

## ACCEPTANCE AND UTILIZATION BY SWINE OF AFLATOXIN-CONTAMINATED CORN TREATED WITH AQUEOUS OR GASEOUS AMMONIA<sup>1</sup>

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### SUMMARY

Four trials involving 356 pigs were conducted to evaluate acceptance and utilization of ammoniated corn. Certain of the corns had natural contamination with aflatoxins (36, 39 or 90 ppb of B<sub>1</sub>) and ammoniation proved effective in reducing the aflatoxin concentration to a non-detectable level as determined by chemical analysis. Ammoniated corns fed free choice with supplement were consumed in lesser quantities than non-ammoniated corns, with associated greater consumptions of supplement. Acceptance and utilization of mixtures of ground ammoniated corn and supplement, however, were equal to non-ammoniated corn and supplement mixtures when water-extractable ammonia content of the corn dry matter was approximately .1% or less.

**Key Words:** Aflatoxin, Ammonia, Corn, Swine.)

### INTRODUCTION

Consumption of aflatoxin-contaminated feedstuffs can adversely affect animal performance. Tissue aflatoxin residues have been detected in adult swine fed contaminated diets

(Krogh *et al.*, 1973; Murphy *et al.*, 1975). Since corn is of paramount importance in U.S. swine production and is subject to aflatoxin contamination, a means of detoxification would be highly beneficial. Brekke *et al.*<sup>4</sup> have demonstrated that application of aqueous or gaseous ammonia effectively reduces aflatoxin levels on corn below the current Food and Drug Administration (FDA) guideline level of 20 ppb.

The objectives of these trials were to evaluate acceptance and utilization by swine of ammoniated corn. Some of the corns used were naturally contaminated with aflatoxin before they were ammoniated.

### EXPERIMENTAL PROCEDURE

Three hundred and fifty-six crossbred pigs were used in a series of four trials. In each trial, pigs were randomly assigned to dietary treatment from outcome groups based on ancestry, weight and sex. Each treatment group was housed in an environmentally controlled building with partially or totally slotted floors. The respective corns were either ground and mixed with a fortified 42% protein supplement (table 1) to provide a 16% crude protein diet for pigs up to 55 kg, 14% from 55 kg to final weight, or fed each free choice with the supplement.

*Trial I.* Sixty-four finishing pigs were used to obtain preliminary evaluation of acceptance of ammonia-treated corn. They averaged 63 kg initial weight, eight pigs per group, and were on test for 6 days. Yellow dent corn (Ref. No. 4-02-992) contaminated with 4 ppb of aflatoxin B<sub>1</sub> was treated with aqueous ammonia (28% ammonia). Levels of ammonia on corn were .5, 1.0, 1.5 and 2.0% (dry matter basis). The respective corns were fed (1) free-choice with supplement and (2) in a ground corn-supplement mix.

*Trial II.* One hundred pigs, average initial weight of 22.7 kg were used. There were two

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<sup>4</sup>Brekke, O. L., A. J. Peplinski and E. B. Lancaster. 1975. Aflatoxin inactivation in corn by aqua ammonia. Presented as Paper No. 75-3507, ASAE, Chicago. Brekke, O. L., A. J. Peplinski, G. W. Nofsinger, A. C. Stringfellow, H. F. Conway, R. R. Montgomery, R. W. Silman, V. E. Sohns and E. B. Bagley, 1976. Aflatoxin inactivation of corn by ammonia gas. A field trial. Presented as Paper No. 76-3526, ASAE, Chicago.

TABLE 1. COMPOSITION OF SUPPLEMENT

Ingredient	Internat'l ref. no.	Supplement
Soybean seeds w/o hulls, solv-extd grnd, mx 3% fiber	5-04-612	86.3%
Calcium phosphate, dibasic, commercial	6-01-080	5.6%
Calcium carbonate, CaCO <sub>3</sub> , commercial, mn 38%	6-01-069	4.7%
Salt, trace minerals added <sup>a</sup>		1.9%
Vitamin premix <sup>b</sup>		.7%
Antibiotic <sup>c</sup>		.8%
Calculated crude protein, %		42.0%

<sup>a</sup>Contained as a percent of the mix: NaCl, 83.0; zinc, 2.86; manganese, .571; iron, 2.57; copper, .229; iodine, .011; cobalt, .22; and selenium, .00286.

<sup>b</sup>Contained per kilogram: 1.1 g riboflavin; 6.0 g calcium pantothenate; 16.5 g nicotinic acid; 165.0 g choline chloride; 18.0 mg vitamin B<sub>12</sub> activity; 3.3 million IU vitamin A; 330,000 IU vitamin D<sub>2</sub> and 22,000 IU of vitamin E (D- $\alpha$ -tocopherol acetate).

<sup>c</sup>Contained 33.0 g streptomycin (as streptomycin sulfate) and 11 g of procaine penicillin per kilogram.

pens of 10 pigs each per treatment for the 46-day period. Regular corn, regular corn:ammonia-treated corn, or ammonia treated corn was ground and mixed with supplement or the regular and ammonia treated corns were fed free choice with supplement. The white dent corn (Ref. No. 4-02-928) initially assayed 100 ppb total aflatoxin (90 ppb B<sub>1</sub>) and 11% moisture. Ammonia equal to 1.1% of corn dry matter had been absorbed by the corn from an ammonia-air mixture recirculated for 72 hours. Aflatoxin B<sub>1</sub> content fell to 10 ppb after 120 hr from start of the ammonia treatment and no aflatoxins (B<sub>1</sub>, B<sub>2</sub>, G<sub>1</sub>, G<sub>2</sub>) were detected when the bin was emptied 7 months later. Water-extractable ammonia (WE-NH<sub>3</sub>) values of the corn after five days in the treatment bin, after removal from the bin 7 months later, and at the time the feeding started 4 weeks after removal from the bin were .7, .3, and .1%, respectively (ammonia extractions were made on whole grain)<sup>4</sup>.

*Trial III.* Ninety-six pigs, average initial weight of 20 kg, were used to evaluate acceptance and utilization of aflatoxin-contaminated white dent corn over a 67-day period. In phase 1 of the trial, contaminated, ammonia-treated and regular corns were ground and mixed with the 42% crude protein supplement or fed free choice with the supplement. In phase 2, these corns were offered free choice only to evaluate selection preference. Feeders containing the respective corns were randomly realigned every third day to minimize location effect. There was one pen of 10 pigs per treatment in phase

1, two pens of eight pigs each in phase 2.

The contaminated corn was ammoniated in two batches, with initial assay values of 39 and 36 ppb aflatoxin B<sub>1</sub>, respectively. Detoxification was achieved by recycling an ammonia-air mixture in a sealed, 5.5 m diameter metal bin equipped with a drying floor. Water had been added to raise the corn moisture level to about 17.5%. The two batches of corn were treated with 1.4 and 1.6% ammonia, respectively, on corn dry matter basis. After 1 day, the corn was batch dried with heated air to 10.7% moisture. There was no aflatoxin and very little ammonia odor detectable in the dried corn.

*Trial IV.* Ninety-six pigs were used to compare acceptance and utilization of diets containing either non-contaminated yellow hybrid corn, equal parts of regular corn and aflatoxin-contaminated white dent corn, or aflatoxin-contaminated white dent corn (same as that in Trial III) treated with ammonia. The pigs were fed the diets from 33 kg to 98 kilogram. There were four pens of eight pigs each on each treatment.

## RESULTS AND DISCUSSION

*Trial I.* The results of this short-term trial, the length of which was determined by the quantity of corn available, indicated an effect of corn ammonia level on acceptance of the corn by the pig (table 2). Average daily intake was highest with the diet containing the .5% ammonia corn, i.e., corn with 13% WE-NH<sub>3</sub>. With the 2.0% level of ammonia addition (1.2% WE-NH<sub>3</sub>) intake was half of that of the .5%

TABLE 2. ACCEPTANCE BY PIGS OF AMMONIA-TREATED CORN FED IN MIXED DIETS AND FREE CHOICE WITH SUPPLEMENT (TRIAL I)

Item	Ammonia added, % of corn dry matter <sup>a</sup>			
	.5	1.0	1.5	2.0
WE-NH <sub>3</sub> in corn, % <sup>b</sup>	.13	.50	.90	1.20
Mixed diet <sup>c,d</sup>				
Number of days	3	4	4	6
Avg. daily feed, kg <sup>e</sup>	3.4	2.5	2.5	1.7
Free choice <sup>d,f</sup>				
Avg. daily feed, kg				
Corn	1.49	1.38	1.42	1.39
Supplement	.71	.72	.88	.81

<sup>a</sup>Corn contained about 15% moisture.

<sup>b</sup>Water-extractable ammonia, estimated from extractions made of whole corn 18 days after ammonia addition.

<sup>c</sup>Ground corn and supplement mixed in a ratio of 83:17.

<sup>d</sup>Each value is an average for one pen of eight pigs each, initial weight 63 kilograms.

<sup>e</sup>Each pen of eight pigs provided with 82 kg of diet.

<sup>f</sup>The respective corns and the supplement available to the pigs for 6 days.

level. When offered free choice with supplement for 6 days, the ratio of corn to supplement decreased because the pigs consumed

relatively more supplement as WE-NH<sub>3</sub> content of the corn increased.

*Trial II.* The results in table 3 show nonsignificant differences among dietary treatments. The apparent differences in feed intake and gain:feed ratio between the regular corn and ammoniated corn mixed diets may be, in part, a reflection of the different corns—yellow dent corn, .26% lysine dry matter basis; white dent corn, .39% lysine on dry matter basis. The amino acid balance may have been better in the ammoniated white corn:supplement mixture than in the yellow corn:supplement mixture. The difference in selection ratios of corn to supplement in the free choice treatments would likely represent more of an ammonia than an amino acid effect. This is based on the assumption, of course, that nontreated, non-contaminated white corn would be as acceptable as the regular yellow dent corn.

*Trial III.* When mixed diets were fed, it seemed that neither the level of aflatoxin on the corn nor the ammonia treatment significantly affected feed intake and utilization (table 4). When fed free choice, voluntary consumption of aflatoxin corn and ammoniated corn was less and supplement consumption higher than with regular corn. Total daily consumption of free choice corn and supplement for regular, aflatoxin and ammoniated corns were, respectively, 2.29, 2.21 and 2.01 kilograms.

During days 1 to 14 of the preference test (table 5), 82% of the corn consumed was

TABLE 3. PERFORMANCE OF GROWING PIGS FED AMMONIA-TREATED CORN IN MIXED DIETS OR FREE CHOICE WITH SUPPLEMENT (TRIAL II)

	% in diet			Free choice	
	78	39	...	100	...
Regular corn <sup>a</sup>	78	39	...	100	...
Ammonia-treated corn <sup>b</sup>	...	39	78	...	100
Avg daily gain, kg <sup>c</sup>	.72	.72	.68	.72	.66
Avg daily feed, kg	2.05	1.84	1.86	1.98 <sup>d</sup>	1.89 <sup>e</sup>
Gain/feed	.351	.391	.365	.363	.349

<sup>a</sup>Yellow dent corn, 10.1% crude protein, .29% lysine on dry matter basis.

<sup>b</sup>White dent corn, .39% lysine on dry matter basis. Initially 100 ppb total aflatoxin, then treated with anhydrous ammonia gas. When fed, had no detectable aflatoxins and a water-extractable ammonia content of .1% (dry matter basis).

<sup>c</sup>Each value is an average for two pens of 10 pigs each, average initial weight of 23 kilograms. Average final weight was 56 kilograms.

<sup>d</sup>The pigs selected 2.3 parts corn to 1 part of supplement.

<sup>e</sup>The pigs selected 1.17 parts corn to 1 part of supplement.

TABLE 4. PERFORMANCE OF PIGS FED DIETS CONTAINING REGULAR CORN, CORN CONTAMINATED WITH AFLATOXIN OR AMMONIA-TREATED AFLATOXIN CORN TRIAL III, PHASE 1)

	% corn in diet					Free choice		
	83.0	...	...	37.5	37.5	+	-	-
Regular corn <sup>a</sup>	83.0	...	...	37.5	37.5	+	-	-
Aflatoxin corn <sup>b</sup>	...	75.0	...	37.5	...	-	+	-
Ammoniated corn <sup>c</sup>	...	...	75.0	...	37.5	-	-	+
Avg daily gain, kg <sup>d</sup>	.79	.79	.79	.77	.79	.79	.74	.70
Avg daily feed, kg	2.19	2.07	2.12	2.06	2.10	2.29 <sup>e</sup>	2.21 <sup>f</sup>	2.01 <sup>g</sup>
Gain/feed	.361	.382	.373	.379	.376	.345	.335	.348

<sup>a</sup>Assumed 9.8% crude protein on dry matter basis.

<sup>b</sup>White dent corn, 8.3% crude protein, dry matter basis. Initial aflatoxin B<sub>1</sub> levels of 37 ppb.

<sup>c</sup>Same as b but treated with 1.4 to 1.6% water-extractable ammonia on corn dry matter basis. At start of trial, corn assayed .07% ammonia, dry matter basis. No detectable aflatoxins at time of trial. This corn assayed 10.0% crude protein on a dry matter basis, but since this value would likely include treatment-ammonia nitrogen, the value of 8.3%, footnote b, was used in diet formulation.

<sup>d</sup>Each value is an average for one pen of 10 pigs, average initial weight of 20 kilograms.

<sup>e</sup>Pigs selected 3.5 parts corn to 1 part of supplement.

<sup>f</sup>Pigs selected 2.0 parts corn to 1 part of supplement.

<sup>g</sup>Pigs selected 1.7 parts corn to 1 part of supplement.

TABLE 5. ACCEPTANCE OF NONTREATED AND AMMONIA-TREATED AFLATOXIN CONTAMINATED BORN BY GROWING PIGS (TRIAL III, PHASE 2)

Item	Preference period, days	
	1 to 14	15 to 28
Avg daily gain, kg <sup>a</sup>	.69	.64
Avg feed intake, kg <sup>b</sup>		
Supplement	43	54
Corn	109	122
(Regular) <sup>c</sup>	(90) <sup>d</sup>	... <sup>e</sup>
(Aflatoxin) <sup>f</sup>	(9)	(99)
(Ammoniated) <sup>g</sup>	(10)	(23)
Gain/feed	.508	.408

<sup>a</sup>Each value is an average for two pens of eight pigs each, average initial weight of 18.5 kilograms.

<sup>b</sup>Total feed per period.

<sup>c</sup>Yellow dent corn.

<sup>d</sup>Significantly greater ( $P < .05$ ) than quantities of aflatoxin and ammoniated corns.

<sup>e</sup>Regular corn was not offered during the 15- to 28-day period.

<sup>f</sup>White dent corn, initial aflatoxin B<sub>1</sub> level of about 37 ppb.

<sup>g</sup>White dent corn, initial aflatoxin B<sub>1</sub> level of about 37 ppb, treated with 1.4 to 1.6% ammonia on corn dry matter basis. At start of trial, no detectable aflatoxin and .07% water-extractable ammonia, corn dry matter basis.

regular corn. Selections of aflatoxin and ammoniated corns were less ( $P < .05$ ). During days 15 to 28, when regular corn was not available, aflatoxin corn was selected in preference to the ammoniated corn.

*Trial IV.* Excellent performance was obtained with all diets (table 6). Rates of gain did not differ significantly, but average daily feed ( $P < .01$ ) and gain/feed ( $P < .05$ ) did. The lower feed intake and higher gain/feed from the diet with 75% ammoniated corn perhaps indicated a better amino acid balance in the 75% ammoniated corn:25% supplement mixture than in the 83% regular corn:17% supplement mixture, both mixtures containing 16% crude protein.

The appropriate use of ammoniation to reduce the aflatoxin B<sub>1</sub> level to a nondetectable level in the corn lots fed in these tests has been demonstrated (Brekke *et al.*)<sup>4</sup>. The ammoniated corns were effectively used by pigs in our feeding trials. Acceptance of the corn itself and of mixed diets in which the ammoniated corn was a major constituent appeared to reflect the WE-NH<sub>3</sub> content of the corn. This was most evident when the corn was offered "as is" free choice with supplement. In trial I, increasing amounts of supplement, in relation to corn, were consumed as WE-NH<sub>3</sub> content of the corn increased from .13 to 1.2%. Indeed, when corn containing 1.2% WE-NH<sub>3</sub> corn was ground and

TABLE 6. RESPONSE OF GROWING-FINISHING SWINE TO DIETS CONTAINING REGULAR CORN OR AMMONIATED CORN (TRIAL IV)

	% in diet		
	Regular corn <sup>a</sup>	83.0	37.5
Ammoniated corn <sup>b</sup>	0	37.5	75.0
Avg daily gain, kg <sup>c</sup>	.78	.78	.75
Avg daily feed, kg <sup>d</sup>	2.52	2.56	2.36
Gain/feed <sup>e</sup>	.309	.305	.318

<sup>a</sup>Yellow dent corn, 10.1% crude protein, .29% lysine on dry matter basis.

<sup>b</sup>White dent corn, initial aflatoxin B<sub>1</sub> level of 37 ppb, treated with 1.4 to 1.6% ammonia, on corn dry matter basis. After treatment, no detectable aflatoxin and .07% water-extractable ammonia, corn dry matter basis. Assayed 10.0% crude protein on dry matter basis. Since this value would likely contain some treatment-ammonia nitrogen, a protein content of 8.3% dry matter basis, from assay made prior to ammoniation, was used for diet formulation.

<sup>c</sup>Each value is an average for four pens of eight pigs each for a period of 84 days. Average initial weight, 33 kilograms.

<sup>d</sup>Significant (P<.01) difference among diets.

<sup>e</sup>Significant (P<.05) difference among diets.

mixed with supplement, feed intake was lowest. These values are only indicators, however, since the supply of ammoniated corns allowed only a few days comparison. In subsequent trials, WE-NH<sub>3</sub> levels in the corn were .1 and .07%. These levels also caused a noticeable decrease in the acceptance of corns fed free choice with

supplement. However, the effect of ammonia level was modified when the corn was ground and mixed with supplement. In addition to dilution of the ammonia content and odor with supplement, grinding the corn probably resulted in ammonia loss. In a laboratory evaluation, ground corn immediately after grinding contained .08% WE-NH<sub>3</sub>. After 24 hr exposure to air, the level was .02% (*personal communication*).

That ammoniation can affect acceptance of corn was evident in trial III when pigs given a choice consumed, during a 14-day period, over four times as much aflatoxin-corn as ammoniated aflatoxin-corn. When samples of these corns were ground and mixed with supplement, intakes of the two mixtures were similar.

These results show that aflatoxin-contaminated corns treated with aqueous or gaseous ammonia were readily accepted and efficiently utilized in mixed diets for growing-finishing swine. Additional studies are underway (*personal communication*) to procure the required data to support application for approval of the ammoniation process for treatment of aflatoxin-contaminated corns.

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