Effects of a Hydrated Sodium Calcium Aluminosilicate (T-Bind™) on Mycotoxicosis in Young Broiler Chickens

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ABSTRACT

Experiments were conducted to determine the ability of a hydrated sodium calcium aluminosilicate (T-Bind™) sorbent to reduce the toxicity of aflatoxins (AF) or T-2 toxin in male broiler chickens from day of hatch to 21 d of age. In Experiment 1, the sorbent was added at 0.250 or 0.375% to diets containing AF at 5 or T-2 toxin at 8 mg/kg of diet. When compared with controls, AF reduced BW gain by 27% and T-2 toxin reduced BW gain by 17%. The addition of the sorbent at 0.250 or 0.375%, in the absence of added mycotoxins, did not alter the performance of the chicks. The sorbent reduced the toxic effects of 5 mg AF/kg of diet on BW gain by 43% but did not significantly diminish the toxic effects of 8 mg T-2 toxin/kg of diet. The decreased efficiency of feed utilization and the increased relative organ weights caused by AF were significantly diminished to differing degrees by the sorbent. Oral lesions caused by T-2 toxin were not affected by the sorbent. In Experiment 2, the sorbent was added at 0.80% to a diet containing 8 mg T-2 toxin/kg of diet. The sorbent did not diminish the toxic effects of T-2 toxin when added at 0.80% of the diet. These data demonstrate that this specific sorbent can provide protection against the toxicity of AF, but not T-2 toxin, in young broiler chicks.

(Key words: aflatoxin, T-2 toxin, sorbent, toxicity, broiler)


INTRODUCTION

Aflatoxins (AF), a group of extremely toxic chemicals, are produced by certain species of fungi in the genus Aspergillus and have been detected as contaminants of crops before harvest, between harvest and drying, in storage, and after processing and manufacturing (Council for Agricultural Science and Technology, 1989). Aflatoxins cause severe economic losses in the poultry and livestock industries. In many cases, AF contamination may mean the difference between profit and loss to the poultry industry (Jones et al., 1982; Nichols, 1983; Hamilton, 1984). Experimentally induced toxicity in young growing chickens has been well documented, as indicated by Huff et al. (1988).

The T-2 toxin is a naturally occurring mycotoxin produced by several species of fungi in the genus Fusarium (Bamburg et al., 1970) that are found in many cereals, feeds, and vegetables. The T-2 toxin causes reductions in weight gain and feed consumption and severe oral lesions in chickens (Wyatt et al., 1972, 1973b; Chi et al., 1977; Chi and Mirocha, 1978; Hoerr et al., 1981a,b, 1982a,b; Huff et al., 1988; Kubena et al., 1989a,b, 1990a, 1994), abnormal behavior (Wyatt et al., 1973a), altered feathering (Wyatt et al., 1975), and a coagulopathy (Doerr et al., 1981).

Methods to detoxify mycotoxin-containing feedstuffs on a large scale and in a cost-effective manner are not currently available. Numerous strategies, such as physical separation, thermal inactivation, irradiation, microbial degradation, and treatment with a variety of chemicals, have been used for the detoxification or inactivation of mycotoxin-contaminated feedstuffs (Goldblatt, 1971; Goldblatt and Dollear, 1979; Anderson, 1983). Many of the techniques are impractical, ineffective, or potentially unsafe. An additional approach to the detoxification of AF is the use of inorganic sorptive materials in the diet to reduce AF absorption from the gastrointestinal tract. Dalvi and Ademoyero (1984) and Dalvi and McGown (1984) reported a trend toward improvement in feed consumption and weight gain...
when activated charcoal was added to poultry diets containing AF. Kubena et al. (1990b) and Edrington et al. (1996) observed no improvement in performance from the dietary addition of charcoal when growing broilers or turkey pouls were fed diets containing AF. Dietary additions of zeolite (Smith, 1980), bentonite (Carson, 1982), or spent bleaching clay from canola oil refining (Smith, 1984) have been reported to diminish the effects of T-2 toxin and zearalenone in rats. Clays and zeolitic materials are a complex and widely diverse family of aluminosilicates with a variety of functional properties. Some aluminosilicates bind aflatoxin B1 (AFB1) in vitro to varying degrees and form complexes of varying strengths with AFB1. One compound, a specific hydrated sodium calcium aluminosilicate (HSCAS) (NovaSili™),3 formed a more stable complex with AFB1 than many of the other compounds evaluated in vitro (Phillips et al., 1988) and was selected for extensive in vivo experimental evaluation. The HSCAS at a concentration of 0.5 to 2.0% of the diet significantly diminished many of the adverse effects caused by AFB1 or AF in chickens (Kubena et al., 1987, 1990a,b, 1992, 1993; Phillips et al., 1988; Huff et al., 1992), in turkeys (Kubena et al., 1991), in swine (Colvin et al., 1989; Harvey et al., 1989), and in lambs (Harvey et al., 1991), and reduced the concentration of aflatoxin M1 in the milk of lactating dairy cows (Harvey et al., 1991) and lactating dairy goats (Smith et al., 1994). Several other adsorbent materials showed protection against the toxicity of AF ranging from 0 to 75% in chickens (Kubena et al., 1992, 1993; Harvey et al., 1993) and in swine (Harvey et al., 1994). None of the sorbents evaluated in vitro have shown protection against T-2 toxin, diacetoxyscirpenol, or ochratoxin A (Kubena et al., 1990a,b, 1993; Huff et al., 1992). The purpose of the present research was to evaluate the efficacy of an adsorbent (T-Bind)4 for reducing the toxicity of AF and T-2 toxin in young growing broiler chicks.

MATERIALS AND METHODS

Day-old male broiler chicks were obtained from a commercial hatchery and individually weighed and wing-banded. The chicks were maintained in electrically heated batteries under continuous fluorescent lighting with feed and water provided for ad libitum consumption. The experimental design for Experiment 1 consisted of nine dietary treatments: 1) Control with 0 mg AF, 0 mg T-2 toxin, 0% adsorbent; 2) 0.250% adsorbent; 3) 0.375% adsorbent; 4) 5.0 mg AF/kg of diet; 5) 8.0 mg T-2 toxin/kg of diet; 6) 5.0 mg AF/kg of diet plus 0.250% adsorbent; 7) 5.0 mg AF/kg of diet plus 0.375% adsorbent; 8) 8.0 mg T-2 toxin/kg of diet plus 0.250% adsorbent; 9) 8.0 mg T-2 toxin/kg of diet plus 0.375% adsorbent. There were six replicates of six broilers per dietary treatment and the chicks were maintained on these treatments to 3 wk of age. The chicks were fed a basal commercial corn-soybean meal-based diet (without added antibiotics, coccidiostats, or growth promoters) that contained or exceeded the levels of nutrients recommended by the National Research Council (1994).

The AF for the experiments was produced through the fermentation of rice by Aspergillus parasiticus NRRL 2999 by methods previously described by Kubena et al., (1990a). The AF content was measured by spectrophotometric analysis (Nabney and Nesbith, 1965), as modified by Wiseman et al. (1967). The AF within the rice powder consisted of approximately 79% AFB1, 16% AFG1, 4% AFB2, and 1% AFG2. The rice powder was incorporated into the basal diet to provide the desired level of 5.0 mg AF/kg of diet. Through nuclear magnetic resonance and mass spectrometry, the T-2 toxin5 was determined to be greater than 99% pure. The T-2 toxin was incorporated into the diet by dissolving the toxin in 95% ethanol and then mixing the appropriate quantities with 1 kg of the diet. After drying, the dissolved toxin was mixed with the basal diet to produce the treatments containing T-2 toxin. The basal diet was analyzed for mycotoxins and was found to be below detection limits for AF, deoxynivalenol, zearalenone, ochratoxin, and cyclopiazonic acid as established by the methods described by Clement and Phillips (1985).

Broilers were weighed individually on a weekly basis, feed consumption was recorded weekly, and mortality was recorded as it occurred. When the chicks reached 3 wk of age, the feeding trial was terminated and 12 broilers (6 replicates of 2 chicks each) from each treatment were bled by cardiac puncture for serum biochemical analyses. Eight blood samples from these same chicks from each treatment were used for hematochemical determinations. Twelve broilers (two chicks from each replicate) were killed by cervical dislocation and the liver, kidney, heart, spleen, pancreas, proventriculus, gizzard, and bursa of Fabricius were removed and weighed.

At the termination of the study, all chicks in the control group, 0.375% adsorbent group, and all groups of fed diets containing T-2 toxin were visually scored for oral lesions (using a four-point scoring system ranging from 1 to 4) by the same individual without knowledge as to treatment groups. A lesion score of 1 indicated no visible lesions; a lesion score of 2 was seen as one or two mouth lesions clearly visible on either the lower or upper mandible; a lesion score of 4 was seen as large lesions occurring at several sites within the mouth, principally on the upper and lower mandibles, the corners of the mouth, and the back of the tongue; lesions scored as 3 were intermediate in appearance to lesions scored 2 or 4.

Hemoglobin was measured as cyanmethemoglobin.6 Erythrocyte count, mean corpuscular volume, and

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3Engelhard Corp., Beachwood, OH 44122.
4Biotech Development Co., Atlanta, GA 30338.
5Kindly provided by G. H. Rottinghaus, Veterinary Medical Diagnostic Laboratory, College of Veterinary Medicine, University of Missouri, Columbia, MO 65202.
6Coulter Electronics, Hialeah, FL 33012.
TABLE 1. Effects of a hydrated sodium calcium aluminosilicate (T-Bind<sup>™</sup>) on BW gains, efficiency of feed utilization, mortality, and oral lesions of broiler chicks fed diets containing no detectable mycotoxins, 5.0 mg aflatoxin (AF)/kg, or 8 mg T-2 toxin (T-2)/kg, Experiment 1<sup>1</sup>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>BW gain</th>
<th>Change from control</th>
<th>Consumption per bird</th>
<th>Feed:gain</th>
<th>Mortality</th>
<th>Oral lesion scores&lt;sup&gt;2&lt;/sup&gt;</th>
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<tbody>
<tr>
<td></td>
<td>1 to 7 d</td>
<td>8 to 14 d</td>
<td>15 to 21 d</td>
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<td></td>
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<tr>
<td>T-Bind™</td>
<td>AF</td>
<td>T-2</td>
<td>(%)</td>
<td>(g)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>(%)</td>
<td>(mg/kg)</td>
<td></td>
<td></td>
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<td>37</td>
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</table>

<sup>a</sup>Means within a column with no common superscript differ significantly (P < 0.05).
<sup>1</sup>Values represent the X of six groups of six broilers each per treatment minus mortality.
<sup>2</sup>Visually scored for oral lesions by the same individual (1 = no lesion; 4 = severe lesion).
<sup>3</sup>LSD = least significant difference as determined by Fisher’s Protected LSD procedure.

Results

Data from Experiment 1 (Table 1) show that BW gains, feed consumption, efficiency of feed utilization, mortality, and lesion scores were not significantly influenced by the adsorbent in the absence of added toxins. When compared with controls, BW gains were reduced during the first time period (1 to 7 d) only for the chicks fed T-2 toxin with or without the adsorbent. During the second period, BW gains for the AF alone, AF plus 0.25% adsorbent, and all T-2 toxin treatments were reduced. There was no significant difference between the BW gains of the AF plus 0.375% adsorbent and controls during this time period. During the third period (15 to 21 d) and the overall experimental period (1 to 21 d) BW gains for all toxin treatments were reduced. The reduction in BW gain caused by 5.0 mg AF/kg of diet was diminished by the addition of 0.25 or 0.375% adsorbent. The addition of the adsorbent did not alter the effects caused by 8 mg T-2 toxin/kg of diet.

When compared with controls, feed consumption per bird was reduced in all toxin treatments. The efficiency of feed utilization was significantly reduced in only the AF alone treatment. Mortality ranged from 0 to 14% with the chicks receiving the diet with AF alone having 14% mortality, which was significantly higher than the control treatment. All of the surviving chicks from the control, 0.375% adsorbent, and treatments containing T-2 toxin were examined for oral lesions at 3 wk of age; however, oral lesions were observed only in chicks receiving the diets containing T-2 toxin. There were no differences in lesion scores in chicks receiving T-2 toxin with or without the adsorbent.

Data presented in Table 2 (Experiment 1) show the effects of dietary treatment on relative organ weights. Feeding AF alone caused significant increases in the relative weights of the liver, kidney, heart, spleen, pancreas, and proventriculus. Feeding T-2 toxin with or
TABLE 2. Effects of a hydrated sodium calcium aluminosilicate (T-Bind™) on relative organ weights of broiler chicks fed diets containing no detectable mycotoxins, 5.0 mg aflatoxin (AF)/kg, or 8 mg T-2 toxin (T-2)/kg, Experiment 1 at 21 d

<table>
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<tr>
<th>Treatment</th>
<th>T-Bind™</th>
<th>AF (mg/kg)</th>
<th>T-2 (mg/kg)</th>
<th>Liver (g/100 g BW)</th>
<th>Kidney (g/100 g BW)</th>
<th>Heart (g/100 g BW)</th>
<th>Spleen (g/100 g BW)</th>
<th>Pancreas (g/100 g BW)</th>
<th>Proventriculus (g/100 g BW)</th>
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<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>3.28±d</td>
<td>0.48c</td>
<td>0.76b</td>
<td>0.112±cd</td>
<td>0.37bc</td>
<td>0.68b</td>
</tr>
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<td>0.25</td>
<td>0</td>
<td>0</td>
<td>3.06±d</td>
<td>0.48c</td>
<td>0.75b</td>
<td>0.106±d</td>
<td>0.33c</td>
<td>0.65b</td>
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<tr>
<td>0.375</td>
<td>0.375</td>
<td>0</td>
<td>0</td>
<td>3.06±d</td>
<td>0.48c</td>
<td>0.75b</td>
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</tr>
<tr>
<td>0</td>
<td>0.375</td>
<td>0</td>
<td>0</td>
<td>3.30±cd</td>
<td>0.52c</td>
<td>0.76b</td>
<td>0.085f</td>
<td>0.34c</td>
<td>0.66b</td>
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<td>0.25</td>
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<td>0</td>
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<td>0</td>
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<td>0.76b</td>
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<td>0.092d</td>
<td>0.38c</td>
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LSD2 0.58 0.14 0.53 0.037 0.046 0.10

Means within a column with no common superscripts differ significantly (*P* < 0.05).

1Values represent the x of six groups of two broilers each per treatment.

2LSD = least significant difference as determined by Fisher’s Protected LSD procedure.

without the adsorbent did not alter relative organ weights. Addition of the adsorbent to the diet containing AF alleviated or significantly diminished the effects of AF on the relative weights of all organs (Table 2). None of the treatments altered the relative weights of the gizzard or bursa of Fabricius (data not shown).

Data in Table 3 (Experiment 1) show that serum concentrations of total protein, albumin, cholesterol, and calcium were reduced and serum concentration of urea nitrogen and activity of creatine kinase were increased in chicks fed AF alone. Chicks fed the diet containing T-2 toxin plus 0.25% adsorbent had a reduced serum concentration of total protein, when compared with controls. The adverse effects of AF on serum concentrations of albumin and cholesterol and the activity of creatine kinase were reduced by the addition of the adsorbent at 0.375% and also by 0.25% in the case of albumin.

The results of Experiment 2 are presented in Table 4. Beginning with the first period (1 to 7 d) and continuing for the remainder of the experiment, BW gain was significantly reduced in chicks fed the diets containing 8 mg T-2 toxin/kg of diet. The addition of the adsorbent at 0.80% did not protect against the toxicity of T-2 toxin. Feed consumption per bird was significantly reduced in the two T-2 toxin treatments. When compared with controls, efficiency of feed utilization was significantly decreased in those birds receiving T-2 toxin alone.

DISCUSSION

Aflatoxin and T-2 toxin are important to the poultry industry because of their toxicity and frequency of occurrence in feedstuffs. The toxicity of AF in poultry has been well documented, as indicated by Huff et al. (1988). Although not as extensively studied as AF, the
TABLE 4. Effects of a hydrated sodium calcium aluminosilicate (T-Binder™) on BW gain and efficiency of feed utilization of broiler chicks fed diets containing no detectable mycotoxins or 8.0 mg T-2 toxin (T-2)/kg, Experiment 2

<table>
<thead>
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<th>Treatment</th>
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<th>Feed:gain</th>
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<tr>
<td>T-Binder™ T-2</td>
<td>1 to 7 d</td>
<td>7 to 20 d</td>
<td>1 to 20 d</td>
<td>(%)</td>
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<tr>
<td>(%)</td>
<td>(mg/kg)</td>
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<td>87b</td>
<td>408b</td>
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<td>LSD</td>
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1Values represent the x of six broilers per treatment.

2LSD = least significant difference as determined by Fisher’s Protected LSD procedure.

The toxicity of T-2 toxin in poultry has been well documented, as indicated by Kubena et al. (1997a). The addition of the adsorbent (T-Binder™) at 0.25, 0.375, or 0.80%, in the absence of added mycotoxins, did not alter the performance of the chicks. In Experiment 1, the addition of 5.0 mg AF/kg or 8.0 mg T-2 toxin/kg of diet significantly reduced BW gain and feed efficiency. The addition of 0.25 or 0.375% adsorbent resulted in a 15% reduction in BW gain in chicks fed the AF diet, representing a protective effect of approximately 43%. These data agree with previous results on the protective effects of an HSCAS compound (Nova Sil™) on body weights in chickens (Kubena et al., 1987, 1990a,b, 1993, 1994; Phillips et al., 1988; Huff et al., 1992; Abo-Norag et al., 1995) in turkeys (Kubena et al., 1992), in swine (Colvin et al., 1989; Harvey et al., 1989), and in lambs (Harvey et al., 1991). Previous studies in lactating dairy cows (Harvey et al., 1991) and lactating dairy goats (Smith et al., 1994) also mirror the effects reported here. Several other adsorbents showed protection against the toxicity of AF in chickens (Kubena et al., 1992, 1993; Harvey et al., 1993) and in swine (Harvey et al., 1994).

The addition of the adsorbent at 0.25 or 0.375% resulted in no significant protection against the toxicity of T-2 toxin. The lack of protection against the toxicity of T-2 toxin agrees with previous work where no protection in vivo was observed against T-2 toxin, diacetoxyscirpenol, or ochratoxin A with several adsorbents (Kubena et al., 1990a,b, 1992, 1993; Huff et al., 1992).

Feed consumption was reduced in all treatments receiving diets containing toxins; however, the efficiency of feed utilization was adversely affected in only the AF alone treatment. When compared with controls, mortality was significantly increased only in chicks receiving the diet with AF alone. Oral lesions were observed in only chicks receiving diets containing T-2 toxin and the incidence and severity did not differ with the addition of the adsorbent.

The liver is considered to be the principal target organ for aflatoxicosis; and in poultry, the relative weight of the liver is increased more than that of any other organ by lower concentrations of AF (Smith and Hamilton, 1970; Huff et al., 1986). The present data indicate that the relative weights of the liver were significantly increased in chicks fed diets containing AF alone and AF plus 0.25% adsorbent. There was significant protection against this adverse effect by 0.375% adsorbent. These data show the protective effects of 0.375% adsorbent with respect to liver damage, as indicated by less liver enlargement, when 0.375% adsorbent was added to the diet containing 5 mg AF/kg. The relative weights of the kidney were significantly increased in chicks fed the diet containing AF; however, significant protection against these increases was provided for the kidney, pancreas, and proventriculus by 0.375% adsorbent, with values in between the control and AF alone treatment. The addition of T-2 toxin to the diet did not significantly affect any of the relative organ weights. The relative weights of the bursa and gizzard were not affected by any of the dietary treatments (data not shown). Reduced serum concentrations of total protein and albumin, indicators of protein synthesis (Tung et al., 1975) and aflatoxicosis Huff et al., 1986; Kubena et al., 1992), were observed in chicks fed the diets containing AF alone. The reduced serum concentration of cholesterol by AF is most likely due to the inhibition of cholesterol biosynthesis, with liver involvement, and perhaps a shift of concentration from the blood to the liver (Kubena et al., 1993). The increased serum activity of creatine kinase most likely reflects tissue damage and leakage into the blood (Tietz, 1976; Kubena et al., 1995a,b, 1997b). The reduction in serum concentration of calcium may be a reflection of reduced feed intake. The increased concentration of blood urea nitrogen, coupled with the kidney enlargement observed, may indicate some kidney damage due to AF. The protection against changes in serum biochemical values provided by the adsorbent varied, but noteworthy were the significant improvements in serum concentrations of albumin and cholesterol and the activity of the enzyme creatine kinase.

The addition of the adsorbent at 0.80% did not protect against the toxicity of 8.0 mg T-2 toxin/kg of diet, as evidenced by the lack of significant differences between the T-2 toxin alone and the T-2 toxin plus adsorbent treatments for BW gains, feed consumption per bird, or
efficiency of feed utilization. These data agree with previous research using lower concentrations of adsorbents.

The present data and previous data clearly demonstrate that specific adsorbents can greatly diminish the toxicity of AF in young growing chicks. To date, none of the adsorbents evaluated have provided protection against any mycotoxins except AF. The basic mechanism for protection against the toxicity of AF appears to involve sequestration of AF in the gastrointestinal tract and chemisorption (i.e., tight binding) to the adsorbent, which reduces the bioavailability of AF (Davidson et al., 1987; Phillips et al., 1990a). More specifically, a proposed mechanism of AF chemisorption by the adsorbent (HSCAS) is the formation of a complex by the B-carbonyl system of the AF with uncoordinated "edge site" aluminum ions in HSCAS (Phillips et al., 1990b; Sarr et al., 1990). The research to date indicates that adsorbent compounds, when used in conjunction with other sound mycotoxin management practices, may prove to be another tool for the development of an integrated approach to the preventive management of AF-contaminated feedstuffs in poultry.

ACKNOWLEDGMENTS

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doses of either T-2 toxin or diacetoxyscirpenol. Avian Pathol. 11:269–383.


