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Evaluation of Pearled Deoxynivalenol (DON)-contaminated Barley on Growth Performance of Early-Weaned Pigs

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ABSTRACT

96 Cotswold pigs initial body weight (BW) of 5.96 ± 0.12 kg were blocked based on BW and sex. After 1-week adaptation pigs were randomly assigned to 4-dietary treatments: corn diet (control) and 3-diets of pearled DON-contaminated barleys: 1.2, 4.4 and 7.6ppm, respectively. Each dietary treatment has 6 replicate pens of 4 pigs each in a two-phase feeding program: 5 – 10 kg and 10 – 20 kg BW range. Each phase lasted for 2 weeks. Animals were monitored weekly for average daily feed intake (ADFI), average daily gain (ADG) and feed efficiency (FE). There were significant ($P = 0.0356$) reductions in ADFI for barley diets compared to control; no differences ($P > 0.05$) in ADG; FE of barley diets were higher ($P = 0.0201$) compared with control in phase 1. No differences ($P > 0.05$) in the ADFI and ADG amongst diets. However, there was highly significant ($P = 0.0004$) difference in the FE as barley diets demonstrated better FE compared with control in phase 2. Overall, there were no differences ($P > 0.05$) in ADFI and ADG, but with a tendency ($P = 0.0626$) for a reduction in ADFI of the barley diets compared to control. Barley diets had superior ($P = 0.0026$) FE compared to control. It was concluded that commercial pearling was effective in reducing DON and fibre contents of DON-contaminated barley to acceptable levels for use in the rations of early-weaned pigs.

INTRODUCTION

The incidence of *Fusarium* especially *F. graminearum* in cereal crops particularly barley is on the increase (Clear *et al.,* 2000). This fungus is known to produce a metabolite known as DON also known as vomitoxin in affected crops in the field and in storage. The presence of DON in pig diets leads to severe feed refusal and depressed growth due to the high susceptibility of pigs to the anorectic effects of DON than other livestock (Rotter *et al.,* 1995, 1996 and House *et al.,* 2002). These effects increase the time required for pigs to reach market weights resulting in losses of revenue to the hog farmers (Williams *et al.,* 1988; House *et al.,* 2002).

The negative metabolic effects of DON in pigs may be worse in the young piglets as DON is capable of depressing growth, weakens their developing immune system thereby rendering them more susceptible to pathogenic infections (Chavez and Rheaume, 1986). To this point, Rotter *et al.* (1994) showed linear feed intake reductions in young pigs fed diets containing varying levels of DON at 0, 0.75, 1.5 and 3 ppm in their diets, respectively. Reduction in feed intake invariably would result in reduced ADG. Therefore, there is a need to develop a strategy for managing DON in cereal crops, such as barley for young piglets.

It has been suggested that one of the ways the nutritive value of barley can be increased is through de-hulling as it can effectively remove DON from DON-contaminated barley (Lee *et al.,* 1992 and House *et al.,* 2003). However, this suggestion has not been fully tested, especially at the commercial level involving early-weaned piglets. Therefore, the objective of this study was to evaluate the growth performance of early-weaned piglets fed different pearled DON-contaminated barley-based diets in comparison with a standard corn/soybean diet.

MATERIALS AND METHODS

Piglets and Housing

Ninety-six Cotswold piglets (48 males and 48 females) averaging 5.96 ± 0.12 (mean ± SD) kg BW and weaned at 17 ± 1d (mean ± SD) were acquired from Glenlea Research Station, University of Manitoba, Winnipeg, Manitoba, Canada in two batches (a week difference) as: 24 males and 24 females, respectively and housed in the Animal Science Research Unit. The animals were blocked on the basis of sex and BW and housed 4 pigs per pen. Initially, pigs were fed a standard commercial starter diet for a 7-day adaptation period with water provided *ad libitum*. At the end of the adaptation period, pigs were randomly assigned from within blocks to dietary treatments. Each dietary treatment was assigned to 6 replicate pens with 4 pigs per pen. The animals had unlimited access to experimental diets and water. Individual BW and pen feed disappearance were monitored weekly. The room temperature was initially set at 29.50C and gradually reduced by 1.50C per week throughout the 4 weeks (28-days) experimental period. All experimental procedures were reviewed and approved by the University of Manitoba Animal Care Committee and pigs were cared for according to the guidelines of the Canadian Council on Animal Care (CCAC, 1993).

Experimental Diets

There were four dietary treatments. The first was a standard corn diet (control diet) whereas the other three were pearled DON-contaminated barley-based diets that contained DON at: 1.2, 4.4 and 7.6ppm designated as low, medium and high DON diets, respectively before pearling by way of passing them through the Satake^{TM} abrader machine 3 times. Diets were formulated to meet or exceed the NRC, (1998) recommended levels of nutrient requirements for 5 to 10kg BW piglets for phase 1 and 10 to 20kg BW piglets for phase 2, respectively (Tables 1 and 2).

Table 1: Ingredient composition of diets (%)

	Phase 1 Diets				Phase 2 Diets			
Ingredient	Corn	L_DON	M_DON	H_DON	Corn	L_DON	M_DON	H_DON
Corn	38.75	-	-	-	64.29	-	-	-
L_DON barley	-	43.57	-	-	-	67.18	-	-
M_DON barley	-	-	43.61	-	-	-	68.21	-
H_DON barley	-	-	-	43.84	-	-	-	66.95
SMB, 48%	24.75	25.00	25.00	24.75	32.00	27.50	26.50	26.50
Lactose	10.00	10.00	10.00	-	-	-	-	-
Dried whey	15.00	10.00	10.00	-	-	-	-	-
SDBP	7.00	6.00	6.00	6.00	-	-	-	-
Veg. oil	1.00	1.80	1.80	1.80	-	1.50	1.50	2.73
Vit-Min Pxm[a]	3.45	3.50	3.50	3.50	3.50	3.50	3.50	3.50
LYS.HCL	-	0.05	0.03	0.03	0.21	0.27	0.26	0.26
DL-Met	0.05	0.08	0.06	0.08	-	0.05	0.03	0.06
Total	100	100	100	100	100	100	100	100
DE (kcal/kg)	3,525	3,756.9	3,752.8	3,662.7				

[a]Supplied per kg of diet: Ca, 2.51/1.8g; P, 1.19/0.85g; NaCl, 0.84/0.6g; Na,0.34/0.24g; Mg, 0.04/0.03g; Mn,9.8/7mg; Fe, 42.7/30.5mg; Zn, 38.5/27.5mg; Cu, 35/24mg; I, 0.21/0.15mg and Se, 0.08/0.06mg. vit. A, 3290/2350 IU; vit. D_3, 420/300 IU; vit. E, 14/10 IU, vit. K, 0.49/0.35 mg; choline chloride, 21/15mg; Niacin, 10.64/7.6mg; Calcium pantothenate, 10.01/7.15mg, Riboflavin, 2.8/2mg; Thiamine, 0.28/0.2mg; Pyridoxine, 0.28/0.2mg; vit. B_{12}, 7.7/5.5mg, Biotin, 28/20mcg and Folic acid, 0.14/0.1mg for diets phase one and two, respectively.

Table 2: Calculated nutrient contents[1] of diets

	PHASE 1 DIETS				PHASE 2 DIETS			
Item	Corn	L_DON	M_DON	H_DON	Corn	L_DON	M_DON	H_DON
DE (kcal/kg)	3492	3472	3472	3435	3445	3416	3412	3423
N, %	22.17	22.42	22.71	22.72	20.25	20.14	20.24	20.24
Tlys, %	1.47	1.47	1.47	1.46	1.34	1.34	1.33	1.33
Tmet, %	0.36	0.37	0.36	0.37	0.32	0.32	0.32	0.32
Tcys, %	0.48	0.47	0.47	0.48	0.36	0.36	0.36	0.36
Tmet+Cys, %	0.84	0.84	0.84	0.84	0.68	0.68	0.68	0.69
Thr, %	1.02	0.99	1.03	1.01	0.78	0.76	0.81	0.78
Trp, %	0.31	0.32	0.31	0.31	0.25	0.27	0.25	0.25
Leu, %	1.60	1.78	1.81	1.81	1.17	1.46	1.50	1.49
Phe, %	1.14	1.18	1.19	1.22	1.02	1.05	1.06	1.09
His, %	0.61	0.61	0.62	0.61	0.56	0.55	0.54	0.54
Arg, %	1.29	1.36	1.39	1.40	1.26	1.27	1.30	1.30
Ca, %	0.83	0.82	0.82	0.82	0.76	0.76	0.76	0.76
Ava. P, %	0.16	0.11	0.11	0.11	0.08	0.04	0.04	0.04
Total P, %	0.71	0.72	0.72	0.72	0.70	0.73	0.72	0.72
Ca: P	1.18	1.14	1.14	1.14	1.09	1.05	1.05	1.06

[1]Based on NRC, (1998) nutrient requirements. Phase 1 diets were used for (d 0 – d 14) later switched over to phase 2 diets (d 14 – d 28), respectively.

Experimental Design

The experiment was designed and carried out as a completely randomized design. Individual BW and pen feed disappearance were monitored weekly as a measure of feed intake relative to BW gain used in the computation of gain to feed ratio (feed efficiency). Animals had unlimited access to feed and water throughout the experimental period.

General Conduct of Study

At the beginning of each phase in the week the different feeds were weighed into the individual pen feeders and then monitored to minimize feed waste. Depending on the rate of feed disappearance from the feeders more feeds were weighed into the feeders. At the end of each week residual feeds in the feeders were collected and weighed. The difference between the total quantity of the feed weighed into the feeders and residuals represents the actual feed consumed for the week.

Average daily feed (ADFI) was computed as the difference between the total amount of feed served and remnants divided by the number of pigs in the pen and then by fourteen (number of days in the phase). Average daily gain (ADG) for each phase was determined by computing the weight gained by each pig at the end of the previous phase to the beginning of a new phase and divided by the number of days in the phase. Feed efficiency (FE) gains: feed was computed by dividing the ADG by the ADFI for each phase. The overall for ADFI, ADG and FE were also computed for the study.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using general linear model (GLM) procedure of SAS (SAS Inst., Cary, NC). Means were compared using Bonferoni's test and α-level of *0.05* was used for statistical difference. The model was $Y_{ij} = \mu + X_i + E_{ij}$: where Y_{ij} = individual observation of the treatment, μ = population mean, X_i = effect of the i^{th} treatment and E_{ij} = the error term.

RESULTS

All animals in each dietary treatment readily consumed their rations and grew throughout the experimental duration. The results of the ADFI, ADG and FE are presented in Table 3.

Table 3: Growth performance of piglets fed corn and pearled DON-contaminated barley-diets

	DIETS					
Item	Corn	L_DON	M_DON	H_DON	SEM[1]	*P-Value*
PHASE 1 (5 – 10 kg)						
ADFI (g/d)	432.8[a]	390.2[ab]	346.2[b]	383.7[ab]	18.46	0.0356
ADG (g/d)	346.3	354.8	331	340.3	11.09	0.5030
G: F	0.81[a]	0.91[ab]	0.96[b]	0.90[ab]	0.03	0.0201
PHASE 2 (10 – 20 kg)						
ADFI (g/d)	667.7	645.8	623.3	626.5	17.04	0.2701
ADG (g/d)	484.2	502.7	525.8	539	14.9	0.0860
G: F	0.73[a]	0.79[ab]	0.85[b]	0.87[b]	0.02	0.0004
OVERALL (5 – 20 kg)						
ADFI (g/d)	550.3	518	484.8	505.1	15.81	0.0626
ADG (g/d)	415.3	428.8	428.4	439.7	11.24	0.5182
G: F	0.77[a]	0.85[ab]	0.91[b]	0.88[b]	0.02	0.0026

SEM[1] = standard error of the mean. [a,b]Means with different superscripts within the same row are significantly ($P < 0.05$) different.

In phase 1, there was significant ($P < 0.05$) difference between the control and barley-based diets. Animals on the control diet consumed more of their diet compared with animals on the barley diets. However, there was no difference between the consumption rates between the control and low DON diets. Irrespective of the differences in the ADFI there were no differences ($P > 0.05$) in the ADG. Nevertheless, the FE of the barley-diets were superior ($P < 0.05$) to the control, particularly the medium DON diet. In phase 2, there were differences ($P > 0.05$) in the ADFI and ADG for all dietary groups. Although there were no differences in the ADFI and ADG, the FE of the barley diets were superior ($P < 0.05$), particularly that of the medium barley diet. The performances of the animals in phase 2 were mirrored in the overall (Table 3).

DISCUSSION

DON is a known anorectic agent in pigs. For instance when pigs were fasted for 24 hours to favor feed intake after which diets containing DON were offered the pigs refused to consume them due to the anorectic properties of DON (Williams *et al.,* 1988). Therefore, the acceptability of the pearled DON-contaminated barley diets in this study is a confirmation that commercial pearling was effective in removing DON from DON-contaminated barley for pigs, including the early-weaned piglets (House *et al.* 2002 and 2003). This assertion becomes stronger when one considers the initial DON level in the high DON barley (7.6 ppm) diet. Williams *et al.* (1988) that investigated the effect of DON on feed intake of young growing pigs found that most of the pigs that readily consumed the DON-contaminated diets for the first 10 – 15 minutes later ate sparingly or not at all for the next 2 hours. This led to reduced voluntary feed intake, reduced growth rate and some pigs even lost weights significantly due to feed refusal. Pigs on the high DON-containing diet vomited within 20 – 30 minutes of consuming the DON diets. This is why DON is also known as vomitoxin. Thus, pearling can be recommended for adoption in dealing with DON in barley for the swine industry in regions where the DON menace is endemic. This is more so as the technique is less labor-intensive.

There were differences in the ADFI in the first phase amongst dietary treatments. The ADFI of the barley diets were lower than that of the control. However, the difference disappeared in the second phase amongst the animals on the four diets, including the overall. The lowered ADFI for the barley diets might not be related to DON but might be more related to the concentrated nature of their energy and other nutrients. This assertion is dependable because the piglets did not show any sign of feed refusal indicating that DON was significantly removed to the level that piglets found the diets palatable (Trenholm *et al.* 1991; Lee *et al.* 1992). The barley diets would have supplied its energy to the animals more in the form of glucose that is readily available in the small intestine due to reduced fibre levels compared with the intact corn (Moeser *et al.* 2002) thereby met more readily the energy requirements of the animals compared to the intact corn diet. This also implied that more of the corn diet needs to be consumed to meet the energy requirements of the animal as the animals at that physiological stage totally depend on glucose from the grains for their energy. Therefore, the increased ADFI for the intact corn diet could be an attempt by the animas to ingest enough energy for their maintenance and production purposes.

Fibre is an anti-nutritive factor in pig nutrition, especially for early-weaned piglets, therefore, the presence of fibre in corn and barley would undoubtedly impact their digestibilities and hence their digestible energy values as well as other nutrients they provide, such as protein and amino acids. Corn is known to contain fibre in its hulls as with other cereals, but in addition contains some fibre in the germ of the kernel. The fibre contain in the hull of corn contributes approximately 5% of the total kernel weight and this has been shown contribute about 51% of the total kernel fibre with the one in the germ of the kernel contributing about 11% of the total kernel weight and also contribute about 16% of the total fibre (Watson, 1987). This chemistry of corn fibre compositions would therefore affect the availability of energy and other nutrients in the corn diets of both phases 1 and 2 as they were used as intact corn compared with the barley diets that were pearled before incorporation in the diets that would have removed most of the hulls in the barleys (Trenholm *et al.,* 1991; House *et al.,* 2003). The negative impacts of fibre on nutrient availability is more severe with young piglets because of their fragile and low capacity of their gastrointestinal tract to handle bulky feedstuffs, particularly fibre as they are deficient in enzymes that degrade fibre (Grieshop *et al.,* 2001; Lampe *et al.,* 2004).

The difference in the ADFI but similar ADG amongst animals of all treatment groups therefore resulted in better FE for the barley diets. The findings in this study are in agreement with data found in the literature such as those of Rodas *et al.* (1995) and Dritz *et al.* (1996). The effect of sex on pigs consuming DON-containing diets had been inconsistent. Williams *et al.* (1988) did not find any effect whereas House *et al.* (2002) found difference in the sex response of barrows and gilts that consumed diets containing low levels of DON. In this study, the effect of sex and its interaction with the diets were included in the model to evaluate possible gender effect on the growth parameters studied; there was no gender difference in the response of animals to diets and their interactions.

CONCLUSIONS

Commercial pearling is effective in removing DON and fibre from DON-contaminated barley for use in the nutrition of swine, including early-weaned piglets. Pearling eliminates the anorectic effects of DON and minimizes fibre contents of DON-contaminated barley thereby rendering such barley acceptable grain for pigs, including piglets. Additionally, pearling due to fibre removal improved the feeding value of DON-contaminated barley for swine. Therefore the pearling technology can be adopted in managing DON in grains for the swine industry in any DON endemic region.

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