Effect of Sorghum Grain Variety and Processing Method on the Site and Extent of Starch Digestion in Steers

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Story in Brief

Hetero-yellow (H-Y), red (RED) and brown (BR) sorghum grain varieties were incorporated into 88 percent grain diets as either dry rolled or reconstituted-rolled (RED and BR only) grain to evaluate the effects of variety and processing (reconstitution) on the site and extent of starch digestion in steers. Five Hereford-Angus steers (750 lb) fitted with ruminal, duodenal and ideal T-type cannulae were utilized in a 5 x 5 latin square. Total tract starch digestion of the dry rolled sorghums ranged from 86.9 percent for the RED to 91.4 percent for the H-Y sorghum diet. Larger differences between dry rolled sorghums were observed in the rumen where starch digestion (percent of total) was 69.1 percent for the RED vs 82.7 percent for the BR. Reconstitution increased ($P<.05$) ruminal starch digestion of the RED sorghum from 69.1 percent to 91.1 percent of total with little effect on the BR. A significant quantity (626 g) of the ruminally undigested starch from the reconstituted BR diet was digested in the small intestine resulting in essentially complete (97.3 percent) starch digestion for both of the reconstituted sorghum diets by the time the digesta reached the ileum. Steers fed the dry rolled RED sorghum digested 622 g of starch in the large intestine suggesting that this organ may compenstate for incomplete starch digestion of poorly processed grain. Both sorghum grain variety and processing method appear to alter the site and extent of starch digestion in steers, differences that are probably translated into variation in animal performance.

Introduction

Decreasing ground water supplies and escalating irrigation costs may increase the use of drought tolerant crops such as sorghum grain in the Great Plains. Many livestock producers tend to discriminate against sorghum grain because of highly variable quality and the fact that the grain must be processed before feeding. Previous studies in our laboratory have illustrated large variation in the chemical composition and IVDMD of different sorghum grain varieties. Additional studies in our laboratory have shown that different varieties of sorghum respond uniquely to reconstitution. How these differences in laboratory responses translate into animal parameters such as digestibility remains unknown. The following study was performed to determine how sorghum grain variety and processing method affect the site and extent of starch digestion in steers and the relationship of these parameters to laboratory analyses.

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Materials and Methods

Three varieties of sorghum, hetero-yellow (H-Y), red (RED) and brown (BR) were obtained from three locations in Oklahoma (Table 1). Dry sorghum grain was either dry rolled or reconstituted-rolled (RED and BR only) before incorporation into an 88 percent grain ration (Table 2). Reconstitution was performed by adding adequate water to raise the moisture level to 30 percent after which the grain was placed in large polyurethane bags (75 lb/bag) and stored for 21 days before rolling.

The five sorghum rations (3 dry rolled and 2 reconstituted-rolled) were fed to five Hereford-Angus steers (750 lb) fitted with ruminal, duodenal and ileal T-type cannulae using a 5 x 5 latin square design. Steers were fed equal portions twice daily at 2 percent (DM) of body weight. Experimental periods were 10 days in length; 7 days of adaptation and 3 days of sampling performed at 1000, 1400 and 1800 hours. Digesta samples were composited across time and day within each period and dried in a forced air oven at 130°F. Feed and digesta samples were ground through a 1 mm screen in a Udy mill prior to analysis.

Grain, feed and digesta samples were analyzed for dry matter, starch (glucose polymers), crude protein, tannin (catechin equivalents) and ash. Digestibility of starch was determined by chromic oxide ratios. *In vitro* dry matter disappearnce (IVDMD) of grain and feed samples was determined with an 18 hour incubation with buffered, strained rumen fluid. *In vitro* gas production (IVGP) was evaluated after a 12-hour incubation with an amyloglucosidase enzyme and commercial baker's yeast.

Table 1. Descriptive characteristics of sorghum grains

Sorghum	Abbreviation	Pericarp color	Endosperm color	Testa layer[a]
Hetero-yellow	H-Y	Yellow	Hetero-yellow	Absent
Red	RED	Red	White	Absent
Brown	BR	Brown	White	Present

[a]Presence of testa layer indicative of high tannin content and bird resistance.

Table 2. Ingredient composition of experimental diets (dry matter basis).

Ingredient	IFN#	%
Sorghum grain	4-04-383	88.0
Cottonseed hulls	1-01-599	8.0
Supplement		
Urea	5-05-070	1.20
Dicalcium phosphate	6-01-080	0.44
Calcium carbonate	6-01-069	0.93
Potassium chloride	6-03-756	0.57
Sodium sulfate	6-04-292	0.36
Sodium chloride	6-04-152	0.25
Chromic oxide		0.20
Vitamin A	7-05-143	2200 IU/kg

Results and Discussion

Crude protein content ranged from 10.37 percent for the RED to 14.08 percent for the H-Y sorghum (Table 3). Reconstitution had no effect ($P > .05$) on crude protein content. The RED sorghum contained more ($P < .05$) starch than the BR. Tannin content was highest ($P < .05$) for the BR sorghum. Eighteen-hour *in vitro* dry matter disappearance (IVDMD) was lower ($P < .05$) for the dry rolled BR than the dry rolled RED sorghum. Reconstitution increased ($P < .05$) the IVDMD of both the RED and BR sorghums for both the grain and complete feed. Reconstitution increased the starch availability (measured by *in vitro* gas production - IVGP), of the BR sorghum grain to a greater extent than the RED. For the complete feed, however, the greatest reconstitution response was noted for the RED sorghum.

Although daily dry matter intake was equalized across treatments, starch intake varied because starch content of the sorghums differed (Tables 3 and 4). Total tract starch digestibility of the dry rolled sorghums ranged from 86.9 percent for the RED to 91.4 percent for the H-Y (Table 4). Differences between varieties in ruminal starch disappearance were much greater ($P < .05$), from 69.1 percent for the RED to 82.7 percent for the BR sorghum. Disappearance in the small (668 g) and large intestine (622 g) compensated for low ruminal fermentation of RED sorghum starch.

Reconstitution increased ($P < .05$) ruminal starch disappearance (from 2899 to 4280 g/day) for the RED sorghum but not the BR (Table 4). In fact, the amount of digestible starch disappearing from the rumen increased ($P < .05$) from 69.1 to 91.1 percent for the reconstituted RED sorghum. Starch from the reconstituted sorghums was easily digested in the small intestine (70 percent for the RED and 67.5 percent for the BR). Consequently, disappearance of reconstituted sorghum starch was almost complete (97.3 percent) when the digesta reached the ileum.

Large quantities of starch (622 g for the RED sorghum) disappeared in the large intestine of steers fed the dry rolled sorghum diets (Table 4). Thus, the large intestine can compensate to some extent for incomplete digestion of starch in the rumen and small intestine of steers fed poorly processed grain. Poor utilization of starch fermented in the large intestine due to altered fermentation patterns and poor absorption or organic compounds other than volatile fatty acids suggests that large intestinal fermentation should be avoided.

This study suggests that both variety and processing method can alter the site and extent of sorghum grain starch digestion. For example, decreased ruminal starch fermentation for the dry rolled RED sorghum resulted in larger quantities of starch disappearing in the small and large intestine (Figure 1). Reconstitution resulted in almost complete starch digestion in segments prior to the large intestine. The major response, however, occurred in the rumen for the reconstituted RED sorghum but in the small intestine for the reconstituted BR.

The observed differences between varieties and their response to reconstitution were substantial, even at an intake level of 2 percent of body weight. Higher intake levels typical of cattle on feed (2.5 percent of body weight or greater) may further increase the differences observed in this study.

Agreement between IVDMD patterns and actual ruminal starch disappearance was poor except for the reconstitution response of the RED sorghum. Inoculum for the IVDMD was obtained from a steer fed a low tannin diet while the steers in the digestion trial were allowed seven days to adapt to the tannin

Table 3. Chemical characteristics, IVDMD and IVGP of processed sorghum grains and complete mixed feeds (dry matter basis).

	Dry-rolled			Reconstituted		
	Het-yel	Red	Brown	Red	Brown	SE
Grain						
Crude protein (%)[bd]	14.08	10.37	13.35	10.76	13.22	.28
Starch (%)[b]	68.44	70.79	64.97	72.92	65.70	.66
Tannin (cat. eq./g)[bd]	.06	.03	1.31	.04	1.21	.06
IVDMD, 18-h (%)[ab]	48.6	50.1	36.6	54.7	42.6	1.9
IVGP, 12-h (ml gas/g DM)[cdefgh]	96.6	121.2	97.6	132.4	121.5	2.3
Feed						
Crude protein (%)[bd]	16.88	13.31	15.47	13.39	15.31	.14
Starch (%)[ab]	66.65	69.32	62.44	66.94	57.93	1.46
Tannin (cat. eq./g)[cdfgh]	.03	.04	1.22	.04	.86	.02
IVDMD, 18-h (%)[ab]	49.5	52.7	39.2	54.4	44.3	1.7
IVGP, 12-h (ml gas/g DM)[cdefgh]	103.5	100.4	91.5	130.2	103.2	1.1

[a]Dry rolled (RED and BR only) vs. reconstituted ($P<.05$).
[b]RED vs. BR ($P<.05$).
[c]Variety X processing interaction ($P<.05$).
[d]HY vs. all others ($P<.05$).
[e]Dry rolled RED vs. reconstituted RED ($P<.05$).
[f]Dry rolled BR vs. reconstituted BR ($P<.05$).
[g]Dry rolled RED vs. dry rolled BR ($P<.05$).
[h]Reconstituted RED vs. reconstituted BR ($P<.05$).

Table 4. Site and extent of starch digestion of dry rolled or reconstituted sorghum varieties.

	Dry-rolled			Reconstituted		
	Het-yel	Red	Brown	Red	Brown	SE
Starch intake, g/day	4679	4822	4501	4762	4126	46
Ruminal starch disappearnce, g/day[bdf]	3316	2899	3370	4280	3183	173
Percent of total[bdef]	77.8	69.1	82.7	91.1	81.2	3.2
Small intestinal starch disappearance, g/day[bdf]	411	668	403	282	626	93
Percent[ac]	28.6	33.4	34.8	70.9	67.5	3.3
Starch digestibility through ileum, Percent of total[ac]	87.5	85.5	92.6	97.3	97.3	1.8
Large intestinal starch disappearance, g/day[ac]	543	622	305	125	102	80
Percent[g]	57.3	48.6	42.1	40.8	18.0	15.8
Total tract starch digestibility, Percent[bd]	91.4	86.9	90.8	98.4	94.8	1.5

[a]Dry rolled (RED and BR only) vs. reconstituted ($P < .05$).
[b]Variety X processing interaction ($P < .05$).
[c]HY vs. all others ($P < .05$).
[d]Dry rolled RED vs. reconstituted RED ($P < .05$).
[e]Dry rolled RED vs. dry rolled BR ($P < .05$).
[f]Reconstituted RED vs. reconstituted BR ($P < .05$).
[g]No significant differences ($P > .05$).

levels in the BR sorghum. The IVGP data did a better job of predicting the observed reconstitution response but did not predict the differences between the RED and BR sorghums adequately.

The performance of the high tannin, brown sorghum in this study might tempt one to conclude that high tannin sorghums are not detrimental. There are sorghum varieties, however, with at least twice as much tannin which may yet affect utilization. Previous studies have shown decreased digestibility and performance with high tannin sorghums.

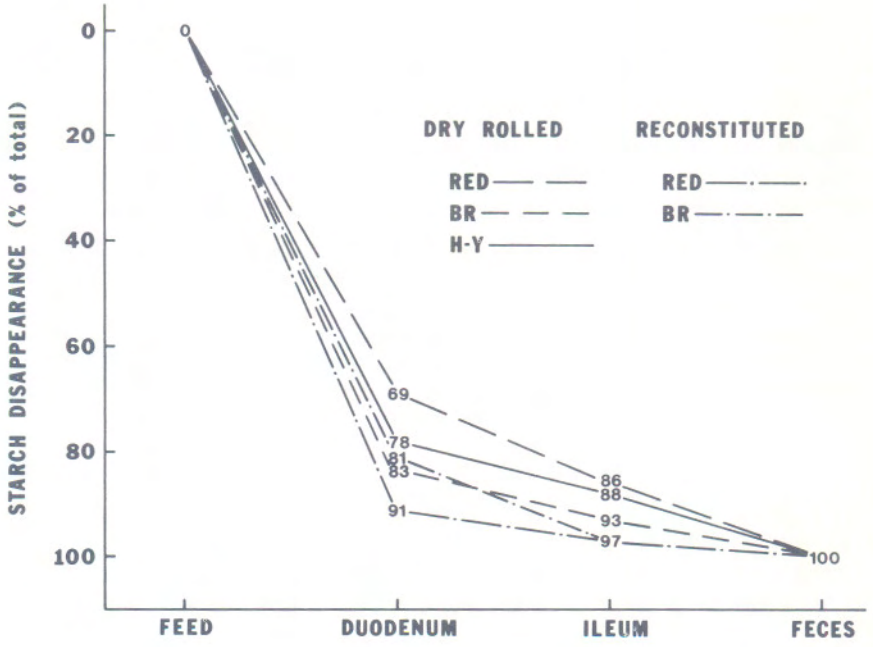

Figure 1. Disappearance of starch in various segments of the digestive tract of steers fed dry rolled or reconstituted sorghum grain varieties.