IN VITRO DIGESTIBILITY OF SORGHUM PARENT LINES PREDICTS NUTRITIONAL VALUE OF THEIR HYBRID OFFSPRING IN CANNULATED FINISHING PIGS

B. J. Healy, J. D. Hancock, P. J. Bramel-Cox[1], and R. H. Hines

Summary

Nutritional value of eight sorghum hybrids, resulting from matings of four male lines with two male-sterile lines, was determined. The male lines were two sorghums with consistently high in vitro digestibility (High-digestibility 1 and High-digestibility 2) and two sorghums with consistently low in vitro digestibility (Low-digestibility 1 and Low-digestibility 2). The male-sterile lines were Kansas 52 and Redlan, two lines commonly used for genetic testing by sorghum breeders. The hybrids were fed to eight barrows fitted with ileal T-cannulas and also evaluated for starch digestibility in ruminal fluid. Corn was used as a control. Corn had greater ileal and total tract digestibilities of DM, GE, N, and starch than the hybrids, but was similar to the sorghums for starch digestibility in ruminal fluid. Ileal digestibilities were not different for the male-sterile parent lines, but hybrids of Kansas 52 had greater DM, GE, and N digestibilities over the total tract than hybrids of the Redlan parent line. Among the male parent lines, hybrids from the two lines with high in vitro digestibility had greater total tract digestibilities of DM, GE, and N than lines with low in vitro digestibilities. In conclusion, selection based on our laboratory procedure was an effective predictor of total tract nutrient digestibility of sorghum in pigs. Also, differences among parent lines for nutrient digestibility were still evident in their hybrid offspring.

(Key Words: Finishing, Sorghum, Digestibility, In Vitro.)

Introduction

Sorghum grain often is considered variable in nutrient content and quality, with a relative feeding value of 93 to 97% that of corn. However, there are reports of sorghums with nutritional value equal to that of corn, indicating that environment, genotype, processing, and(or) other factors can combine to produce sorghums with excellent feeding value. Costs of elaborate processing techniques and lack of an effective means to control the environment make genetic improvement a preferred goal. To accomplish this, plant breeders must have simple and appropriate tests for likely nutritional value to avoid discarding valuable germplasm. Animal feeding experiments require large amounts of test material and are time consuming, labor intensive, and costly, all of which limit their use as screening tools for plant breeding programs. In the 1991 KSU Swine Day Report, we suggested that in vitro protein digestibility (i.e., a laboratory assay) could be used to select sorghum parent lines with greater nutritional value for broiler chicks and finishing pigs. The objective of the experiment reported herein was to determine the nutritional value of sorghum hybrids, resulting from parent lines selected for different in vitro protein digestibility, in cannulated finishing pigs and ruminal fluid.

Procedures

[1]Department of Agronomy.

Sorghum parent lines were selected from 100 S_2 families of the sorghum population KP7B. Two lines having consistently low (Low-digestibility 1 and 2) and two having consistently high (High digestibility 1 and 2) in vitro pepsin digestibility were selected and grown for two generations to increase quantities of seed. These parent lines were evaluated for nutritional value in broiler chicks and finishing pigs, and the results from those experiments were reported in the 1991 KSU Swine Day Report (page 27). The parent lines with greater in vitro digestibility were indeed of greater nutritional value for chicks and pigs. However, sorghums are marketed as hybrids, not parent lines. Thus, we still questioned whether the differences in the parent lines would be passed to their hybrid offspring.

To evaluate the differences in nutritional value of the parent lines when used to create hybrid offspring, the four sorghum lines were mated with two male-sterile lines (Kansas 52 and Redlan). The resulting eight hybrids were evaluated in pigs (ileal digestibility experiment) and an in vitro starch degradation assay using ruminal fluid. Corn was included as a control. Eight barrows, fitted with ileal T-cannulas, were used in an incomplete Latin square design with pig and period as the blocking criteria. Initial body wt of the barrows was 212 lb. The barrows were housed in metabolism crates (2 ft × 5 ft) for the experiment.

The basal diet was corn-soybean meal-based and formulated to 15% CP, .65% Ca, and .55% P (Table 1). The sorghums were used to replace the corn on a wt/wt basis, with all grains ground through a hammermill with a 1/8" screen. Chromic oxide was added to the diets as an indigestible marker. Water was provided ad libitum, and feed was provided using the equation: daily feed=.05 × body $wt^{.9}$. Feed was offered as a wetted mash in two equal portions at 7 a.m. and 7 p.m. each day. Collection periods consisted of a 4-d adjustment to diet followed by 36 h of total feces collection and 2 d (12 h/d) of ileal digesta collection. Feces and ileal digesta were homogenized, dried, and ground prior to analyses for DM, N, GE, and starch concentrations.

Table 1. Composition of the Basal Diet[a]

Item	Amount, %
Grain source	77.58
Soybean meal (48% CP)	19.46
Dicalcium phosphate	1.03
Limestone	1.03
Salt	.25
Vitamins and minerals[b]	.40
Chromic oxide[c]	.25
Total	100.00

[a]Formulated with corn to 15% CP, .65% Ca, and .55% P; other grain sources replaced corn on a wt:wt basis.
[b]KSU vitamin and mineral premixes.
[c]Chromic oxide was added as an indigestible marker.

For determination of digestibility in ruminal fluid, cleaned whole grain was ground in a laboratory mill equipped with a 1 mm screen. Ruminal fluid was collected from a fistulated steer, strained through cheesecloth, and transported to the lab. Inoculum was made by mixing McDougall's buffer with the ruminal fluid, and 15 mL of inoculum was added to test tubes containing .5 g of cereal grain. The tubes were filled with CO_2 and incubated at 102°F, and the fermentation was stopped in two tubes per treatment at 4, 8, 12, 16, and 24 h by adding ice-cold acetate buffer. Rate of starch degradation was calculated by regressing the natural log of percentage starch remaining vs duration of incubation.

Data were analyzed with the contrasts: 1) corn vs the sorghums; 2) Kansas 52 vs Redlan; 3) Low-digestibility 1 and Low-digestibility 2 vs High-digestibility 1 and High-digestibility 2; 4) Low-digestibility 1 vs Low-digestibility 2; 5) High-digestibility

1 vs High-digestibility 2; 6) Low-digestibility 1 and Low-digestibility 2 vs High-digestibility 1 and High-digestibility 2 × Kansas 52 vs Redlan; 7) Low-digestibility 1 vs Low-digestibility 2 × Kansas 52 vs Redlan; and 8) High-digestibility 1 vs High-digestibility 2 × Kansas 52 vs Redlan. In the in vitro starch degradation assay, the model included the main effects of grain source and the interaction of grain source × duration of incubation.

Results and Discussion

The hybrids varied in pericarp color (i.e., red, yellow, brown, and mixed), and hybrids with Low-digestibility 1 as a parent had moderate (.56 and 1.53 mg catechin/100 mg DM) levels of tannins as did the Low-digestibility 2 × Redlan hybrid (.97 mg catechin/100 mg DM). Tannins are associated with the presence of a pigmented testa. The presence or absence of the pigmented testa is controlled by two complementary genes, with the testa present when both genes are dominant. Thus, expression of these genes accounts for not only the detectable levels of tannin, but also the brown and mixed pericarp colors for the Low-digestibility 1 × Kansas 52, Low-digestibility 1 × Redlan, and Low-digestibility 2 × Redlan hybrids.

Nutrient digestibilities at the terminal ileum ($P<.001$) and for the total tract ($P<.07$) were greater for corn than the sorghum hybrids, but disappearance of starch in the large intestine was greater for the sorghum hybrids ($P<.001$). Starch disappearing in the large intestine would be used largely for microbial activity and is of less benefit to the host animal. Thus, total tract digestibility of starch would overestimate the nutritional value of the sorghum hybrids relative to corn.

For the sorghums, digestibilities of nutrients at the terminal ileum were similar for hybrids from Kansas 52 and Redlan, but total tract digestibilities of DM, GE, and N were greater ($P<.05$) for hybrids from Kansas 52. Selected line × male-sterile interactions for total tract DM digestibility were detected, probably because of the expression of the tannin genes in the Low-digestibility 2 × Redlan mating.

Digestibility of nutrients at the terminal ileum were similar ($P>.13$) for hybrids from High-digestibility 1 and 2 and Low-digestibility 1 and 2 parent lines. However, total tract digestibilities of DM, GE, and N were greater ($P<.01$) for hybrids from the High-digestibility vs Low-digestibility parent lines. This was undoubtedly because of tannins in the hybrids from Low-digestibility parent lines.

Digestibilities of nutrients at the terminal ileum were greater ($P<.01$) for hybrids from High-digestibility 2 than High-digestibility 1, whereas total tract digestibilities of nutrients were similar ($P>.10$). As previously discussed, nutrients absorbed in the small intestine are of greater value to the pig than those digested and absorbed in the large intestine. Thus, the hybrids of High-digestibility 2 would be of greater nutritional value to the animal. Starch degradation in ruminal fluid did not differ for the sorghums.

In conclusion, results of this experiment support our earlier findings that in vitro pepsin digestibility can be used to rank sorghum grains for overall nutrient utilization by pigs. Moreover, selected parent lines passed those differences to their hybrid progeny. However, the male-sterile parents had greater effects on nutritional value of the offspring than the male parents. Thus, if male-steriles with high protein digestibility could be found or developed, it would simplify breeding for improved nutritional value in sorghum grain.

Table 2. Composition of Corn and Sorghum Hybrids[ab]

		Kansas 52				Redlan			
Item	Corn	LD1	LD2	HD1	HD2	LD1	LD2	HD1	HD2
Physical traits									
Pericarp color	—	mixed	yellow	red	yellow	brown	brown	red	red
Endosperm									
Color	—	hetero	white	white	white	white	white	white	white
Texture	—	3	2	3	2	4	2	3	4
Type	normal	normal	normal	normal	normal	normal	normal	normal	normal
Chemical analyses									
CP, %	8.4	12.2	13.7	13.2	12.6	11.5	13.0	12.5	12.2
Fat, %	5.6	4.2	3.9	4.3	4.0	3.4	3.3	4.1	4.5
Ash, %	1.1	2.0	1.9	1.9	1.9	1.9	1.7	1.9	2.1
Starch, %	73.9	72.9	74.3	74.1	74.0	75.4	73.9	72.9	74.5
GE, Mcal/lb	2.13	2.06	2.11	2.10	2.10	2.09	2.10	2.11	2.09
Moisture, %	12.7	13.1	13.2	13.7	13.3	13.7	12.9	13.3	13.6
Tannin[c]	ND	.56	ND	ND	ND	1.53	.97	ND	ND
Pepsin digestibility, %	74.4	50.0	61.4	54.7	59.1	42.2	43.2	60.9	59.7
Amino acids, %									
Lysine	.30	.28	.28	.29	.28	.29	.29	.30	.27
Methionine	.20	.25	.23	.25	.22	.26	.23	.23	.20
Threonine	.33	.41	.40	.44	.42	.43	.42	.42	.36
Tryptophan	.04	.07	.09	.10	.04	.09	.08	.10	.04

[a]Dry matter basis.
[b]LD1=Low-digestibility 1; LD2=Low-digestibility 2; HD1=High-digestibility 1; and HD2=High-digestibility 2.
[c]Milligrams of catechin/100 mg grain DM.

Table 3. Apparent Nutrient Digestibility in Pigs and Starch Degradation in Ruminal Fluid of Corn and Sorghum Hybrids[a]

		Kansas 52[b]				Redlan[b]					Contrasts[cd]							
Item	Corn	LD1	LD2	HD1	HD2	LD1	LD2	HD1	HD2	SE	1	2	3	4	5	6	7	8
Dry matter, %																		
Small intestine	78.08	70.41	68.05	67.80	69.23	67.78	68.64	69.43	70.83	.58	.001	—	—	—	.007	—	—	—
Total tract	87.67	84.09	86.70	86.06	86.53	83.14	82.77	86.48	85.79	.26	.005	.04	.01	—	—	.08	.09	—
Difference[e]	9.59	13.68	18.65	18.26	17.30	15.36	14.13	17.05	14.96	.59	.001	—	—	—	.01	—	—	—
Gross energy, %																		
Small intestine	79.66	71.08	68.26	67.90	69.72	68.75	69.49	69.95	71.17	.60	.001	—	—	—	.005	—	—	—
Total tract	87.34	82.58	85.29	84.39	85.32	81.61	80.95	84.91	84.08	.31	.001	.05	.01	—	—	—	—	—
Difference	7.68	11.50	17.03	16.49	15.60	12.86	11.46	14.96	12.91	.60	.001	—	—	—	.02	—	—	—
Nitrogen, %																		
Small intestine	80.60	70.42	70.35	69.75	70.64	69.16	68.66	72.75	72.84	.57	.001	—	—	—	.007	—	—	—
Total tract	85.03	75.16	79.14	79.25	79.15	73.82	72.52	78.06	77.53	.52	.001	.03	.01	—	—	—	—	—
Difference	4.43	4.74	8.79	9.50	8.51	4.66	3.86	5.31	4.69	.75	—	.07	—	—	—	—	—	—
Starch, %																		
Small intestine	97.57	91.15	87.77	87.73	90.51	89.53	89.50	90.16	90.76	.45	.001	—	—	—	.009	—	—	—
Total tract	99.71	98.97	99.22	99.39	99.38	99.26	98.55	99.30	99.24	.09	.07	—	—	—	—	—	—	—
Difference	2.14	7.82	11.45	11.66	8.87	9.73	9.05	9.14	8.48	.47	.001	—	—	—	.01	—	—	—
In vitro degradation																		
% starch/h[f]	3.27	3.13	3.16	3.04	3.15	2.97	3.01	3.17	3.25	.04	—	—	—	—	—	—	—	—

[a]Values for digestibilities in pigs are means of five or six pigs with chromic oxide used as an indigestible marker. Values for starch degradation in ruminal fluid are for 10 test tubes each.

[b]LD1=Low-digestibility 1; LD2=Low-digestibility 2; HD1=High-digestibility 1; and HD2=High-digestibility 2.

[c]Contrasts: 1) Corn vs Sorghums; 2) Kansas 52 vs Redlan; 3) LD1 and LD2 vs HD1 and HD2; 4) LD1 vs LD2; 5) HD1 vs HD2; 6) LD1 and LD2 vs HD1 and HD2 × Kansas 52 vs Redlan; 7) LD1 vs LD2 × Kansas 52 vs Redlan; and 8) HD1 vs HD2 × Kansas 52 vs Redlan.

[d]Dashes indicate P>.10.

[e]Difference was calculated by subtracting small intestine digestibility from total tract digestibility.

[f]Degradation rate was calculated by regressing the natural log of percentage starch remaining on duration of incubation.