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ORIGINAL PAPER

Effects of deoxynivalenol (DON) in the lactation diet on the feed intake and fertility of sows

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Abstract A diet contaminated with 2.8 mg deoxynivalenol (DON)/kg was fed at 6 kg per day to 32 mycotoxin-exposed pluriparous sows (M) during lactation. The 31 control sows (C) received 6 kg of an uncontaminated diet. Although more contaminated diet was refused (P=0.05), DON exposure had no effect (P>0.1) on body weight loss of the sows during lactation (M: 27.9±12.3 kg; C: 29.7±10.2 kg), the number of weaned piglets (M: 9.8±1.4; C: 9.7±1.6) and their daily weight gain (M: 266±70 g; C: 272±64 g). Several sows were culled after weaning for reasons unrelated to the experiment. Compared with the remaining 21 C sows, the remaining 26 M sows had an identical interval between weaning and the next farrowing (M: 120±1 days; C: 120±1 days) and a similar litter size (M: 14.5±2.7; C: 14.9±3.0; P>0.10). The daily intake of 17 mg DON during lactation thus did not affect the reproductive performance of the sows.

Keywords Deoxynivalenol · Fertility · Sow · Piglet · Feed intake

Introduction

Cereal plants grown in regions with a temperate climate are often infected by *Fusarium* fungi, which are capable of producing various mycotoxins. Pigs are very sensitive to deoxynivalenol (DON), the *Fusarium* toxin most frequently detected in cereal grains. Feed intake of ad libitum fed growing pigs is reduced at dietary DON levels as low as 1 mg/kg, whereas higher doses of DON are cytotoxic (Pestka 2007). The viability of spermatozoa, oocytes and embryos is therefore likely to be affected by DON.

In most experimental investigations of the effects of DON on the reproductive performance of pigs, exposure to DON only began once the gilts had been mated (Friend et al. 1983, 1986; Chavez 1984; Etienne et al. 2006; Diaz-Llano and Smith 2006; Dänicke et al. 2007; Goyarts et al. 2007). No negative effects on reproductive performance were observed in these trials as long as dietary DON did not markedly affect feed intake. However, in the aforementioned experiments the question of whether mycotoxin exposure before oestrus affects the fertility of pigs was not studied. Alm et al. (2006) reported that the intake of diets containing 6–10 mg DON/kg and 0.2–0.4 mg zearalenone/kg affected oocyte quality and postulated that impaired oocyte quality may in turn affect the reproductive performance of pigs. Gutzwiller et al. (2009), feeding gilts a diet contaminated with 2 mg DON/kg and 0.4 mg zearalenone/kg starting 2 months before mating, observed no negative effects on their fertility, possibly because DON exposure was lower than in the experiment reported by Alm et al. (2006). In the experiment reported here, the effects of a DON-contaminated diet fed to lactating sows were thus studied for the following reasons. The nutrient requirements—and therefore also feed intake—are high during lactation, resulting in a high mycotoxin intake even at a moderate mycotoxin contamination of the feed. Moreover, as milk production has priority over maintenance of body reserves, a reduced feed intake caused by an aversion to the DON-contaminated feed could result in excessive body weight loss, a condition known to affect fertility (Close and Cole 2000). In the present experiment, the effects of DON exposure on the feed intake of lactating sows, growth of the suckled piglets and on fertility in the subsequent reproduction period were studied.

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Table 1 Composition of the DON-contaminated (*M*) and uncontaminated (*C*) lactation diets (amount per kilogram of air-dried feed). *ND* not detected; the detection limit was 0.2 mg and 0.05 mg per kg for DON and zearalenone, respectively

	M	C
Ingredients, g/kg		
Contaminated wheat	400	
Uncontaminated wheat		400
Barley	323	330
Soybean meal, expelled	100	100
Rapeseed meal, expelled	50	50
Potato protein	57	51
Mixed animal fat	35	34
L-Lysine HCl	3.0	3.0
L-Threonine	0.4	0.5
L-Tryptophan	0.1	0.1
Dicalcium phosphate	8.8	8.8
Calcium carbonate	9.6	9.6
Sodium chloride	4.9	5.0
Vitamin-trace element premix	4.0	4.0
Pelleting aid	4.0	4.0
Metabolisable energy (calculated), MJ/kg	13.9	13.9
Proximate analysis, g/kg		
Dry matter	880	890
Crude protein	190	190
Crude fibre	50	40
Crude fat	60	50
Ash	50	50
Nitrogen-free extract (calculated)	530	560
Mycotoxin analysis, mg/kg		
Deoxynivalenol (DON)[a]	2.8	ND
Zearalenone[b]	ND	ND

[a] Determined by gas chromatography-mass spectroscopy analysis

[b] Determined by ELISA

Animals, material and methods

Feed manufacturing, sampling and analysis A batch of DON-contaminated wheat from a wheat field with *Fusarium* head blight was acquired from a feed mill. Two pelleted lactation diets for sows, one containing 40% mycotoxin-contaminated wheat (diet M) and one containing 40% uncontaminated wheat (control diet C), were manufactured in the feed mill of Agroscope (Table 1). Because minor differences in nutrient levels can affect feed intake and animal performance, both diets were formulated to contain equal amounts of nutrients and digestible energy (DE), using the feed formulation programme Allix2 (A-Systems, Versailles, France).

The proximate nutrients (crude protein, crude fat, crude fibre and ash) of the feedstuffs and of the two experimental feeds were analysed as described by Naumann and Bassler (1997). All batches of wheat, barley, soybean meal and rapeseed meal used as ingredients of the two lactation diets were analysed for DON and zearalenone using ELISA tests (Ridascreen Fast DON and Ridascreen Fast zearalenone, r-biopharm, Darmstadt, Germany) with a detection limit of 0.2 mg/kg for DON and 0.05 mg/kg for zearalenone. Zearalenone was detected in none of the ingredients, and DON was detected in the contaminated wheat batch only. The positive DON result of the wheat batch was confirmed using gas chromatography-mass spectrometry after extraction with an acetonitrile/water mixture and a clean-up in a Mycosep column (Romer Labs, Tulln, Austria). The detection limit of this method for DON was 0.2 mg/kg. Gas chromatography-mass spectrometry was also used for the analysis of DON in diets M and C. The trichothecene mycotoxins, acetyl-deoxynivalenol, nivalenol, 4-acetylnivalenol, T-2 toxin, HT-2 toxin and diacetoxy-scirpenol, were furthermore analysed in a sample of contaminated wheat in an external laboratory using the HPLC method.

Table 2 Effect of DON contaminated (*M*) and uncontaminated (*C*) feed offered during lactation on piglet and sow performance

	M[a]	C	*P* value[b]
Sows, *n*	32	31	
Lactation period, days	38.1±4.9	38.2±4.9	0.92
Suckled piglets, *n*	10.3±1.3	10.1±1.5	0.68
Weaned piglets, *n*	9.8±1.4	9.7±1.6	0.78
Piglet body weight at 8 days of life, kg	2.90±0.69	2.96±0.74	0.30
Piglet weight gain 8th–28th day, g/day	266±70	272±64	0.30
Sow feed allowance, kg/day	6.1±0.5	6.1±0.5	0.82
Sow feed intake, kg/day	6.0±0.6	6.1±0.5	0.42
Sow BW after farrowing[c], kg	261±33	266±29	0.57
Sow BW loss during lactation, kg	27.9±12.3	29.7±10.2	0.54

[a] Diet M was offered from the 8th day after farrowing until weaning

[b] Probability of error using the two-tailed *t*-test to compare the data of the two groups

[c] The sows were weighed within 24 h after farrowing

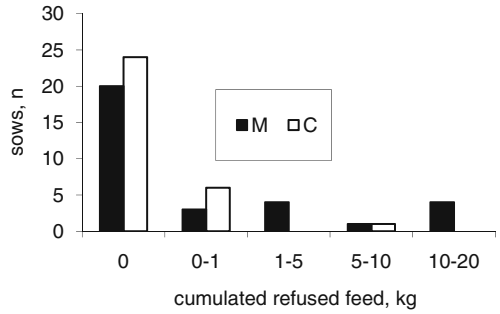

Fig. 1 Effect of DON-contaminated (*M*) and uncontaminated (*C*) feed offered on cumulated feed leftovers from the 8th day of lactation until weaning 38 days after farrowing. The mycotoxin-exposed sows M tended to refuse more feed than the control sows C ($P=0.05$; Mann-Whitney test)

Animals and experimental procedures Pluriparous Large White sows originating from the ALP sow herd, which farrowed between May and November 2007, were used in the experiment. Standard management practices such as ear-tagging of the newborn piglets, iron supplementation by injection, castration of the male piglets and culling of sows after weaning were maintained during the study. The sows were transferred to the individual farrowing pens 1 week before farrowing and remained there until the piglets were weaned. Since piglet mortality caused by inanition and crushing is highest during the first few days of life and the number of suckled piglets was an important criterion for sow allocation to the treatment groups, each sow entered the experiment when the piglets were 1 week old. A total of 63 sows suckling at least eight piglets were equally assigned to dietary treatments M (mycotoxin) and C (negative control) taking into account the number of suckled piglets, the sows' body weight (BW), the number of previous farrowings and the size of the previous litters.

The 31 C sows continued to receive the uncontaminated control diet C which had been fed to all sows during the first week of lactation, whereas the 32 M sows received the mycotoxin contaminated diet M until the piglets were weaned. The daily feed allowance for the lactating sows was 2.2 kg for maintenance plus 0.4 kg for each suckled piglet. The pelleted lactation feed was offered twice a day in a trough where it was mixed with water. Feed leftover was collected, dried at 60°C for 24 h and weighed. The piglets had access to an uncontaminated creep feed. They were weighed at the age of 8 and 28 days and were weaned at an average age of 38 days.

On the day of weaning, the sows were weighed and transferred to the breeding unit, where they were fed an uncontaminated diet. Ten C sows and six M sows were culled after weaning for reasons unrelated to the experiment. The sows of group M and C which remained in the experiment did not differ as to BW after farrowing, parity and the size of the previous litters. They were mated during the first oestrus after weaning and were then moved to the group pen for gestating sows. Sows returning to oestrus after 3 weeks were mated again. Sows which were not pregnant after one or two oestrus periods were culled. At the next farrowing, the newborn piglets were counted and weighed.

The experiment was approved by the competent Swiss authorities (approval no.: FR 66/06, 2006).

Statistics The data were analysed using the statistics software NCSS 2000 (NCSS, Kaysville, Utah, USA). The Mann-Whitney test was used to compare the cumulated amount of refused feed between the two treatment groups, whereas the other data were compared using the two-tailed *t*-test. Differences were considered statistically significant at $P<0.05$.

Results and discussion

The composition and the concentration of proximate nutrients of both experimental lactation diets (Table 1) were similar. Except for DON, which was detected at concentrations of 7.5 and 2.8 mg/kg in the contaminated wheat and diet M, respectively, no *Fusarium* toxins were detected. The levels of acetyl-deoxynivalenol, nivalenol, 4-acetylnivalenol, and of T-2 toxin, HT-2 toxin and diacetoxyscirpenol in the contaminated wheat were below the detection limits of 0.05 and 0.03 mg/kg, respectively. The zearalenone concentration in the contaminated wheat was below the detection limit of 0.05 mg/kg.

Table 3 Effect of DON-contaminated (*M*) and uncontaminated (*C*) feed offered during lactation on fertility traits

	M	C	P^b
Sows remaining in the experiment, *n*	26	21	
Interval weaning-oestrus, days	4.3±0.5	4.5±0.7	0.25
Interval weaning-next farrowing, days	120±0.9	120±1.3	0.78
Sows not pregnant after 2 matings, *n*	1	1	
Farrowing sows, *n*	25	19[a]	
Litter size, *n*	14.5±2.7	14.9±3.0	0.66
Litter weight, kg	20.3±3.7	21.1±4.1	0.48

[a] One animal of treatment C died 2 weeks after mating

[b] Probability of error using the two-tailed *t*-test to compare the data of the two groups

The number of previous parities (M: 3.6±1.9; C: 2.0±0.4; P=0.45) and the length of the lactation period (M: 38.1±4.9 days; C: 38.2±4.9 days; P=0.92) did not differ between the two groups of sows. The intake of the DON contaminated diet by the sows influenced neither the mortality nor the growth of the piglets (Table 2). Although the cumulated amount of refused feed tended to be higher (P=0.05) in group M (Fig. 1), these feed refusals, which represented on average less than 2% of the M diet offered, did not significantly affect feed intake and BW loss of the sows (Table 2). As can be seen in Fig. 1, the sows differed very much in their aversion to the DON-contaminated feed: whereas 20 sows completely ate up their ration, four sows refused up to 10% of their feed.

Most sows of both groups were in oestrus within a few days after weaning (Table 3), which shows that DON intake during lactation did not delay the resumption of ovarian activity. Most sows were successfully mated during the first oestrus, resulting in an identical weaning-to-farrowing interval of 120 days in both groups. One sow in each group failed to conceive after being mated twice at two consecutive oestrus periods. The intake of the DON-contaminated feed neither affected the size nor the weight of the next litter (Table 3).

In short, the daily intake of 17 mg DON by the pluriparous sows from the second week of lactation until weaning (i.e. approximately 0.07 mg DON/kg BW per day) merely resulted in a slight increase in feed refusal among a few sows. No further negative effect was observed, neither during lactation nor during the following reproduction period. Lactating pluriparous sows thus seem to be less sensitive to the anorectic effect of DON than growing pigs, which respond with decreased feed intake and growth when exposed to 0.07–0.08 mg DON/kg BW per day (Pestka and Smolinski 2005). Lactating first litter sows seem to be more sensitive to DON than multiparous sows too, since diets containing 2 and 3 mg DON/kg, respectively, significantly depressed feed intake (Etienne et al. 2006) and significantly increased BW loss (Chavez 1984) of lactating primiparous sows. This age effect on the refusal of DON-contaminated feed is not surprising, since first litter sows are known to have difficulties ingesting the high amounts of feed which are necessary to meet the nutrient demand for milk production. They tend to eat insufficient amounts even of good quality feed, and the response to an unpalatable feed is probably more pronounced in these young sows than in pluriparous sows. Therefore, it cannot be ruled out that first litter sows would have reacted differently to the contaminated feed than the pluriparous sows used in the present experiment, at least with regard to feed intake.

The fact that the daily intake of 0.07 mg DON/kg BW did not affect the fertility of the sows seemingly contradicts the hypothesis of Alm et al. (2006) that DON exposure prior to oestrus, via a reduction of oocyte quality, may affect the reproductive performance of sows. One possible reason for this discrepancy lies in the difference of mycotoxin exposure. Oocyte quality was reduced in gilts at a daily exposure of 0.1 and 0.15 mg, but not of 0.05 mg DON/kg BW (Alm et al. 2006). On the other hand, it has not been proven yet that an increased proportion of low quality oocytes necessarily result in a reduced number of piglets born: ovulation rate of sows generally exceeds the number of fetuses that can be carried to term, and many fetuses die and are resorbed because of a limited uterine capacity (Foxcroft et al. 2006). In case fewer embryos will develop, a higher proportion of the surviving embryos may thus be carried to term.

In conclusion, the results of the present experiment support the statement of Erikson and Pettersson (2004) that it is considered unlikely that DON would influence reproduction at levels having no effects on feed intake in the maternal pigs.

References

Alm H, Brüssow KP, Torner H, Vanselow J, Tomek W, Dänicke S, Tiemann U (2006) Influence of *Fusarium*-toxin contaminated feed on initial quality and meiotic competence of gilt oocytes. Repr Tox 22:44–50

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

Close WH, Cole DJA (2000) Nutrition of sows and boars. Nottingham University Press, Nottingham

Dänicke S, Brüssow K-P, Goyarts T, Valenta H, Ueberschär K-H, Tiemann U (2007) On the transfer of the *Fusarium* toxins deoxynivalenol (DON) and zearalenone (ZON) from the sow to the full-term piglet during the last third of gestation. Food Chem Toxicol 45:1565–1574

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

Erikson GS, Pettersson H (2004) Toxicological evaluation of trichothecenes in animal feed. Anim Feed Sci Technol 114: 205–239

Etienne M, Oswald I, Bony S, Lallès JP, Pinton P, Trépier B, Lessard M (2006) Effets de la contamination par le déoxynivalénol (DON) de l'aliment des truies reproductrices. Journées Recherche Porcine 38:233–240

Foxcroft GR, Dixon WT, Novak S, Putman CT, Town SC, Vinsky MDA (2006) The biological basis for prenatal programming of postnatal performance in pigs. J Anim Sci 84:105–112

Friend DW, Trenholm HL, Fiser PS, Thompson BK, Hartin KE (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

Friend DW, Thompson BK, Trenholm HL, Hartin KE, Prelusky DB (1986) Effects of feeding deoxynivalenol (DON)-contaminated wheat diets to pregnant and lactating gilts and on their progeny. Can J Anim Sci 66:229–236

Goyarts D, Dänicke S, Brüssow KP, Valenta H, Ueberschär KH, Tiemann U (2007) On the transfer of the *Fusarium* toxins deoxynivalenol (DON) and zearalenone (ZON) from sows to their fetuses during days 35–70 of gestation. Tox Letters 171:38–49

Gutzwiller A, Gafner J-L, Stoll P (2009) Effects of a diet containing fusarium mycotoxins on the fertility of gilts and on bulbourethral gland weight of barrows. Arch Anim Nutr 63:16–25

Naumann C, Bassler R (1997) Die chemische Untersuchung von Futtermitteln. VDLUFA, Darmstadt

Pestka JJ (2007) Deoxynivalenol: toxicity, mechanisms and animal health risks. Anim Feed Sci Technol 137:283–298

Pestka JJ, Smolinski AT (2005) Deoxynivalenol: toxicology and potential effects on humans. J Toxicol Environ Health Part B 8:39–69