Efficacy of Commercial Products on Growth Performance of Nursery Pigs Fed Diets with Fumonisin-Contaminated Corn

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Summary

Two experiments were conducted to determine the efficacy of various commercial products on growth performance of 20- to 50-lb nursery pigs fed diets high in fumonisin (FUM) concentration. In Exp. 1, a total of 350 pigs (241 × 600; DNA, Columbus, NE; initially 21.8 lb) were used. There were 5 pigs per pen and 14 replicates per treatment. After weaning, pigs were fed common diets for 21 d before the experiment started. Five dietary treatments were utilized and consisted of a positive control (low FUM), a negative control (approximately 50 to 60 ppm of FUM), and 3 other treatments as negative control with one of 3 different commercial products (Kallsil Dry, Kemin Industries Inc., Des Moines, IA; Feed Aid Wide Spectrum, NutriQuest, Mason City, IA; Biofix Select Pro, Biomin America Inc., Overland Park, KS). Diets were fed in mash form for 14 d and followed with a low FUM mash diet for 13 d as a post-treatment period. For the 14-d treatment period, pigs fed the high FUM negative control, or high FUM diets with Kallsil Dry or Feed Aid Wide Spectrum had decreased ($P < 0.05$) average daily gain (ADG), average daily feed intake (ADFI), and d 14 body weight (BW), and poorer ($P < 0.05$) feed efficiency (F/G) compared to the positive control and treatment with Biofix Select Pro. Pigs fed the high FUM diet with Biofix Select Pro had similar performance to pigs fed the low FUM diet. During the 13-day post-treatment period, pigs previously fed the high FUM negative control, or high FUM diets with Kallsil Dry or Feed Aid Wide Spectrum had improved F/G compared with pigs previously fed the low FUM diet or high FUM diet with Biofix Select Pro. Although the performance of the pigs previously fed the high FUM diets without additive or with Kallsil Dry or Feed Aid Wide Spectrum improved, their d 27 BW were still lower ($P < 0.05$) compared to pigs previously fed the positive control and high FUM diet with Biofix Select Pro.

In Exp. 2, a total of 300 pigs (241 × 600; DNA; initially 23.0 lb) were used. Procedures were similar to Exp. 1 except there were 12 replicate pens per treatment and high FUM diets contained 30 ppm FUM, and experimental diets were fed for 28 d. Similar to Exp. 1, for the 28-d treatment period, pigs fed the high FUM negative control, or high FUM

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diets with Kallsil Dry or Feed Aid Wide Spectrum had decreased (*P* < 0.05) ADG, ADFI, and d 28 BW, and poorer (*P* < 0.05) F/G compared to the positive control and treatment with Biofix Select Pro. Pigs fed the high FUM diet with Biofix Select Pro had similar performance to pigs fed the low FUM diet. In summary, adding Biofix Select Pro to diets containing 30 to 50 ppm of FUM appeared to mitigate the negative effects of FUM, while Kallsil Dry and Feed Aid Wide Spectrum did not influence pig performance.

Introduction

Fumonisin contamination in corn has been an emerging issue in swine feed production. Ingesting fumonisin-contaminated corn could reduce growth performance, and damage the liver, lungs, kidneys, and gastrointestinal structure of pigs. In severe cases, it could lead to death. In a preliminary study conducted at Kansas State University, we fed increasing amounts of naturally fumonisin-contaminated corn to achieve final diet FUM levels of 7 to 35 ppm. We observed a reduction in growth performance with a dietary FUM level greater than 21 ppm.[3]

Several commercial products have the potential to mitigate the effects of FUM, but little in vivo research is available to verify their efficacy. Furthermore, we are unaware of any research that has directly compared different commercially available products to each other. Consequently, two experiments were conducted to compare 3 commercially available products (Kallsil Dry, Kemin Industries Inc., Des Moines, IA; Feed Aid Wide Spectrum, NutriQuest, Mason City, IA; Biofix Select Pro, Biomin America Inc., Overland Park, KS) on their potential to ameliorate the negative effects of FUM on growth performance of pigs from 20- to 50-lb BW.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocols used in these experiments and they were conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Each pen (4 × 4 ft) was equipped with a 4-hole, dry self-feeder and a nipple waterer to provide *ad libitum* access to feed and water.

In both experiments, pigs were weaned at approximately 21 d of age and placed in pens of 5 pigs each based on initial BW and gender. A common phase 1 pelleted diet was fed for 7 d and a common phase 2 mash diet was fed for another 14 d. At d 21 after weaning, which was considered d 0 of the trial, pens of pigs were randomly allotted to treatment in a randomized complete block design with BW as the blocking factor.

For Exp. 1, a total of 350 pigs (241 × 600; DNA, Columbus, NE; initially 21.8 lb) were used in a 27-d growth trial. There were 5 pigs per pen and 14 replicates per treatment. Five dietary treatments were utilized and consisted of a positive control (low FUM), a negative control (approximately 50 to 60 ppm of FUM), and 3 other treatments as negative control with one of 3 different commercial products (Kallsil Dry, Kemin

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Industries Inc., Des Moines, IA; Feed Aid Wide Spectrum, NutriQuest, Mason City, IA; Biofix Select Pro, Biomin America Inc., Overland Park, KS). The inclusion rates were 0.3% for Kallsil Dry and Feed Aid Wide Spectrum, and 0.17% for Biofix Select Pro with 0.13% sand. High FUM diets were fed in mash form for 14 d and followed with a low FUM mash diet for 13 d as a post-treatment period. Pen weights and feed disappearance were measured on d 0, 7, 14, 21, and 27 to determine ADG, ADFI, and F/G.

For Exp. 2, a total of 300 pigs (241 × 600; DNA; initially 23.0 lb) were used in a 28 d growth trial with 5 pigs per pen and 12 replicates per treatment. Experimental treatments were exactly the same as Exp. 1, with the exception that the high FUM diets contained approximately 30 ppm FUM. Pen weights and feed disappearance were measured on d 0, 7, 14, 21, and 28 to determine ADG, ADFI, and F/G.

All diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center in Manhattan, KS. All diets met or exceeded the NRC[4] energy and nutrient requirement estimates. Diet samples were combined and thoroughly mixed within treatment before analysis for each experiment. Samples were analyzed for dry matter, crude protein, calcium, phosphorus, neutral detergent fiber, and fat (Ward Laboratories, Inc., Kearney, NE).

For Exp. 1, two diets (Table 1) were formulated using control corn (low FUM) or FUM-contaminated corn (approximately 80 ppm of FUM). The diet manufactured with low FUM corn was used as the positive control. The diet manufactured with FUM-contaminated corn was manufactured as a single large batch of basal diet. During the bag-off process, each bag was stacked sequentially on 12 numbered pallets to allow FUM to be evenly distributed in all treatment diets. Three pallets of bags were randomly selected for each of the 4 FUM treatments. Each treatment's basal diet was then mixed again with sand or one of the 3 commercial products to produce the final treatment diet. These experimental diets were fed during the 14-d treatment period. Meanwhile, a low FUM diet for the 13-d post treatment period was formulated and manufactured identically to the positive control diet that was used in the 14-d treatment period. Representative diet samples were obtained from every fifth bag of feed manufactured.

For Exp. 2, a low FUM common diet was manufactured identically to the positive control diet (Table 2) in Exp. 1 to be used as positive control. The remaining high FUM diets (approximately 50 to 60 ppm) that were manufactured in Exp. 1 were blended with the positive control diet to produce treatment diets with approximately 30 ppm of FUM. During blending, each treatment diet was mixed with sand or one of the 3 commercial products to produce the same product inclusion rate as Exp. 1. Representative diet samples were obtained from 24 bags per treatment.

Diets from Exp. 1 and FUM-contaminated corn were analyzed for all major mycotoxins without and with 100× sample dilution, and diets from Exp. 2 were analyzed twice with 100× sample dilution at the North Dakota State University Veterinary Diag-

[4] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

nostic Laboratory (Fargo, ND). Diets from both experiments were also analyzed with 10× sample dilution for FUM at Trilogy laboratory (Washington, MO). Both NDSU and Trilogy laboratories utilized a 10-ppm FUM standard curve. Diluting samples was required for the high FUM levels to be within the standard curve used in each of the laboratories.

Data were analyzed as a randomized complete block design with block as a random effect and pen as the experimental unit. Models accounted for heterogenous variance when appropriate. Pairwise comparisons were conducted on treatment means using a Tukey adjustment to prevent inflation of Type I error due to multiple comparisons. Data were analyzed using R program (R Core Team, Vienna, Austria). Results were considered significant at $P \le 0.05$ and marginally significant at $0.05 < P \le 0.10$.

Results and Discussion

Chemical analysis of both experiments for dry matter, crude protein, calcium, phosphorus, neutral detergent fiber, and fat was within formulated range and similar between treatments.

Mycotoxin Analysis

All major mycotoxins except FUM were below detectable level (Table 3 and Table 4). Dietary FUM (B1 + B2) analysis results were different between the NDSU and Trilogy laboratories. The results (FB1 + FB2) of Trilogy laboratory for each high FUM treatment was 10 to 15 ppm lower in Exp. 1, and 5 to 6 ppm lower in Exp. 2 than their corresponding NDSU values. In Exp. 1, values for the 4 high FUM diets were similar within lab, which verified that FUM was evenly distributed in each high FUM diet. Some variability in analytical results was expected because of the dilution required for these high FUM levels to be within the standard curve used in the lab. These results suggest that new standard curves for high FUM levels may be needed for high mycotoxin levels found in feed ingredients in some regions of the United States.

Experiment 1

From d 0 to 14 (treatment period), pigs fed the high FUM negative control diet or high FUM diet with Kallsil Dry or Feed Aid Wide Spectrum had decreased ($P < 0.05$) ADG, ADFI, d 14 BW, and poorer ($P < 0.05$) F/G compared to those fed the positive control and high FUM diet with Biofix Select Pro (Table 5). There were no differences ($P > 0.05$) between the high FUM negative control and high FUM diet with Kallsil Dry or Feed Aid Wide Spectrum on any growth performance criteria. There were no differences ($P > 0.05$) between the positive control and high FUM diet with Biofix Select Pro for any growth performance criteria.

During the 13-day post-treatment period, pigs previously fed the high FUM negative control diet, or high FUM diets with Kallsil Dry or Feed Aid Wide Spectrum had improved F/G compared with pigs previously fed the low FUM diet or high FUM diet with Biofix Select Pro. Feeding a low FUM diet from d 13 to 27 improved ADG from 0.5 to 1.5 lb/day, ADFI from 1.1 to 2.2 lb/day, and F/G from 2.1 to 1.5. Although the performance of the pigs previously fed high FUM diets without additive or with Kallsil Dry or Feed Aid Wide Spectrum improved, their d 27 BW were still 7 to 8 lb lighter

($P < 0.05$) than pigs fed the positive control diet and high FUM diet with Biofix Select Pro. These results suggest that pigs experienced a period of compensatory growth after short-term (2 weeks) exposure to 50 to 60 ppm FUM; however, the improvement to recover to similar BW as the positive control did not occur in the 13-day period.

Experiment 2

Similar to Exp. 1, from d 0 to 28, pigs fed the high FUM negative control diet or high FUM diet with Kallsil Dry or Feed Aid Wide Spectrum had decreased ($P < 0.05$) ADG, ADFI, d 28 BW, and poorer ($P < 0.05$) F/G compared to positive control and high FUM diet with Biofix Select Pro (Table 6). There were no differences ($P > 0.05$) between pigs fed the high FUM negative control and those fed high FUM diet with Kallsil Dry or Feed Aid Wide Spectrum on any growth performance criteria. There also were no differences ($P > 0.05$) between pigs fed the positive control and those fed the high FUM diet with Biofix Select Pro for any growth performance criteria.

These results from both experiments indicate that Kallsil Dry and Feed Aid Wide Spectrum had no effect on ameliorating FUM's negative effect on growth performance. Biofix Select Pro reduced the negative effect of FUM and maintained growth performance to the same level as the positive control, low FUM diet.

Table 1. Diet composition, Exp. 1 (as-fed basis)[1]

Item	Positive control	Negative control[2]
Ingredients, %		
Corn	64.70	---
Fumonisin corn[3]	---	64.48
Soybean meal	28.00	28.00
Soybean oil	3.00	3.00
Monocalcium phosphate	0.85	0.85
Calcium carbonate	0.75	0.75
Sodium chloride	0.60	0.60
L-Lysine HCl	0.55	0.55
DL-Methionine	0.21	0.21
L-Threonine	0.23	0.23
L-Tryptophan	0.06	0.06
L-Valine	0.16	0.16
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Phytase[4]	0.08	0.08
Sand	---	0.30
Total	100	100
Standard ileal digestible (SID) amino acids, %		
Lysine	1.30	1.30
Isoleucine:lysine	53	53
Leucine:lysine	111	111
Methionine:lysine	36	36
Met and cysteine:lysine	56	56
Threonine:lysine	63	63
Tryptophan:lysine	20.0	20.0
Valine:lysine	69	69
Histidine:lysine	35	35
Net energy, kcal/lb	1,152	1,149
Crude protein, %	19.8	19.8
Calcium, %	0.61	0.61
STTD P,[5] %	0.44	0.44

[1]Diets were fed during the 14-d treatment period. During the 13-d post treatment period, positive control was fed to all groups of pigs.
[2]Three high FUM diets with products were manufactured by using negative control with product added at the expense of sand: 0.3% of Kallsil Dry (Kemin Industries Inc., Des Moines, IA), 0.3% of Feed Aid Wide Spectrum (NutriQuest, Mason City, IA), and 0.17% of Biofix Select Pro (Biomin America Inc., Overland Park, KS) with 0.13% of sand.
[3]The level of FUM in the corn was approximately 80 ppm which resulted in diets with 50 to 60 ppm.
[4]Ronozyme HiPhos GT 2700 (DSM Nutritional Products, Basel, Switzerland) provided 306 FTU per lb of feed and an expected P release of 0.10%.
[5]STTD P = standardized total tract digestible phosphorus.

Table 2. Diet composition, Exp. 2 (as-fed basis)

Item	Positive control[1]	Negative control[2]
Ingredients, %		
Exp. 1 diet	---	62.50
Positive control[1]	---	37.39
Corn	64.70	---
Soybean meal	28.00	---
Soybean oil	3.00	---
Monocalcium phosphate	0.85	---
Calcium carbonate	0.75	---
Sodium chloride	0.60	---
L-Lysine HCl	0.55	---
DL-Methionine	0.21	---
L-Threonine	0.23	---
L-Tryptophan	0.06	---
L-Valine	0.16	---
Vitamin premix	0.25	---
Trace mineral premix	0.15	---
Phytase[3]	0.08	---
Sand	---	0.11
Total	100	100
SID amino acids, %		
Lysine	1.30	1.30
Isoleucine:lysine	53	53
Leucine:lysine	111	111
Methionine:lysine	36	36
Met and cysteine:lysine	56	56
Threonine:lysine	63	63
Tryptophan:lysine	20.0	20.0
Valine:lysine	69	69
Histidine:lysine	35	35
Net energy, kcal/lb	1,152	1,149
Crude protein, %	19.8	19.8
Calcium, %	0.61	0.61
STTD P,[4] %	0.44	0.44

[1]Positive control diet was identical to the positive control diet used in experiment 1 and used as blending diet.
[2]Three high FUM diets with products were manufactured by using negative control with product added at the expense of sand: 0.11% of Kallsil Dry (Kemin Industries Inc., Des Moines, IA), 0.11% of Feed Aid Wide Spectrum (NutriQuest, Mason City, IA), and 0.06% of Biofix Select Pro (Biomin America Inc., Overland Park, KS) with 0.05% of sand.
[3]Ronozyme HiPhos GT 2700 (DSM Nutritional Products, Basel, Switzerland) provided 306 FTU per lb of feed and an expected P release of 0.10%.
[4]STTD P = standardized total tract digestible phosphorus.

Table 3. Dietary mycotoxin levels, Exp. 1 (as-fed basis, ppb)[1,2,3]

	Positive	Negative	Negative control with		
Item	control	control	Kallsil Dry	Feed Aid	Biofix
Fumonisin B1					
NDSU (undiluted)	2,325	49,362	48,428	49,394	50,476
NDSU (diluted 100×)	3,067	46,762	42,951	47,889	40,582
Trilogy (diluted 10×)	1,800	35,100	36,800	37,000	37,000
Fumonisin B2					
NDSU (undiluted)	574	11,954	12,128	12,154	12,700
NDSU (diluted 100×)	974	11,435	11,165	12,922	11,223
Trilogy (diluted 10×)	100	5,900	6,700	7,100	6,900
Fumonisin B1 + B2					
NDSU (undiluted)	2,899	61,316	60,556	61,548	63,176
NDSU (diluted 100×)	4,041	58,197	54,116	60,811	51,805
Trilogy (diluted 10×)	1,900	41,000	43,500	44,100	43,900
Fumonisin B3					
Trilogy (diluted 10×)	200	4,200	4,500	4,800	4,600
Aflatoxin B1	< 20	< 20	< 20	< 20	< 20
Aflatoxin B2	< 20	< 20	< 20	< 20	< 20
Aflatoxin G1	< 20	< 20	< 20	< 20	< 20
Aflatoxin G2	< 20	< 20	< 20	< 20	< 20
HT-2 toxin	< 200	< 200	< 200	< 200	< 200
T-2 toxin	< 20	< 20	< 20	< 20	< 20
Ochratoxin	< 20	< 20	< 20	< 20	< 20
Sterigmatocystin	< 20	< 20	< 20	< 20	< 20
Zearalenone	< 100	< 100	< 100	< 100	< 100
Vomitoxin	< 200	< 200	< 200	< 200	< 200

[1]A representative sample of each diet was collected from every fifth bag of feed manufactured for each treatment.
[2]All mycotoxins were analyzed at North Dakota State University Veterinary Diagnostic Laboratory (Fargo, ND) by LC/MS/MS. The standard curve for fumonisin was up to 10 ppm.
[3]Fumonisin B1, B2, and B3 were analyzed at Trilogy laboratory (Washington, MO) by LC/MS/MS. The standard curve for fumonisin was up to 10 ppm.

Table 4. Dietary mycotoxin levels, Exp. 2 (as-fed basis, ppb)[1, 2, 3]

	Positive	Negative	Negative control with		
Item	control	control	Kallsil Dry	Feed Aid	Biofix
Fumonisin B1					
NDSU 1st	4,104	24,957	25,100	21,409	20,593
NDSU 2nd	3,243	23,827	23,729	21,259	23,449
Trilogy	2,700	18,900	19,100	17,300	19,200
Fumonisin B2					
NDSU 1st	1,065	6,055	7,310	5,174	6,516
NDSU 2nd	958	6,649	7,061	5,633	6,534
Trilogy	500	4,400	4,900	3,600	4,700
Fumonisin B1 + B2					
NDSU 1st	5,169	31,012	32,410	26,583	27,109
NDSU 2nd	4,201	30,476	30,790	26,892	29,983
Trilogy	3,200	23,300	24,000	20,900	23,900
Fumonisin B3					
Trilogy	400	2,700	2,600	2,100	2,600
Aflatoxin B1	< 20	< 20	< 20	< 20	< 20
Aflatoxin B2	< 20	< 20	< 20	< 20	< 20
Aflatoxin G1	< 20	< 20	< 20	< 20	< 20
Aflatoxin G2	< 20	< 20	< 20	< 20	< 20
HT-2 toxin	< 200	< 200	< 200	< 200	< 200
T-2 toxin	< 20	< 20	< 20	< 20	< 20
Ochratoxin	< 20	< 20	< 20	< 20	< 20
Sterigmatocystin	< 20	< 20	< 20	< 20	< 20
Zearalenone	< 100	< 100	< 100	< 100	< 100
Vomitoxin	< 200	< 200	< 200	< 200	< 200

[1]A representative sample of each diet was collected from 24 bags of feed for each treatment.
[2]All mycotoxins were analyzed at North Dakota State University Veterinary Diagnostic Laboratory (Fargo, ND) by LC/MS/MS. The standard curve for fumonisin was up to 10 ppm.
[3]Fumonisin B1, B2, and B3 were analyzed at Trilogy laboratory (Washington, MO) by LC/MS/MS. The standard curve for fumonisin was up to 10 ppm.

Table 5. Effect of commercial products on growth performance of nursery pig fed diets with fumonisin-contaminated corn, Exp. 1[1,2]

Item	Positive control	Negative control	Negative control with Kallsil Dry	Feed Aid	Biofix	SEM
BW, lb						
d 0	21.8	21.8	21.9	21.8	21.7	--[5]
d 14	36.7[a]	30.3[b]	29.0[b]	29.9[b]	35.7[a]	0.67
d 27	57.6[a]	50.1[b]	48.0[b]	49.0[b]	56.8[a]	0.95
d 0 to 14 (treatment period)[3]						
ADG, lb	1.06[a]	0.59[b]	0.50[b]	0.57[b]	1.00[a]	0.03
ADFI, lb	1.58[a]	1.23[b]	1.12[b]	1.14[b]	1.52[a]	0.04
F/G	1.49[b]	2.11[a]	2.26[a]	2.11[a]	1.52[b]	--[6]
d 14 to 27 (post-treatment period)[4]						
ADG, lb	1.57[ab]	1.50[bc]	1.44[c]	1.47[bc]	1.62[a]	0.03
ADFI, lb	2.61[a]	2.22[b]	2.17[b]	2.22[b]	2.58[a]	0.05
F/G	1.67[a]	1.48[c]	1.50[c]	1.51[c]	1.59[b]	0.02

[a,b,c]Means within a row with different superscripts differ (*P* < 0.05).
[1]A total of 350 pigs (241 × 600; DNA, Columbus, NE; initially 21.8 lb) were used in a 27-d experiment with 5 pigs per pen and 14 pens per treatment. Except for positive control (low FUM), other treatment diets contain approximately 50 to 60 ppm of FUM.
[2]BW = body weight. ADG = average daily gain. ADFI= average daily feed intake. F/G = feed efficiency.
[3]Except for pigs in positive control group, all other pigs were fed high FUM diets for 14 d.
[4]All pigs were fed low FUM common diet for 13 d.
[5]Heterogenous SEM: Positive control (0.32), negative control (0.33), Kallsil Dry (0.32), Feed Aid (0.32), and Biofix (0.37).
[6]Heterogenous SEM: Positive control (0.01), negative control (0.08), Kallsil Dry (0.08), Feed Aid (0.12), and Biofix (0.03).

Table 6. Effect of commercial products on growth performance of nursery pig fed diets with fumonisin-contaminated corn, Exp. 2[1,2]

Item	Positive control	Negative control	Negative control with Kallsil Dry	Feed Aid	Biofix	SEM
BW, lb						
d 0	23.0	23.1	22.9	23.1	22.9	0.40
d 28	62.6[a]	55.1[b]	57.0[b]	56.1[b]	62.5[a]	1.15
ADG, lb	1.38[a]	1.14[b]	1.20[b]	1.16[b]	1.38[a]	0.03
ADFI, lb	2.00[ab]	1.86[b]	1.91[ab]	1.86[b]	2.06[a]	0.05
F/G	1.46[b]	1.63[a]	1.59[a]	1.61[a]	1.49[b]	0.02

[a,b]Means within a row with different superscripts differ (*P* < 0.05).
[1]A total of 300 pigs (241 × 600; DNA, Columbus, NE; initially 23.0 lb) were used in a 28-d experiment with 5 pigs per pen and 12 pens per treatment. Except for positive control (low FUM), other treatment diets contain approximately 30 ppm of FUM.
[2]BW = body weight. ADG = average daily gain. ADFI= average daily feed intake. F/G = feed efficiency.