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THE EFFECTS OF SORBIC ACID IN HIGH MOISTURE SORGHUM GRAIN DIETS ON PERFORMANCE OF WEANLING SWINE[1,2,3]

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ABSTRACT

Three experiments were conducted with 288 weanling pigs to determine the effects of sorbic acid (SA) added to dry (DSG), high moisture (HMSG) or reconstituted (RSG) sorghum grain diets on gains and feed conversion. Dietary treatments for Exp. 1 were: DSG with and without .1% SA; HMSG with .1% SA and RSG with .1% SA. The DSG diets were fed ad libitum. The HMSG and RSG diets were mixed fresh from oxygen-limiting storage every 3 and 7 d and were also fed ad libitum. Pigs fed RSG diets consumed more feed than those fed HMSG diets (P<.08). Performance was similar between pigs fed DSG diets without or with SA. Dietary treatments for Exp. 2 and 3 consisted of sorghum grains reconstituted to two moisture contents (MC), with additions of either 0, .05 or .1% SA. The diets were mixed fresh from oxygen-limiting storage every 7 d and fed ad libitum. In Exp. 2 and 3, pigs fed the higher MC diets were more efficient in feed conversion (P<.03) than those fed the lower MC diets. In Exp. 3, a quadratic response (P<.04) for average daily gain and average daily feed intake was observed for the main effect of SA. Feed efficiency improved (P<.05) in a linear fashion as SA levels were increased in the diets. The results of these experiments indicate that weanling pigs may be fed HMSG or RSG without adverse effects on pig performance. Inconsistencies in pig response to SA were observed. Feed temperature measurements indicated that SA prevented heat production in the RSG diets for at least 10 d after removal from oxygen-limiting storage, while diets without SA became moldy within 5 d.
(Key Words: Pigs, Moisture Content, Feed Grains, Reconstitution, Sorbic Acid, Mold.)

Introduction

Molds play a major role in the deterioration of high moisture (HM) grain. Because molds are aerobic, the quality of HM grains can be maintained if it is stored in oxygen-limiting structures. However, once HM grain is removed from such storage, mold growth occurs rapidly. Certain molds can produce mycotoxins that if consumed by swine, may be detrimental to their health and reproduction. Thus, it is necessary to feed HM grain frequently to maintain its feeding value.

High moisture sorghum grain (HMSG) has a feeding value for swine similar to that of dry sorghum grain (DSG; Trotter and Allee, 1976; Crenshaw et al., 1984). However, the need for frequent feeding of HM grain has limited its use.

Several mold inhibitors deter fungal growth in agricultural commodities (Ray and Bullerman, 1982). Theoretically, mold inhibitors should delay mold growth in HM grain after removal from oxygen-limiting storage, thus eliminating the need for daily feeding. Therefore, the objectives of the research reported herein were: 1) determine the effects of sorbic acid[7] (SA) and dietary moisture content on weanling pig performance and 2) determine the influence of SA on microbial heating and the feeding quality of HMSG diets after removal from oxygen-limiting storage.

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TABLE 1. COMPOSITION OF DIETS (EXP. 1)[a]

Ingredient	Sorghum grain diet (dry matter basis)			
	DSG[b]	DSG[b]	HMSG[b]	RSG[b]
	%			
Sorghum grain	71.24	71.24	71.45	70.71
Soybean meal	25.09	25.09	24.91	25.66
Dicalcium phosphate	1.03	1.03	1.04	1.02
Limestone	.97	.97	.93	.94
Premix[c]	1.67			
Premix + sorbic acid[d]		1.67	1.67	1.67

[a]Diets were calculated to provide as a percentage of diet (dry matter basis): crude protein, 20; lysine, 1.02; calcium, .73 and phosphorus, .61.

[b]DSG (dry sorghum grain, 13.5% moisture); HMSG (high moisture sorghum grain, 23.4% moisture) and RSG (reconstituted sorghum grain, 23.2% moisture). Respective analysis of percentage of crude protein (dry matter basis) and dry matter for DSG, DSG + sorbic acid, HMSG and RSG diets were: 20.5, 87.0; 20.3, 88.1; 20.4, 82.8; and 20.5, 81.5.

[c]Contributed the following as a percentage of premix: vitamin concentrate, 13.3; iodized salt, 33.3; trace mineral premix, 6.7; selenium premix, 3.3; antibiotic, 16.7; ground corn, 26.7. Vitamin concentrate provided the following per kg diet: vitamin A, 5500 IU; vitamin D_3, 440 IU; riboflavin, 2.9 mg; d-pantothenic acid, 22 mg; niacin, 22 mg; choline chloride, 220 mg; vitamin B_{12}, .022 mg; ethoxyquin 4.4 mg; menadione sodium bisulfate, 2.2 mg; vitamin E, 22 IU. Trace mineral premix contributed the following in mg/kg diet; Zn, 200; Fe, 100; Mn, 55; Cu, 10; I, 1.5. Selenium premix contributed .1 mg Se/kg diet. Antibiotic contributed the following in mg/kg diet: chlortetracycline, 110; sulfamethazine, 110 and penicillin, 55.

[d]Same as footnote c, except as a percentage of the premix corn, was 20 and sorbic acid was 6.7. As a percentage of the diet, sorbic acid was .10.

Experimental Procedures

Exp. 1. The HMSG was harvested on a private farm[8] and unloaded from a combine into 208-liter drums lined with plastic bags. The bags were sealed with tape and the HMSG was stored at room temperature (20 C) until use. Later, DSG was harvested from the same field. Some of the DSG was reconstituted (RSG) as described by Crenshaw et al. (1984), placed in 208-liter drums lined with plastic bags, sealed and stored at room temperature (20 C) for at least 21 d before feeding. The remaining DSG was stored in open 208-liter drums at room temperature (20 C). Moisture contents of the DSG, HMSG and RSG were 13.5, 23.4 and 23.2%, respectively. All of the sorghum grain was processed through the same hammermill to provide a fine to medium particle size.

Basal dietary treatments (table 1) containing either DSG, HMSG or RSG were formulated to be isonitrogenous on a dry matter basis and to meet the nutritional requirements for 10- to 20-kg pigs (NRC, 1979). Sorbic acid (dry form) was added to a premix (table 1, footnote d) before being mixed into the respective diets.

The treatment groups were DSG diets with and without .1% SA; harvested HMSG diets + .1% SA and RSG diets + .1% SA. Dry sorghum grain diets were fed ad libitum. The HMSG and RSG diets were mixed fresh from oxygen-limiting storage every 3 or 7 d to supply enough feed for ad libitum intake during a 3- or 7-d feeding period. Any HMSG or RSG feed remaining after the feeding period was weighed and discarded.

Ninety-six crossbred weanling pigs (4 to 5 wk of age) were randomly allotted to six treatment groups. Because of a limited supply of HMSG and RSG, the treatment groups were randomly assigned to an unequal number of pens. Six pens (four pigs/pen; two gilts and two barrows) were assigned to each of the DSG diets and three pens were assigned to all other treatment groups. Average initial weight of the pigs was 10.6 kg. Pigs were housed in an environmentally controlled nursery with 1.5- x 1.8-m pens containing partially slatted floors and nipple waterers. Pig weights and feed intakes were recorded weekly.

Pen averages of the data were tested for the effect of treatment group and replication with 12 residual degrees of freedom as the error

[8]Arnold Schroeder, RFD, Palmyra, NE 68418.

TABLE 2. COMPOSITION OF BASAL RECONSTITUTED SORGHUM GRAIN DIETS (EXP. 2 AND 3)

	Sorghum grain, % moisture content			
Ingredient	17.7(2)[a]	20.5(2)[a]	19.7(3)[a]	22.5(3)[a]
	% dry matter basis			
Sorghum grain	68.61	68.57	68.27	68.25
Soybean meal	27.31	27.30	27.62	27.62
Dicalcium phosphate	1.72	1.81	1.77	1.78
Limestone	.76	.72	.74	.75
Salt	.50	.50	.50	.50
Trace mineral premix[b]	.05	.05	.05	.05
Selenium premix[c]	.05	.05	.05	.05
Vitamin premix + additives[d]	1.00	1.00	1.00	1.00

[a]Values in parenthesis indicate Exp. 2 and 3. Grain with lower and higher moisture contents were used to form the six treatments within each experiment.

[b]Provided the following mg/kg diet: Zn, 100; Fe, 50; Mn, 27.5; Cu, 5; I, .75.

[c]Provided .1 mg selenium/kg diet.

[d]Contributed the following as a percentage of premix: vitamin concentrate, 20; sorbic acid, 0, 5 or 10; ground corn, 55, 50 or 45. Contributed the following per unit of diet: vitamin concentrate (same as table 1, footnote c); carbadox, 55 ppm.

term, using a general linear regression model with initial weight as a covariate (Barr et al., 1976).

Exp. 2 and 3. Dry sorghum grain was obtained from a local elevator, then reconstituted, stored and processed as described for the RSG used in the first experiment. Dietary treatments were arranged in a 2 × 3 factorial plan and consisted of sorghum grain reconstituted to two moisture contents and fed with three levels of SA (0, .05 and .1%). The two moisture contents of the RSG for Exp. 2 and 3 were 17.7 and 20.5% and 19.7 and 22.5%, respectively. The basal RSG diets (table 2) were formulated on an equal lysine and dry matter basis to meet or exceed the nutrient requirements of 5- to 10-kg pigs (NRC, 1979). The diets were mixed fresh from oxygen-limiting storage every 7 d and fed ad libitum. Feed remaining in the feeders after 7 d was weighed and discarded.

At the start of Exp. 2 and 3, samples (approximately 23 kg) of the diets were stored in open containers within the nursery environment. Thermometers were placed in the center of the sample mass. Feed temperatures were recorded twice daily for the duration of the experiment. Room temperature and relative humidity were recorded continuously with a thermo-humidigraph[9]. Average room temperature and relative humidity for Exp. 2 and 3 were 25 C and 27% and 23 C and 19%, respectively.

Since Webb et al. (1960) suggested that microbial heating in feedstuffs was caused primarily by molds and Sauer et al. (1975) observed that molds usually appeared in high moisture grain when its temperature had increased 2 C, temperature of the diets was obtained as an estimate of microbial activity. The thermometers used in these experiments were accurate to 1 C, thus a temperature increase of 3 C was used as the point of probable initiation of mold growth.

Ninety-six crossbred weanling pigs (192 total) were allotted to six dietary treatments, using initial weight (average 5.8 and 8.7 kg for Exp. 2 and 3, respectively) as the blocking criterion, in a randomized complete-block design. Exp. 2 and 3 were terminated after 19 and 28 d, respectively. Animal housing and data collection were the same as described for Exp. 1.

Experiments 2 and 3 were designed as a randomized complete-block (Steel and Torrie, 1980). Pen means of the response criteria were tested for the main effects of moisture content, SA level and their interactions using the F-test with a general linear regression model (Barr et al., 1976).

[9]Model 4096TH. The Bristol Co., Waterbury, CT 06708.

TABLE 3. CRUDE PROTEIN AND DRY MATTER COMPOSITIONS OF DIETARY TREATMENTS (EXP. 2 AND 3)[a]

	Dietary moisture					
	Low			High		
	Sorbic acid, %					
Item	0	.05	.10	0	.05	.10
Exp. 2						
Crude protein, %[b]	20.5	20.9	20.3	20.7	20.5	20.6
Dry matter, %	83.4	83.7	83.6	81.8	81.2	80.9
Exp. 3						
Crude protein, %[b]	21.4	21.1	20.7	20.4	20.9	20.8
Dry matter, %	82.4	82.5	81.9	78.8	78.4	78.9

[a]Values are mean of duplicate samples.

[b]Dry matter basis.

Laboratory Analyses. For Exp. 1, 2 and 3, N content of the diets, sorghum grain and soybean meal was determined using a Kjeldahl procedure[10] similar to that described by AOAC (1980). Dry matter content of the diets, sorghum grain and soybean meal was determined by oven-drying approximately 4-g samples for 12 h at 105 C. Crude protein and dry matter composition of the diets (Exp. 2 and 3) are presented in table 3. Samples of each diet were taken from the feeders after each 7-d feeding period and were analyzed for mycotoxins[11] by the Department of Veterinary Science, University of Nebraska, Lincoln.

Results and Discussion

Exp. 1. The effects of dietary treatment and feeding period on average daily gain (ADG), average daily feed intake (ADFI) and feed to gain ratio (F/G) are shown in table 4. The ADFI (dry matter basis) was lower ($P<.08$) for pigs fed the HMSG diets than for those fed the RSG diets. Overall, none of the treatment differences in F/G was significant. Average daily gain, ADFI and F/G were not different between pigs fed DSG diets with or without SA. The response criteria were not affected by the 3- or 7-d feeding schedule.

Research comparing performance of weanling pigs fed DSG, HMSG or RSG is limited. However, Allee et al. (1975) and Allee (1976) observed similar feeding values for weanling pigs fed HMSG and DSG diets. Crenshaw et al. (1984) reported significant improvements in apparent N digestibility for 30-kg pigs fed RSG and HMSG diets compared with those fed DSG diets. Also, RSG diets had higher N digestibility than HMSG diets.

Previous observations during a field trial indicated that HMSG would begin to mold within 3 d after removal from an oxygen-limiting storage structure. Apparently, SA preserved the HMSG and RSG diets at least 7 d because no heating, bridging of feed or visual signs of mold were noted in these diets throughout the experiment.

Exp. 2 and 3. Results of performance data for both experiments are presented in table 5. In Exp. 2, ADG and ADFI (dry matter basis) were not different for the main effects of moisture content (MC), SA level or their interactions. However, pigs that were fed diets with the higher MC (18.7%) were more efficient ($P<.03$) in feed conversion than those fed diets with the lower MC (16.4%). Also, a quadratic interaction ($P<.05$) between MC and SA was observed for feed efficiency. At the lower MC (16.4%) pigs fed .05% SA were least efficient, whereas at the higher MC (18.7%) pigs fed the same level of SA were more efficient than those fed 0 or .10% SA. The average effects of SA

[10]Tecator Kjeltec System 1003 distilling unit and Tecator Kjeltec System 20 digestor, Hoganas, Sweden.

[11]Aflatoxin B_1, B_2, G_1 and G_2; zearalenone; zearalonol; ochratoxin A; T-2 toxin; diacetoscirpenol; deoxynivalenol and fusarenone X.

TABLE 4. RESPONSE OF WEANLING PIGS FED DRY, HARVESTED HIGH MOISTURE AND RECONSTITUTED SORGHUM GRAIN DIETS CONTAINING SORBIC ACID (EXP. 1)[a]

	Sorghum grain diet						
	DSG[bc]		HMSG[bc]		RSG[bc]		
	ad libitum		3 d	7 d	3 d	7 d	
Item	–[d]	+[d]	+	+	+	+	CV, %[e]
Avg daily gain, kg	.34	.33	.38	.38	.41	.47	25.1
Avg daily feed intake, kg[f]	.64	.64	.66	.69	.76	.87	17.3
Feed/gain	1.91	1.97	1.83	1.89	1.86	1.97	12.0
No. replications (pens)	6	6	3	3	3	3	

[a]Values are the least-squares treatment means of pen averages adjusted by initial weight as a covariate; four pigs/pen; 21-d experiment.

[b]DSG (dry sorghum grain); HMSG (high moisture sorghum grain) and RSG reconstituted sorghum grain).

[c]DSG diets fed ad libitum; HMSG and RSG diets mixed and fed ad libitum every 3 or 7 d.

[d]Sorbic acid, .1%.

[e]Coefficients of variation.

[f]Values adjusted to 100% dry matter basis; HMSG vs RSG (P<.08).

were not different for any of the performance criteria (P>.30).

In Exp. 3 (table 5), a quadratic response to SA for ADG and ADFI was detected (P<.04). Feed efficiency was improved (P<.05) as SA levels were increased in the diets. As a result, quadratic interactions (P<.05) were detected between MC and SA for ADG, ADFI and F/G. Average daily gain and ADFI were lower and F/G was improved (P<.03) for pigs fed diets with the higher MC (21.3%). Overall, the best results were obtained when pigs were fed diets containing .10% sorbic acid.

For Exp. 2 and 3, visual detection of molds and physical detection of heating or bridging of the RSG diets treated with SA was not observed in the feeders after the 7-d feeding periods were completed. Within 5 d of the 7-d feeding period, RSG diets without SA began to heat and form aggregates, but no mycotoxins were detected in the samples collected from the feeders after the 7-d feeding periods.

These observations were confirmed in the samples from which temperature recordings were made (table 6). Temperatures of the RSG diets without SA exceeded room temperature by 3 C within 5 d. An additional 5 to 10 d passed before diets containing .05% SA had heated 3 C above room temperature. Heating in diets containing .10% SA did not occur for an additional 8 to 15 d after the control samples first began to heat. However, by the end of the experiments all diets were visibly contaminated with mold.

As MC of the diets containing .05% SA increased, the days to initial heating of the diets tended to decrease (Exp. 2) or remain the same (Exp. 3). However, when .10% SA was added to the diets, its effectiveness in delaying a temperature rise in the samples was improved with increasing moisture content. Other researchers (Dixon and Hamilton, 1981; Smith et al., 1983) have reported that the effectiveness of mold inhibitors in grain or feed decreases with increasing MC. This variance might be due to differences in types and solubility of mold inhibitors.

Apparently, the heating and bridging of the RSG diets without SA had no detrimental effect on feed intake in either experiment, since the pigs fed these diets consumed as much or more feed than pigs fed the diets containing SA. In Exp. 3, F/G improved linearly as SA levels were increased in the diets. Although no mycotoxins were detected in any of the diets, pigs fed diets without SA were consuming moldy feed for at least 2 d during every week of the experiment. Therefore, the poorer F/G of pigs fed diets without SA in Exp. 3 may have been due to a reduction in metabolizable energy intake and protein retention. Bartov (1983) reported that metabolizable energy, dry

TABLE 5. RESPONSE OF WEANLING PIGS FED RECONSTITUTED SORGHUM GRAIN DIETS CONTAINING SORBIC ACID (EXP. 2 AND 3)[a]

Item	Dietary moisture, %	Sorbic acid (SA), %			Avg for moisture
		0	.05	.10	
Exp. 2					
Avg daily gain, kg	16.4	.37	.36	.38	.37
	18.7	.37	.36	.38	.37
	Avg for SA	.37	.36	.38	
Avg daily feed intake, kg	16.4	.60	.62	.59	.60
	18.7	.56	.55	.60	.57
	Avg for SA	.58	.59	.60	
Feed/gain[bc]	16.4	1.61	1.70	1.57	1.63
	18.7	1.54	1.53	1.58	1.55
	Avg for SA	1.58	1.62	1.58	
Exp. 3					
Avg daily gain, kg[bcd]	17.3	.49	.44	.51	.48
	21.3	.45	.46	.46	.46
	Avg for SA	.47	.45	.49	
Avg daily feed intake, kg[bcd]	17.3	.84	.74	.85	.81
	21.3	.73	.77	.70	.73
	Avg for SA	.79	.76	.78	
Feed/gain[bce]	17.3	1.73	1.68	1.67	1.69
	21.3	1.62	1.69	1.53	1.61
	Avg for SA	1.68	1.69	1.60	

[a]Values are the means of four pens/treatment; four pigs/pen. Respective initial weights for Exp. 2 and 3 were 5.8 and 8.7 kg. Experiment 2 lasted 19 d; Exp. 3, 28 d. Coefficients of variation for average daily gain, average daily feed intake and feed to gain ratio were 5.3, 8.0 and 4.3% (Exp. 2) and 4.3, 2.3 and 3.3% (Exp. 3), respectively.

[b]Main effect of moisture ($P<.03$).

[c]Quadratic interaction, moisture × sorbic acid ($P<.05$).

[d]Quadratic response to sorbic acid ($P<.04$).

[e]Linear response to sorbic acid ($P<.05$).

TABLE 6. EFFECT OF SORBIC ACID ON TEMPERATURE CHANGES IN RECONSTITUTED SORGHUM GRAIN DIETS (EXP. 2 AND 3)

	Dietary moisture (%)			
	Exp. 2		Exp. 3	
Sorbic acid, %	16.4	18.7	17.7	21.3
	Days[a]			
0	5	5	5	4
.05	15	12	10	10
.10	13	19	15	19

[a]Values are the number of days until feed temperature exceeded room temperature by 3 C.

matter digestibility and protein retention were reduced when poultry were fed diets containing moldy corn.

Under the conditions of these experiments, mold did not develop in the non-treated RSG diets until 5 d after mixing. The average relative humidity in the room in which the pigs were housed was less than 30% for both Exp. 2 and 3. Although relative humidity was not a controlled experimental factor, the low room humidity may have had a significant effect on delaying mold development in the RSG diets.

Based on the results of feed temperature measurements in Exp. 2 and 3, microbial heating of RSG diets was suppressed with SA for at least 10 d after removal from oxygen-limiting storage. Overall, pig performance was not influenced by SA. Feed efficiency was improved for pigs that were fed diets containing the higher moisture content.

Literature Cited

Allee, G. L. 1976. Effects of processing methods on the nutritional value of sorghum for weaned pigs. Kansas Agr. Exp. Sta. Swine Industry Day. p 24.

Allee, G. L., B. A. Koch and R. H. Hines. 1975. Effect of grain processing methods on the nutritional value of milo for weaned pigs. Kansas Agr. Exp. Sta. Swine Industry Day. p 1.

AOAC. 1980. Official Method of Analysis (13th Ed.). Association of Official Analytical Chemists, Washington, DC.

Barr, A. J., J. H. Goodnight, J. P. Sall and J. T. Helwig. 1976. SAS User's Guide. Statistical Analysis System Institute. Cary, NC.

Bartov, I. 1983. Effects of propionic acid and of copper sulfate on the nutritional value of diets containing moldy corn for broiler chickens. Poult. Sci. 62:2195.

Crenshaw, J. D., E. R. Peo, Jr., A. J. Lewis, B. D. Moser and T. D. Crenshaw. 1984. The nutritional value of high moisture and reconstituted sorghum grain for swine. J. Anim. Sci. 58:1222.

Dixon, R. C. and P. B. Hamilton. 1981. Evaluation of some organic acids as mold inhibitors by measuring CO_2 production from feed and ingredients. Poult. Sci. 60:2182.

NRC. 1979. Nutrient Requirements of Domestic Animals, No. 2. Nutrient Requirements of Swine. Eighth Revised Ed. National Academy of Sciences–National Research Council, Washington, DC.

Ray, L. L. and L. B. Bullerman. 1982. Preventing growth of potentially toxic molds using antifungal agents. J. Food Prot. 45:953.

Sauer, D. B., T. O. Hodges, R. Burroughs and H. H. Converse. 1975. Comparison of propionic acid and methylene bis propionate as grain preservatives. Trans. Amer. Soc. Agr. Eng. 18:1162.

Smith, P. A., S. Nelson, L. K. Kirby, Z. B. Johnson and J. N. Beasley. 1983. Influence of temperature, moisture and propionic acid on mold growth and toxin production on corn. Poult. Sci. 62:419.

Steel, R.G.D. and J. H. Torrie. 1980. Principles and Procedures of Statistics, Second Edition. McGraw-Hill Book Co., New York.

Trotter, M. and G. L. Allee. 1976. High-moisture sorghum for growing-finishing swine. Kansas Agr. Exp. Sta. Swine Industry Day. p 22.

Webb, B. D., M. E. Bayliss and L. R. Richardson. 1960. Relation of interspace relative humidity to growth of molds and heating in feed ingredients and feed mixtures. Agr. Food Chem. 8:371.