SIGNIFICANCE OF FEED-BORNE *FUSARIUM* MYCOTOXINS ON LIVESTOCK HEALTH AND REPRODUCTION

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SUMMARY

Reproducing pigs, broiler chickens and dairy cows are all adversely affected by feed-borne *Fusarium* mycotoxins. The most significant economic effect is likely immunosuppression resulting in increased frequency of secondary mycotoxic diseases, lack of response to medications and failure of vaccination programs. Contaminated feedstuffs should be fed only with caution.

Keywords: *Fusarium* mycotoxins, reproduction, pigs, broiler breeders, dairy cows, immuno-suppression

INTRODUCTION

Mycotoxins are fungal metabolites which can reduce performance and alter metabolism of livestock and poultry (Wannemacher *et al*., 1991). The pathological states arising from the consumption of feeds contaminated with mycotoxins are mycotoxicoses. Mycotoxins can be formed in the field preharvest and may continue to be formed under suboptimal storage conditions postharvest. High moisture content often predisposes feedstuffs to fungal growth and mycotoxin formation. Temperature is another key factor. Some fungi, such as *Aspergillus flavus*, are usually found in tropical and semi-tropical climates. This mould produces the carcinogenic hepatotoxin aflatoxin. *Fusarium* fungi, however, are more common in temperate climates and *Fusarium* mycotoxins are likely the most common mycotoxins on a global basis (Wood, 1992).

There are many reports of the effects of *Fusarium* mycotoxins on growth rates and metabolism in livestock and poultry but less research has been devoted to the effects of *Fusarium* mycotoxins on reproduction. This is no doubt a reflection of the complexity of such experiments. Ruminant animals have been considered to be more resistant to the effects of feed-borne mycotoxins because of the detoxifying potential of rumen microorganisms. Charmley *et al.* (1993), Ingalls (1996) Trenholm *et al*. (1985) reported few adverse effects of deoxynivalenol (DON, vomitoxin) contaminated feed on performance of lactating and non-lactating dairy cows. Friend *et al*. (1983) fed 3.45 mg DON / kg feed to gestating sows and noted a significant reduction in feed intake, body weight gain, fetal length and fetal weight at 20–54 days of gestation. Chavez (1984) fed sows naturally-contaminated wheat to provide up to 3.29 mg DON / kg feed for the last 90 days of gestation. No effect was seen on litter size or piglet weight at birth but reduced feed intake and weight gain were observed. There have been even fewer reports of the effect of feed-borne *Fusarium* mycotoxins on reproduction in broiler breeder chickens. Brake *et al*. (1999) fed up to 20 mg diacetoxyscirpenol (DAS)/kg feed to breeder hens and roosters and observed decreased fertility in broiler breeder males.

Experiments were conducted, therefore, to determine the effect of feed-borne *Fusarium* mycotoxins on reproduction and metabolism in sows, broiler breeder hens and roosters and lactating dairy cows.

MATERIALS AND METHODS

FEEDING TRIAL WITH DAIRY CATTLE

A study was conducted to determine the effect of feeding lactating dairy cows TMR containing wheat, corn and hay naturally-contaminated with *Fusarium* mycotoxins. A total of 18 mid-lactation Holstein cows (6 cows per diet) with an average milk production of 30 – 35 kg / day were fed for 56 days. Treatments included: (1) control (2) contaminated grains (3) contaminated grains + 0.2% GMA (Mycosorb, Alltech Inc., Nicholasville, KY), a polymeric glucomannan mycotoxin adsorbent. DON was the major contaminant and was found at up to 3.6 mg/kg in TMR dry matter. Zearalenone and 15-acetyl DON were found in lesser concentrations. Body weight, body condition score, milk production, milk composition, somatic cell count (SCC), blood serum chemistry, haematology, total immunoglobulin (Ig) count and coagulation profile were measured.

FEEDING TRIALS WITH SWINE

A study was conducted to determine the effects of feeding a blend of corn and wheat naturally-contaminated with *Fusarium* mycotoxins to gestating and lactating sows. A total of 36 first parity Yorkshire gilts (12 per treatment) were housed in individual stalls for 21 days before farrowing and 21 days after farrowing. During gestation, feed was restricted to 2.4 kg/pig/day. Treatments included (1) control (2) contaminated grains (3) contaminated grains + 0.2% GMA. DON was the major contaminant and was present at 5.7 mg/kg in contaminated diets and 0.2 mg/kg in the control diet. Zearalenone and 15-acetyl DON were found in lesser concentrations. Parameters measured included body weight change, feed consumption, numbers and weights of piglets born, numbers of stillborn and mummified piglets, milk composition, and viability of piglets until weaning, blood chemistry and weaning to oestrus interval.

FEEDING TRIAL WITH POULTRY

A study was conducted to determine the effects of feeding a blend of corn and wheat naturally-contaminated with *Fusarium* mycotoxins to broiler breeder hens and roosters. Forty-two 26-wk-old broiler breeder hens and nine roosters (Ross 308) were weighed and randomly assigned to individual wire cages serving as 14 and 3 replicates respectively for each of the three treatment groups. Feed consumption of hens was restricted to 133 g/bird/d increasing to 155 g/bird/d at the end of the experiment. Diets included (1) control (2) contaminated grains (3) contaminated grains + 0.2% GMA. The major contaminant was DON which was found at about 13 mg/kg in contaminated diets and 0.2 mg/kg in the control diet. Zearalenone and 15-acetyl DON were again found in lesser concentrations. Contaminated rooster diets contained an average of 7.8 mg/kg DON with the control diet containing 0.9 mg/kg. Hens were individually inseminated three times during the week before egg collection with 50 ul of fresh pooled semen from roosters fed corresponding diets. Experimental parameters measured included feed consumption, body weight change, egg production, egg weight, shell deformity, albumin height, yolk weight, shell weight, shell thickness, weights of liver, spleen and kidney, biochemistry, haematology, serology, hatchability, progeny performance and rooster fertility.

DETERMINATION OF DIETARY MYCOTOXIN CONCENTRATIONS
Dietary contents of 19 mycotoxins including DON, 3-acetyl DON, 15-acetyl DON, nivalenol, T-2 toxin, iso T-2 toxin, acetyl T-2 toxin, HT-2 toxin, T-2 triol, T-2 tetraol, fusarenone-X, diacetoxyscirpenol (DAS), scirpentriol, 15-acetoxyscirpentriol, neosolaniol, zearalenone, zearalenol, aflatoxin and fumonisin were analyzed by gas chromatography and mass spectrometry (Raymond *et al*., 2003). The detection limits were 0.2 mg/kg with exception of aflatoxin and fumonisin which were detected at 0.02 and 2 mg/kg respectively.

RESULTS AND DISCUSSION

FEEDING TRIAL WITH DAIRY CATTLE
There was no effect of diet on feed consumption, body weight change, body condition score, milk production, milk composition or milk somatic cell count. Total serum protein and globulin concentrations were increased after 42 days of feeding in cows fed contaminated TMR while albumin:globulin ratio decreased compared to controls (Table 1). Cows fed contaminated TMR + GMA were not significantly different from controls. These changes might reflect the beginning of liver damage due to mycotoxin exposure. The changes in serum proteins do not appear to be a sign of acute inflammation as there was no elevation in other markers of inflammation.

The feeding of contaminated TMR resulted in a continuous elevation in serum urea concentrations throughout the experiment and this effect was prevented by dietary supplementation with GMA. It is not clear whether the elevated blood urea concentrations are due to the effect of DON and other trichothecene mycotoxins in inhibiting protein synthesis in rumen microbes or in inhibiting hepatic protein synthesis.

The feeding of contaminated TMR also significantly reduced serum IgA concentrations after 36 days of feeding and this was prevented by dietary supplementation with GMA. This likely reflects the immunosuppressive effects of *Fusarium* mycotoxins as has been described in monogastric species.

It was concluded that feed naturally contaminated with *Fusarium* mycotoxins, even in low concentrations, can affect metabolic parameters and immunity of dairy cows and the feeding of GMA can prevent many of these effects

FEEDING TRIALS WITH SWINE
There was no effect of diet on average daily feed intake of gilts in gestation (Table 2). Weight gain and gain:feed ratios, however, were reduced by the feeding of contaminated grains and this was prevented by the feeding of GMA. Serum chemistry was unaffected by diet. The percentage of stillbirths was higher and the total piglets born was lower for gilts fed contaminated grains compared to those fed contaminated grains + GMA. There was no effect of diet on frequency of mummies at birth, total piglets born or body weight of piglets at birth. In the lactation period, feed intake and weight gain were reduced by diets containing contaminated grains (Table 3). Blood chemistry, milk composition and piglet weights at weaning were not affected by diet. There was a strong trend, however, to increase weaning to oestrus interval when sows were fed contaminated grains.

It was concluded that the feeding of grains naturally contaminated with *Fusarium* mycotoxins to gestating and lactating sows results in increased numbers of stillborn piglets but piglets that are born alive are viable and thrive throughout the lactation period. This is achieved, however, by a marked depletion of body reserves resulting in trend towards increased weaning to oestrus intervals.

FEEDING TRIALS WITH POULTRY

There was no effect of diet on feed consumption or feed efficiency (feed consumed / egg produced) and body weights were also not affected (Table 4). There was a trend towards reduced egg production in birds fed the contaminated grains and this was significant in week 6. The feeding of contaminated grains did, however, reduce eggshell thickness after 4 weeks and this was accompanied by an increase in early (1–7 d) embryonic mortality. These effects were prevented by the feeding of GMA. It has been demonstrated that shell thickness affects moisture loss during incubation prompting early embryonic mortality. There was no effect of diet on other egg parameters including weight, yolk weight, albumen height, eggshell deformity or eggshell weight. Weights of liver, spleen and kidney were also not affected by diet. There was no effect of diet on weight or viability of newly hatched chicks.

The feeding of contaminated grains decreased serum antibody titres against infectious bronchitis virus after 12 weeks and this was prevented by the feeding of GMA. There was no effect of diet, however, on serum antibody titres against Newcastle disease virus. The absence of the effect of diet on titres against Newcastle disease virus is likely due to the fact that Newcastle disease is not endemic in Canada. Reduced antibody titres against infectious bronchitis is a reflection of the immunosuppressive properties of the trichothecene mycotoxins.

Rooster semen volume and sperm concentration, viability, motility and relative weights of testes were not significantly affected by diet.

CONCLUSIONS

It can be concluded that there are adverse effects of feed-borne *Fusarium* mycotoxins on reproduction in swine, poultry and dairy cows with the severity declining in that order. These effects can largely be prevented by the feeding of GMA. This has important economic consequences when wide spread contamination of the feed supply forces the feeding of contaminated grains or when favourable pricing prompts the intentional feeding of contaminated materials.

REFERENCES

Brake, J., P.B. Hamilton and R.S. Kittrell. 2002. Effect of the trichothecene mycotoxin diacetoxyscirpenol on egg production of broiler breeders. Poult. Sci. 81: 1807–1810.

Charmley, E., Trenholm, H.L., Thompson, B.K., Vudathala, D., Nicholson, J.W.G., Prelusky, D.B. and Charmley L.L. 1993. Influence of level of deoxynivalenol in the diet of dairy cows on feed intake, milk production, and its composition. J. Dairy Sci. – 3587.

Chavez, E.R. 1984. Vomitoxin-contaminated wheat in pig diets: pregnant and lactating gilts and weaners. Can. J. Anim. Sci. 64: 717–723.

Diaz-Llano, G. and T.K. Smith. 2006. Effects of feeding grains naturally contaminated with *Fusarium* mycotoxins with and without a polymeric glucomannan mycotoxin adsobent on reproductive performance and serum chemistry of pregnant gilts. J. Anim. Sci. 84: 2361–2366.

Diaz-Llano, G. and T.K. Smith. 2007. The effects of feeding grains naturally contaminated with *Fusarium* mycotoxins with and without a polymeric glucomannan mycotoxin adsorbent on lactation, serum chemistry and reproductive performance after weaning of first-parity lactating sows. J. Anim. Sci. 85: *in press*.

Friend, D.W., H.L. Trenholm, P.S. Fiser, B.K. Thompson and K.E. Hartin. 1983. Effect on dam performance and fetal development of deoxynivalenol (vomitoxin) contaminated wheat in the diet of pregnant gilts. Can. J. Anim. Sci. 63: 689–698.

Ingalls, J.R. 1996. Influence of deoxynivalenol on feed consumption by dairy cows. Anim. Feed Sci. Tech. 60: 297–300.

Raymond, S.L., T.K. Smith and H.V.L.N. Swamy. 2003. Effects of feeding a blend of grains naturally contaminated with *Fusarium* mycotoxins on feed intake, serum chemistry, and haematology of horses, and the efficacy of a polymeric glucomannan mycotoxin adsorbent. J. Anim. Sci. 81: 2123–2130.

Trenholm, H.L., B.K. Thompson, K.E. Hartin, R. Greenhalgh and A.J. McAlister. 1985. Ingestion of vomitoxin (deoxynivalenol) contaminated wheat by nonlactation dairy cows. J. Dairy Sci. 68: 3580 – 3587.

Wannemacher, R.W., D.L. Bunner, and H.A. Neufeld. 1991. Toxicity of trichothecenes and other related mycotoxins in laboratory animals. *In: Mycotoxins and Animal Feeds* (J.E. Smith and R.S. Henderson, eds) CRC Press, Boca Raton, FL.

Wood, G.E. 1992. Mycotoxins in foods and feeds in the United States. J. Anim. Sci. 70: 3941–3949.

Yegani, M., T.K. Smith, S. Leeson and H.J. Boermans. 2006. Effects of feeding grains naturally contaminated with *Fusarium* mycotoxins on performance and metabolism of broiler breeders. Poult. Sci. 85: 1541–1549.

Table 1. Effect of feeding TMR naturally-contaminated with *Fusarium* mycotoxins on production and metabolism of dairy cows

Diet	Feed Intake (kg/cow/day)	Milk Production (kg/cow/day)	SSC (sc/ml x 10^3)	Serum IgA (g /L serum)	Serum Urea (mmol/L)
Control	48.5	30.0	64.56	0.35	5.3
Contaminated	49.5	34.0	57.25	0.16	6.3
Contaminated + 0.2% GMA	44.4	28.9	40.88	0.27	5.5
Control vs Contaminated	NS[1]	NS	NS	0.01	0.01
Control vs Contaminated + GMA	NS	NS	NS	NS	NS

[1]Not significant (P>0.05)

Table 2. Effect of feeding blends of grains naturally-contaminated with *Fusarium* mycotoxins on performance of gestating gilts[1]

Diet	ADFI (kg/d)	ADG (kg/d)	G:F %	Stillbirths %	Born Alive
Control	2.41[a]	1.14[a]	0.37[a]	6.27[a,b]	90.5[a,b]
Contaminated grains	2.12[a]	0.62[b]	0.19[b]	15.52[b]	80.8[b]
Contaminated grains + 0.2% GMA	2.15[a]	0.80[a,b]	0.37[a,b]	4.6[a]	95.4[a]

[1]From Diaz-Llano and Smith, 2006.
[a,b,c]Means within a row with different superscripts are different (P<0.05).

Table 3. Effect of feeding blends of grains naturally-contaminated with *Fusarium* mycotoxins on performance of lactating sows[1]

Diet	ADFI (kg/d)	ADG (kg/d)	Weaning To Estrus Interval (d)
Control	4.87[a]	0.050[a]	6.33[a]
Contaminated grains	3.56[b]	–0.592[b]	15.00[a]
Contaminated grains	3.43[b]	–0.465[b]	15.33[a]

[1] From Diaz-Llano and Smith, 2007
[a,b,c] Means within a row with different superscripts are different (P<0.05)

Table 4. Effect of feeding blends of grains naturally-contaminated with *Fusarium* mycotoxins on performance of broiler breeder hens[1]

Diet	Egg Production (%)	Eggshell Thickness (um)	Early Embryonic Mortality (%)	IBV titre
Control	84.3	32.1	5.4	12,653
Contaminated grains	78.8	30.1	21.5	8,012
Contaminated grains + 0.2% GMA	86.7	31.5	2.3	9,340
Control vs	NS[2]	0.04	0.03	0.02
Contaminated				
Control vs Contaminated + GMA	NS	NS	NS	NS

[1] From Yegani et al., 2006
[2] Not significant (P>0.05)