Dairy Nutrition

Relation of Method of Processing Sorghum Grain to Utilization by Dairy Cows

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Story in Brief

Since sorghum grain is widely used as a major component in concentrate mixtures for dairy cows, it is important to identify methods of processing which result in greatest improvement in its nutritive value for dairy cattle. The approach to this problem has been to first determine the particle size of ground grain utilized by cows with greatest efficiency and then to compare other processing methods with grinding to this extent.

In one trial with lactating cows, additional information was obtained to further quantify the relationship between mean particle size of ground grain and milk production. Milk yield increased as particle size decreased to approximately 475 microns, beyond which no further improvement was obtained. No differences in milk composition were observed. Although several factors have some influence on particle size of ground grain, use of a grinder screen with openings measuring 3/32 inch, or smaller, appears necessary to produce the desired product.

Steers with abomasal fistulas were used in an attempt to determine the influence of fineness of grinding on the extent of nutrient digestion in different parts of the digestive tract. Both ruminal and post-ruminal digestion of starch tended to be higher for the ration containing the more finely ground sorghum grain.

In another trial involving lactating cows, rations containing grain processed by fine grinding, steam rolling, and micronizing were compared. There was very little difference among treatments in milk production; however, milk fat test was particularly low when micronized grain was fed. Changes observed in proportions of rumen volatile fatty acids (VFA) at three hours after feeding were consistent with this lowered milk fat percentage. Only small differences were observed in digestibility of the rations containing grain processed by the different methods.

Introduction

In previous work reported last year, Bush *et al.* (1972) observed that cows fed a concentrate mixture with very finely ground sorghum grain produced more milk than cows receiving more coarsely ground grain. Increased starch digestibility, higher total concentration of rumen VFA and slightly greater weight gain were also observed in the group fed the more finely ground grain. However, a fairly wide range in particle size (expressed as geometric mean diameter) between the very finely ground and medium ground grain in that study pointed up the need for additional work to further define the relationship between particle size and production response.

Improvements in the performance of animals fed grain processed in different ways have been attributed primarily to differences in carbohydrate digestion. Recent indications are that the site and rate of starch digestion may vary due to intake by the animal and method by which the grain is processed. Karr *et al.* (1966) observed that 16 to 38 percent of the starch consumed by steers on a high concentrate diet entered the lower tract. Tucker *et al.* (1968) showed that increases in starch intake resulted in increases in the percentage of starch passing into the intestines of sheep. McNeil (1970) observed differences in the extent of ruminal digestion of starch in sorghum grain processed by different methods as follows: steam flaked, 83 percent; reconstituted and ground (5/16" screen), 67 percent; micronized, 43 percent; and dry ground (5/16" screen), 42 percent. Information on the extent of nutrient digestion in different parts of the digestive tract when rations contain sorghum grain ground to different degrees of fineness has not been reported.

One objective of these trials was to further evaluate the effect of particle size of ground sorghum grain in rations on performance of dairy cows and on the site and extent of nutrient digestion. The objective of a second phase was to compare production responses of cows fed sorghum grain processed by different methods.

Materials and Methods

Two separate trials with lactating cows have been completed. One of these dealt with the relationship between particle size of ground sorghum grain and milk yield. Another compared the responses of cows fed sorghum grain either finely ground, steam rolled, or micronized. In addition, a trial using steers with abomasal fistulas was conducted to obtain information regarding the site of nutrient digestion.

Trial 1

Mention of this trial as being in progress was made in a previous report (Designated Trial 4 in report by Bush *et al.*, 1972).

Thirty-six lactating cows (24 Holsteins and 12 Ayrshires) were used in a switchback trial involving three treatments. Comparison periods were six weeks in duration, with data from the last four weeks used for analysis and the first two weeks of each period allowed for change-over from one ration to another. Cows started the first comparison period approximately eight 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 for this experiment. Since grain comprised 70 percent of the concentrate mixture and equal amounts of concentrate and hay were fed, sorghum grain made up 35 percent of the total ration.

Variation in average particle size of the ground sorghum grain was achieved by using three different screens with openings measuring 8/64, 6/64, and 4/64 inch in diameter. Representative samples were taken at each grinding and particle size determined by the method of Ensor *et al.* (1970). Particle size of the grain designated as fine, medium and coarse ground fell within the range desired to complement the previous trial (Table 2).

Feed allowances for the cows were calculated on the basis of size, age, milk production and milk fat percentage according to 1965 NRC

Table 1. Composition of Concentrate Mixtures

Item	Trial 1 & 2	Trial 3
Ingredient		
Sorghum grain	70	70[1]
Soybean meal, 44%	10	10
Wheat middlings	10	10
Molasses, dried	7	7.5
Beet pulp	1	—
Dicalcium phosphate	1	1
Trace mineral salt	1	0.5
Urea	—	1
Chemical analysis, dry basis		
Protein (N x 6.25)	16	17
Starch	64	—
Non-starch carbohydrate	12	—

[1] Weight of ground, steam rolled, and micronized grain varied as necessary to use like amount of grain dry matter in mixture.

Table 2. Particle Size of Sorghum Grain

Items	Fineness of Grind		
	Coarse (8/64)	Medium (6/64)	Fine (4/64)
	(microns)		
Geometric mean diameter, d_{gw}	602	507	398
Geometric standard deviation, S_{gw}	1.42	1.39	1.35

requirements. The allowances were reduced by 10 percent of the initial amount at the beginning of the second and third six-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 comparison period.

Trial 2

Three abomasal fistulated dairy steers were used in a digestion trial to characterize digestion of nutrient components of the same rations fed to the lactating cows in Trial 1. A 3 x 3 rotational (Latin square) design provided for each animal to be fed each ration in turn according to a pre-determined sequence. Comparison periods were three weeks in duration. Feed allowances sufficient for maintenance and approximately 2.0 lb. gain per day were calculated using net energy and digestible protein requirements for growing cattle (Lofgreen and Garrett, 1968).

Apparent ruminal and total digestion of nutrient components were determined by using chromic oxide as an external indicator during the last two weeks of each comparison period. Abomasal and fecal samples were collected twice daily on the last five days of each period.

Trial 3

In this trial, 24 lactating cows (18 Holsteins and 6 Ayrshires) were used to compare rations containing finely ground, steam rolled, and micronized sorghum grain. Average particle size (geometric mean diameter)

of the finely ground grain was 285 microns. The steam rolled grain was processed by steaming for 20 to 30 minutes and afterwards rolling in a manner to produce minimal flattening of the kernels. The micronized material was prepared by vibrating the grain on a heated metal plate until thoroughly heated and then rolling in a manner to produce a product having approximately 24 pounds test weight per bushel.

Ration allowances were calculated according to the 1971 NRC energy requirements for dairy cattle. Rumen samples were taken at three hours after the morning grain feeding for determination of the proportion of ruminal volatile fatty acids (VFA). Digestibility of ration components was determined by use of chromic oxide as an external indicator during the last 12 days of each comparison period. Other experimental conditions were the same as described for Trial 1.

Results and Discussion

Effects of Fineness of Grinding

Several cows required a few days to adjust to the concentrate mixtures with very finely ground grain, but consumed it readily thereafter. Intakes of concentrate mixture and hay were nearly equal as planned (Table 3).

Cows fed the concentrate mixtures with medium and fine grain produced significantly more milk than those receiving the coarsely ground grain. Milk composition was essentially the same for all groups. Average feed intake was slightly more, i.e., .3 lb./day, when the cows were fed fine or medium ground grain. However, higher milk yield of cows fed these rations cannot be attributed to this small difference in intake because the net energy value of this amount of feed would be insufficient to account

Table 3. Responses of Cows Fed Sorghum Grain Ground to Different Degrees of Fineness

Item	Coarse	Medium	Fine
Feed intake, D.M. basis			
Hay, lb./day	17.1	17.3	17.3
Concentrate, lb./day	17.9	18.0	18.0
Milk production			
Daily yield, lb.	42.2[a]	43.2[b]	43.4[b]
Fat, %	3.97	3.95	3.93
Non-fat solids, %	9.49	9.51	9.53
Weight change			
Gain per 6-wk., lb.	19.2	21.8	20.8

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

for the difference in milk production. Moreover, the difference in energy intake could be equated with the energy value of the additional weight gain by cows fed more finely ground grain.

Considering the responses of cows in this trial along with the results obtained previously (Figure 1), it appears that a curvilinear relationship may exist. Projecting an increase in milk yield with decreasing particle size of ground sorghum grain to a point beyond which yield levels off appears to allow the best interpretation of both sets of data. With this assumption, it appears that maximum milk yield is reached when average particle size is around 475 microns. The actual particle size produced when sorghum grain is ground is influenced by several factors such as moisture content of the grain and flow rate, as well as screen size. Nevertheless, it appears that a screen with 6/64 inch, or smaller, openings would generally need to be used to grind sorghum grain for maximum utilization by dairy cows.

Apparent digestibility of ration components by dairy steers tended to be higher when the concentrate mixture contained finely ground grain, although the differences were not statistically significant ($P>.05$). In particular, starch digestion tended to increase with decreasing particle

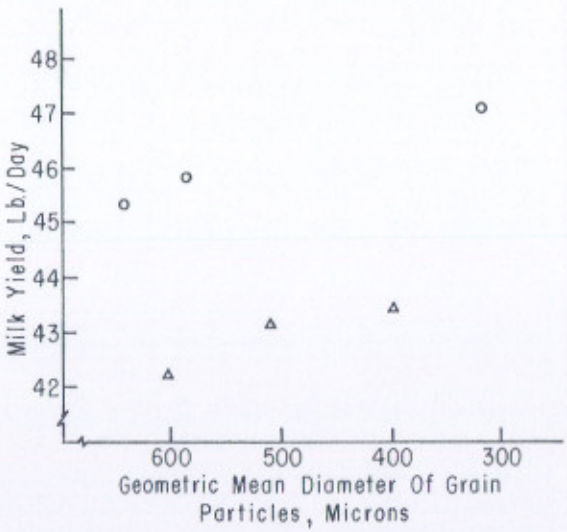

Figure 1. Average daily milk yield in relation to fineness of grinding sorghum grain. Points designated by "O" represent data from trial previously reported (Bush et al., 1972); points designated by "△" represent data from present study.

size of ground sorghum grain which was in agreement with previous observations on digestibility by lactating cows (Bush *et al.*, 1972). Apparent ruminal digestion coefficients for crude protein, either extract and non-starch carbohydrate were negative (Table 4). Poor sampling of abomasal contents of one steer due to improper placement of the abomasal fistula appeared to be responsible for these discrepant values. Exclusion of the data on this steer resulted in positive values in all treatment groups for the nutrient components. Linear increases in ruminal starch digestion in relation to decreasing particle size approach statistical significance ($P<.08$).

Average starch intake by the steers on the three rations was 2.08 lb./day (Table 5). Starch in the more finely ground sorghum grain tended to have higher digestibility both in the rumen and intestines. A high percentage of the starch in all the rations was digested in the rumen. Additional work would be needed to definitely establish whether or not there are real differences in ruminal starch digestibility that account for the observed differences in animal performance.

Comparison of Methods of Processing

There was very little difference in milk yield of cows fed rations containing sorghum grain processed by fine grinding, steam rolling, or micronizing (Table 6). The most notable difference among treatments was in regard to milk fat percentages. For unknown reasons, fat test was lower when cows were fed finely ground grain than when fed steam rolled grain.

Table 4. Apparent Digestibility Coefficients of Ration Components

Component	Ration treatments					
	Coarse		Medium		Fine	
	(%)					
Ruminal Digestion						
Dry matter	10.7[1]	(38.5)[2]	31.2	(43.0)	16.9	(29.9)
Crude protein	−31.3	(18.1)	− 7.7	(21.6)	−11.2	(1.4)
Ether extract	−25.5	(7.1)	− 9.1	(1.9)	8.0	(7.4)
Starch	80.8	(83.4)	84.5	(88.4)	87.2	(89.0)
Non-starch CHO	− 3.0	(28.2)	17.4	(38.6)	5.7	(14.8)
Total Digestion						
Dry matter	52.3		52.0		57.5	
Crude protein	54.3		51.8		58.7	
Ether extract	53.0		48.6		64.4	
Starch	92.4		94.3		95.5	
Non-starch carbohydrate	33.9		35.6		41.7	

[1] Average of three observations.
[2] Mean digestion coefficient based on two steers; one steer sampled poorly due to placement of fistula.

Table 5. Starch Intake and Digestion at Different Sites Along the Digestive Tract

	Ration treatment		
	Coarse	Medium	Fine
Mean starch intake, lb./day	2.08	2.08	2.08
Apparent digestibility in rumen, %	80.8	84.5	87.2
Starch entering intestine, lb./day	.40	.32	.27
Apparent post-ruminal digestibility, %	60.8	63.0	65.3
Total starch digested, lb./day	1.92	1.96	1.99
Apparent total digestibility, %	92.45	94.28	95.52

Table 6. Feed Intake and Milk Yield of Cows

Item	Method of processing		
	Ground	Steam rolled	Micronized
Feed intake			
Grain, lb./day	18.7	18.9	18.3
Hay, lb./day	18.7	18.7	18.3
Milk production			
Milk yield, lb./day	59.2	59.4	58.7
Fat, %	2.8a	3.0b	2.6c
Non-fat solids, %	8.6	8.6	8.6
SCM, lb./day	48.6	49.9	47.3

abc Means with different superscript significantly different ($P<.05$).

The fat content of milk produced by cows fed finely ground grain in previous trials was not particularly low, and no differences in fat test have been associated with fineness of grinding.

The depression in fat test when micronized grain was fed was consistent with the observed changes in proportions of rumen VFA (Table 7). In particular, a lower percentage of acetic and increased propionic acid have been observed by various workers (e. g., Balch *et al.*, 1955; Shaw *et al.*, 1959; Baumgardt, 1967) when milk fat test was depressed. Whether sorghum grain can be micronized in a manner to produce some degree of starch gelatinization and consequent rumen VFA proportions commensurate with normal milk fat percentage remains to be determined.

There was very little difference in overall digestibility of the rations used in this trial (Table 8). Small differences in digestibility of single components, e. g., protein, in favor of the micronized grain were not sufficiently large to have an appreciable effect on total dry matter or organic matter digestibility. The relatively high digestibility coefficients observed

Table 7. Molar Percentages of Rumen VFA

Acid	Method of processing		
	Ground	Steam rolled	Micronized
Acetic	68.0a	64.9a	58.9b
Propionic	21.1a	23.3ab	27.3b
Butyric	8.9a	9.6a	11.6b
Iso-valeric	1.0a	1.1a	0.7b
Valeric	1.0a	1.1a	1.5b

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

Table 8. Apparent Digestibility of Ration Components

Component	Method of processing		
	Ground	Steam rolled	Micronized
	(%)		
Dry matter	80.4	80.3	81.8
Protein	81.5ab	81.2b	83.2a
Organic matter	81.9	82.1	83.5

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

in this trial were attributed to the fact that the forage portion of the ration was of very high quality as evidenced by 24 percent total protein content on a dry basis.

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