METHODS OF FEED PREPARATION

FOR LACTATING DAIRY COWS

BY

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INTRODUCTION

Sorghum grain is readily available in most sections of the country and thus constitutes a large proportion of feeds for ruminants. With the recent trend in ruminant rations toward a wider ratio of concentrates to roughages, attention is being focused on various processing methods for grains of all types. The market for sorghum grain is increasing steadily as research leads to more effective use of this product.

The results of feeding high concentrate rations to dairy cows have generally been favorable with respect to the composition of the milk produced. Consumer acceptance of low fat-high solids milk has also encouraged the feeding of these rations.

Recently some reports have been made concerning the effects of various heat treatments on grains. Few of these, however, have employed sorghum grain as the chief ration constituent. Indications in the literature that certain of these treatments may produce higher milk yields and desirable changes in milk composition prompted this study.

The objectives of the research reported herein were to determine: (1) what effect, if any, various heat treatments of sorghum grain have upon the molar concentration of rumen volatile fatty acids and (2) to what degree this effect, if present, is reflected in the production of milk, milk fat, milk protein and total solids, and in the efficiency of feed utilization.

LITERATURE REVIEW

Effect of Grinding Grains

Poor utilization of whole sorghum grain was suggested by Fitch and Wolberg (15). They reported that 43% of the seed in sorghum silage was voided in the feces of cows when fed in combination with a grain mixture. When fed as the sole concentrate with alfalfa hay, 62% of the seeds were lost. Likewise, Atkeson and Fountaine (4) found that 62% of ingested sorghum seed was excreted in the feces when fed as the only concentrate to dairy cows. Wilbur (51) reported similar losses when whole oats were fed to cows. He obtained significantly higher milk production from feeding medium-ground oats than from oats fed whole or ground to a powdery fineness. A study by Olson (31) suggested a slightly decreased efficiency of milk production when finely-ground sorghum grain replaced a more coarsely-ground ration. However, no differences in body weight change of cows or digestibility of the rations were observed.

Effect of High Concentrate Rations

Powell (35) was among the first to report profound alterations in milk composition due to special rations. The fat content of milk was found to be regulated by the physical characteristics of the roughage in the ration. The author's suggestion that more than the form and amount of roughage in the ration contributed to changes in milk composition prompted extensive research in this area.

Tyznik and Allen (48) noted decreases in milk fat ranging from one to two percentage units when the roughage was limited to 3 lb./day and concentrates were fed ad libitum. This low fat content persisted until the cows were returned to a more normal roughage intake, at which time the fat per cent quickly returned to normal. These workers noted that, in every instance, depression of milk fat per cent was associated with a change in the ratios of rumen volatile fatty acids (VFA). Proportionally, propionate increased, acetate decreased and butyrate remained essentially the same. On the basis of these observations it was postulated that a cause-and-effect relationship exists between the ratio of rumen acetate to propionate and milk fat per cent.

Similar changes in rumen VFA concentrations in dairy cows were reported by Balch et al. (7) when a ration containing relatively large amounts of flaked (steam rolled) maize was compared to rations of normal roughage content. When the hay allowance was reduced to 2 lb., the per cent of rumen acetate decreased from 55 to 35, and that of propionate increased from 23 to 33. An appreciable concentration of lactate was found in the rumen contents shortly after feeding. Accompanying these changes was a 30% decrease in the yield of milk fat and a significant increase in the content of solids-not-fat (SNF) of the milk. No differences in milk yield were reported. In another study, Balch et al. (5) found similar results with respect to milk yield and composition when comparing a commercial dairy cube containing maize, barley and wheat to a concentrate mixture containing flaked maize. In this case, the rise in per cent SNF was attributed to an increase in the per cent protein in the cows' milk. These changes in milk composition were corrected by returning the cows to a hay allowance of 18 lb./day. In a later trial Balch et al. (6)

found no change in SNF and a decrease in fat content and milk yield when feeding flaked maize instead of maize meal to dairy cows.

Balch et al. (5) showed, using a digestion trial, that the depression in milk fat per cent was not due to differences between rations with respect to digestibility of dry matter, crude protein, ether extract or crude fiber. The essential difference between diets producing low fat milk and those producing milk of normal fat content was that the former provided a higher intake of starch and possessed few of the physical properties of roughage.

Work by Balch et al. (5,7) and by Balch and Rowland (8) strongly suggested that the amount of concentrate in the ration is of considerable importance in effecting intra-ruminal changes and, eventually, alterations in milk composition. Subsequent research by other workers substantiated this belief (20, 21). Holmes et al. (21) fed four levels of concentrate to lactating cows receiving limited amounts of hay and dried grass. Grass silage was fed ad libitum. The concentrate levels ranged from 0 to 6 lb./gal. of milk produced. The average daily milk yield per cow increased from 22.2 lb. when no concentrate was fed to 27.6 lb. when 6 lb. of concentrates were fed/gal. of milk produced. A significant difference in milk yield response was found between higher-yielding and lower-yielding groups of cows. The SNF content of the milk increased from 8.3% when no concentrate was fed to 8.6% when 4 or 6 lb. of concentrates were fed/gal. of milk produced. There were no significant differences in fat per cent of the milk produced on the four rations.

Peters et al. (32) observed that a ration containing 63% more crude fiber and 14% more dry matter than another resulted in significantly higher mean averages with respect to per cent total solids (TS), fat and

SNF. However, total milk production was significantly increased with the low roughage-high concentrate ration. These data were not converted to fat-corrected-milk (FCM) values.

Hinders and Owen (20) fed rations which supplied either 30, 50, 70, or 90% of the estimated net energy (ENE) in the form of concentrates. They noted no changes in milk production or per cent fat, but attributed the lack of differences to the fact that the concentrate rations contained a relatively large amount of crude fiber, being high in beet pulp and wheat bran. SNF per cent increased only slightly when the level of concentrate was raised. Increasing the concentrate increased the per cent total digestible nutrients (TDN) in the ration and the apparent digestibility of the dry matter, fat, nitrogen-free-extract (NFE) and gross energy. The high concentrate rations decreased the proportion of rumen acetate and increased that of butyrate. There was a closer relationship between the acetate to butyrate ratio and energy utilization above maintenance than between the acetate to propionate ratio and energy utilization above maintenance.

Heat-Treated and Pelleted Rations

Results from various trials differed considerably, and in trials where increased concentrates did alter the milk composition, the effect was believed to be due to an increased availability of readily-fermentable carbohydrates in the ration (5, 7, 8). This concept appeared worthy of investigation, in view of reports by Blosser (10) and Tillman (47) that certain treatments of grain, including pelleting, required heat sufficient to produce varying degrees of gelatinization of the grain starch molecules. Tillman (47) suggested that this partial degradation of the starch could result in more rapid enzymatic and microbial digestion.

Pursuing the above concept, Ensor _et al._ (13) demonstrated that depression of milk fat per cent could indeed be more readily effected when heated, rather than ground, corn made up the concentrate portion of high concentrate rations. This effect was most marked when alfalfa hay was fed ground and/or pelleted instead of being fed in the long form. The decreased fat content of the milk was accompanied by a marked decrease in the proportion of acetate and an increase in the propionate in the rumen fluid. None of the rations significantly changed milk yield. These authors did not report information regarding SNF production. In a similar trial, King and Hemken (25) found no significant differences with respect to quantity and composition of milk between ground and flaked corn when each was fed in combination with long alfalfa hay. However, when equal amounts of pelleted and ground hay comprised the roughage part of the ration, flaked corn had a striking effect on the fat content of the milk. As the content of milk fat from cows fed the flaked corn decreased by 33%, the protein content increased by 5%, resulting in a significant rise in SNF per cent. Although the pellets proved to be less palatable than long hay, this was not reflected in any change in the quantity of milk produced. Analysis of rumen fluid showed a decrease in acetate and an increase in propionate corresponding to the decrease in fat per cent. The ground corn, when fed with pelleted and ground hay, gave an even more marked decrease in milk fat per cent, but other measurements were affected less profoundly than those taken from cows receiving the flaked corn.

Bishop _et al._ (9) obtained a highly significant increase in milk yield, a decrease in fat content and no change in protein or SNF content of milk from cows fed pelleted concentrate as compared to those receiving the concentrate in meal form. The concentrate mixture consisted largely of corn and contained lesser amounts of oats, wheat bran, corn distillers dried grains and soybean oil meal. Each form of concentrate was fed either ad libitum or at the rate of 1 lb./4 lb. milk produced. The high concentrate ration produced a significant increase in milk yield and per cent protein, and a decrease in fat content. A significant increase in rumen acetate and a decrease in rumen butyrate occurred with the low concentrate ration, but no appreciable differences in rumen VFA were noted between the pelleted and ground rations.

Jorgensen and Schultz (24) investigated the effects of feeding normal levels of concentrate in either pelleted or ground form. Hay was fed either long or pelleted. Pelleting of either the roughage or concentrate lowered the fat test of the milk, lowered the per cent of rumen acetate and raised the per cent of rumen propionate. When pelleted corn was fed there was a significant increase in blood ketone levels. However, when pelleted hay was fed there was a significant decrease in blood ketone levels. The authors indicated the lack of an explanation for these differences in effects from roughage and concentrates, but suggested that an increased content of rumen butyrate in cows receiving pelleted corn contributed to the ketone level and overshadowed the antiketogenic effect from the likewise increased propionate level. No advantage in milk yield was observed for the pelleted feeds except when compared to a ration containing only long hay and beet pulp. Cows receiving the latter ration also consumed significantly less dry matter than others, presumably due to the bulky nature of the feed. No changes in per cent SNF in the milk were found.

In recent work concerning the effects of pelleting, Hawkins et al. (17) found concentrate rations consisting of either 35 or 49% pelleted and ground oats or corn more effective in producing depressions in the fat content of milk than a similar ration containing only 19% of these grains. Pelleting of either corn or oats significantly decreased rumen acetate and increased propionate and butyrate when the ration contained either 35 or 49% concentrates, but had no effect when the grains were fed at the 19% level. Pelleting of the higher concentrate rations significantly decreased the daily production of 4% FCM below that of cows receiving the ground grain.

Ronning (38) reported that milk fat dropped from 2.6 to 2.1% when cows consuming an all-pelleted alfalfa hay ration were switched to a diet containing 45% pelleted concentrates consisting of barley and beet pulp. No change was noted when only 15% concentrates were fed. Although cows fed high concentrate pellets showed an increase in milk production, this difference was not significant when converted to a FCM basis.

Instead of finding any advantage for pelleting concentrates for dairy cows, Adams and Ward (1) reported that a pelleted feed actually lowered the yield of FCM and resulted in a highly significant decrease in fat test. The effect on fat per cent was not significant when a high quality forage was fed. When using either high or low quality roughage, the combined effects of decreased fat content and lowered milk yield resulted in a significant decrease in the production of FCM. In contrast, Putnam and Davis (36) reported no depression in milk fat content and no change in milk yield between a pelleted complete ration and a conventional feed containing long hay and concentrates in meal form.

Shaw et al. (41) noted decreases in milk fat per cent when high starch concentrates such as rice, potato meal and bread were subjected to moist heat and fed to lactating dairy cows. Milk fat per cent declined by 30% on the bread ration but there were no significant changes in SNF. These workers reported a correlation of 0.64 between milk fat per cent and the amount of rumen acetate and a correlation of -0.63 between the fat per cent and the amount of rumen propionate present. Milk yield declined more rapidly on the high starch rations as compared to one containing a high protein concentrate.

Using both cattle and sheep, Newland et al. (30) reported significant changes in rumen VFA when each of three types of processed corn, flaked, crumbled or commercially heated, were compared to unheated ground corn. Alfalfa hay comprised not more than 50% of the total ration. The most marked change in the acetate to propionate ratio, a narrowing from 3.42:1 to 1.97:1, occurred when flaked corn replaced ground corn. However, Hentges et al. (19) observed only a slight increase in rumen propionate when cracked or flaked corn replaced ground corn under conditions where grass hay was fed ad libitum.

In a trial involving wether lambs, Woods and Luther (52) reported that adding ground corn to an all-hay ration significantly narrowed the acetate to propionate ratio. They also observed that heating the concentrate was effective in lowering the pH of the rumen below that in lambs receiving pelleted or reground pelleted rations. Finely-ground hay increased the proportion of propionate in the rumen fluid when the rations contained concentrates, but not when an all-hay ration was fed. Other workers (16, 33) reported similar decreases in the rumen pH of animals receiving heated concentrates. Likewise Hungate et al. (23) observed that large quantities of starch or glucose led to the production of lactate which lowered the pH of the rumen. They reported pH values as low as 4.0 when sufficient carbohydrates were available to rumen microflora. It was suggested that this highly acid condition and consequently modified rumen function are largely responsible for indigestion and bloat often associated with high concentrate rations. Balch and Rowland (8) suggested that the lowered rumen pH caused by high starch diets encourages the proliferation of organisms that produce less acetic acid than is produced by those predominating when high roughage rations are fed.

Effect of Grain Processing on Growth Response and Feed Efficiency

Haenlein et al. (16) used growth data from 12 dairy heifers to compare expanded and non-expanded corn and soybean rations to a completely pelleted feed. All rations contained alfalfa hay and concentrates in the ratio of 2:1. Digestion coefficients for all the constituents of the expanded grain were equal or superior to those of the other two rations. Digestibility of crude fiber was most markedly increased by expanding. Total feed and dry matter consumption was highest in the group of animals fed the expanded feed and lowest in the group on the pelleted ration. Rates of gain over the 56 day period were greatest for animals fed expanded grain and lowest for those receiving pelleted feed. The efficiency of feed conversion was higher in the pelleted and expanded feed groups than in the control group, but not significantly different. Increase in heart girth was significantly greater in the expanded grain-fed heifers.

Other reports concerning the effects of processing corn on growth response were in general agreement that the intra-ruminal changes produced were reflected in more efficient utilization of feed (13, 19, 30, 42). Work involving barley (12, 18, 46) and sorghum grain (34) did not produce similar results. One possible explanation for the differences between grains in their response to heating has been discussed by Alsberg and Rask (2) and Radley (37). Both these groups reported that the gelatinization temperatures of the starch of grains were highly variable between species and between varieties within a species.

Physiological Causes of Changes in Milk Composition

While the literature cited thus far fairly well confirmed the belief that different feeding regimes can at least alter the physiological processes of the animal body sufficiently to produce some change in the amount and quality of milk produced, few of the studies attempted to explain by what mechanisms these changes are produced.

Three theories have been advanced as to the reason why fat per cent of milk produced on various diets is lowered. These were reviewed by Van Soest (50).

The first theory is that a deficiency of acetate in the rumen results in a lowered blood level of acetate, thereby resulting in decreased availability of acetate for milk fat synthesis. The fact that acetate levels in the rumen are often lowered when fat per cent of milk is depressed supports this theory to a degree, since it has been demonstrated that acetic acid is the primary precursor of milk fat. Also, one group (7) reported a lower Reichert-Meissl number of milk fat from cows fed high concentrate rations. This observation suggested that during such a feeding regime the milk fat is made from longer chain fatty acids than when the animals are fed rations which produce milk of more normal fat content. However, it has been shown that blood levels of acetate do not necessarily drop when milk fat per cent is depressed. Thus, the change in milk fat per cent could also be due to an increased concentration of propionate, a condition usually accompanying production of low fat milk. The infusion of propionic acid into the blood of lactating cows has been shown to depress milk fat per cent.

The second theory suggests that the low milk fat per cent associated with increased rumen propionate levels is a result of a deficiency in the amount of beta-hydroxy-butyric-acid (BHBA) available for milk fat synthesis. BHBA has been shown to be another essential precursor of milk fat. Van Soest (50) indicated that since propionic acid is almost entirely glucogenic with respect to the citric acid cycle, an increased blood propionate level could possibly result in the reduction of the relative amount of BHBA available to the mammary gland. This theory is supported by some work in which milk fat content was depressed when the level of ketone bodies in the blood decreased. Some evidence that the relation between rumen acid ratios and milk fat per cent is not completely consistent limits the extent to which this theory is acceptable.

The third theory reviewed by Van Soest (50) was originated by McClymont and Vallance (27). They proposed that perhaps the glucogenic response during high propionate production slows down the mobilization of fat from body tissues. This, they suggested, causes a decline in blood lipids which are required for milk fat synthesis. Van Soest (50) cited work in which it was reported that levels of plasma glycerides and non-esterified fatty acids (NEFA) were suppressed when milk fat per cent declined. He also indicated that the introduction of various glucogenic substances into the venous blood system causes an increased secretion of insulin. This, he stated, may result in the inhibition of the "fat mobilization factor" of the pituitary gland. Then, in succession, the blood glycerides, the NEFA and the synthesis of blood glycerides are lowered. He also indicated that the lack of any good explanation in this theory for the decrease in short chains of milk fat under conditions of low milk fat may be overcome if it is considered that the depression of the "fat mobilization factor" results in a decrease in liver ketones. Such a decrease could result in a lowered blood ketone level.

Consumer Acceptance of Low Fat Milk

Some studies have been made to determine if consumers have preferences for milk of low or high fat content. In a study by Stull and Hillman (44) it was reported that non-trained persons could consistently differentiate between milk beverages with variations in fat and SNF of 0.5 to 1.0%, respectively. Beverages with 1.0% added SNF were preferred over those with a lower SNF content. There was no difference between the preference for whole milk (3.5% fat; 8.5% SNF) and a low fat drink (2.0% fat; 10.0% SNF). Ul-Hamid and Manus (49) observed that milk containing 2.0 or 3.0% fat was more acceptable in flavor than milk with 4.0% fat. Each treatment was standardized to 12.0, 13.0, 14.0 or 15.0% TS. No difference in flavor preference was shown between milk containing 2.0 and 3.0% fat when each was standardized to either 11.0 or 13.0% SNF, but both were more acceptable in flavor than unfortified milk containing 3.7% fat and 9.2% SNF. In comparison, the latter was watery and flat-tasting.

In later work Stull and Hillman (45) reported that the addition of only 1.0% SNF caused a highly significant improvement in acceptance of whole, low fat or nonfat milk beverages. Slightly significant preference was shown for a fortified whole milk over a non-fortified, higher fat milk.

EXPERIMENTAL METHODS

TRIAL I

Selection of Cows and Assignment of Treatments

The study was divided into two trials to meet the objectives set forth. In Trial I, 24 Ayrshire cows were allotted to groups (squares) of three cows each on the basis of date of freshening. They were randomly assigned within squares to three treatment groups according to the plan for a balanced 3 X 3 Latin square design. This design was employed to eliminate the carry-over effects of treatments, since no change-over period between treatments was allowed.

After calving, each cow was gradually adjusted to a ration having a 50:50 concentrate to roughage ratio during a 6-wk. pre-experimental period. The composition of the concentrate ration, which was pelleted through a 5/8 in. die, is presented in Table I. Alfalfa hay was fed as the only roughage.

TABLE I

CONCENTRATE RATION FOR PRELIMINARY PERIOD-
TRIAL I

Ingredient	% of Total Concentrate Ration
Ground Sorghum	50
Ground Barley	25
Wheat Bran	10
Molasses, Liquid Blackstrap	7
Cottonseed Meal	5
Urea	1
Dicalcium Phosphate	1
Trace Mineral Salt	1

Cows within a square were started on the pre-experimental ration together and thus completed the entire experiment simultaneously.

Grain Treatments

Sorghum grain for the different mixtures received one of the following treatments: (a) fine grinding only, (b) fine grinding and steam rolling, (c) fine grinding, steam rolling and dry heat for 1 hr. These grains were ground through a 3/64 in. screen. In the steam rolling process, the grain was exposed to steam in a conditioning bin prior to rolling; the temperature of the grain immediately after rolling was 76.5°C. In addition to grinding and steam rolling, the grain for treatment "c" received dry heat for 1 hr. Heating was done in metal pans large enough to contain about 25 lb. of the grain spread to a depth of 2.5 in. Temperature readings were taken at 5 min. intervals and the feed stirred every 10 min. Table II is an example of typical temperatures during the 1-hr. heating period.

TABLE II

TYPICAL TEMPERATURES IN DRY HEAT TREATMENT-TRIAL I

Time (min.)	Oven Temperature (C°.)	Grain Temperature (C°.)
5	121	82
10	149	93
15	154	104
*20	177	107
25	177	107
30	177	107
*35	193	121
40	204	130
*45	204	138
50	204	147
*55	210	155
60	219	165

*Grain was stirred at these intervals.

After the grain received one of the treatments, other ingredients needed to balance the rations were added and each ration pelleted through a 3/8 in. die. Thus, the rations were identical except for the preparation of sorghum in each. The composition of the rations is presented in Table III.

TABLE III

EXPERIMENTAL RATIONS-
TRIALS I & II*

Ingredient	% of Total Concentrate Ration
Ground Sorghum	75
Wheat Bran	10
Molasses, Liquid Blackstrap	7
Cottonseed Meal	5
Urea	1
Dicalcium Phosphate	1
Trace Mineral Salt	1

*This mixture constituted both the preliminary and experimental rations for Trial II.

A sample of each ration was ground through a Wiley mill using the intermediate size screen. The samples were refrigerated for subsequent proximate analysis and use in artificial rumen studies. Proximate analyses of the rations and hay are presented in Table IV.

TABLE IV

PROXIMATE ANALYSES OF EXPERIMENTAL RATIONS-
TRIAL I

Ration	Dry Matter	Ash	Crude Protein	Ether Extract	Crude Fiber	NFE
			(%, air-dry basis)			
Ground	91.54	5.17	14.70	3.07	2.53	66.07
Ground and Steamed	90.22	5.52	13.74	2.81	2.56	65.59
Ground, Steamed & Dry Heated	90.48	5.04	14.24	3.00	2.92	65.28
Alfalfa Hay	93.29	10.17	21.10	1.95	22.09	37.98

Feed Allowances

Body weight was recorded for each cow on each of the last three days of the pre-experimental period. The average weights thus obtained and the average daily milk yield on the last seven days of the pre-experimental period were used to compute initial feed allowances according to the upper limit of Morrison's TDN standard (29). Additional allowances were given first and second calf heifers. Good quality alfalfa hay was fed in equal proportion to grain. For each 6-wk. period, feed allowances were reduced by 10% of the previous period's allotment.

Collection of Data

Cows were fed at 3:30 A.M. and 3:30 P.M. Refused feed was weighed and recorded each morning after feeding. The cows were afforded outside exercise from 9:00 A.M. until 2:00 P.M. each day. The remainder of the time they were bedded on wood shavings in individual stanchions in an enclosed barn. Clean water was provided.

Body weights were recorded on each of the last three days of each experimental period. The average weight change per cow for each treatment period was thus available.

Rumen samples were taken from the first 18 cows to complete the experiment 3 hr. after the evening feeding on the last day of each period. The pH values of the samples were determined immediately using a portable pH meter. The samples were strained through cheese cloth, centrifuged to remove solid material, and frozen for later VFA analysis.

Milk yield was recorded twice daily and milk samples were taken at four consecutive milkings each week.

Milk Analyses

Milk from each cow was collected at four consecutive milkings weekly, milk yield was recorded and each sample was placed in a separate bottle. The four samples for each cow were then composited by taking 5 ml./lb. milk produced at that milking. The following analyses were performed on the composite for each cow:

(a) Milk fat, using the Babcock procedure (3).

(b) Total Solids, using the Mojonnier method (28).

(c) Protein, using the Kjeldahl procedure (3).

(d) Iodine number of the fat, using the Hanus method (3).

VFA Analysis

Preparation and analysis of the rumen samples for VFA content followed the procedure outlined by Erwin et al. (14). An Aerograph Model A-600-B "Hy-Fi" gas chromatograph machine with a hydrogen flame ionization detector was used. The hydrogen flow rate was set at 20 ml./min. Nitrogen was the carrier gas for eluting the VFA. A flow rate of 23 ml./min. was used. The column was packed with 20% Tween 80, 2% Phosphoric acid (85%) on Chromosorb W. Oven temperature was 120° C. and injection block temperature was 300° C.

The fatty acids in the rumen fluid were calculated from peaks obtained after the injection of 10 µl. of sample into the chromatograph machine. The area of the respective peaks obtained following the injection of an aliquot of a standard solution was assumed to represent the computed micromoles of the respective acids per 10 µl. of standard (Table V). The amount of each fatty acid in the rumen fluid was then

TABLE V

STANDARD VFA SOLUTION

Acid	ml./l.	g./l.	µg./µl.	µM/10µl.
Acetic	4.12	4.4440	4.4440	0.7393
Propionic	2.24	2.2488	2.2488	0.3036
Butyric	1.44	1.4901	1.4901	0.1691
Valeric	0.26	0.3112	0.3112	0.0305

computed by dividing the area obtained for the rumen fluid sample by that obtained with the standard fatty acid solution and multiplying the result by the computed micromoles/10 µl. in the standard solution.

Artificial Rumen Studies

The procedure for following the disappearance of readily-hydrolyzable-dry-matter (RHDM) in each ration was a modified version of that originated by Huhtanen *et al.* (22) and used by Salsbury *et al.* (39, 40). Rumen fluid (inoculum) for this phase of the study was obtained from permanently-fistulated steers receiving a ration consisting of equal parts of concentrate and roughage. Though more than one animal was used during the study, the same animal was used for all treatments within any particular trial.

The donor animal was fasted for 15 hr. prior to sampling, but allowed free access to water. Ingesta was dipped from the rumen into a metal cylinder with a hole 3/4 in. in diameter in the bottom. A metal plunger forced the more liquid portion of the ingesta through a fine screen wire, two thicknesses of cheese cloth and the hole into an insulated bottle which had been prewarmed to 39° C.

An electric heating wire was arranged on the floor of the drum of an International Size 2 centrifuge to preheat the centrifuge bottles and maintain a temperature of about 39° C. while centrifugation proceeded. The inoculum was placed in the bottles and spun at 1200 r.p.m. for 10 min. These conditions rendered the samples reasonably free of dry matter while maintaining the desired temperature. The supernatant of each bottle was decanted into a 1000 ml. volumetric flask which was immediately placed in a water bath at 39° C.

Two 20 ml. aliquots of inoculum were transferred to weighed centrifuge tubes via a 25 ml. pipette which had enough of the tip removed to permit passage of all feed particles. One drop of approximately 2N H_2SO_4 was added to each aliquot and they were then refrigerated.

Inoculum was mixed with weighed samples of each ration in 250 ml. Erlenmeyer flasks. Enough feed from each ration was used to produce mixtures containing 2.5% dry matter. Two aliquots of 20 ml. from each mixture were transferred to weighed centrifuge tubes, one drop of 2N H_2SO_4 added, and the samples refrigerated. These samples represented inoculum-feed mixtures which were not incubated in the water bath.

Four 20 ml. aliquots of each mixture were pipetted into separate 6-in.-long dialysis sacs. The sacs were prepared from 1-in.-wide dialysis tubing by cutting the tubing at 7 in. intervals, allowing 1 in. for securely tying one end of the segment. Sacs containing the fermentation mixtures were immediately placed in 120 ml. glass jars containing 80 ml. of a pre-warmed mineral solution simulating saliva. The uppermost portion of each dialysis sac was folded and 0.5 in. allowed to remain outside the jar when the lid was secured. One group of samples, containing duplicate pairs of each treatment, was thus incubated at 39^{o} C. for 12 hr. and another group, also containing duplicates for each treatment, was incubated for 24 hr.

The artificial saliva was made in the manner described by Salsbury et al. (39) and its composition is presented in Table VI. The pH of the solution was adjusted to a point between 6.7 and 7.0 by bubbling slowly with CO_2 just prior to transferring it to the glass jars.

TABLE VI

COMPOSITION OF ARTIFICIAL SALIVA USED FOR IN VITRO STUDY

Salt	Concentration (g./l.)
$NaHCO_3$	4.9
$Na_2HPO_4 \cdot 12H_2O$	4.7
NaCl	0.24
KCl	0.29
$CaCl_2 \cdot 2H_2O$	0.026
$MgCl_2 \cdot 6H_2O$	0.064
$FeSO_4 \cdot 7H_2O$	0.04
$ZnSO_4 \cdot 7H_2O$	0.002
$CuSO_4 \cdot 5H_2O$	0.001
$MnSO_4 \cdot H_2O$	0.001

After 3 hr. of fermentation, jar lids were loosened and the gas formed in the sacs allowed to escape. This was done to prevent rupture of the sacs. At this point, the saline in each jar was again bubbled with CO_2 to maintain anaerobic conditions. After the lids were secured the jars were inverted slowly several times to re-mix the contents.

After the samples fermented for the designated lengths of time, they were washed into weighed centrifuge tubes and diluted to 80 ml. with absolute ethanol. Any material adhering to the sides of the tubes was returned to the ethanol medium. They were centrifuged for 15 min. at 1800 r.p.m. and the supernatant drawn off with a water-powered aspirator. They were dried for 18 hr. at 95° C., dessicated for 1 hr. and weighed.

To each tube was added 10 ml. of 2N HCl. A glass stirring rod was used to pulverize the dried mixture and mix it thoroughly with the acid. Hydrolysis was speeded by placing the mixtures in an oven for 2 hr. at 121° C. Upon removal they were washed with 80% ethanol a minimum of two times, and centrifuged and aspirated with each washing. When the addition of ethanol produced a milky appearance in the tube, washing was continued until no such condition existed. When the mixtures were not washed a sufficient number of times to remove all the HCl, they charred to varying degrees upon subsequent drying. Finally, the samples were dried for 18 hr. at 95° C., dessicated 1 hr. and weighed.

Calculation of RHDM Disappearance

The difference between the weight of a tube and its contents before and after hydrolysis represented the amount of RHDM in that sample. To obtain the RHDM value for the substrate, that obtained for the inoculum was subtracted. Dividing the RHDM value for a substrate fermented for X hr. (either 12 or 24) by that for the non-fermented substrate of the same treatment, and multiplying by 100, gave the percentage of RHDM remaining in that substrate. This value was subtracted from 100 to give the percentage of RHDM disappearing at X hr. The values for each set of duplicates were averaged to arrive at a single figure for disappearance of RHDM.

Alterations in the Artificial Rumen Technique

Salsbury et al. (40) reported fairly consistent values between duplicates when hydrolyzing corn starch with 0.5N HCl for 1 hr. However, in the present study, unrealistically low values were obtained under these conditions. When the normality of the acid was increased to 2N and the length of hydrolysis time extended to 2 hr., values for RHDM disappearance between duplicates were much more consistent and realistic. This observation indicates that there may be appreciable differences in the starch of corn and that of sorghum grain with respect to the readiness with which each is hydrolyzed in vitro.

Another interesting observation in the present study was that the exposure of sorghum grain treated in various ways to rumen microorganisms for increasing lengths of time apparently caused the dry matter which remained to become increasingly susceptible to chemical hydrolysis. This was evidenced by the varying amounts of dry matter still present in the samples after hydrolysis. Ideally, the combined actions of the microorganisms and the acid should have removed the same amount of material from each sample, regardless of the length of fermentation time. However, it was noted that in almost every case the amount of dry matter remaining after hydrolysis varied inversely as the length of time the sample was fermented with rumen fluid. More work is needed to accurately define the optimum strength of acid required to uniformly hydrolyze substrates which have been fermented for varying lengths of time.

Another change in the artificial rumen technique involved weighing the desired amount of feed into dialysis sacs and adding the correct amount of inoculum directly to the sacs. This procedure removed errors in mixing the feed and inoculum in a large container and in transferring by pipette to the sacs. When using the procedure as originally described, it was necessary to assume that precisely the same amount of feed dry matter was pipetted into each sac. Using the direct weighing method, additional accuracy was afforded.

Statistical Analysis

An analysis of variance procedure (11) was used to test for differences among treatments for each criterion studied. Since the application of the "F" test (43) indicated that no significant differences were present at the 0.05 level, no further tests were made.

TRIAL II

Selection of Cows and Assignment of Treatments

In Trial II, 12 Holstein cows were used in a switchback design as described by Lucas (26). This design was used because it permitted the elimination of error due to: (a) the period effects due to change in environment, (b) all of the linear portion of the between-cow variation in persistency, (c) part of the between-cow variation in level of production. Treatment patterns for two blocks of cows are presented in Table VII. These sequences were repeated for the remaining two blocks of cows.

Blocks were determined by the order in which the cows freshened, with cows of comparable age and productive ability assigned to the same block whenever possible.

TABLE VII

TREATMENT SEQUENCES FOR SWITCHBACK TRIAL—TRIAL II

Period	Block 1 Treatment Sequences			Block 2 Treatment Sequences		
1	1	2	3	1	2	3
2	2	3	1	3	1	2
3	1	2	3	1	2	3

A pre-experimental period of 6 wk. was allowed during which time the cows were accustomed to an unpelleted ration having a 50:50 concentrate to roughage ratio. The roughage was alfalfa hay. Composition of the grain mixture is presented in Table III.

Feed Allowances

At the end of the pre-experimental period, cows were weighed and feed allowances computed using body weight and milk production as in Trial I. Feed allowances were reduced by 10% each 6-wk. experimental period.

Grain Treatments

Sorghum grain for the different rations received one of the following treatments: (a) fine grinding only, (b) moist heat to produce approximately 25% gelatinization of the grain starch, (c) moist heat to produce approximately 75% gelatinization of the grain starch.

The gelatinizing or expanding process first involved grinding of the sorghum grain. In a continuous operation, water and steam were added to attain a maximum temperature of 138° C. at a moisture content of 20 to 21%. The total process time (including moistening, heating by injected steam coupled with mechanical forces, and extrusion through dies to form expanded pellets) was about 20 seconds. Actual cooking time in the temperature range 77° to 138° C. was approximately 10 seconds. The expanded pellets lost most of their excess moisture immediately upon emergence from the dies, and were then further dried in a common pellet dryer. The intermediate or partially gelatinized grain was obtained by subjecting a more coarsely ground sorghum than was used for the completely gelatinized product to the above heat treatment. The effectiveness of this procedure rested upon the theory that a larger particle of grain should undergo less gelatinization than a smaller one. All heat-treated grain for this trial was obtained from Grain Products Inc., Dodge City, Kansas.

All of the sorghum grain was re-ground through a 3/64 in. screen and the remaining ingredients added to complete the rations. The composition of these rations was the same as those for Trial I (Table III), and proximate analyses are presented in Table VIII.

Statistical Analysis

Statistical analysis followed that outlined by Lucas (26) for switchback trials. The analysis of variance was performed for each criterion studied, and in cases where the "F" test (43) revealed a significant difference among treatments, Duncan's new multiple-range test (43) was applied to locate the differences.

TABLE VIII

PROXIMATE ANALYSES OF EXPERIMENTAL RATIONS—
TRIAL II

Ration	Dry Matter	Ash	Crude Protein	Ether Extract	Crude Fiber	NFE
			(%, air-dry basis)			
Ground	89.54	4.81	12.68	2.37	2.20	67.48
Ground and Partially Gelatinized	89.69	4.55	12.27	1.52	1.99	69.36
Ground and Gelatinized	89.02	5.06	12.60	1.43	2.00	67.93
Alfalfa Hay	91.09	8.52	18.55	2.06	21.99	39.97

RESULTS AND DISCUSSION

TRIAL I

Composition of Rations

Proximate analyses of the rations used in Trial I (Table IV) revealed few differences in their composition due to heat treatments. The two rations containing heat-treated sorghum grain had about 1% less dry matter than the one containing unheated grain, conceivably due to the uptake of moisture during the steaming process. The feed containing ground and steamed grain was intermediate between the others with respect to crude protein and ether extract content. The reasons for these differences, if real, are not understood and are probably not of sufficient magnitude to merit concern. The hay used proved to be of excellent quality, a fact evidenced by its high protein content. No statistical analysis was performed on values obtained from proximate analyses of feeds used in either trial. All samples were analyzed in triplicate and the results averaged for a given feed (hay or concentrate). When triplicate values for a feed varied more than 1%, the analysis was repeated.

Response Criteria

Feed Consumption. The responses of cows to various rations are summarized in Tables IX and X. There were no statistically significant differences ($P<0.05$) among any of the treatments for any of the criteria

TABLE IX

FEED CONSUMPTION, WEIGHT CHANGE AND MILK PRODUCTION—
TRIAL I

	Rations		
	Ground	Ground and Steamed	Ground, Steamed and Dry Heated
Dry Matter Consumed, lb./cow/period	1223	1231	1246
Milk, lb./cow/day	36.3	36.5	35.8
Fat, lb./cow/period	57.3	56.6	57.0
% Fat	3.76	3.69	3.79
4% FCM, lb./cow/day	35.0	34.8	34.7
lb. FCM/lb. Dry Matter Consumed	1.20	1.18	1.16
Total Solids, lb./cow/period	190.8	191.3	188.8
% Total Solids	12.52	12.46	12.55
Protein, lb./cow/period	46.8	47.3	46.1
% Protein	3.07	3.08	3.06
Wt. Change, lb./cow/period	+2.29	-1.69	+5.08
Average Iodine No.	31.7	31.8	30.8

TABLE X

VFA AND pH OF RUMEN FLUID 3 HOURS AFTER FEEDING—
TRIAL I

Ration	pH	Acetic	Propionic	Butyric	Valeric	C_2/C_3
Ground	6.96	68.2	17.2	13.3	1.2	3.95
Ground & Steamed	6.91	69.5	16.3	12.9	1.3	4.26
Ground, Steamed & Dry Heated	6.98	69.5	17.6	11.4	1.5	3.94

tested. The increased dry matter consumption by cows fed the ground, steamed and dry heated ration approached significance ($P<0.05$). This increase was due almost entirely to an increased consumption of hay. The fact that no constituent was apparently lacking in the concentrate to cause a desire by the cows to consume more hay, plus the fact that not all the cows on this ration did so probably accounts for the lack of significance of the increase.

Milk Production. The small decrease in actual milk production by cows fed the ground, steamed and dry-heated ration was non-significant, due to lack of consistent variation by the cows. All three rations were similar with respect to the fat, protein and TS content of the milk. The percentage of fat and TS varied inversely with the amount of milk produced, thus resulting in very similar values for treatments for pounds of FCM, fat and TS.

Body Weight Change. Body weight changes, being quite variable among cows on a given treatment were not analyzed statistically. These averaged 2.29, -1.69 and 5.08 lb. per cow for the ground, ground and steamed, and ground, steamed and dry heated rations, respectively. Since these small differences represent a gain or loss for a 6-wk. period, they are not of any practical significance.

VFA Production. If it is assumed that the literature cited previously is for the most part accurate in its description of the manner in which rumen VFA affect the quantity and composition of milk, the milk production data from Trial I are logical. The relative amounts of VFA in rumen fluid taken from 18 cows 3 hr. after feeding did not vary significantly ($P < 0.05$) from one ration to the next when values for all cows were averaged (Table X). Lack of significant changes ($P < 0.05$) in iodine number of the milk fat (Table IX) agrees with the similarity of rumen VFA production for the different rations. The degree of breakdown of the sorghum starch in the heated rations apparently was not sufficient to cause any noticeable change in rumen pH and, subsequently, microbial population. In a few cases, however, examination of VFA data from individual cows gave an indication that the heated grain had such an effect. For example, one cow, when switched from the ground to the ground, steamed and dry heated ration showed an increase in rumen propionate from 12.0 to 24.9% and a decrease in acetate from 77.2 to 60.2%. Accompanying these changes was a decrease of the pH from 6.7 to 5.8. On the other hand, another cow switched identically displayed a drop in pH from 8.1 to 6.4 and essentially no change in the relative proportions of propionate and acetate. In general, however, when pH of the rumen fluid dropped below 6.5, there was a rather marked increase in the relative proportion of propionate. This observation is in agreement with some of the work discussed earlier (8, 23, 33). However, the fact that these changes occurred almost as frequently in cows fed non-heated rations as in those receiving heat-treated grain is not fully understood.

Disappearance of RHDM In Vitro

The average percent of RHDM disappearing at 12 and 24 hr. of fermentation from when measured by the artificial rumen technique is expressed in Table XI. RHDM was used as a relative measure of the availability of the starch to rumen microorganisms. There was no indication that either of the heat treatments drastically affected the rate at which rumen microorganisms attacked the starch *in vitro* at either 12 or 24 hr. Conditions between artificial rumen trials, especially with respect to homogeneity of the inoculum used, were not standard enough to permit meaningful statistical analysis of the results obtained. The figures presented (Table XI) are average disappearance values.

TABLE XI

RELATIVE AVAILABILITY OF GRAIN STARCH TO RUMEN MICROORGANISMS *IN VITRO*, USING RHDM (READILY-HYDROLYZABLE-DRY-MATTER) AS A MEASURE OF STARCH-TRIAL I

Ration	Length of Fermentation	Average RHDM Disappearance
	hr.	%
	12	69.74
Ground	24	90.29
Ground and	12	75.01
Steamed	24	91.02
Ground, Steamed	12	68.58
& Dry Heated	24	84.16

Interpretation of Results of Trial I

In view of the lack of differences in the rations as shown by the *in vitro* study and the proximate analyses, no marked changes in the production of rumen VFA would be expected. Consequently, the lack of significant differences among rations in response criteria is consistent with the laboratory data.

Three possibilities as to why the heat treatments of sorghum grain failed to produce the expected effects in the rumen are presented: (a) insufficient heating of the grain, (b) a masking effect caused by pelleting, (c) a too-narrow ratio of concentrate to hay.

The first possibility appears unlikely. The temperatures attained during dry heating (Table III) were comparable to those reported by Alsberg and Rask (2) as being necessary for the gelatinization of maize starch. It was evident from visual observation that the dry heat had changed the physical appearance of the grain by imparting to it a darker color. This change, however, may have been purely physical, since no marked differences were found among treatments in *in vitro* starch availability.

As indicated previously, there were no drastic differences between any of the rations with respect to VFA or milk production response. As a rule, all cows performed at a fairly consistent level, regardless of treatment. This suggests a close similarity between all rations used, a condition which may have been brought about by the pelleting process. As previously indicated, pelleting temperatures may produce quite marked changes in grains (47). Even if one or both heat treatments in this trial caused some changes in the starch molecule of the grain, it is conceivable that pelleting produced a similar effect in the previously unheated grain without further affecting the heated grain. Thus any differences in the original treatments would have been obscured. With this possibility in mind, the rations for Trial II were fed in the form of a finely-ground meal.

Most of the work reported on heat processing of grains for dairy cows up to now has involved limiting and/or pelleting the roughage portion of the ration (9, 17, 38, 41). Rations producing the most marked VFA and milk production responses contained pelleted hay and/or concentrates and thus had few physical properties of roughage (13). The rations in Trial I were composed of 50% long alfalfa hay by weight. It is possible that this amount of hay in the diet maintained a normal population of rumen microorganisms and, as a result, no marked changes in rumen VFA or milk production occurred, even though differences in nutrient availability between concentrates may have been present.

TRIAL II

Composition of Rations

Proximate analyses of the experimental rations (Table VIII) showed that both processed rations contained almost 30% less ether extract than the non-heated concentrate. Pope et al. (34) reported a similar decrease in a ration containing similarly processed sorghum grain. It appears that the heating of sorghum either destroys some of the fat or renders it non-extractable by ether. Haenlein et al. (16) noted unrealistically low values for the ether extract of expanded corn rations. They therefore used a hydrolytic fat determination method which is recommended for baked goods (3).

Response Criteria

Feed Consumption. Feed consumption is expressed as "lb. dry matter consumed/cow/period" (Table XII). The values presented are consistent with the visual observation that the cows apparently had no strong preference for the unheated sorghum over that processed with heat. Refusals of grain occurred only at the first feeding or two after the animals were switched from one ration to the next.

Milk Production. Cows consistently produced more milk ($P < 0.01$) when fed the untreated ration than when fed those containing heat-treated sorghum (Table XII). Cows receiving partially gelatinized grain averaged 1.1 lb./day less milk than those fed gelatinized grain. This latter difference, however, was shown to be non-significant due to lack of consistency of variation from cow to cow. As in Trial I, per cent fat varied inversely as milk production, resulting in very similar values for pounds of 4% FCM/day.

TABLE XII

FEED CONSUMPTION AND MILK PRODUCTION — TRIAL II

	Rations		
	Ground	Ground and Partially Gelatinized	Ground and Gelatinized
Dry Matter Consumed, lb./cow/period	1524	1517	1514
Milk, lb./cow/day	52.9[a]	50.2[b]	51.3[b]
Fat, lb./cow/period	63.91	66.14	63.67
% Fat	2.88	2.99	2.96
4% FCM, lb./cow/day	43.5	43.7	43.3
lb. FCM/lb. Dry Matter Consumed	1.20	1.21	1.20
Total Solids, lb./cow/period	252.7[a]	247.7[b]	248.9[b]
% Total Solids	11.38	11.74	11.56
Protein, lb./cow/period	66.08[a]	63.76[b]	65.15[a]
% Protein	2.98	3.02	3.03

[a,b]Numbers with different superscripts are significantly different ($P < 0.01$) according to Duncan's new multiple range test (43).

The daily production of significantly more ($P < 0.01$) pounds of total solids by cows consuming the unheated ration was a result of the increased milk production, since this feed did not display any advantage in per cent total solids. Similarly, the partially gelatinized ration showed a significantly lowered ($P < 0.01$) production of protein due to the decreased production of milk rather than to a lowered protein per cent. An analysis of variance for each criterion in which a significant difference among treatments was found is presented in Tables XIII, XIV, and XV.

TABLE XIII

ANALYSIS OF VARIANCE ON ACTUAL MILK PRODUCTION-
TRIAL II

Source of Error	Degrees of Freedom	Sums of Squares	Mean Squares	F Value
Total	11	88753	8068	
Blocks	3	26306	8768	
Treatment	2	49781	24890	11.79*
Error	6	12665	2110	

TABLE XIV

ANALYSIS OF VARIANCE ON TOTAL SOLIDS - TRIAL II

Source of Error	Degrees of Freedom	Sums of Squares	Mean Squares	F Value
Total	11	742.04	67.45	
Blocks	3	616.05	205.35	
Treatment	2	110.46	55.23	21.34*
Error	6	15.52	2.58	

TABLE XV

ANALYSIS OF VARIANCE ON PROTEIN - TRIAL II

Source of Error	Degrees of Freedom	Sums of Squares	Mean Squares	F Value
Total	11	43.39	3.944	
Blocks	3	16.84	5.616	
Treatment	2	21.73	10.868	13.57*
Error	6	4.80	.800	

*Tabular "F" at 0.01 level = 10.92 (43).

Although both degrees of heat processing resulted in decreased production of milk, efficiency of production in terms of pounds of FCM produced /lb. dry matter consumed was essentially the same for all rations (Table XII). This resulted from the slightly decreased consumption of feed and compensatory increases in milk fat per cent by cows fed the heated concentrates.

Disappearance of RHDM In Vitro

The artificial rumen study indicated that there may have been some differences among rations in starch availability to rumen microorganisms in vitro (Table XVI). Initial breakdown of RHDM was most rapid in the gelatinized feed. However, values after 24 hr. of fermentation were quite similar for all rations.

TABLE XVI

RELATIVE AVAILABILITY OF GRAIN STARCH TO RUMEN MICROORGANISMS IN VITRO, USING RHDM (READILY-HYDROLYZABLE-DRY-MATTER) AS A MEASURE OF STARCH — TRIAL II

Ration	Length of Fermentation	Average RHDM Disappearance
	hr.	%
	12	48.25
Ground	24	75.94
Ground and	12	35.82
Partially Gelatinized	24	82.51
Ground and	12	69.04
Gelatinized	24	81.50

Interpretation of Results of Trial II

If previously cited reports (6, 33) are accurate with respect to the effects of heating sorghum on rumen VFA ratios, and if the theory involving rumen VFA ratios and milk fat per cent is true (50), it may be assumed that the expected changes in VFA did not occur in this trial.

Since rumen samples were not taken and iodine number of the milk fat was not determined, no direct data were available on the effect of heat treatments of grain upon rumen conditions.

The conditions to which the grain in rations receiving heat treatment were subjected should have been sufficient to produce changes in rumen VFA. There is the possibility that these treatments were too severe and that the starch was actually made less available to rumen microorganisms. Though the in vitro study did not give such an indication, it is conceivable that less heat and/or pressure or a different combination of the two might have been more effective.

The presence of too much roughage in the rations appears to be the most logical explanation of the results from Trial II. The most marked changes in milk composition when feeding heated concentrates usually occur either when the roughage is severely limited (7, 35, 48) or pelleted (13, 25). More studies with concentrate to hay ratios in combination with heated sorghum are needed to more clearly define the optimum conditions for milk production.

SUMMARY AND CONCLUSIONS

Two trials were used to test the effects of feeding various types of heated sorghum grain to lactating dairy cows.

In Trial I, 24 Ayrshire cows were used in a Latin square design to compare concentrate rations containing 75% sorghum grain receiving one of the following treatments: (a) fine grinding only, (b) fine grinding and steam rolling, (c) fine grinding, steam rolling and dry heat. Alfalfa hay was fed in equal proportion to concentrates. Feed allowances for each period were reduced by 10% of the previous period's allowance. Composite samples from four consecutive milkings weekly were analyzed for fat, total solids, protein and iodine number of the fat. Rumen samples were analyzed for pH and volatile fatty acid content. No statistically significant differences among treatments were found in the criteria tested. Proximate analyses and in vitro studies showed no marked differences among rations with respect to composition.

In Trial II, 12 Holstein cows were used in a switchback design to compare concentrate rations containing 75% sorghum grain which had received one of the following treatments: (a) fine grinding only, (b) fine grinding and partial gelatinization, (c) fine grinding and gelatinization. Alfalfa hay constituted 50% of the rations by weight. Feed reductions were made each period as in Trial I. Milk yields were recorded daily and four consecutive milkings weekly were sampled for fat, protein and total solids analyses. Significant differences ($P < 0.01$) between treatments were found in yield of actual milk, total solids and protein, with the control ration ranking first in each case. Milk production efficiency was similar for all rations. No rumen samples were taken for analysis. Proximate analyses showed a decrease in ether extract in the two processed rations.

Possible explanations for the absence of the expected responses from various heat treatments were discussed. It is concluded that the heat treatments of sorghum grain studied are ineffective in producing alterations in the rumen volatile fatty acid ratios and subsequent desirable changes in milk yield and composition when such grain is fed in equal proportion by weight to long alfalfa hay. Under the conditions of these experiments processing in addition to grinding the sorghum grain was economically unfeasible. The need for more research into the use of these types of grains in rations having a wider concentrate to hay ratio is evident.

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