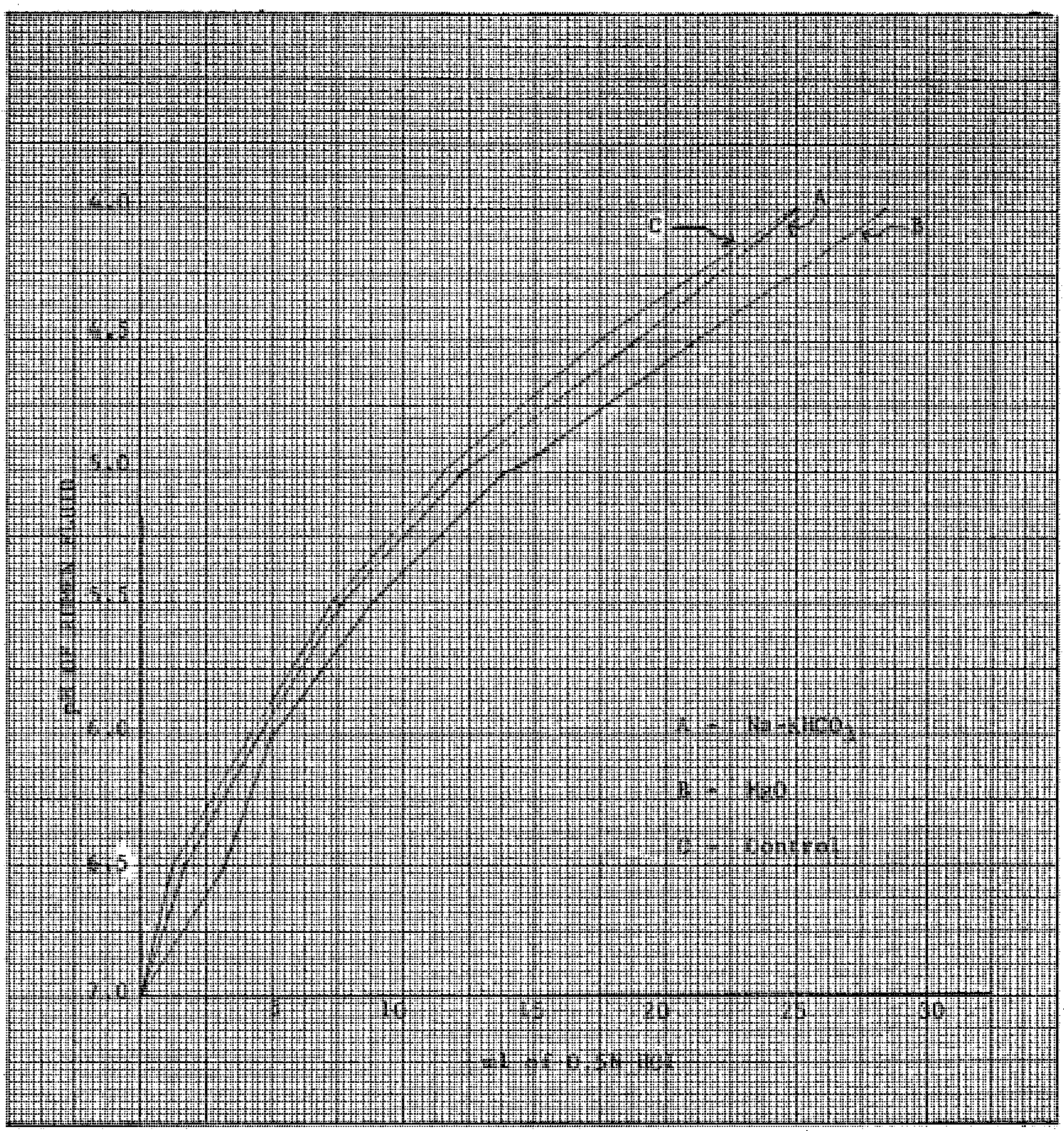

Figure 1. Buffering Capacity of Rumen Fluid

during the experiment the new plug would work out. When the fistula plug was out, the steer would not consume his feed. The plug was normally returned within a few hours and the steers would have consumed his ration by the next feeding time.

TABLE IX

BUFFERING CAPACITY OF RUMEN FLUID

Steer no.	Rations		
	$Na+KHCO_3$	MgO	Control
	(ml of 0.5N HCl)		
10	26.2	29.0	24.9
12	24.5	31.3	25.7
35	24.6	24.5	24.2
Avg.	25.1	28.3	24.9

The mole percentages of the VFA were typical of the ratios found in animals fed rations with high forage levels. There was no appreciable difference among rations with respect to VFA percentages (Table X).

TABLE X

MOLE PER CENT OF VFA IN RUMEN FLUID

Rations	C_2	C_3	C_4	Iso-C_5	C_5
$Na+KHCO_3$	69.1	16.8	10.7	2.0	1.4
MgO	69.8	15.4	12.4	1.9	1.5
Control	68.6	14.9	12.4	2.3	1.8

There was no appreciable difference in rumen pH values of the rumen fluid of the steers. The average pH values for steers fed sodium plus potassium bicarbonate, magnesium oxide and control rations were 6.2, 6.2, and 6.1, respectively.

SUMMARY AND CONCLUSIONS

Two trials were conducted to test the effect of mineral buffers on ration palatability and rumen fluid characteristics. The supplemented rations contained either 1.5% each of sodium and potassium bicarbonate, or 1.5% magnesium oxide.

In Trial I, 24 lactating cows were grouped according to stage of lactation, age, breed, and production level, and assigned to treatment sequences according to a 3 X 3 Latin square. The grain offered the cows amounted to 140% of the TDN requirements for milk production with 70% from each of the two concentrates fed simultaneously. Alfalfa hay was fed free choice.

The amount of the rations consumed per cow per week averaged 46.6, 54.7, and 82.1 lb, respectively, for the bicarbonate, magnesium oxide and control rations. There was a significant difference ($P < .01$) between the amount of the control ration consumed compared to the buffered rations. The magnesium oxide ration was preferred by more cows than the bicarbonate ration, but the difference in the amount consumed was not statistically significant. The cows in early lactation refused a higher percentage of the concentrates offered than did the late lactation cows. Late lactation cows consumed 62.4, 62.4, and 83.6% of the bicarbonate, magnesium oxide, and control rations, respectively, whereas early lactation cows had a respective consumption of 30.9, 44.2, and 71.1%.

In Trial II, three fistulated steers were assigned to a 3 X 3 Latin square treatment sequence. The buffered rations were fed in a finely ground state with long alfalfa hay. A 60:40 grain to hay ratio was maintained. The buffering capacity, pH, and mole percentage of VFA of the rumen fluid were the criteria measured.

There were no appreciable differences in the mole percentage of VFA or pH values of rumen fluid of the steers fed sodium plus potassium bicarbonate, magnesium oxide, or control rations. The mole percentages of VFA were typical of the ratios found in animals fed high roughage rations. The buffering capacity of the rumen fluid was similar for each ration.

It was concluded that the palatability of a pelleted concentrate ration would be reduced by the addition of 1.5% each of sodium and potassium bicarbonate, or 1.5% magnesium oxide. Rations supplemented with 3.0% sodium plus potassium bicarbonate, or 1.5% magnesium oxide, were not effective in altering the characteristics of rumen fluid of animals fed grain:hay ratios of 60:40.

LITERATURE CITED

(1) Autrey, K. M. 1964. Effect of Ration on Composition of Bovine Saliva and on Volume of Saliva Flow. J. Dairy Sci., 47: 698. (Abstr.)

(2) Balch, C. C., Balch, D. A., Bartlett, S., Bartrum, P. M., Johnson, V. W., Rowland, S. J., and Turmer, J. 1955. Studies of the Secretion of Milk of Low Fat Content by Cows on Diets Low in Hay and High in Concentrates. VI. The Effect of the Physical and Biochemical Processes of the Reticulo-Rumen. J. Dairy Sci., 22: 271.

(3) Beitz, D. C., and Davis, C. L. 1964. Relationship of Certain Milk Fat Depressing Diets to Changes in the Proportions of the Volatile Fatty Acids Produced in the Rumen. J. Dairy Sci., 47: 1213.

(4) Card, C. S., and Schultz, L. H. 1953. Effect of the Ration on Volatile Fatty Acid Production in the Rumen. J. Dairy Sci., 36: 599. (Abstr.)

(5) Davis, C. L., Brown, R. E., Beitz, D. C. 1964. Effect of Feeding High-Grain Restricted-Roughage Rations With and Without Bicarbonates on the Fat Content of Milk Produced and Proportions of Volatile Fatty Acids in the Rumen. J. Dairy Sci., 47: 1217.

(6) Emery, R. S., and Brown, L. D. 1961. Effect of Feeding Sodium and Potassium Bicarbonate on Milk Fat, Rumen pH, and Volatile Fatty Acid Production. J. Dairy Sci., 44: 1899.

(7) Emery, R. S., Brown, L. D., and Bell, J. W. 1965. Correlation of Milk Fat With Dietary and Metabolic Factors in Cows Fed Restricted-Roughage Rations Supplemented with Magnesium Oxide or Sodium Bicarbonate. J. Dairy Sci., 48: 1647.

(8) Emery, R. S., Brown, L. D., and Thomas, J. W. 1964. Effect of Sodium and Calcium Carbonates on Milk Production and Composition of Milk, Blood, and Rumen Contents of Cows Fed Grain Ad Libitum With Restricted Roughage. J. Dairy Sci., 47: 1325.

(9) Erwin, E. S., Marco, G. J., and Emery, E. M. 1961. Volatile Fatty Acid Analysis of Blood and Rumen Fluid by Gas Chromatography. J. Dairy Sci., 44: 1768.

(10) Hinders, R. G., and Owen, F. G. 1963. Relationship Between Efficiency of Milk Production and Ruminal Volatile Fatty Acids of Cows Fed Isocaloric (ENE) Rations of Varied Concentrate Levels. J. Dairy Sci., 46: 1246.

(11) Hinders, R. G., Vidacs, G., and Ward, G. M. 1961. Effects of Feeding Dehydrated Alfalfa Pellets as the Only Roughage to Dairy Cows. J. Dairy Sci., 44: 1178. (Abstr.)

(12) Hoglund, C. R. 1963. Economic Analysis of High-level Grain Feeding for Dairy Cows. J. Dairy Sci., 46: 401.

(13) Huber, J. T. 1966. The Effect of Dietary Whey on Milk Composition and Production and on Rumen VFA of Cows on a High-Grain, Low Forage Ration. ADSA Paper Southern Division.

(14) Jorgensen, N. A., and Schultz, L. H. 1965. Ration Effects on Rumen Acids, Ketogenesis and Milk Composition. II. Restricted Roughage Feeding. J. Dairy Sci., 48: 1040.

(15) Jorgensen, N. A., Schultz, L. H., and Barr, G. R. 1965. Factors Influencing Milk Fat Depression on Rations High in Concentrates. J. Dairy Sci., 48: 1031.

(16) Kesler, E. M., and Spahr, S. L. 1964. Physiological Effects of High Level Concentrate Feeding. J. Dairy Sci., 47: 1122.

(17) Lassiter, J. W., and Cook, M. K. 1963. Effect of Sodium Bicarbonate in the Drinking Water of Ruminants on the Digestibility of a Pelleted Complete Ration. J. Dairy Sci., 22: 384.

(18) Lassiter, J. W., Hamdy, M. K., and Buranamanas, P. 1963. Effect of Sodium Bicarbonate on Microbial Activity in the Rumen. J. Animal Sci., 22: 335.

(19) Lassiter, J. W., and Alligood, V. 1964. Consumption of Sodium Bicarbonate Water by Steers on All-Concentrate Rations. J. Animal Sci., 23: 304. (Abstr.)

(20) Miller, R. W., Hemken, R. W., Waldo, D. R., Okamoto, M., and Moore, L. A. 1965. Effect of Feeding Buffers to Dairy Cows Fed a High Concentrate, Low Roughage Ration. J. Dairy Sci., 48: 1455.

(21) Miller, R. W., Hemken, R. W., Vandersall, J. H., Waldo, D. R., Okamato, M., and Moore, L. H. 1965. Effect of Feeding Buffers to Dairy Cows Grazing Pearl Millet or Sudan Grass. J. Dairy Sci., 48: 1319.

(22) Miller, W. J., and Clifton, C. M. 1964. Influence of Experimental Design on Results of Palatability Studies. J. Dairy Sci., 47: 927.

(23) Moody, E. G., and Cook, A. P. 1961. Whole Cottonseed in Limited-Fiber Rations for Dairy Cows. J. Dairy Sci., 44: 1176. (Abstr.)

(24) Nicholson, J.W.G., and Cunningham, H.M. 1961. The Addition of Buffers to Ruminant Rations. 1. Effect on Weight Gains, Efficiency of Gains and Consumption of Rations With and Without Roughage. Can. J. Animal Sci., 41: 134.

(25) Nicholson, J.W.G., Cunningham, H. M., and Friend, D. W. 1962. The Addition of Buffers to Ruminant Rations. 2. Additional Observations on Weight Gains, Efficiency of Gains and Consumption by Steers of All-Concentrate Rations. Can. J. Animal Sci., 42: 75.

(26) Nicholson, J.W.G., Cunningham, H. M., and Friend, D. W. 1962. The Addition of Buffers to Ruminant Rations. 3. The Effect of Additions of Sodium Bicarbonate, Sodium Propionate, Limestone and Cod Liver Oil on Apparent Digestibility and Nitrogen Retention of an All-Concentrate Ration. Can. J. Animal Sci., 42: 82.

(27) Nicholson, J.W.G., Cunningham, H. M., and Friend, D. W. 1963. The Addition of Buffers to Ruminant Rations. 4. The Effect of Additions of Sodium Bicarbonate, Sodium Propionate, Limestone and Cod Liver Oil on Intra-rumen Environment. Can. J. Animal Sci., 43: 309.

(28) Nicholson, J.W.G., Cunningham, H. M., and Friend, D. W. 1963. Effect of Adding Buffers to All-Concentrate Rations on Feed Lot Performance of Steers, Ration Digestibility, and Intra-rumen Environment. J. Animal Sci., 22: 368.

(29) Palmquist, D. L., Smith, L. M., and Ronning, M. 1964. Effect of Time of Feeding Concentrates and Ground, Pelleted Alfalfa Hay on Milk Fat Percentage and Fatty Acid Composition. J. Dairy Sci., 47: 516.

(30) Peters, I. I., Harris, R. R., Mulay, C. A., and Pinkerton, F. 1961. Influence of Feed Upon the Composition of Milk. II. Low Versus High Fat Rations. J. Dairy Sci., 44: 1293.

(31) Raun, N. S., Burroughs, W., and Woods, W. 1962. Dietary Factors Affecting Volatile Fatty Acid Production in the Rumen. J. Animal Sci., 21: 838.

(32) Schultz, L. H., Jorgenson, N. A., and Pendleton, R. A. 1964. Effect of the Addition of Sodium Bicarbonate to Pelleted Rations Which Depress Milk Fat Percentage. J. Dairy Sci., 48: 808. (Abstr.)

(33) Shelton, M., and Ellis, W. C. 1965. Buffering Agents in All-Concentrate Ration for Lambs. J. Animal Sci., 24: 289.

(34) Stone, J. B. Feb. 10, 1966. New Grain Feeding Guides for Cows in Milk. Hoard's Dairyman, 132.

(35) Stone, J. B., Spalding, R. W., Merrill, W. G., and Reid, J. T. Nov. 1963. A Revised Grain Feeding Guide for Lactating Dairy Cows. Mimeo. Material Dept. of Animal Husbandry, Cornell University, Ithaca, New York.

(36) Tyznik, W., and Allen, N. N. 1951. The Relation of Roughage Intake to the Fat Content of the Milk and the Fatty Acids in the Rumen. J. Dairy Sci., 34: 493. (Abstr.)

(37) Van Soest, P. J. 1963. Ruminant Fat Metabolism With Particular Reference to Factors Affecting Low Milk Fat and Feed Efficiency. (A Review) J. Dairy Sci., 46: 204.

(38) Warner, R. G. 1965. The Relationship of the Diet of Dairy Cows to Milk-Fat Percentage. Proceeding of DFRC 20th Conference, 20: 15.

(39) Wise, M. B., Blumer, T. N., Matrone, G., Barrick, E. R. 1961. Investigations on the Feeding of All-Concentrate Rations to Beef Cattle. J. Animal Sci., 20: 561.

VITA

Jack Dean Stout

Candidate for the Degree of

Master of Science

Thesis: MINERAL BUFFERS IN DAIRY COW RATIONS

Major Field: Dairy Science

Biographical:

Personal Data: Born in Arkansas City, Kansas, March 3, 1933.

Education: Graduated from Skiatook High School in 1951; received the B.S. degree from Oklahoma Agriculture and Mechanical College, Stillwater, Oklahoma in 1955 with a major in Dairy Production.

Experience: Reared the son of a bricklayer-farmer on a small diversified farm in Tulsa County, Oklahoma; active in FFA activities attaining American Farmer degree; operated own dairy and bottled milk sales at Stillwater, Oklahoma while in college; four years as apprentice and journeyman bricklayer with Manhattan Construction Co., Muskogee, Oklahoma; Instructor of Dairy Science at Murray State Agricultural College, 1957-60; Farm Manager for Cooper Farms, Inc., 1960-65; Instructor of Dairy Science, Oklahoma State University, February 1965 to date.

Member: American Dairy Science Association, Ayrshire Breeders Association, First Christian Church, Masons 32°.