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Effectiveness of Different Types of Clay for Reducing the Detrimental Effects of Aflatoxin-Contaminated Diets on Performance and Serum Profiles of Weanling Pigs[1,2]

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ABSTRACT: Three trials were conducted with recently weaned pigs (n = 198) to determine the effects of feeding different types of clay in conjunction with aflatoxin-contaminated diets. In Trial 1, pigs (n = 54; trial length 4 wk) were assigned to either an uncontaminated treatment (NC), 800 ppb of aflatoxin from contaminated corn (AC), or AC with one of four clays. In Trial 2 (n = 81; trial length 5 wk), pigs were assigned to NC, AC (500 ppb of aflatoxin from rice starch), or AC with one of seven types of clay. In both trials, pigs fed AC had decreased ADG and gain:feed ratios ($P < .05$) compared with controls. The clays differed in their ability to produce gains similar to those of controls. The clays did reduce changes in the serum measurements normally affected by aflatoxin, including albumin, total protein, gamma glutamyltransferase (GGT), and alkaline phosphatase (ALP) levels, in a manner similar to their effect on ADG. In Trial 3, pigs (n = 63) were assigned to one of seven diets for 4 wk: NC, AC (800 ppb of aflatoxin) with no clay, AC with one of four levels of a treated Ca bentonite (.25, .5, 1, and 2%), or AC and .5% hydrated sodium calcium aluminosilicate. The addition of treated Ca bentonite to AC improved ADG ($P < .05$) and ADFI ($P < .01$) linearly. Gain:feed ratios were not affected by treatments. The inclusion of treated Ca bentonite to the AC diet linearly decreased aspartate aminotransferase (AST) levels and quadratically decreased ALP and GGT levels ($P < .05$). Feeding certain clays can effectively prevent some of the negative effects associated with feeding AC to weanling pigs, and some clays are more effective than others.

Key Words: Pigs, Aflatoxins, Bentonite, Zeolites, Sepiolite, Palygorskite

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Introduction

Weanling swine fed aflatoxin-contaminated diets grow more slowly, consume less feed, and in some cases have lower gain:feed ratios than controls (Panangala et al., 1986; Lindemann et al., 1993). Additionally, liver damage characterized by enlargement and the release of the enzymes aspartate aminotransferase (**AST**), gamma glutamyltransferase (**GGT**), and alkaline phosphatase (**ALP**) into the blood has been reported in pigs fed 500 ppb of aflatoxin (Harvey et al., 1990).

Recently, Lindemann et al. (1993) reported that .5% hydrated sodium calcium aluminosilicate (**HSCA**) in a diet with 840 ppb of aflatoxin prevented most of the reductions in daily gains and feed intake in weanling swine. Furthermore, Harvey et al. (1990) reported a reduction of elevated serum levels of GGT, AST, and ALP associated with aflatoxin-induced liver damage as a result of the addition of HSCA to diets contaminated with aflatoxin.

The purpose of the present research was to evaluate the effectiveness of other types of clay in reducing the negative effects caused by feeding aflatoxin-contaminated diets to weanling swine and to evaluate the level of inclusion of one of those clays.

Materials and Methods

Two trials using a total of 135 recently weaned crossbred barrows and gilts were conducted to determine the effectiveness of several types of clay in

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[2]Mention of trade names does not constitute a guarantee or warranty by VPI&SU and does not imply its approval to the exclusion of other products that may be suitable.

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preventing negative effects associated with feeding aflatoxin-contaminated diets. A third trial using 63 pigs evaluated the level of inclusion of a clay that had demonstrated a positive effect in one of the initial two trials.

In all trials, pigs were housed in .91-m × 1.22-m plastic-coated, welded-wire-floored pens (three pigs per pen) in an environmentally regulated nursery. The room temperature was set initially at 26°C and was reduced weekly to maintain a zone of thermoneutrality appropriate for the smallest pigs. Access to feed and water was ad libitum. Pigs were weighed and feed intake for each pen of pigs was determined weekly. Blood was taken via jugular venipuncture for serum clinical chemistry analysis at the end of each trial. Serum analysis was performed at the Virginia-Maryland Regional College of Veterinary Medicine using a Kodak Ektachem 700 analyzer (Eastman Kodak, Rochester, NY).

In Trial 1, 9 d after weaning, 54 crossbred gilts and barrows with an average weight of 10.7 kg and an average age of 40.4 d were blocked on weight and sex and randomly assigned to a pen. One of six dietary treatments, uncontaminated corn (**NC**), aflatoxin-contaminated corn (**AC**), or AC and one of four clays, was then randomly assigned to each pen within the three replicate sets of pens. The clays were a palygorskite, a sepiolite, a treated Ca bentonite (chemically and physically modified to increase Na content and to produce a uniform particle size), or a hydrated sodium calcium aluminosilicate (Table 1). The aflatoxin-contamination level (800 ppb) was achieved by replacing uncontaminated corn with corn naturally contaminated with aflatoxin. Aflatoxin content of the corn used in the diets was determined by HPLC (Pons et al., 1980). The clay level was .5% of the diet, which was found to be an effective inclusion level for Na bentonite (Lindemann et al., 1993). The length of the trial was 4 wk.

In Trial 2, after a postweaning adjustment period of 7 to 9 d, 81 crossbred pigs with an average weight of 9.65 kg and an average age of 38.7 d were used. Animal allotment and treatment assignment (Table 2) were as in Trial 1. Diet 1 was an uncontaminated diet and Diets 2 to 9 were contaminated with 500 ppb of aflatoxin B_1 in rice starch using the procedure of Shotwell et al. (1966) with the modifications of West et al. (1973) and Wiseman et al. (1970). Seven types of clay were added at a level of .5%, replacing corn. Because of their large size, one replicate (27 pigs, one pen per treatment) completed the trial on d 33, whereas the other two replicates completed the trial on d 40.

In Trial 3, after a postweaning adjustment period of 7 d, 63 crossbred pigs with an average weight of 9.9 kg and an average age of 35.0 d were used to evaluate the seven dietary treatments (Table 1). Animal allotment and treatment assignment were as in Trial 1. Naturally contaminated corn was used to formulate the diets that contained 800 ppb of aflatoxin B_1. The clay levels were determined based on the findings of Lindemann et al. (1993). Pigs remained on treatment for 4 wk.

The data from all trials were analyzed within trial using the GLM procedure of SAS (1988). Models contained diet and replicate effects. For Trials 1 and 2, differences among means were tested with the Duncan's multiple-range test procedure ($\alpha = .05$) in GLM. For Trial 3, nonorthogonal contrasts were used to determine specific diet effects as well as linear and quadratic effects.

Table 1. Percentage composition of normal corn and aflatoxin-contaminated corn diets (as-fed) in Trials 1 and 3[a]

	Diet[b]	
Item	1 Normal corn	2 Aflatoxin corn
Uncontaminated corn	68.70	34.00
Contaminated corn[c]	—	34.70
Soybean meal (48% CP)	26.90	26.90
Soybean oil	1.00	1.00
Dicalcium phosphate	1.20	1.20
Limestone	1.00	1.00
VPI vitamin premix[d]	.25	.25
Trace mineral premix[e]	.05	.05
Salt	.40	.40
Antibacterial[f]	.50	.50

[a]Calculated to supply 19.0% CP, 1.02% lysine, .81% Ca, and .65% P.

[b]In Trial 1, Diets 3 to 6 contained .5% palygorskite (Min-U-Gel), sepiolite (Sepiogel UF), marketed by Floridin Co., Tallahassee, FL, treated Ca bentonite (Astra-Ben 20), obtained from ECC America, Inc., Gonzales, TX, or hydrated sodium calcium aluminosilicate (HSCA) (Novasil), marketed by Englehard Corp., Cleveland, OH, respectively. Clays were added at the expense of uncontaminated corn. In Trial 3, Diets 3 to 6 contained .25, .5, 1, and 2% treated Ca bentonite (Astra-Ben 20), respectively, and Diet 7 contained .5% HSCA. Clays were added at the expense of uncontaminated corn.

[c]Contaminated corn contained 2,300 ppb of aflatoxin B_1.

[d]Supplied per kilogram of diet: 4.34 mg of riboflavin, 22 mg of pantothenic acid, 22 mg of niacin, 22 μg of vitamin B_{12}, 440 mg of choline chloride, 4,409 IU of vitamin A, 441 IU of vitamin D, 11 IU of vitamin E, 1,102 μg of vitamin K (as menadione sodium bisulfate complex), and .3 mg of Se.

[e]Supplied per kilogram of diet: 150 mg of Zn, 176 mg of Fe, 60 mg of Mn, 17 mg of Cu, 2 mg of I.

[f]Supplied 110 mg of chlortetracycline, 110 mg of sulfamethazine, and 50 mg of procaine penicillin per kilogram of diet.

Results

Trial 1. Pigs fed the aflatoxin-contaminated diet with no clay had lower ($P < .05$) ADG and gain:feed ratios than did control pigs (Table 3). Pigs fed the aflatoxin with sepiolite, calcium bentonite, or HSCA had higher ($P < .05$) ADG than pigs fed the aflatoxin without the addition of clay, whereas only pigs fed the diet with sepiolite added had distinctly improved gain:feed ratio ($P < .05$). Although there was some

Table 2. Percentage composition of diets (as-fed) in Trial 2[a]

Item	Diet 1	2	3	4	5	6	7	8	9
Corn	70.50	70.50	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Soybean meal (48% CP)	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Soybean oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VPI vitamin premix[b]	.25	.25	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix[c]	.05	.05	.05	.05	.05	.05	.05	.05	.05
Salt	.40	.40	.40	.40	.40	.40	.40	.40	.40
Antibacterial[d]	.50	.50	.50	.50	.50	.50	.50	.50	.50
Palygorskite 1[e]	—	—	.50	—	—	—	—	—	—
Palygorskite 2[e]	—	—	—	.50	—	—	—	—	—
Sepiolite[e]	—	—	—	—	.50	—	—	—	—
Zeolite[f]	—	—	—	—	—	.50	—	—	—
HSCA[g]	—	—	—	—	—	—	.50	—	—
Na bentonite[h]	—	—	—	—	—	—	—	.50	—
Treated Ca bentonite[i]	—	—	—	—	—	—	—	—	.50
Aflatoxin[j]	—	+	+	+	+	+	+	+	+

[a]Calculated to supply 18.2% CP, .96% lysine, .77% Ca, and .59% P.
[b]Supplied per kilogram of diet: 4,400 IU of vitamin A, 440 IU of vitamin D, 11 IU of vitamin E, 4.4 mg of riboflavin, 22 mg of d-pantothenic acid, 22 mg of niacin, 489.5 mg of choline, .022 mg of vitamin B_{12}, .5 mg of menadione, .44 mg of d-biotin, and .3 mg of Se.
[c]Supplied per kilogram of diet: 150 mg of Zn, 176 mg of Fe, 60 mg of Mn, 17 mg of Cu, and 2 mg of I.
[d]Supplied 110 mg of chlortetracycline, 110 mg of sulfamethazine, and 50 mg of penicillin per kilogram of diet.
[e]15 RVM, 55 RVM, and 80 RVM for palygorskite 1, 2, and the sepiolite, respectively, obtained from Floridin Co., Tallahassee, FL.
[f]Zeobrite obtained from Zeotech Corp., Albuquerque, NM.
[g]Hydrated sodium calcium aluminosilicate (NovaSil) marketed by Englehard Corp., Cleveland, OH.
[h]FD-181 obtained from American Colloid Co., Arlington Heights, IL.
[i]AB-20 obtained from ECC America, Inc., Gonzales, TX.
[j]Diets 2 to 9 contained 500 ppb of mixed aflatoxin (88% of aflatoxin was B_1) obtained from a culture of *A. parasiticus* on rice starch.

variation, each of the clays moderated the gain:feed ratio ($P < .05$); all pigs fed clay treatment had gain: feed ratios similar to those of pigs fed the uncontaminated control diet. There were no differences in ADFI.

Pigs fed the aflatoxin-contaminated diet with no clay had the lowest numerical serum total protein and albumin levels; however, the values did not differ from those of pigs fed the control diet (Table 3). When the various clays were added, the values were elevated, but only in the sepiolite-supplemented pigs was the magnitude sufficient to differ for total protein ($P < .05$) and in both sepiolite-supplemented and Ca bentonite-supplemented pigs for albumin ($P < .05$). Serum AST, GGT, and ALP levels were elevated ($P <$

Table 3. Performance and serum clinical chemistry analysis of weanling pigs fed aflatoxin-contaminated diets with several types of clay in Trial 1

Item[c]	Diet[a] 1 Normal corn	2 Aflatoxin corn (AC)[b]	3 AC + palygorskite	4 AC + sepiolite	5 AC + Ca bentonite	6 AC + HSCA	SEM
ADG, kg	$.64^{d}$	$.48^{f}$	$.53^{ef}$	$.60^{de}$	$.62^{d}$	$.58^{de}$	.02
ADFI, kg	1.32	1.17	1.17	1.18	1.33	1.27	.05
Gain/feed	$.48^{d}$	$.41^{e}$	$.46^{de}$	$.50^{d}$	$.47^{de}$	$.46^{de}$	.02
Total protein, g/dL	5.9^{de}	5.8^{e}	6.1^{de}	6.2^{d}	6.2^{de}	6.0^{de}	.1
Urea N, mg/dL	14.6	11.3	13.3	11.8	12.2	13.4	1.4
Albumin, g/dL	4.1^{de}	3.8^{e}	4.1^{de}	4.4^{d}	4.4^{d}	4.1^{de}	.1
AST, U/L	42^{d}	78^{e}	56^{de}	51^{de}	55^{de}	44^{d}	9
GGT, U/L	37^{d}	70^{f}	53^{e}	40^{d}	36^{d}	44^{de}	3
ALP, U/L	174^{d}	252^{e}	212^{de}	182^{d}	175^{d}	189^{d}	18

[a]Four-week trial with three pens of three pigs per pen per treatment mean (initial weight, 10.7 kg); see Table 1 for product identification.
[b]Diets contaminated with 800 ppb of aflatoxin.
[c]AST = aspartate aminotransferase; GGT = gamma glutamyltransferase; ALP = alkaline phosphatase.
[d,e,f]Means with different superscripts within rows differ ($P < .05$).

Table 4. Performance and serum clinical analysis of weanling pigs fed aflatoxin-contaminated diets and several types of clay in Trial 2

	Diet[a]									
Item[c]	1 Normal corn	2 Aflatoxin corn (AC)[b]	3 AC + .5% palygorskite 1	4 AC + .5% palygorskite 2	5 AC + .5% sepiolite	6 AC + .5% zeolite	7 AC + .5% HSCA	8 AC + .5% Na bentonite	9 AC + .5% Ca bentonite	SEM
ADG, kg	.66[d]	.46[f]	.54[e]	.57[e]	.58[de]	.58[de]	.63[de]	.61[de]	.61[de]	.02
ADFI, kg	1.41[de]	.97[h]	1.13[g]	1.19[fg]	1.31[def]	1.26[efg]	1.44[d]	1.32[def]	1.31[def]	.05
Gain/feed	.47	.47	.48	.48	.44	.46	.44	.46	.46	.02
Total protein, g/dL	6.4	6.0	6.0	6.4	6.3	6.1	6.0	6.3	6.3	.1
Urea N, mg/dL	14.2[d]	9.7[fg]	10.6[fg]	8.7[g]	10.3[fg]	10.7[fg]	11.4[fg]	13.9[de]	11.9[def]	.8
Albumin, g/dL	4.0[d]	3.4[e]	3.7[de]	3.9[de]	4.1[d]	3.9[de]	3.8[de]	4.0[de]	4.1[d]	.2
AST, U/L	64[de]	80[de]	80[de]	63[de]	74[de]	86[d]	55[e]	69[de]	57[e]	7
GGT, U/L	49[f]	85[d]	58[ef]	75[de]	47[f]	57[ef]	47[f]	53[f]	45[f]	6
ALP, U/L	171[d]	357[e]	179[d]	213[d]	188[d]	205[d]	169[d]	161[d]	178[d]	44

[a]Three pens of three pigs/pen per treatment mean; see Table 2 for product identification (initial weight, 9.66 kg).
[b]Diets contaminated with 500 ppb of aflatoxin.
[c]AST = aspartate aminotransferase; GGT = gamma glutamyltransferase; ALP = alkaline phosphatase.
[d,e,f,g,h]*Means with different superscripts within rows differ* ($P < .05$).

.05) in pigs fed aflatoxin with no clay compared with control pigs. Although there was some variation, addition of each of the clays to the aflatoxin-contaminated diet reduced serum concentrations of liver enzymes. In general, the magnitude of the recovery of performance and the restoration of serum variables was lowest for pigs fed the palygorskite diet. Serum urea N (12.8 mg/dL), Ca (10.3 mg/dL), P (8.64 mg/dL), Mg (1.86 mg/dL), Na (145 mmol/L), and K (6.76 mmol/L) were not affected by treatments.

Trial 2. Average daily gain and ADFI were decreased ($P < .05$) for pigs fed the aflatoxin-contaminated diet with no clay compared with those for pigs fed the control diet, but gain:feed ratios were unaffected (Table 4). The addition of all clays (palygorskites, sepiolite, zeolite, HSCA, NA bentonite, and treated Ca bentonite) to the aflatoxin diet improved ($P < .05$) ADG and ADFI compared with those of pigs fed the aflatoxin control diet. The magnitude of the improvement varied among clays. There was no effect of the clays on feed efficiency.

Pigs fed the aflatoxin diet with no clay had decreased ($P < .05$) serum urea N and albumin levels compared with control pigs (Table 4). The addition of Na bentonite increased ($P < .05$) serum area N compared with that in pigs fed aflatoxin diets with no clay, whereas pigs fed the other clays had intermediate values. Pigs fed aflatoxin diets with sepiolite or Ca bentonite had serum albumin levels greater ($P < .05$) than those of pigs fed the AC diet; intermediate values were observed for the other clays.

Serum ALP and GGT levels were higher ($P < .05$) in pigs fed the aflatoxin diets with no clay than in pigs fed the control diet. Increased ALP and GGT levels were prevented ($P < .05$) by the addition of each of the clays to the aflatoxin diet compared with the aflatoxin diet alone, except palygorskite 2 for GGT levels. Pigs fed the zeolite-supplemented diet had higher serum AST levels than pigs fed the HSCA and Ca bentonite-supplemented diets, whereas pigs on the other treatments had intermediate values. Serum total protein (6.2 g/dL), Ca (10.9 mg/dL), Mg (2.0 mg/dL), P (8.6 mg/dL), Na (148 mmol/L), and K (6.3 mmol/L) were not affected by aflatoxin or clay treatments.

Trial 3. Feeding the diet with contaminated corn decreased ($P < .01$) ADG and ADFI compared with feeding the uncontaminated diet; gain:feed ratios were similar (Table 5). The addition of Ca bentonite to the contaminated diets improved ADG ($P < .05$) and ADFI ($P < .01$) linearly and somewhat of a plateau was reached at .5%, but the recovery of ADG was not complete. Pigs fed Ca bentonite had gain:feed ratios similar to those of pigs fed the uncontaminated control diet; however, there was a linear decrease ($P < .01$) in gain:feed ratios with increasing levels of Ca bentonite. Pigs fed the HSCA diet also had improved ($P < .01$) ADG and ADFI compared with pigs fed the aflatoxin diet with no clay.

Because of a question regarding the possibility that pigs in one pen that were to receive the contaminated unamended diet may have received an improper diet the day before blood sampling, the entire replicate was deleted from the analysis. Pigs fed the aflatoxin diet with no clay had higher ($P < .05$) serum AST and GGT levels than pigs fed the control diet (Table 5). Adding Ca bentonite to the diet linearly decreased ($P < .05$) AST levels and quadratically decreased ($P < .05$) serum ALP and GGT levels. The HSCA was also effective in preventing high serum GGT levels when added to the aflatoxin-contaminated diet ($P < .01$).

Table 5. Performance and serum clinical chemistry analysis of weanling pigs fed aflatoxin-contaminated diets with graded levels of calcium bentonite (CB) or hydrated sodium calcium aluminosilicate (HSCA) in Trial 3

	Diet[a]							
Item	1 Normal corn	2 Aflatoxin corn (AC)[b]	3 AC + .25% CB	4 AC + .5% CB	5 AC + 1% CB	6 AC + 2% CB	7 AC + .5% HSCA	SEM
ADG, kg[ceh]	.63	.52	.59	.60	.60	.61	.61	.02
ADFI, kg[cfh]	1.29	1.02	1.14	1.24	1.22	1.29	1.23	.05
Gain/feed[f]	.49	.51	.52	.49	.49	.47	.49	.01
Total protein, g/dL	5.4	5.8	5.9	5.4	5.7	6.0	6.0	.2
Urea N, mg/dL	10.8	12.2	11.7	12.5	12.7	13.2	12.7	1.7
Albumin, g/dL[gi]	3.4	3.2	3.6	3.3	3.4	3.8	3.8	.2
AST, U/L[de]	47	75	64	50	55	49	62	6
ALP, U/L[j]	134	163	171	134	125	156	155	13
GGT, U/L[cghj]	37	53	35	40	39	40	33	2

[a]Three pens of three pigs/pen per treatment mean (initial weight, 10 kg), for performance means and two pens of three pigs/pen for serum analysis means; see Table 1 for product identification.
[b]Diets contaminated with 800 ppb of aflatoxin.
[c,d]Aflatoxin effect, Diet 1 vs Diet 2 ($P < .01$, .05, respectively).
[e,f,g]Linear calcium bentonite effect, Diets 2 through 6 ($P < .05$, .01, .12, respectively).
[h,i]Hydrated sodium calcium aluminosilicate effect, Diet 2 vs Diet 7 ($P < .01$, .10 respectively).
[j]Quadratic calcium bentonite effect, Diets 2 through 6 ($P < .05$).

There was no effect of aflatoxin or clay on serum total protein (5.85 g/dL), albumin (3.59 g/dL), urea N (12.2 mg/dL), Ca (9.96 mg/dL), Mg (2.02 mg/dL), P (8.50 mg/dL), Na (144 mmol/L), and K (6.95 mmol/L).

Discussion

The results of these studies are in agreement with other reports in which marked improvements in performance were observed when clays were added to aflatoxin-contaminated diets (Harvey et al., 1990; Lindemann et al., 1993). In all three trials, ADG and ADFI were decreased by 25 to 30% by the addition of aflatoxin to the diets. Feeding aflatoxin without clay also decreased gain:feed ratios in Trial 1, which is similar to the results of Panangala et al. (1986). In contrast, gain:feed ratios in Trials 2 and 3 were unaffected, which is in agreement with the findings of Lindemann et al. (1993).

Serum profiles in all the trials were similar to those obtained by Harvey et al. (1989a,b), who reported that aflatoxin reduced indicators of protein synthesis such as serum albumin, total protein, and urea N. The high levels of serum liver enzymes found in this study are consistent with the results of Harvey et al. (1990) and Lindemann et al. (1993), who reported high levels of AST, GGT, and ALP in the serum of pigs fed aflatoxin-contaminated diets. The clays were effective in reducing the high levels of these enzymes, which is in agreement with the findings of Lindemann et al. (1993). They reported a similar serum enzyme reduction with the addition of .5% sodium bentonite or HSCA.

The clays differed in their ability to recover the aflatoxin-decreased performance and to correct aberrations in serum profiles. The performance data for Trial 1 indicate an advantage for pigs fed the treated Ca bentonite because these pigs had higher ADG than did pigs fed the other clays. The pigs fed the HSCA and sepiolite had intermediate performance, whereas pigs fed the palygorskite were at a disadvantage because their performance remained below that of pigs fed the uncontaminated control diet ($P < .05$). The serum profiles reflected the growth response data because pigs fed the treated Ca bentonite and the sepiolite tended to have the greatest numerical improvements in serum values. It should be noted that because various clays have been demonstrated to bind aflatoxin in aqueous solution (Masimanco et al., 1973), the presumed mechanism of action of the clay is to bind irreversibly with the toxin in the gut and, thereby, to prevent absorption of the toxin across the intestinal wall. The recovery, or restoration of performance, then refers only to the expression of a particular response trait in the direction of that exhibited by pigs fed the uncontaminated diet. It is presumed that when a particular type of clay produces a response it is by reducing the availability of the toxin and that the action is, therefore, prophylactic rather than therapeutic.

The results of Trials 1 and 2 are in agreement. Pigs fed the treated Ca bentonite had performance levels similar to those of the control pigs, whereas pigs fed the palygorskite performed only slightly better than the pigs fed aflatoxin without clay. Pigs fed the diets supplemented with Na bentonite, HSCA, sepiolite, and zeolite all had gains similar to pigs fed the uncontaminated control diet. Again, the serum profiles reflected the growth performance data; pigs fed aflatoxin-contaminated diets with clay added that performed the best had serum values closer to the values of the control pigs. The variation in the ability of the clays to prevent characteristic aflatoxin-induced changes in serum profiles may reflect the differing abilities of the clays to bind toxins.

In the dose-response trial (Trial 3) with treated Ca bentonite, pigs fed the .5% Ca bentonite diet performed similarly to pigs fed the control diet and had serum AST, ALP, and GGT levels similar to those of controls. This is in agreement with the results of Lindemann et al. (1993), who reported no additional improvement in performance with inclusion levels of Na bentonite > .5% to diets similarly contaminated with 800 ppb aflatoxin. At inclusion rates of 1 to 2%, there was not an appreciable increase in performance or additional benefit to serum profiles. The linear ($P <$ .01) decline in gain:feed ratio is anticipated when adding these non-energy-containing compounds to the diet; it is a simple diet dilution effect. These results indicate no appreciable additional benefit from the inclusion of Ca bentonite to aflatoxin-contaminated diets at levels > .5%. Additionally, the performance recovery and serum profiles of the pigs fed .5% treated Ca bentonite and the pigs fed the HSCA were similar to those of pigs fed these clays in Trials 1 and 2 as well as elsewhere (Lindemann et al., 1993).

The lack of a response of serum Ca, Mg, P, Na, and K to feeding aflatoxin also agrees with the results of Lindemann et al. (1992) in which no effects were found on these variables.

Implications

When diets contaminated with 500 to 800 ppb of aflatoxin B_1 are fed to young swine, there are reductions in growth rate and there are metabolic alterations that are reflected in an altered serum clinical profile. The addition of certain clays can prevent many of the negative, toxin-induced effects. The degree to which the clays can accomplish this seems to be dependent on the specific clay.

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