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

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

**Abstract**

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 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.

**Keywords**
corn, fumonisin (FUM), nursery, pigs

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**Authors**


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

Zhong-Xing Rao, Mike D. Tokach, Steve S. Dritz,1 Jason C. Woodworth, Joel M. DeRouchey, Robert D. Goodband, and Hilda Calderon Cartagena2

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 Industries Inc., Des Moines, IA; Feed Aid Wide Spectrum, NutriQuest, Mason City, IA; Biofix Select Pro, Biomin America Inc., Overland Park, KS).

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-

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 heterogeneous 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 $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

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.

*Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.*
Table 1. Diet composition, Exp. 1 (as-fed basis)\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Positive control</th>
<th>Negative control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ingredients, %</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>64.70</td>
<td>---</td>
</tr>
<tr>
<td>Fumonisin corn(^3)</td>
<td>---</td>
<td>64.48</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>28.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Monocalcium phosphate</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>L-Lysine HCl</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>DL-Methionine</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>L-Threonine</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>L-Tryptophan</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>L-Valine</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>Vitamin premix</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Trace mineral premix</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Phytase(^4)</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Sand</td>
<td>---</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Standard ileal digestible (SID) amino acids, %

<table>
<thead>
<tr>
<th>Item</th>
<th>Positive control</th>
<th>Negative control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysine</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>Isoleucine:lysine</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>Leucine:lysine</td>
<td>111</td>
<td>111</td>
</tr>
<tr>
<td>Methionine:lysine</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Met and cysteine:lysine</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Threonine:lysine</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Tryptophan:lysine</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Valine:lysine</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>Histidine:lysine</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td><strong>Net energy, kcal/lb</strong></td>
<td>1,152</td>
<td>1,149</td>
</tr>
<tr>
<td><strong>Crude protein, %</strong></td>
<td>19.8</td>
<td>19.8</td>
</tr>
<tr>
<td><strong>Calcium, %</strong></td>
<td>0.61</td>
<td>0.61</td>
</tr>
<tr>
<td><strong>STTD P, %</strong></td>
<td>0.44</td>
<td>0.44</td>
</tr>
</tbody>
</table>

\(^1\)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)

<table>
<thead>
<tr>
<th>Item</th>
<th>Positive control¹</th>
<th>Negative control²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exp. 1 diet</td>
<td>---</td>
<td>62.50</td>
</tr>
<tr>
<td>Positive control¹</td>
<td>---</td>
<td>37.39</td>
</tr>
<tr>
<td>Corn</td>
<td>64.70</td>
<td>---</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>28.00</td>
<td>---</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>3.00</td>
<td>---</td>
</tr>
<tr>
<td>Monocalcium phosphate</td>
<td>0.85</td>
<td>---</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>0.75</td>
<td>---</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>0.60</td>
<td>---</td>
</tr>
<tr>
<td>L-Lysine HCl</td>
<td>0.55</td>
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</tr>
<tr>
<td>DL-Methionine</td>
<td>0.21</td>
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<tr>
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<tr>
<td>L-Valine</td>
<td>0.16</td>
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<tr>
<td>Vitamin premix</td>
<td>0.25</td>
<td>---</td>
</tr>
<tr>
<td>Trace mineral premix</td>
<td>0.15</td>
<td>---</td>
</tr>
<tr>
<td>Phytase³</td>
<td>0.08</td>
<td>---</td>
</tr>
<tr>
<td>Sand</td>
<td>---</td>
<td>0.11</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

| 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, %                 | 0.44                | 0.44              |

¹Positive control diet was identical to the positive control diet used in experiment 1 and used as blending diet.
²Three 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.
³Ronozyme HiPhos GT 2700 (DSM Nutritional Products, Basel, Switzerland) provided 306 FTU per lb of feed and an expected P release of 0.10%.
⁴STTD P = standardized total tract digestible phosphorus.
Table 3. Dietary mycotoxin levels, Exp. 1 (as-fed basis, ppb)\textsuperscript{1,2,3}

<table>
<thead>
<tr>
<th>Item</th>
<th>Positive control</th>
<th>Negative control</th>
<th>Negative control with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kallsil Dry</td>
</tr>
</tbody>
</table>

- **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

\textsuperscript{1}A representative sample of each diet was collected from every fifth bag of feed manufactured for each treatment.

\textsuperscript{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.

\textsuperscript{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>
<thead>
<tr>
<th>Item</th>
<th>Positive control</th>
<th>Negative control</th>
<th>Negative control with</th>
<th>Kallsil Dry</th>
<th>Feed Aid</th>
<th>Biofix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fumonisin B1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDSU 1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>4,104</td>
<td>24,957</td>
<td>25,100</td>
<td>21,409</td>
<td>20,593</td>
<td></td>
</tr>
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<td>NDSU 2&lt;sup&gt;nd&lt;/sup&gt;</td>
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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     |        |     |
| d 14                     | 36.7\(^{a}\)     | 30.3\(^{b}\)     | 29.0\(^{b}\)          | 29.9\(^{b}\) | 35.7\(^{a}\) |        |     |
| d 27                     | 57.6\(^{a}\)     | 50.1\(^{b}\)     | 48.0\(^{b}\)          | 49.0\(^{b}\) | 56.8\(^{a}\) | 0.67   |     |
| d 0 to 14 (treatment period)\(^{3}\) |                  |                  |                       |             |          |        |     |
| ADG, lb                  | 1.06\(^{a}\)     | 0.59\(^{b}\)     | 0.50\(^{b}\)          | 0.57\(^{b}\) | 1.00\(^{a}\) |        |     |
| 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\(^{b}\) |        |     |
| d 14 to 27 (post-treatment period)\(^{4}\) |                  |                  |                       |             |          |        |     |
| ADG, lb                  | 1.57\(^{ab}\)    | 1.50\(^{bc}\)    | 1.44\(^{bc}\)         | 1.47\(^{bc}\) | 1.62\(^{a}\) | 0.03   |     |
| ADFI, lb                 | 2.61\(^{a}\)     | 2.22\(^{b}\)     | 2.17\(^{b}\)          | 2.22\(^{b}\) | 2.58\(^{b}\) | 0.05   |     |
| F/G                      | 1.67\(^{a}\)     | 1.48\(^{a}\)     | 1.50\(^{c}\)          | 1.51\(^{c}\) | 1.59\(^{b}\) | 0.02   |     |

\(^{a, b}\)Means within a row with different superscripts differ (\(P < 0.05\)).

\(^{1}\)A total of 350 pigs (241 \(\times\) 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     |        |     |
| 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 \(\times\) 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.