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DRY HEAT PROCESSING

of Sorghum Grain for Beef Cattle

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Contents

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DRY HEAT PROCESSING

of Sorghum Grain for Beef Cattle

J. K. Riggs, J. W. Sorenson, Jr. and Price Hobgood*

SUMMARY: Research was conducted to determine the feasibility of using dry heat in a popping operation to process sorghum grain for finishing beef cattle. An infrared-heated reciprocating steel table machine and a gas-heated vibrating-tray conveyor machine were used in the study.

The grain should be cleaned to assure an even flow free from foreign materials for efficient operation of the reciprocating-table machine. A grain moisture content of 15 percent was optimum for obtaining the highest percentage of completely popped grain. Maximum popping achieved was 45 percent. Bulk density for loose-fill samples ranged from 49 pounds per cubic foot for the original whole grain to about 6 pounds per cubic foot for completely popped grain.

Self-feeding popped - grain mixture, completely popped or partially and nonpopped grain, all crimped, in all-concentrate feed mixtures to finishing steers resulted in significantly reduced feed intake as compared with nonheated, dry-rolled grain. The reduced feed intake was accompanied by an increase in efficiency of feed utilization but a nonsignificant decrease in rate of gain, final weight, carcass weight, dressing percent, carcass grade and fat thickness.

Rumen samples showed significantly lower levels of acetic and isovaleric acids but higher levels of propionic acid in cattle fed the dry heat-treated grains than in those fed the nonheated grain. The resulting narrower acetic:propionic acid ratio coincided with the greater efficiency of feed utilization observed in these cattle.

Cattle fed the dry heat-treated grains showed significantly higher digestibility of dry matter, organic matter, nonprotein organic matter and nitrogen-free extract, but not of fat, fiber or protein. An unknown part of the increased digestibility could be attributed to the lower level of feed intake. No differences in digestibility were found among cattle fed the three heat-treated grain fractions. This indicated that dry heat rather than popping per se was responsible for the changes in performance.

INTRODUCTION

The need for physically processing sorghum grain to improve its utilization by cattle has been recognized for a long time. During the past 40 years, grinding, dry rolling, steam rolling and steam flaking have been the methods used to prepare the grain for commercial cattle feeding operations. All of these methods have received attention by research workers (Jones *et al.*, 1937; Smith and Parrish, 1953; Baker *et al.*, 1955; Smith *et al.*, 1960; Pope *et al.*, 1962; Brethour and Duitsman, 1966; Hale *et al.*, 1966; and Newsome *et al.*, 1966).

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As technological developments in mechanical equipment have occurred, processing methods have become more sophisticated. Today dry grinding is considered inadequate preparation for sorghum grains by some feeders in the modern cattle feeding industry. The moist heat treatment of steam processing followed by flaking is widely accepted.

Until the last 3 or 4 years, the use of dry heat, as in popping, has not been seriously considered as a means of processing grain for cattle feeding. Ellis and Carpenter (1966) reported slightly slower gains but 16.6 percent less feed per unit of gain when 40 percent of cracked milo was replaced by popped milo in an all-concentrate mixture for yearling steers. Durham, Ellis and Cude (1965) reported daily gains of 2.79, 2.46 and 2.70 pounds with almost identical feed conversions for cattle fed cracked, flaked and popped milo, respectively, in all-concentrate mixtures. Cattle fed flaked milo consumed significantly less feed daily than did those fed milo processed by the other two methods.

During fall 1966, equipment became available at Texas A&M University with the capacity to dry heat process enough sorghum grain to feed 30 yearling steers on a continuing basis. A project was planned and enacted during 1967 which provided opportunity to study the equipment requirements, the effect of initial moisture content on popping characteristics of sorghum grain and the bulk densities of the various components of popped grain mixtures. The study evaluated feedlot performance and carcass characteristics of cattle fed the dry heat-processed and nonprocessed grain in all-concentrate finishing mixtures. Rumen volatile fatty acid levels and grain digestibility were also determined. The work was carried out cooperatively by the Departments of Agricultural Engineering and Animal Science at College Station.

EQUIPMENT AND PROCEDURE

Engineering Phase

Two machines, a reciprocating steel table and a vibrating-tray conveyor, were used to process sorghum grain for this work.

Reciprocating Table. The reciprocating-table machine, shown in Figure 1, consisted of a reciprocating steel table one-half inch thick, 34 inches wide and 12 feet long activated by a ½-horsepower electric motor. Six gas-fired infrared generators, rated at 50,000 BTU per hour each and suspended about 6 inches above the table were used to heat the table and also the grain as it was conveyed through the machine.

The machine was equipped with a metering hopper

Figure 1. Reciprocating-table machine used for the tests. Grain was stored in hopper-bottom bin (shown on the left) and automatically conveyed into metering hopper installed on the popping machine. Grain was then metered onto the reciprocating table where it was heated as it was conveyed under a bank of gas infrared burners and finally discharged from the machine as popped grain.

which could be adjusted to feed grain onto the table at the desired rate. Grain was metered onto a vibrating screen where sand, weed seed and broken grain were removed. The cleaned grain flowed onto one end of the reciprocating table, passed under the infrared generators as it moved along the table and was discharged from the opposite end as popped grain at a temperature of 300 to 310°F. The rate at which the grain moved through the machine could be varied by changing the angle of inclination of the table, by changing the length of the reciprocating stroke and by changing the rate of reciprocation of the table. Stroke length for all tests conducted in this study was eleven-sixteenths inch.

This machine was used to process approximately 63,000 pounds of sorghum grain for use in cattle feeding experiments conducted by the Department of Animal Science. Experience in processing soon indicated that the variability in percentage of popped grain obtained would necessitate separating the processed grain into two fractions, that which was completely popped and that which was not popped or was only partially popped, if meaningful results were to be obtained. Accordingly, the popped-grain mixture coming from the machine was discharged onto a 3/16-inch screen. The completely popped grain remained on and passed over the screen while the nonpopped and partially popped grain fell through. Hence, three products, the popped-grain mixture, the completely popped grain only and a mixture of partially-popped and nonpopped grain, were prepared for testing in comparison with original grain. The separate components were discharged into roller mills with the rolls set at 1/64-inch clearance where the material was crimped and conveyed into burlap bags, Figure 2. Under commercial operating conditions the popped-grain mixture could be conveyed directly into hopper bottom bins for automatic handling.

Records were kept of the weight of whole grain supplied to the machine and of the processed material to determine the machine capacity.

At various intervals during the operating period, tests were made to determine bulk densities of the various popped-grain components and the percentage of popped and partially-popped grain. Test samples were taken at random, placed in a 1-cubic foot capacity container and weighed to find the bulk density of the different components. These measurements were made for whole grain and for loose and packed fills of crimped and noncrimped samples of mixtures of the popped-grain components. For these tests, a loose fill was obtained by permitting the material to discharge from the machine directly into the container until it was filled to overflowing. It was then leveled off and weighed. A packed fill was obtained by catching the material from the machine until the container was full. The container was then dropped from a height of 4 inches onto a concrete floor. Additional material was then added to refill the container, and the container was dropped again from the same height. This procedure was repeated three times before the container and its contents were weighed.

Vibrating-Tray Conveyor. A vibrating-tray conveyor used for these tests was similar to the machine

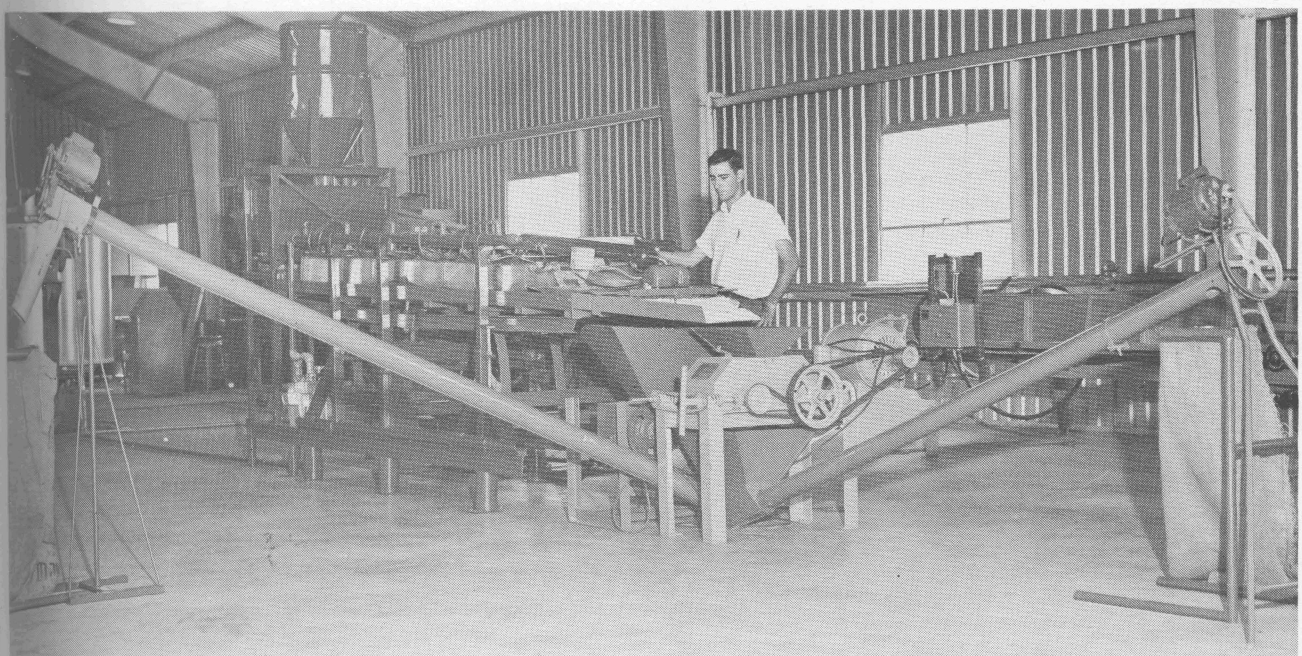

Figure 2. The popped-grain mixture was separated into two components as it was discharged from the popping machine. The separate components then passed through roller mills where the materials were crimped and then conveyed into burlap bags. The popped-grain mixture could be conveyed directly into hopper-bottom storage bins for automatic handling.

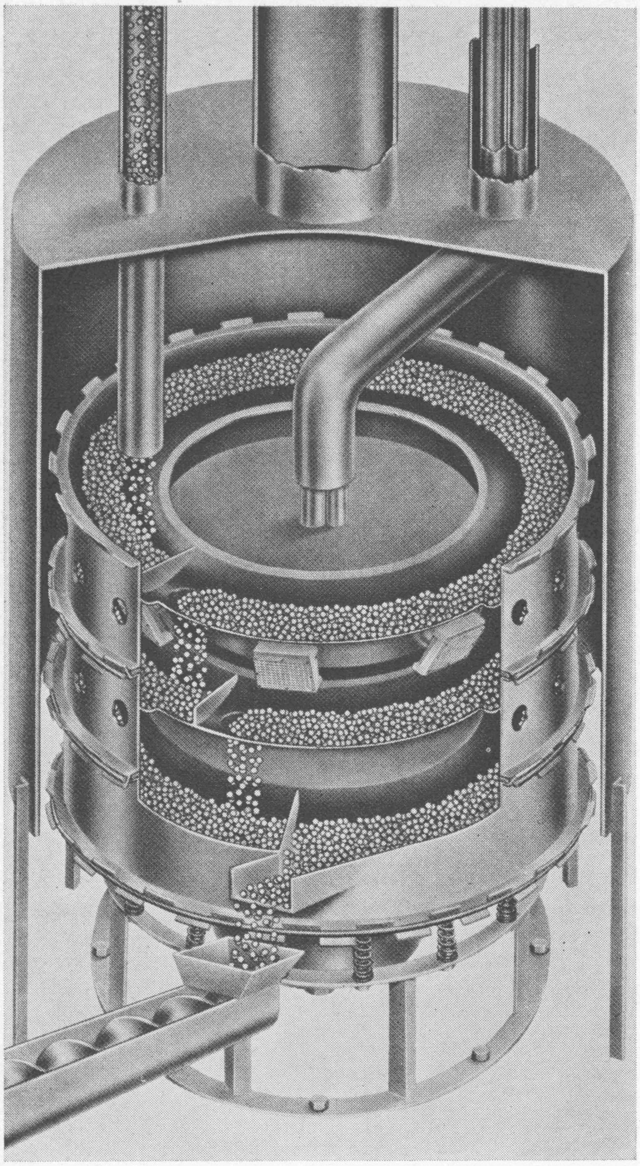

Figure 3. Cut-away view of a vibrating tray-conveyor. Vibrating motion is generated by an electric motor with eccentric weights. The product is metered onto the top tray and is conveyed through the machine as shown above. The number of trays used can be varied from one to three. In these tests, grain was processed on one tray only.

shown in Figure 3. It consisted of a 5-foot diameter, heated, vibrating tray enclosed in an insulated housing. A natural gas burner, mounted underneath the tray, was used to heat the tray to the desired temperature. A vibrating motion was imparted to the tray by a 2-horsepower electric motor equipped with eccentric weights. The motor was mounted vertically in a housing attached directly to the frame supporting the tray. The rate at which the grain was conveyed through the machine was controlled by positioning the eccentric weights on the motor shaft. Grain was metered onto the tray where it was heated and popped as it was conveyed a distance of 15.7 feet on the heated-tray surface. The popped-grain mixture was then discharged from the machine through an unloading spout.

Tests were made with this machine to determine the effect of initial grain moisture content on the popping characteristics of sorghum grain. Four lots of the grain with initial moisture contents ranging from 11 to 17 percent, wet basis, were processed for these experiments. The processed material from each lot was passed over No. 4 and No. 6 sieves in order to separate it into the following components: completely popped grain; partially-popped grain; and nonpopped grain, Figure 4. The completely popped grain remained on the No. 4 sieve. Material passing through the No. 4 sieve but remaining on the No. 6 sieve was designated as partially-popped grain. The material passing through the No. 6 sieve was mostly whole grain and foreign material (sticks, stems and some charred grain).

Cattle Feeding and Nutrition Aspects

Sorghum grain of one kind from a single source and processed in four ways was available for studying the processing effect on utilization of the grain by cattle: original grain; popped-grain mixture; completely popped grain only; and partially-popped and nonpopped grain.

Both the original and heat-treated grains were dry-rolled before formulating into all-concentrate mixtures containing approximately 13 percent crude protein as follows: 92 percent of the mixture was grain; 7 percent was cottonseed meal; and 1 percent was minerals and salt. Aureomycin and vitamin A concentrate were added to all mixtures at levels to provide 4.5 mg. and 1000 IU, respectively, per pound of finished feed.

Forty Santa Gertrudis yearling steers, weighing approximately 750 pounds, were divided into four uniform groups of 10 each. Previously, the steers had been self-fed a high concentrate mixture based on ground dry sorghum grain for about 90 days. One group was assigned to each type of grain indicated above and self-fed in drylot for 84 days. All steers were implanted with 30 mg. of diethylstilbestrol.

The steers were weighed individually on 2 consecutive days at the beginning and end of the experiment and each 14 days during its course. Feed intake records were maintained on a group basis by 14-day periods thus providing six records of mean intake for each group for statistical analysis.

The day after final weights were taken, rumen samples were drawn from all the steers by means of stomach tube and vacuum pump between 9 a.m. and 12 noon. Metaphosphoric acid was added to each sample flask to halt fermentation, and the samples were refrigerated until laboratory determinations of volatile fatty acids could be made by gas chromatograph.

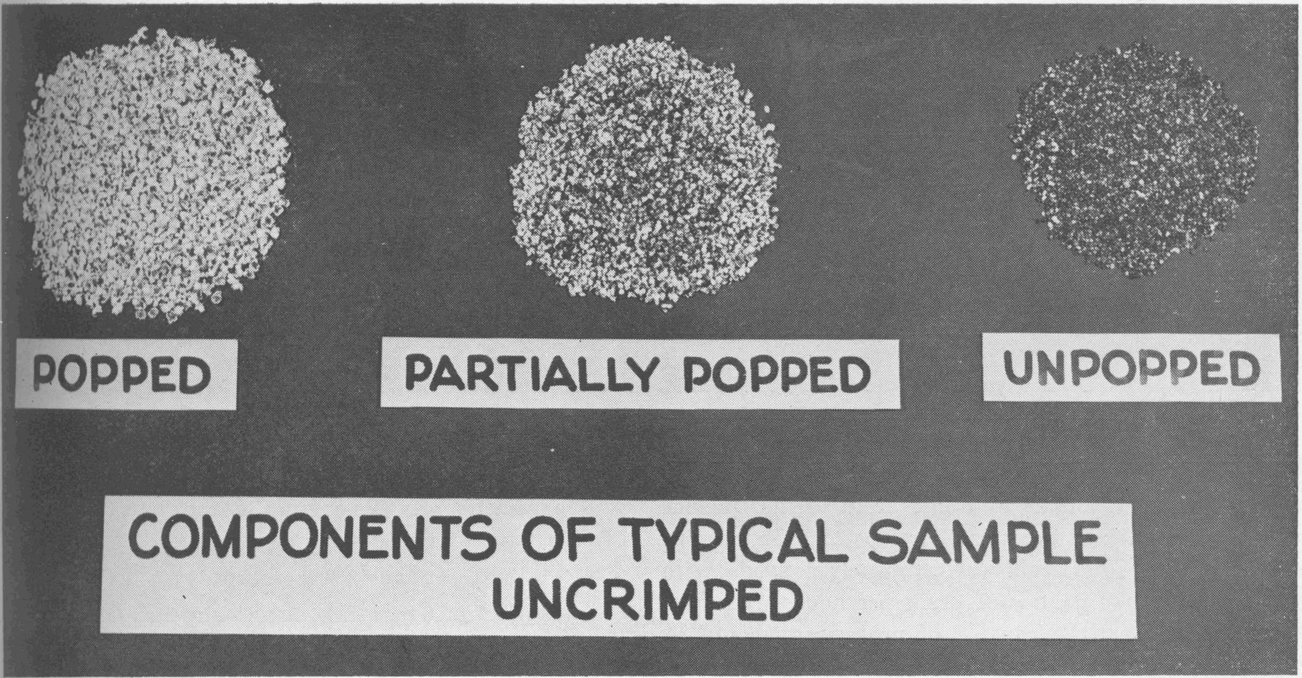

Figure 4. Components of a typical popped-grain mixture.

Individual warm carcass weights and USDA carcass grades were obtained when the steers were slaughtered at the end of the feeding period. Tracings of ribeye and fat cover were made at the 12th rib for determination of ribeye area and fat thickness.

Four Hereford yearling steers were used in a 4 x 4 Latin square experiment to determine the digestibility of four forms of sorghum grain by the total collection method. Each of the 7-day collection periods was preceded by a 14-day adjustment period to accustom the animals to the grains and establish intake levels. The grains only were fed with a mineral supplement; intake levels, although somewhat variable, did not differ significantly. Fecal collection bags were used, and 10 percent aliquots of each 24-hour collection were taken, as were representative feed samples, for analysis by standard proximate analysis procedures (A.O.A.C., 1960).

The data were analyzed statistically by analysis of variance; differences between means were determined by Duncan's New Multiple Range Test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Engineering Phase

Machine Operation and Capacity. From approximately 63,000 pounds of commercial sorghum grain put through the reciprocating-table machine, approximately 58,000 pounds of processed grain were obtained. The total loss, amounting to 8 percent of the original weight, was brought about first by screening the grain over ¼-inch hardware cloth to remove small stones, clods and light weight material such as fragments of sticks, stems and leaves. If not removed, these foreign materials would lodge in the openings of the metering hopper and eventually jam the metering shaft, causing the feeding operation to stop. This would then result in varied feeding rates, reduced capacity and low efficiency. As the grain was metered onto the vibrating screen, loose sand, weed seeds and broken grain dropped out. During the heating process, moisture content of the grain was reduced from 10.5 to 2.5 percent, a decrease of 8 percentage points in the cleaned grain. The exact loss in foreign materials was not determined, but it had to be low since the total weight loss was 8 percent.

High temperature processing of air-dry material implies a degree of precision in the operation to prevent overheating causing scorching, charring or the entire mass to burst into flame. The more flammable sticks, stems and leaves were particularly troublesome in this respect. Also, broken kernels of grain were troublesome, because they would not roll as the whole kernels and tended to overheat and char. For these reasons it appeared necessary to clean the grain rather thoroughly before processing. With this accomplished, an even flow of intact kernels completely covering the table one kernel deep could be maintained. Good results were obtained with the vibrating-tray machine when the temperature was maintained at 450° to 475° F. Temperatures above 500° F caused charring and burning of the grain.

The capacity of the machine, based on 29 capacity

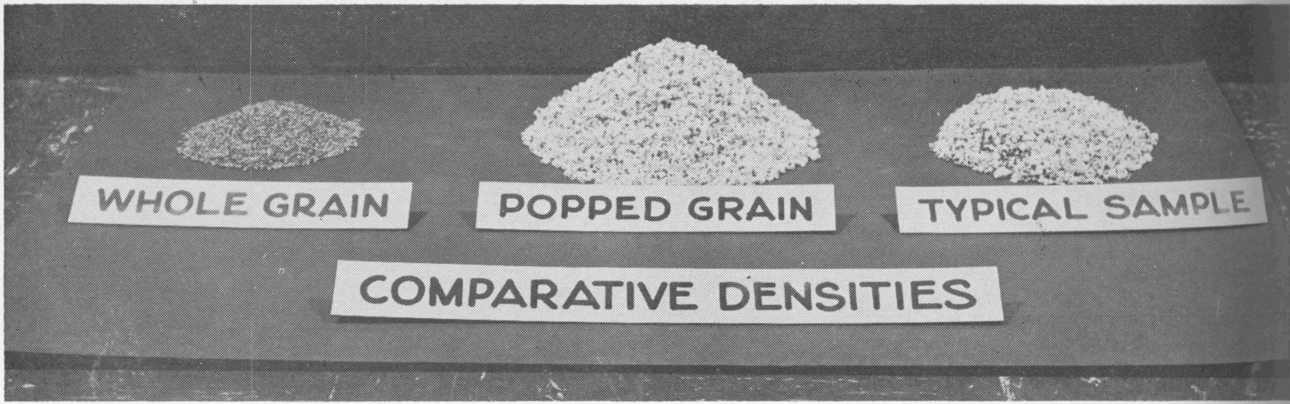

Figure 5. Illustration of comparative densities of whole grain and different components of a typical popped-grain mixture.

checks, was 319 pounds of whole grain or 270 pounds of popped-grain mixture per hour in which an average of 28 percent of the grain was completely popped. With a capacity of 270 pounds of grain per hour, a machine of this size would be capable of processing about 3¼ tons in 24 hours of continuous operation, enough to feed 325 cattle 20 pounds each. The capacity of this machine can doubtlessly be increased considerably by increasing its efficiency through proper hooding and insulation and the inclusion of automatic precision controls. Capacity can definitely be increased either by increasing the width of the steel table with a corresponding increase in the number of infrared generators or by operating a battery of machines the same size as the one used here.

Bulk Density. Measurements were made with both crimped and noncrimped samples of the different components. The density of a typical popped-grain mixture varied with the percentage of popped grain in the mixture. For noncrimped, loose-fill samples, densities ranged from 24.5 pounds per cubic foot for a sample with 13 percent popped grain to 10.6 pounds per cubic foot for a sample with 45 percent popped grain. The effect of percentage of completely popped grain in the mixture on bulk density is shown in Table 1. Comparative densities of whole grain and different components of a typical popped-grain mixture are shown in Table 2 and Figure 5.

TABLE 1. EFFECT OF PERCENTAGE OF COMPLETELY POPPED GRAIN IN A TYPICAL POPPED GRAIN MIXTURE ON BULK DENSITY

Percent of popped grain in mixture[1]	Bulk density of popped-grain mixture, lbs. per cu. ft.			
	Noncrimped		Crimped	
	Loose fill	Packed	Loose fill	Packed
13	24.5			
25	16.5	19.3	20.6	24.0
35	13.0	14.7	20.0	22.0
38	12.3	14.4	18.8	21.2
45	10.6			

[1]Percentage of completely popped grain in a typical mixture of popped, partially-popped and unpopped grain as discharged from the popping machine, based on the total weight of all components in the mixture.

Effect of Grain Moisture Content on Popping Characteristics. The percentage of grain which actually popped varied from 13 to 45 percent. As the moisture content of the original grain increased from 11.3 to 14.7 percent, the percentage of completely popped material in the popped-grain mixture increased from 27.4 to 43.2 percent. Further increase in moisture content to 16.8 percent did not noticeably further enhance popping (Table 3 and Figure 6). This indicates that a moisture content of about 15 percent is desirable from the standpoint of obtaining the highest percentage of completely popped grain of the kind used in these tests. Among the many types of sorghum grains available, the variation in size of seed, character of seed coat and endosperm (waxy or starchy) could greatly influence their popping characteristics.

Cattle Feeding and Nutrition Aspects

Feeding Experiment. The chemical composition of the four experimental feed mixtures is shown in Table 4.

TABLE 2. BULK DENSITIES OF WHOLE SORGHUM GRAIN AND DIFFERENT COMPONENTS OF A TYPICAL POPPED-GRAIN MIXTURE

Sorghum grain	Density, lbs. per cu. ft.
Whole grain	48.8
Completely-popped grain	
Noncrimped	
Loose fill	5.8
Packed	6.8
Crimped	
Loose fill	11.9
Packed	13.3
Mixture of partially-popped and nonpopped grain:	
Noncrimped	
Loose fill	25.8
Packed	28.9
Crimped	
Loose fill	23.2
Packed	27.7

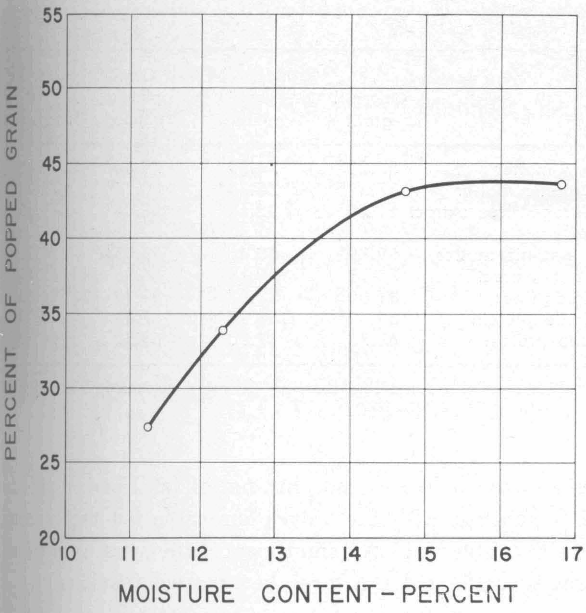

Figure 6. Effect of initial grain moisture content on the percentage of completely popped grain in a popped-grain mixture.

The mixtures were prepared some time in advance of feeding. Although they were sampled at intervals during the course of the experiment, thus allowing time for some equilibration of moisture content between processing and feeding, the dry heat processing reduced moisture content of the grain mixtures as fed by 1.9 to 3.0 percent below the original grain. On dry matter basis, the mixtures with dry heat treated grains showed slight increases in ether extract and ash content with essentially no changes in protein or nitrogen-free extract (NFE), but there was a slight decrease in fiber content as compared with the original grain mixture. The differences are thought to be due to random sampling.

TABLE 3. EFFECT OF INITIAL GRAIN MOISTURE CONTENT ON THE POPPING CHARACTERISTICS OF SORGHUM GRAIN

	Percent of different components in typical popped-grain mixture (based on initial weight of whole grain)			
Initial moisture content of whole grain, percent	Popped grain[1]	Partially popped grain[2]	Non-popped grain[3]	Loss in weight, percent[4]
11.3	27.4	40.5	23.9	8.2
12.3	33.9	31.7	21.3	13.1
14.7	43.2	20.3	22.5	14.0
16.8	43.5	19.7	22.7	14.1

[1]Material remaining on a No. 4 sieve. This was "100 percent popped" grain.

[2]Material passing through a No. 4 sieve, but remaining on a No. 6 sieve. This was grain that had burst open, but was not completely expanded or popped.

[3]Material passing through a No. 6 sieve (mostly whole grain) and foreign material (sticks, stems and some charred grain).

[4]Loss in weight was due primarily to the reduction in grain moisture that occurred during the process.

TABLE 4. PERCENTAGE CHEMICAL COMPOSITION OF FEED MIXTURES AS DETERMINED BY ANALYSIS[1]

Mixtures	Water	Protein	Ether Extract	Fiber	NFE	Ash
Original grain	10.3	14.4	3.1	2.0	77.8	2.7
Popped-grain mixture	7.3	14.6	3.9	1.7	77.0	2.8
Completely popped	8.1	14.4	3.9	1.9	76.6	3.3
Partial and nonpopped	8.4	13.7	3.9	2.0	76.9	3.6

[1]All values except water are expressed as percent of dry matter.

Feedlot performance and carcass information are summarized in Table 5. The most striking feature of the data is the highly significant reduction in feed intake of the groups which received heat treated grains. Those fed the heated grains consumed 16 to 27 percent less dry matter per day than did those fed the original nonheated grain. As would be expected, this significantly reduced feed intake was accompanied by increased efficiency of

TABLE 5. FEEDLOT PERFORMANCE AND SLAUGHTER DATA

	Grain treatments			
	Original grain	Popped-grain mixture	Completely popped	Partial and non-popped
	Values in pounds unless otherwise indicated			
Number Steers	10	10	10	10
Initial weight	755	751	754	757
Final weight	1015	980	968	988
Daily gain	3.10	2.73	2.55	2.75
Daily feed intake:				
As fed	21.2[a]	14.9[c]	15.1[c]	17.5[b]
Dry matter	19.0[a]	13.8[c]	13.9[c]	16.0[b]
Daily feed as percent of average weight:				
As fed	2.4	1.7	1.8	2.0
Dry matter	2.1	1.6	1.6	1.8
Feed per pound gain:				
As fed	6.9	5.5	5.9	6.4
Dry matter	6.1	5.1	5.5	5.8
Slaughter data:				
Warm carcass weight	620	573	574	591
Dressing percent	61.1	58.5	59.3	59.8
U.S.D.A. carcass grades:				
Good	8	7	7	7
Standard	2	3	3	3
Ribeye area, square inch	11.5	11.2	11.0	11.7
Ribeye area per hundredweight warm carcass, square inch	1.9	2.0	1.9	2.0
Fat thickness, inches, average 3 measures	.7	.6	.6	.6
Fat thickness, inches per hundredweight warm carcass	.11	.10	.10	.10
Value per head, dollars[1]	236.36	228.10	225.42	230.10

[a,b,c] Means with different superscripts are significantly different, ($P<0.05$).

[1]Selling price was $24.25 per cwt. based on final weight and 4 percent shrink.

feed utilization but decreased rate of gain, final weight, carcass weight, dressing percent, carcass grade and fat thickness, although none of the differences in these latter parameters was statistically significant.

Rumen Volatile Fatty Acids. Significant differences were found in volatile fatty acids in rumen samples from cattle fed the differently treated grains (Table 6). Acetic and isovaleric acids both showed significantly higher values, but propionic acid showed significantly lower values ($P<.01$) in samples from cattle fed the original grain than in those from cattle fed the heat treated grains. In the case of valeric acid, cattle fed the completely popped grain showed a significantly higher level than did those fed the other grains, but all values from heat-treated grains were somewhat but not significantly higher than that for the original grain group.

The acetic:propionic acid ratio was significantly narrower in the case of all heat-treated grains than in the original grain group. Original grain fed cattle showed a ratio of 1.80 : 1 as compared with 0.88 : 1, 1.01 : 1 and 1.06 : 1 for the cattle fed the popped-grain mixture, completely popped, and partially and nonpopped grains, respectively. The higher levels of propionic acid, lower levels of acetic acid and consequent narrower acetic : propionic acid ratios accompanied greater efficiency of feed utilization in all of the groups fed heat-treated grains.

Digestibility of Grains. Cattle fed the dry heat-treated grains showed significantly higher digestibility of dry matter, organic matter, nonprotein organic matter and nitrogen-free extract, but not of fat, fiber or protein as compared with the values for cattle fed the original grain (Table 7). No significant differences were found among cattle fed the three heat-treated fractions.

TABLE 6. MEAN VALUES FOR VOLATILE FATTY ACIDS IN RUMEN FLUID

	Grain treatments			
Fatty acids	Original grain	Popped-grain mixture	Completely popped	Partial and nonpopped
	mol. percent			
Acetic	54.90[a]	41.92[b]	44.62[b]	45.54[a,b]
Propionic	30.20[a]	47.61[b]	44.27[b]	43.01[b]
Butyric	8.78	7.81	8.29	8.91
Isovaleric	4.32[a]	0.99[b]	0.52[b]	0.76[b]
Valeric	1.20[a]	1.62[a]	2.37[b]	1.58[a]
Acetic: propionic ratio	1.80[a]	0.88[b]	1.01[b]	1.06[b]

[a,b]Values with different superscripts on the same line differed significantly, acetic, propionic and isovaleric at the .01 level and valeric at the .05 level. Values for butyric did not differ significantly.

TABLE 7. COEFFICIENTS OF APPARENT DIGESTIBILITY FOR DIFFERENT NUTRIENTS

	Original grain	Popped-grain mixture	Completely popped	Partial and nonpopped
Dry matter	57.23[a]	74.57[b]	79.34[b]	76.00[b]
Organic matter	57.55[a]	75.33[b]	80.34[b]	77.02[b]
Nitrogen-free extract	61.29[a]	82.65[b]	88.84[b]	83.55[b]
Nonprotein organic matter	59.80[a]	80.41[b]	85.88[b]	81.31[b]
Ether extract	70.11	70.14	66.36	67.96
Crude fiber	31.00	33.67	31.19	26.85
Crude protein	39.50	38.95	37.57	41.05
True protein	68.78	67.00	65.52	70.89

[a,b]Means on the same line bearing different superscripts are significantly different ($P<0.01$).

Discussion

Lowered feed intake, as shown by cattle fed heated grain mixtures in the feeding experiment, is generally accompanied by increased biological efficiency of the animal and consequent lessening of feed required per unit of gain. This has been previously documented by Black *et al.* (1943) who showed in three tests that steers fed 80 percent of a full feed of ground sorghum grain, with other feeds constant or nearly so, required approximately 4 percent less total digestible nutrients per unit of weight gain than did similar steers fed a full feed of ground grain. Hence, part of the improved feed efficiency of the steers fed heat-treated grains in the feeding experiment must be attributed to their lower level of feed intake. Similarly, the steers in the digestion trial consumed slightly but not significantly less grain when fed heated grains than when fed the original nonheated grain. Therefore, an unknown part of the 35 to 40 percent improvement in digestibility shown in Table 7 must also be attributed to a lower level of intake but this can by no means account for all of it. This is confirmed by other data at this station. Dry heat-processed grain produced gains and feed efficiency approximately equal to the values from steam flaked grain under large scale commercial feedlot conditions (Schake *et al.*, 1969). Feed efficiency and net energy values were improved (Eudaly and Riggs, 1969) and carbohydrate utilization was enhanced (McNeill, Potter and Riggs, 1969) by dry heat processing the grain for cattle.

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