Methods of Processing Sorghum Grain for Lactating Dairy Cows

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Story In Brief

Sorghum grain is widely used in the Southwest as the major component in concentrate mixtures for dairy cattle. Consequently, it is important to know which method of processing this grain results in the greatest improvement in nutrient value. Information derived from studies with fattening beef cattle is not directly applicable because of some rather unique problems pertaining to lactating cows.

Three separate trials with lactating cows have been completed. The purpose of one trial was to quantify the relationship between particle size of ground sorghum grain and production of dairy cows. In the other trials, different processing treatments of grain in addition to fine grinding were compared with fine grinding only for dairy rations. Information on rumen fluid characteristics and nutrient digestibility was obtained to aid in interpretation of the results.

In all trials, cows readily consumed the concentrate mixtures with very finely ground grain, except for a day or two after being changed from one ration to another. There was small, but nonetheless consistent, improvement in starch digestibility in favor of the ration with very finely ground grain as compared to rations with grain medium or coarsely ground. Molar percentages of rumen VFA were similar in cows on all rations where these data were obtained, and the ratios of acetic to propionic acid were well within the range known to be commensurate with production of milk with normal fat percentage. Total concentration of rumen VFA at 2, 4 and 6 hours after feeding increased as particle size of grain in the ration decreased.

Milk yield of cows fed very finely ground sorghum grain was greater than that of cows fed medium or coarsely ground grain, with an apparently linear relationship between particle size of the ground grain and milk production response. Fineness of grinding had no effect on percentage of milk fat or total solids.

Dry heating and steaming, or simply steaming the grain in addition to very fine grinding did not improve its feeding value in comparison

to fine grinding only. Pressure cooking and expanding sorghum grain followed by very fine grinding did not improve its value for lactating cows compared to very fine grinding only. There is a need for further research to determine whether some of the newer processing methods might be equal or superior to fine grinding of sorghum grain under conditions where particle size is allowed to vary.

Introduction

Early studies (Fitch and Wolberg, 1934; Darnell and Copeland, 1936; Atkenson and Beck, 1942) established the importance of grinding sorghum grain as opposed to feeding whole grain; however, no critical studies have been conducted heretofore to quantify the relationship between particle size of ground sorghum grain and production responses of dairy cows. With adoption of a method (Ensor *et al.*, 1970) whereby the particle size of ground grain is defined in a standardized manner, meaningful comparisons of results from different studies can now be made.

Experiments comparing different processing treatments of grain for dairy cows are very limited. Fountaine and Bartley (1962) found that steam rolled grain was superior to dry rolled grain in terms of milk yield, but not equal to ground and pelleted grain. Brown *et al.* (1970) observed no difference between steaming, followed by rolling in a conventional manner, and pelleting different proportions of sorghum grain and barley in terms of milk yield, percentage of fat and non-fat solids, and digestibility of various nutrient components.

There is considerable evidence from studies with beef cattle that "fine" grinding (1/8" screen) of sorghum grain improves its digestibility over that obtained with dry rolling or coarse grinding (Smith, *et al.* 1949; Smith and Parrish, 1952; Newson *et al.*, 1968; Totusek, 1969; White *et al.*, 1969). Further, improved feed efficiency was noted by White *et al.* (1969) when very finely ground grain (i.e., ground with 1/16" screen) was compared to finely ground grain for fattening beef steers. Significant increases in dry matter digestibility due to steam flaking, reconstituting, or high-moisture harvesting as compared to coarse grinding or dry rolling, have been observed (McGinty *et al.*, 1967; Husted *et al.*, 1968; Buchanan-Smith *et al.*, 1968). McNeill *et al.* (1970) found that the extent of ruminal digestion of starch in sorghum grain was highly dependent upon the method of processing, with values as follows: dry ground (5/16" screen), 42 percent; reconstituted and ground (5/16" screen), 67 percent; steam flaked, 83 percent; and micronized, 43 percent. It would be logical to expect these different processing treatments to have the same effect on the digestibility of grain by dairy cows as has been observed with beef steers, although the ultimate impact on lactation performance cannot be predicted with confidence.

The main object of these trials was to determine the effect of different methods of processing sorghum grain on production responses of dairy cows. Information on rumen fluid characteristics and nutrient digestibility was obtained simultaneously to aid in interpretation of the results.

Materials and Methods

Three separate trials with lactating cows have been completed. One of these dealt with defining the relationship between particle size of ground sorghum grain and production of dairy cows. In the other two trials, different treatments of the grain in addition to fine grinding were compared with very fine grinding only for dairy rations. Some general observations in this report also will apply to a fourth trial now in progress.

Trial 1.

In this trial, 36 lactating cows (30 Holsteins and 6 Ayrshires) were used to evaluate the effects of grinding sorghum grain to different degrees of fineness on production responses. A 3 x 3 rotational (Latin square) design was used such that each cow was fed each of three rations in turn according to a pre-determined sequence. Periods in the trial were 6 weeks in duration, with data from the last 4 weeks used for analysis and the first 2 weeks of each period allowed for change-over from one ration to another. Cows were started on the experiment at approximately 8 weeks after calving.

The experimental rations consisted of a 50:50 ratio of alfalfa hay and concentrate mixture (Table 1), with the only variable being the particle size of the ground grain. Yellow endosperm hybrid sorghum grain (NK-222) grown at the Ft. Reno Research Station was used in this particular trial. Since grain comprised 70 percent of the concentrate mixture and equal amounts of concentrate and hay were fed, grain made up 35 percent of the total ration.

An attempt was made to grind the grain in a manner to produce three distinctly different particle size distributions by varying screen size and flow rate through the hammermill. This was accomplished to some extent; however, the particle size of the coarse and medium ground grain were not as edifferent as originally expected (Table 2). The very finely ground grain was virtually powdered in comparison to the coarse or medium ground grain.

Table 1. Composition of Concentrate Mixtures

Item	Trial 1 & 4	2	3
Ingredient			
Sorghum grain	70	75	75
Soybean meal, 44%	10	--	--
Wheat middlings	10	--	--
Wheat bran	--	10	10
Molasses, dried	7	--	--
Molasses, liquid	--	7	7
Cottonseed meal	--	5	5
Beef pulp	1	--	--
Urea	--	1	1
Dicalcium phosphate	1	1	1
Salt, trace mineral	1	1	1
Chemical analysis, air-dry basis			
Dry matter	89.0	90.7	89.4
Protein (N x 6.25)	12.5	14.2	12.5
Ether extract	2.7	3.0	1.8
Starch	58.7	--	--
Non-starch carbohydrate	10.7	--	--
Crude fiber	--	2.7	2.1
Nitrogen-free extract	--	65.7	68.3

Feed allowances were calculated with consideration for body weight, age, and initial milk yield and fat test. Energy requirements indicated by Moe *et al.* (1965) were followed, except that extra allowances were made for first and second lactation cows to permit some additional growth. The allowances were reduced by 10 percent of the initial amount at the beginning of the second and third 6-week periods. Intake of nearly equal amounts of concentrate and hay was accomplished by reducing the total allowance by an appropriate amount if more than 10 percent of either hay or concentrate was refused for two consecutive days. Feeding of the planned allotment of feed was resumed as soon as the cow would consume that amount.

Milk production was recorded twice daily. Samples from four consecutive milkings each week were composited for analysis of total solids and fat percentage. The body weight of each cow was recorded on three consecutive days prior to the experiment and during the last three days of each period.

Apparent digestibility of nutrient components was determined during the latter part of each period with 18 cows by using chromic oxide as an external indicator. Concentration and proportion of rumen volatile fatty acids (VFA) were determined in samples collected from each cow on the last day of each period at 2, 4, and 6 hours after the morning grain feeding.

Table 2. Particle Size of Sorghum Grain[1]

Item	Fineness of grind		
	Very fine	Medium	Coarse
		(microns)	
Geometric mean diameter, D_{gw}	315	584	641
Geometric standard deviation, S_{gw}	2.32	2.36	2.36

[1] Determined by a standard procedure adopted by the American Dairy Science Association (Ref.: Ensor *et al.*, 1970).

Trial 2.

In this trial, 24 Ayrshire cows were used to compare the following methods of processing sorghum grain:

a) fine grinding only,
b) fine grinding + steam heating,
c) fine grinding + steam heating + dry heating.

All of the grain was ground to the same particle size to standardize this factor so that the possible merits of the other treatments independent of particle size could be evaluated. Hammermill screen size was 3/64". 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 170° F. In addition to steam rolling and grinding, one-third of the grain was dry heated for one hour, usually reaching a temperature over 300° F. Following processing by the different procedures, the grain was mixed with the other ingredients of the concentrate mixture (Table 1) and pelleted with a ⅜" die.

Cows were started on experiment at approximately 6 weeks after calving. Feed allowances based on body weight and milk yield of each cow were computed according to the upper limit of Morrison's TDN standard. Good quality alfalfa hay was fed in equal proportion to grain. A Latin square design was used so that each cow received each treatment for 6 weeks in a pre-determined sequence. Initial feed allowances were reduced by 10 percent at the end of each 6-week period.

Rumen samples were taken from 18 cows at 3 hours after the evening feeding on the last day of each period for VFA analysis. Milk yield of each cow was recorded twice daily and samples were taken at four consecutive milkings each week for determination of fat, total solids, and protein percentages.

Trial 3.

In this trial, 12 Holstein cows were used in a switchback design to compare the following methods of processing sorghum grain:

a) fine grinding only,

b) fine grinding + pressure cooking and expanding to produce approximately 25 percent gelatinization,[1]

c) fine grinding + pressure cooking and expanding to produce approximately 75 percent gelatinization.[1]

The gelatinization process involved first grinding the grain so that approximately 96 percent passed through a No. 30 U.S.B.S. sieve. Then, in a continuous operation, water and steam were added to attain a maximum temperature of about 270° F. at a moisture content of 20 to 21 percent. 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 180 to 270° F. 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 more coarsely ground grain than was used for the completely gelatinized product to the above treatment on the assumption that a larger particle of grain should undergo less gelatinization than a smaller one.

All of the expanded grain as well as grain for the control ration was ground through a 3/64″ screen and afterwards mixed with the other ingredients of the concentrate mixture (Table 1). The concentrate mixture was fed in loose form.

During a 6-week period after calving, the cows adjusted to an unpelleted concentrate mixture fed in equal proportion with alfalfa hay. Feed allowances were calculated on the basis of body weight and milk yield as in the previous trial, and were reduced by 10 percent at the end of each 6-week period. A switchback design for three treatments as described by Lucas (1956) was used; therefore each cow received one of the three treatments during the first period, a second one during the next 6 weeks, and then reverted back to the first treatment again during the final period. Different sequences were used so that each of the rations was fed to the same number of cows during each period.

Trial 4.

Thirty-six lactating cows were used in this trial to obtain additional information on the relationship of particle size of ground sorghum grain

[1]Expanded grain obtained from Grain Products, Inc., Dodge City, Kansas through the courtesy of Evan W. Williams, Jr.

to milk yield. Data on milk yield and composition, feed intake, and body weight changes were obtained in the same manner as in Trial 1. In addition, steers with abomasal fistulas are being used to obtain information on the site and extent of nutrient digestion when rations contain grain ground to different degrees of fineness.

Results and Discussion

Feed Intake

Intakes of hay and grain by the cows were nearly equal in all three trials, reflecting very few problems with feed consumption. The small amount of hay refused usually consisted of coarse stems or moldy material. In Trial 2, cows fed the dry heated grain tended to consume their allowance of hay more completely for some reason, resulting in slightly higher total dry matter intake by this group. Average dry matter intakes of different rations in Trial 3 were similar and consistent with the visual observation that the cows apparently had no strong preference for the unheated grain over that which had been cooked and expanded. Refusals of grain occured only at the first feeding or two after the animals were switched from one ration to another.

In Trials 1 and 4 where the grain was ground to different degrees of fineness, several cows required one or two days to adjust to the ration with very finely ground grain. Otherwise, the cows readily consumed each of the concentrate mixtures. Intake of the mixture with very finely ground grain simply was not a problem in these trials, and it is apparent that cows need not be fed an exceptionally coarse or bulky concentrate mixture providing the amount and quality of forage in the ration is acceptable.

Digestibility of Rations with Grain Ground to Different Degrees of Fineness.

Apparent digestibility of major components was similar for all three rations (Table 3). Digestibility of starch was of particular interest since it comprised a significant part of the concentrate mixture and was the fraction where differences in digestibility due to grinding the grain to different degrees of fineness could most logically be expected. A high percentage of starch in all three rations was digested, with the values being in the same range as those reported by other workers (Karr *et al.*, 1966; Holmes *et al.*, 1970; McNeill *et al.*, 1970). There was a small, but nonetheless consistent, improvement in starch digestibility in favor of the very finely ground grain as compared to the other two rations. These differences in overall digestibility were consistent with production responses; however, it is recognized that relative changes in the sites of starch digestion in the animal might well be of greater importance than differences in the total amount digested. Work aimed at obtaining information on the relation of particle size of ground grain to site of starch digestion in the animal is in progress at this time.

Rumen VFA Characteristics

Molar percentages of rumen VFA were similar for all rations in both Trial 1 and 2 (Table 4). In Trial 1, the acetic to propionic acid ratio was lower at 2 hours after feeding in the group fed medium ground grain, but overall differences among rations were relatively small without any consistent trend. Moreover, the observed ratios of acetic to propionic acid were well within the range known to be commensurate with production of milk with normal fat percentage (Baumgardt, 1967).

Total concentration of rumen VFA at different times after feeding in Trial 1 increased as the particle size of the sorghum grain decreased. The higher concentration of VFA in samples from the group fed finely

Table 3. Apparent Digestibility of Ration Components

Component	Ration Treatment		
	Coarse	Medium	Very Fine
		%	
Dry matter	67.6	69.5	69.8
Crude protein	65.8	67.1	65.3
Ether extract	61.7	63.6	65.1
Starch	96.4^{ab}	96.3^{a}	98.1^{b}
Non-starch CHO	51.4	54.9	53.6

ab Means with different letters are significantly different ($P < .05$).

Table 4. Molar Percentages of Rumen VFA

Acids	Trial 1 rations[1]			Trial 2 rations[2]		
	Coarse	Medium	Very fine	Ground	Ground and steamed	Ground, steamed and dry heated
Acetic	67	66	67	68	70	70
Propionic	19	20	19	17	16	18
Butyric	13	13	13	14	13	11
Valeric	1	1	1	1	1	1
C_2/C_3	3.4	3.4	3.5	4.0	4.3	3.9

[1] Rumen samples taken at 4 hours after feeding.
[2] Rumen samples at 3 hours after feeding.

ground grain may have been due to more rapid breakdown of starch in this ration by rumen microorganisms. However, the exact mechanism by which this may have affected production response of the cows is not known. Decreases in total feed allowances during the second and third periods of the trial as scheduled were reflected in decreased rumen VFA concentration.

Milk Yield and Composition

Milk yield of cows fed a concentrate mixture with very finely ground sorghum grain was significantly greater than that of cows fed coarsely ground grain. As depicted in Figure 1, there appeared to be a linear relationship between particle size of the ground grain and milk production response. No difference among rations was observed in milk fat or total solids percentage. Overall average fat test was lower than expected and could be attributed to a few individual cows with an exceptionally low test.

The calculated feed allotments were sufficient to sustain an increase in body weight in all treatment groups (Table 5). A small portion of

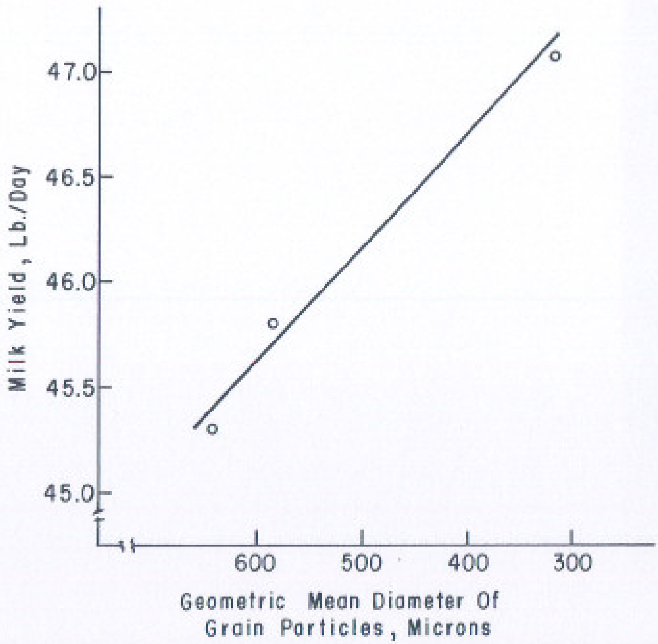

Figure 1. Average daily milk yield in relation to fineness of grinding sorghum grain.

Table 5. Responses of Cows Fed Sorghum Grain Ground to Different Degrees of Fineness

Item	Coarse	Medium	Fine
Feed intake, D. M. basis			
Hay, lb/day	19.6	19.8	19.8
Grain, lb/day	19.6	19.9	19.9
Milk production			
Daily yield, lb	45.3[a]	45.8[ab]	47.1[b]
Fat, %	3.3	3.3	3.3
Total solids, %	11.96	11.96	12.00
Weight change			
Gain per 6-wk, lb	13	26	34

[ab] Means with different letters significantly different ($P \leq .05$).

the gain by cows fed rations with fine or medium ground grain over that by cows fed coarsely ground grain could be accounted for by slightly greater feed consumption by these groups. Assuming an average energy value of body tissue gain in cattle of 3.2 Mcal/lb. (Reid and Robb, 1971), the additional feed consumed would account for approximately 4 lb. of the extra gain by the cows when fed rations with fine or medium ground grain. It was clear that increased milk yield of cows fed the finely ground grain did not reflect greater use of body energy reserves for production. Rather, it appeared that more energy for productive functions was derived from each unit of ration containing finely ground grain.

Dry heating in addition to steaming or simply steaming sorghum grain did not improve its feeding value for lactating cows in comparison to very fine grinding only, under conditions where particle size was held constant (Table 6). Neither yield nor composition of milk was changed by treatments in this trial. Presumably, the heat treatments either did not improve the nutrient value of the grain or any beneficial effects produced thereby were obscured by pelleting the concentrate mixtures. Unfortunately, the heat treatments were not applied in a manner such that dry heating and steaming the grain could be compared independently.

Pressure cooking and expanding sorghum grain to produce partial or nearly complete gelatinization of the starch followed by very fine grinding did not improve its value for lactating dairy cows. Milk yield of cows fed rations containing grain which had been finely ground only was significantly higher than that of those fed the expanded grain (Table 6). However, the milk fat test was slightly lower when cows were fed the ration with unexpanded grain, resulting in nearly the same level of production by all groups when expressed in terms of 4 percent fat-corrected milk. It is possible that cooking of the grain in addition to

Table 6. Feed Consumption and Production by Cows Fed Rations Containing Sorghum Grain Subjected to Different Processing Treatments

Processing method	Dry matter consumed	Milk yield	Fat	Total solids	Weight change
	(lb/day)	(lb)	(%)	(%)	(lb/6wk)
Trial 2					
Finely ground only	29.1	36.3	3.8	12.52	+2.3
Ground & steamed	29.3	36.5	3.7	12.46	—1.7
Ground, steamed & dry heated	29.7	35.8	3.8	12.55	+5.1
Trial 3					
Finely ground only	36.3	52.9[a]	2.9	11.38	+37.3
Ground & part gelatinized	36.1	50.2[b]	3.0	11.74	+23.4
Ground & gelatinized	36.1	51.3[b]	3.0	11.56	+19.0

[ab] Numbers in same column with different letters significantly different ($P < .05$).

grinding to unusually small particle size made the starch susceptible to breakdown by the rumen microorganisms at a rate too rapid for optimum microbial synthesis. Thus, there is a need for further research to determine whether some of the newer processing methods might indeed be equal or superior to fine grinding of sorghum grain under conditions where particle size is allowed to vary.

A comparison of the production of cows fed rations with medium versus finely ground grain merits consideration because the medium ground material would approximate that commonly available at most feed mills. Since, in Trial 1, sorghum grain comprised only 35 percent of the total ration and grinding the grain very finely (see Table 2) gave about a 3 percent increase in milk production, one may surmise that the nutrient value of the grain *per se* was increased by 9 percent. An increase of this magnitude should justify some additional cost for grinding the grain very finely, i.e., using a 3/64 or 4/64 inch screen to produce a product having a geometric mean diameter around 300 microns.

The conclusions in this report about processing of sorghum grain for dairy cows do not necessarily apply to other feed grains. In fact, it was demonstrated many years ago (Wilbur, 1933; Olson, 1942) that medium ground corn and oats were superior to these grains finely ground (pulverized) in terms of milk production of dairy cows.

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