EFFECTS OF SORGHUM STARCH TYPE, ENDOSPERM HARDNESS, AND PROCESSING ON DIGESTIBILITY AND GROWTH PERFORMANCE IN FINISHING PIGS AND CHICKS [1]

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Summary

In finishing pigs, waxy sorghum had lower digestibilities for DM and GE than the other genotypes. Also, the hard sorghums were more digestible (P<.06) than the medium hardness sorghum. In broiler chicks, the waxy sorghum was similar to the other genotypes for growth performance and nutrient digestibility. The soft sorghum was superior to the medium and hard genotypes for nutrient retention but not for growth performance. Fine grinding improved F/G and increased retention of nutrients and steam-flaked sorghum supported greater growth performance than extruded sorghum.

(Key Words: Sorghum, Processing, Chicks, Finishing Pigs.)

Introduction

Previous research from our laboratory indicated that processing technologies and (or) endosperm hardness impact growth performance of chicks and pigs fed sorghums. Additionally, waxy sorghum is more susceptible to enzymes during digestion. However, little is known about potential interactions among endosperm type and processing technologies that might optimize nutrient digestibility and growth performance in swine and poultry. Therefore, experiments were designed to determine the effect of endosperm hardness and starch type on nutrient digestibility in pigs and to investigate the interactions among genotype and processing technology in broiler chicks.

Procedures

Six sorghum genotypes were grouped into soft (851111), medium (279 & PL-1), hard (Segolane & 475), and waxy (739) categories. For the pig experiment, the sorghums were ground to a particle size of 550 μm. For the chick assay, the sorghums were (coarsely ground to 1,000 μm & finely ground to 450 μm) and thermally processed (steam-flaked at 150°F and extruded at 235°F).

For the pig experiment, five barrows (average initial BW of 142 lb) were used in a 5 × 5 Latin square design. The pigs were housed in metabolism cages placed in an environmentally controlled building (70°F). The pigs were fed three times per day (7:00 a.m., 1:00 p.m., and 7:00 p.m.). After a 3-d adjustment period, fresh feces were collected twice each day dried; ground; and analyzed for dry matter, crude protein, gross energy, and chromium. All diets were formulated to .6% lysine, .55% of Ca, and .50% P (Table 1), with the ground sorghums as the only source of energy and protein (Table 1).

In Exp.2, 600 broiler chicks (avg initial BW of 90 g) were used in a 21-d growth assay with 24 treatments (6 genotypes × 4 processing, and 5 pens/trt and 5 chicks/pen). The chicks were housed in brooder batteries and allowed ad libitum access to feed and

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water. Feces (with urine) were collected during the last 2 d of the growth assay; dried; ground; and analyzed for DM, CP, GE, and Cr to determine nutrient retention. All diets were sorghum-soybean meal-based with 1.0% tallow and formulated to 1.32% lysine, 1.1% Ca and 0.9% P (Table 1).

Results and Discussion

Chemical analyses of the grains (Table 2) suggested that they were "normal" for moisture (8 to 12%) and crude protein (9 to 11%). However, notable differences occurred among the sorghums for texture and starch type, which allowed us to categorize the genotypes. Sorghum genotypes had less effect on energy consumption during processing than the processing technologies themselves, with thermal processing using more energy than grinding, and extrusion using more energy than steam flaking (Table 3). Energy consumption was similar among the genotypes, except for the low kwh/ton needed to coarsely and finely grind and steam flake Segolane. Also, waxy sorghum required the least energy to steam flake, suggesting a strong genotype × processing procedure interaction.

In finishing pigs, digestibilities of DM (P<.01) and GE (P<.07) were less for waxy sorghums than the other genotypes (Table 4). Also, the hard sorghums were more digestible (P<.06) than the medium hardness sorghums. Both of these effects were contrary to "conventional wisdom", which would support greater nutrient utilization from waxy and soft endosperm types.

In the broiler experiment (Table 5), no genotype effects on growth performance were observed. Chicks fed soft sorghum had greater (P<.01) retentions of DM, N, and GE compared to chicks fed medium and hard endosperm genotypes, whereas those fed hard sorghums had greater nutrient retention than those fed medium hardness sorghums (P<.02).

Grinding improved ADG (P<.01), ADFI (P<.001), and F/G (P<.04) when compared to thermal processing. However, thermal processing improved retention of DM, N, and GE (P<.03) compared to grinding. Retentions of DM, CP, and GE were improved with fine grinding versus coarse grinding (P<.05) and steam flaking versus extrusion (P<.06).

Interactions among genotypes and processing technologies were observed in feed efficiency. Soft sorghum responded more favorably (P<.05) to coarse grinding than to fine grinding compared to medium and hard types, and hard sorghum responded more favorably (P<.01) to flaking than to extrusion. As for nutrient retention, soft sorghum responded more favorably (P<.01) to thermal processing than to grinding compared to harder sorghums. Harder sorghum responded more favorably (P<..01) to flaking than to extrusion compared to medium sorghums. Waxy sorghums responded more positively to fine grinding (P<.04) and flaking (P<.06) than to coarse grinding and extrusion compared to nonwaxy sorghum.

In conclusion, retention of DM and GE for finishing pigs was greater with hard endosperm than soft and waxy sorghums. Feed efficiency was greatest in chicks fed the hard sorghum and steam-flaked treatments. Retentions of DM, N, and ME were greatest for chicks fed soft genotypes and thermally processed sorghums. However, *within* thermal processing, waxy endosperm sorghum responded more favorably to steam flaking and less favorably to extrusion, whereas soft and medium sorghums showed the opposite response.

Table 1. Compositions of Basal Diets with Exotic Sorghum Genotypes (Exps. 1 and 2)[a]

Ingredient, %	Finisher (Exp. 1)	Chick (Exp. 2)
Sorghum	96.30	53.30
Soybean meal (46.5 % CP)	--	39.80
Tallow	--	1.00
Monocalcium phosphate	1.10	2.30
Limestone	.85	1.50
Salt	.30	.50
Lysine HCl	.40	--
Threonine	.16	.10
D, L-methionine	.11	.26
Tryptophan	.12	--
Vitamin premix	.15	.23
Mineral premix	.10	.28
Sow add pack	.05	.26
Chromium	.25	.20
Copper sulfate	--	.06
Antibiotics [b]	.125	.25

[a]Finisher diets were formulated to .6% lysine, .55% Ca, and .5% P. Chick diets were formulate to 1.32% lysine, 1.1% Ca, and .9% P.
[b]Finisher diets had 40 g/ton tylosin; chick diets had 100 g/ton chlortetracycline and .0125% amprolium.

Table 2. Characteristics of Exotic Sorghum Genotypes

	Soft	Medium		Hard		Waxy
Item	851171	279	PL-1	475	Segolane	739
Physical traits						
Pericap color	white	red	yellow	cream	cream	cream
Endosperm color	white	white	yellow	white	white	white
Texture [a]	soft	medium	medium	hard	hard	soft
Starch type [b]	normal	normal	normal	normal	normal	waxy
Chemical analyses						
Unprocessed						
Moisture, %	10.8	8.5	104	9.5	10.6	11.8
CP, %	11.2	11.3	10.8	10.1	10.0	8.8
Extruded						
Moisture, %	4.4	4.5	4.8	5.5	4.7	5.3
CP, %	12.6	12.2	12.7	10.7	11.5	10.8
Steam-flaked						
Moisture, %	8.9	8.6	11.1	9.9	8.8	11.9
CP, %	10.5	11.1	10.5	10.1	10.0	10.3

[a]Texture was determined using the Single Kernel Characterization (SKC) method.
[b]Starch type was determined by visual appraisal.

Table 3. Processing Energy Consumption of Sorghum Genotypes, kwh/t

	Soft	Medium		Hard		Waxy	Processing
Item	851171	279	PL-1	475	Segolane	739	Mean
Coarse [a]	11.9	13.9	10.8	10.8	8.3	13.6	11.5
Fine [b]	10.3	12.1	12.3	8.2	8.2	15.4	11.1
Flaked [c]	60.4	57.3	50.6	50.6	40.8	36.1	49.3
Extruded [d]	76.0	74.2	72.5	72.1	76.4	66.6	70.2
Genotype mean	39.7	39.4	36.5	35.4	33.4	32.9	

[a]Ground in a roller mill to a mean particle size of 1,039 μm.
[b]Ground in a roller mill to a mean particle size of 440 μm.
[c]Steam-flaked at 150°F.
[d]Extruded at 235°F.

Table 4. Effect of Sorghum Genotype on Nutrient Digestibility in Finishing Pigs[a]

Digestibility,	Soft	Medium	Hard		Waxy		Contrast [b]			
%	851171	PL-1	Segolane	475	739	SE	1	2	3	4
DM	83.8	84.3	86.5	87.2	82.2	.9	--[c]	.06	--	.01
N	69.7	65.6	67.0	68.3	69.5	2.3	--	--	--	--
GE	83.3	83.4	85.8	85.6	82.5	.9	--	.06	--	.07

[a]Five finishers were used (avg initial BW of 160 lb).
[b]Contrast were: 1) soft vs medium & hard; 2) medium vs hard; 3) hard vs hard; and 4) waxy vs others.
[c]Dashes indicated P>.1.

Table 5. Effects of Sorghum Genotypes and Processing on Growth Performance in Chicks[a]

	Soft	Medium		Hard		Waxy	Processing
Item	851171	279	PL-1	475	Segolane	739	Mean
ADG, g [b]							
Coarse	39.1	35.7	40.2	37.7	39.4	38.8	38.5
Fine	37.7	38.4	37.9	39.5	39.0	39.1	38.6
Flaked	37.8	37.7	33.1	39.1	39.7	37.9	37.4
Extrude	33.1	34.2	36.0	35.6	29.0	34.3	33.9
Genotype mean	36.9	36.5	36.8	38.0	36.9	37.5	SE 1.1
ADFI, g [c]							
Coarse	56.3	57.2	63.0	57.3	60.6	56.8	58.5
Fine	57.0	56.1	53.5	59.2	55.4	58.2	56.6
Flaked	58.5	57.8	51.1	58.3	55.0	58.0	56.4
Extruded	52.3	50.1	51.4	57.5	49.0	56.6	53.0
Genotype mean	56.1	55.2	54.7	58.1	55.3	57.4	SE 2.1
F/G [d]							
Coarse	1.43	1.46	1.56	1.52	1.54	1.47	1.52
Fine	1.51	1.53	1.41	1.50	1.42	1.49	1.46
Flaked	1.55	1.46	1.54	1.49	1.40	1.54	1.50
Extruded	1.58	1.56	1.42	1.62	1.70	1.65	1.56
Genotype mean	1.51	1.51	1.48	1.53	1.50	1.53	SE .02

[a]A total of 600 chicks was used (five chicks/pen and five pen/trt) with an avg initial BW of 90 g. [b]Hard vs hard (P<.06); ground vs thermally processed (P<.01); flake vs extruded (P < .01). [c]Ground vs thermally processed (P<.001); flake vs extruded (P<.01); 475 vs Segolane × ground vs thermally processed (P<.08); medium vs hard × flake vs extrusion (P<.01). [d]Ground vs thermally processed (P<.04); coarse vs fine (P<.07); flaked vs extruded (P<.07); soft vs medium & hard × coarse vs fine ground (P<.05); medium vs hard × flaked vs extruded (P<.001).

Table 6. Effects of Sorghum Genotypes and Processing on Nutrient Retention in Chicks[a]

	Soft	Medium		Hard		Waxy	Processing
Item[e]	851171	279	PL-1	475	Segolane	739	Mean
DM, %[b]							
Coarse	73.7	73.9	73.0	75.3	76.9	71.4	74.0
Fine	75.5	78.7	77.2	75.0	76.9	77.5	77.0
Flaked	80.2	67.2	75.6	81.1	71.3	79.5	76.1
Extrude	80.3	72.7	78.1	75.8	80.1	77.8	77.4
Genotype mean	77.7	73.5	76.0	76.8	76.1	76.6	SE 1.1
N, %[c]							
Coarse	58.4	57.79	56.2	59.9	62.5	53.73	58.1
Fine	61.7	63.2	62.4	57.4	59.79	63.1	61.2
Flaked	67.4	42.4	58.5	69.1	46.7	64.7	58.7
Extruded	71.4	54.6	60.8	57.1	67.1	62.3	62.0
Genotype mean	64.7	55.1	59.5	60.9	58.6	61.0	SE 2.3
GE, %[d]							
Coarse	77.2	78.4	76.2	78.5	80.9	74.8	77.7
Fine	80.1	82.3	81.3	79.0	80.9	81.0	80.8
Flaked	83.8	73.2	80.0	84.8	76.4	83.3	80.5
Extruded	84.4	77.6	82.0	79.6	83.6	81.7	81.4
Genotype mean	81.4	78.1	79.9	80.5	80.3	80.2	SE 1.0

[a]A total of 600 chicks was used (five chicks/pen and five pen/trt) with an avg initial BW of 90 g.

[b]Soft vs medium & hard (P<.01); medium vs hard (P<.01); ground vs thermally processed (P<.03), coarse vs fine (P<.001); flaked vs extruded (P<.02); soft vs medium & hard ×thermal processed (P<.001);); medium vs hard × ground vs thermally processing (P < .01); medium vs hard × coarse vs fine ground (P<.01).

[c]Soft vs medium & hard (P<.001); coarse vs fine (P<.05); flaked vs extruded (P<.06); waxy vs others × ground vs thermally processing (P<.05); waxy vs others × coarse vs fine ground (P<. 09); waxy vs others × flaked and extruded (P<.04).

[d]Soft vs medium & hard (P<.01); medium vs hard (P<.01); ground vs thermally processed (P<.001), coarse vs fine (P<.001); flaked vs extruded (P<.08), soft vs medium & hard × ground vs thermal processed (P<.001); medium vs hard × ground vs thermally processing (P<.001); medium vs hard × coarse vs fine ground (P<.03); waxy vs others × ground vs thermally processing (P<.06); waxy vs others × coarse vs fine ground (P<. 04); waxy vs others × flaked and extruded (P<.01).