Defining the tolerable level of ergot in the diet of weaned pigs

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[1]*Prairie Swine Centre Inc., P.O. Box 21057, 2105 8th Street East, S7H 5N9, Saskatoon, Saskatchewan, Canada;* [2]*Department of Animal and Poultry Science, 51 Campus Drive, Saskatoon, Saskatchewan, Canada S7N 5A8;* [3]*Department of Veterinary Pathology, 52 Campus Drive, Saskatoon, Saskatchewan, Canada S7N 5B4;* [4]*Department of Veterinary Biomedical Sciences, 52 Campus Drive, Saskatoon, Saskatchewan, Canada S7N 5B4.* *Received 30 January 2003, accepted 7 May 2003.*

Oresanya, T. F., Patience, J. F., Zijlstra, R. T., Beaulieu, A. D., Middleton, D. M., Blakley, B. R. and Gillis, D. A. 2003. **Defining the tolerable level of ergot in the diet of weaned pigs**. Can. J. Anim. Sci. **83**: 493–500. The present study investigated the effect of ergot alkaloids on performance and clinical symptoms in weaned pigs. Wheat ergot sclerotia (1880 mg alkaloid kg^{-1}; ergocristine, ergotamine, ergosine, ergocryptine, and ergocornine constituting 40, 36, 11, 7, and 6% of the total, respectively) were added on a weight basis to a basal diet at 0.00 (control), 0.05, 0.10, 0.25, 0.50, and 1.00% and fed to 192 weaned pigs (20.4 ± 3.4 d; 6.9 ± 1.3 kg; mean ± SD) for 28 d, beginning 7 d post-weaning. Pigs fed the 1.00% diet gained 82 and 38% less than the control ($P < 0.001$, 211 vs. 39 g d^{-1}, wk 1 and 432 vs. 269 g d^{-1}, wk 2) and body weight on day 28 was reduced quadratically by alkaloids ($P < 0.005$). Ergot alkaloids decreased average daily feed intake (ADFI) quadratically ($P < 0.04$) and feed efficiency linearly ($P < 0.03$) (0.62 vs. 0.44; control vs. 1.00%) over the entire period, but ADFI was not affected during the initial 14 d ($P > 0.20$). Ergot alkaloids decreased serum prolactin quadratically ($P < 0.002$) and urea nitrogen concentrations ($P < 0.05$).

The maximum tolerable ergot level in the diet was 0.10 and 0.05% based on average daily gain (ADG) and ADFI, respectively, corresponding to 2.07 mg and 1.04 mg alkaloid kg^{-1} diet.

Key words: Pig, ergot, alkaloid, toxicity, performance, prolactin

Oresanya, T. F., Patience, J. F., Zijlstra, R. T., Beaulieu, A. D., Middleton, D. M., Blakley, B. R. et Gillis, D. A. 2003. **Seuil de tolérance de l'ergot dans la ration des porcs sevrés**. Can. J. Anim. Sci. **83**: 493–500. L'étude devait préciser l'incidence des alcaloïdes de l'ergot sur le rendement et les symptômes cliniques des porcs sevrés. Les auteurs ont ajouté des sclérotes d'ergot du blé (1 880 mg d'alcaloïdes par kg d'aliments; 40, 36, 11, 7 et 6 % de la ration composé d'ergocristine, ergotamine, ergosine, ergocryptine et ergocornine, respectivement) pour qu'ils constituent 0,00 (témoin), 0,05, 0,10, 0,25, 0,50 ou 1,00 % de la ration de base, selon le poids. Ils en ont ensuite nourri 192 porcs sevrés (20,4 ± 3,4 jours; 6,9 ± 1,3 kg; moyenne ± E.-T.) pendant 28 jours, à partir du septième suivant le sevrage. Les animaux recevant la ration à 1,00 % ont pris 82 % et 38 % moins de poids que les témoins ($P < 0,001$; 211 c. 39 g par jour, 1re semaine, et 432 c. 269 g par jour, 2e semaine) et les alcaloïdes ont entraîné une baisse géométrique de leur poids au 28e jour ($P < 0,005$). Les alcaloïdes de l'ergot ont réduit l'ingestion quotidienne moyenne d'aliments de manière géométrique ($P < 0,04$) et la valorisation des aliments de façon linéaire ($P < 0,03$) (0,62 c. 0,44; témoin c. 1,00 %) durant l'étude, mais l'ingestion quotidienne moyenne n'est pas affectée lors des 14 premiers jours ($P < 0,20$). Les alcaloïdes de l'ergot diminuent géométriquement la concentration de prolactine ($P < 0,002$) et d'azote uréique ($P < 0,05$) dans le sang. La concentration maximale d'ergot dans la ration s'établit respectivement à 0,10 % et à 0,05 % pour le gain quotidien moyen et l'ingestion quotidienne moyenne d'aliments, ce qui correspond à 2,07 mg et à 1,04 mg d'alcaloïdes par kg d'aliments.

Mots clés: Porcins, ergot, alcaloïdes, toxicité, rendement, prolactine

Ergot is produced from the sclerotium of fungi of the Claviceps species. Worldwide, about 36 different filamentous species, of which *Claviceps purpurea* is the most prominent (Lorenz 1979), parasitize the graminae family, including rye, wheat, triticale, barley, oats and others (Baum et al. 1992). In the past, consumption of ergot-contaminated grain resulted in widespread poisoning of humans and animals. Because of strict guidelines that regulate levels of ergot sclerotia in grains destined for human consumption, ergot poisoning or ergotism is no longer prevalent in humans. However, toxicities in livestock may still occur when contaminated grains are used in feeds.

The incidence of ergot infection of grains and its severity vary from year to year. Ergot primarily affects wheat, bar-

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Abbreviations: **ADG,** average daily gain; **ADFI**, average daily feed intake; **DE**, digestible energy; **DM**, dry matter; **SUN**, serum urea nitrogen; **GIT**, gastrointestinal tract; **PBS**, phosphate buffered saline; **pPrl**, porcine prolactin

ley, triticale, and rye and is most prevalent in years with increased moisture available at the soil surface in spring and early summer or with wet weather prevailing during the flowering stage of cereal crops (Pearse 1999). An ergot infection may not reduce grain yield but will reduce grain quality due to the replacement of grain kernels with poisonous alkaloid-containing ergot sclerotia.

The detrimental effects of feeding ergot-contaminated grain to animals are variable, and are dependent on both the ergot content and the alkaloid concentration. Canadian wheat standards allow 0.01% ergot for the highest grade to 0.10% by weight for the lowest grade of most wheat classes (Canadian Grain Commission 2002). When the grain is grown by a pork producer, or when such grain is considered for use in swine feeds, questions arise as to the acceptable safe usage rate in the diets. Inability to utilize ergot-contaminated grain in livestock diets can represent a financial burden to grain-producing or mixed farms, as the market for their product is greatly reduced. Although the removal of ergot from cereal grains is possible, complete removal may be impossible or impractical in a commercial setting. Consequently, the safe upper limit for the utilization of ergoty grain must be defined.

Currently, little information exists to make sound recommendations on safe feeding levels of wheat containing ergot to swine. Ergotism is associated with poor performance in pigs (Whittemore et al. 1976) and alkaloids inhibit the secretion of pituitary hormones, especially prolactin (Melmed 1990), which may interfere with mammary gland development and lactation. Clinical signs, however, have been poorly defined.

The objectives of this experiment were to define the quantity of ergot and ergot alkaloids that may be included in the diet of weaned pigs without an adverse impact on performance, and to identify clinical signs that may be used to identify low-level ergo-toxicity.

MATERIALS AND METHODS

Animal and Housing

A total of 192 pigs (Camborough-15 × Canabrid, Pig Improvement Canada, Acme, AB) were weaned at 20.4 ± 3.4 (mean ± SD) days of age and used in a 28-d growth trial at the Prairie Swine Centre, Saskatoon, SK. At weaning, pigs were placed in one of two nursery rooms, each containing 24 experimental pens (1.27 × 1.04 m) housing four pigs per pen. All pens were equipped with fully slatted floors, a nipple drinker and an adjustable multiple-space dry feeder. Each room had automatic light timers (0800 to 2000) and ventilation controls, including heaters, exhaust fans and powered air inlets. Room temperature was initially set at 30ºC, declining to 24ºC by the end of the experimental period.

Experimental Design

The experiment was conducted in two replicates of 96 pigs each, with each room representing one replicate. Within each room, pens were allocated to one of four quadrants of six pens each, to eliminate possible effects on the pigs due to location; treatments were randomly assigned to pens within block. Within each replicate, pigs were blocked by sex and by weight and then randomly assigned to pens within block. Thus, there were a total of eight observations and 32 pigs per dietary treatment.

Piglets were given ad libitum access to a commercial pelleted phase-1 starter diet (HND Start, Co-op Feeds, Saskatoon, SK) for the first 4-d post-weaning followed by a phase-2 starter diet (Co-op Feeds, Saskatoon, SK) for the next 3 d. Piglets were then given ad libitum access to one of the dry mash experimental diets throughout the entire 28-d experimental period (day 0 to 28). The University Committee on Animal Care and Supply at the University of Saskatchewan (UCACS) approved the animal care protocol (# 010069) for adherence to guidelines of the Canadian Council on Animal Care (1993).

Ergot Sclerotia

Thirty kilograms of ergot sclerotia were separated from approximately 9 t of ergot-contaminated wheat using a gravity separator (Model 50MA; Oliver Manufacturing Co, Rocky Ford, CO). The gravity table separates according to the specific gravity of the product. The portion with the highest concentration of ergot sclerotia was saved and run through a colour sorter (Model Allen Huetronic; Allen Electronics, Newberg, OR). Parameters were set on the colour sorter to remove ergot sclerotia from the wheat based on the actual colour of ergot sclerotia and wheat. The purified sclerotia samples were then analyzed for total alkaloid content and individual alkaloids by high-pressure liquid chromatography (Young 1981).

Diets

A basal diet was formulated using wheat, soybean meal and whey powder as the main ingredients, with smaller amounts of fish meal, canola oil and plasma proteins (Table 1). Synthetic amino acids, vitamins and macro- and micro-minerals were also added as required. The basal diet was formulated to contain 3.5 Mcal DE kg^{-1} and 1.35% total lysine (3.86 g total lysine $Mcal^{-1}$ DE) and met the National Research Council (NRC) (1998) nutrient requirements for weaned pigs (Table 1). The essential amino acid profile was formulated to achieve the ideal amino acid ratio to lysine as defined in the NRC (1998).

Ergot sclerotia were added to the basal diet (0, control) at 0.05, 0.10, 0.25, 0.5, and 1.0 g 100 g^{-1} by weight. These levels were selected to bracket the current recommendation of 0.10% for growing-finishing pigs and higher levels used in previous research (Bailey et al. 1973; Whittemore et al. 1977; Blaney et al. 2000). Ergot sclerotia were ground through a 3.2-mm screen in a hamermill (Model 160-D; Jacobson Machine Works, Minneapolis, MN). To improve the mixing quality of the diets, the ergot was first mixed with 25 kg of basal diet in a vertical mixer (Hobart mixer, model L800; Hobart Co., Troy, OH) prior to mixing into each diet in a horizontal paddle mixer (Marion Mixer, Model 2030; Rapids Machinery Co., Marion, IA). By adding ergot as a discrete ingredient, rather than diluting a contaminated grain sample with clean grain, as is often practiced, the confounding effect across diets of different quantities of different grain samples was avoided.

Table 1. Composition of the basal diet

Ingredient (%)	
Wheat	62.93
Soybean meal (47.5% CP)	17.50
Spray-dried whey	10.00
Fish meal	2.84
Canola oil	2.00
Spray-dried plasma	1.76
Limestone	0.62
Dicalcium phosphate	0.54
PSCI mineral premixz	0.50
PSCI vitamin premixy	0.50
Salt	0.40
L-Lysine-HCl	0.35
L-Threonine	0.06
DL-Methionine	0.05
Calculated nutrient composition, as is	
DE (Mcal kg^{-1})	3.50
Apparent digestible lysine (g $Mcal^{-1}$ DE)	3.30
Total lysine (%)	1.35
Crude protein (%)	21.78
Crude fat (%)	3.70
Crude fibre (%)	2.35
Calcium (%)	0.78
Total phosphorus (%)	0.65
Analyzed nutrient composition, as is[x]	
Crude protein (%)	21.44
Total lysine (%)	1.32
Total threonine (%)	0.85
Total methionine (%)	0.38

[z]Provided per kg of basal diet: zinc, 100 mg; iron, 80 mg; copper, 50 mg; iodine, 50 mg; manganese, 25 mg; selenium, 10 mg.
[y]Provided per kg of basal diet: vitamin A, 3250 IU; vitamin D3, 825 IU; vitamin E, 40 IU; D-pantothenic acid, 15 mg; niacin, 35 mg; riboflavin, 5 mg; menadione, 4 mg; folic acid, 2 mg; thiamine, 1 mg; D-biotin, 0.2 mg; vitamin B_{12}, 0.025 mg.
[x]Other essential amino acids: arginine, 1.12%; isoleucine, 0.83%; leucine, 1.53%; valine, 1.02%; histidine, 0.50; phenyalanine, 0.98%.

Ergot and Diet Alkaloid Content

The total alkaloid content of the ergot sclerotia used was 1880 mg kg^{-1} and ranged from 110 to 755 mg kg^{-1} for the five alkaloids (Table 2). Diet alkaloid content was calculated from ergot alkaloid content and the amount of ergot added into diet. The 0.00 (control), 0.05, 0.10, 0.25, 0.5, and 1.0% diet contained 0.00, 1.04, 2.07, 5.21, 10.41, and 20.82 mg alkaloids kg^{-1}, respectively (Table 3).

Data and Sample Collection

Pigs were weighed on day 7 post weaning when the feeding of experimental diets was initiated (day 0), and weekly thereafter, (days 7, 14, 21, and 28). On each weigh day, feed consumption was measured. The data were used to calculate the ADG, ADFI, and feed efficiency.

Freshly voided faeces were collected from each pen using the grab method over 3 d (days 21 to 23) and pooled per pen. Faeces and feed samples were frozen at –20°C prior to lyophilization.

On day 28, blood samples were collected into serum vacutainer tubes via cranial vena cava venipuncture from one randomly selected gilt and barrow from each pen.

Table 2. Alkaloid composition of the ergot sclerotia

Alkaloid	mg kg^{-1}	Percentage of total alkaloids (%)
Ergocristine	755	40.16
Ergotamine	680	36.17
Ergosine	205	10.90
Ergocryptine	130	6.91
Ergocornine	110	5.85
Total	1880	100.00

Samples were allowed to clot and were centrifuged within 1 h at 700 × g. Serum was collected and stored at –20°C for later assay of prolactin and urea nitrogen content.

In addition, the piglets were monitored daily for abnormal behaviour and for classical signs of ergotism, including gangrenous lesions on extremities (ears, snout, eyelid, and limbs). However, none were observed.

Chemical Analysis

The moisture content of feed and freeze-dried fecal samples was determined by drying at 135ºC in an airflow-type oven for 2 h (Method 930.15; Association of Official Analytical Chemists 1990). Endogenous acid insoluble ash content of the diet was used as an indigestible marker and measured in feed and faeces (McCarthy et al. 1974) to determine dry mater (DM) digestibility. The basal diet was analyzed for amino acid and crude protein content by a commercial laboratory (Degussa, Allendale, NJ).

Serum Prolactin and Urea Nitrogen Assay

Serum was analyzed for porcine prolactin (pPrl) by double antibody radioimmunoassay (Downing et al. 1995) with reagents obtained from Dr. A. F. Parlow (AFP) of the National Hormone & Pituitary Program, Harbor-UCLA Medical Centre, Torrance, CA. Concentrations are expressed in terms of pPrl (AFP-9764B). Standards were prepared in 5% bovine serum albumin (Sigma Chemical Co., St. Louis, MO) in a 0.5 M phosphate buffered saline (PBS). The standard curve ranged from 0.25 to 8 ng mL^{-1}. The antibody used was AFP-084255, diluted in 0.05% Normal Rabbit Serum in 0.5 M PBS (0.2 mL per tube of 1:20 000 dilution). Prolactin AFP-9764B was iodinated using the Chloramine-T procedure (6 µg Chloramine T per µg prolactin to be iodinated) providing 12 000 cpm in 0.2 mL 0.5 M PBS. The bound and free fractions were separated using a sheep-antirabbit double antibody. The sensitivity of the assay, expressed as the lowest standard different from zero using an unpaired *t*-test was 0.25 ng mL^{-1}. Porcine growth hormone, follicle stimulating hormone, luteinizing hormone, thyroid stimulating hormone and human adrenocorticotrophic hormone all showed less than 0.03% cross-reactivity with the antiserum. The intra-assay coefficient of variation was 3.8 and 4.5% for serums with pPrl concentrations of 3.36 and 7.86 ng mL^{-1} respectively.

Serum samples were analyzed for urea nitrogen (SUN) using a commercially-available kit (Sigma-Aldrich, Oakville, ON) according to Fawcett and Scott (1960).

Table 3. Ergot and alkaloid content of diets

	Dietary ergot (%)					
	Control	0.05	0.10	0.25	0.50	1.00
Basal diet (kg)	650.00	649.64	649.29	648.20	646.40	642.80
Ergot (kg)	0.00	0.36	0.72	1.80	3.60	7.20
Alkaloid (mg kg^{-1})	0.00	1.04	2.07	5.21	10.41	20.82

Statistical Analyses

Data were analyzed as a randomized complete block design using the GLM procedures of the SAS Institute, Inc. (1990). The pen was considered the experimental unit. Polynomial regression analysis was conducted to evaluate the dose-response of the dependent variables (ADG, ADFI, feed efficiency and DM digestibility) to ergot level and alkaloid content. The model included the effects of the covariate (initial body weight), replicate, block, and linear and quadratic response to ergot level.

The statistical analysis of the serum prolactin and SUN data was conducted using the MIXED procedures of SAS software. The model included the effect of replicate, block, ergot level, and gender. Body weight on day 28 was used as a covariate for SUN and prolactin analysis.

Dunnett's *t*-like test (Dunnett 1964) was conducted to determine the level of ergot that can be included in the diet without adverse effects on performance or serum prolactin. The two-sided level of statistical significance was set at $P < 0.05$.

RESULTS

Mortality and Signs of Ergo-toxicity

Two pigs on the 0.50 and 1.00% diets were removed from the experiment on day 7 due to unexplained weight loss; however, these pigs did not show clinical signs associated with ergo-toxicity. On days 10 and 20, one pig died on the 0.10% and control diet, respectively. Post-mortem examination failed to reveal evidence of alkaloid toxicity. There were no cutaneous or neural clinical signs of ergo-toxicity observed during this study.

Performance Variables

Average daily gain decreased quadratically with increased ergot level on days 0 to 7 and days 0 to 28 ($P < 0.01$), and linearly on days 8 to 14, days 15 to 21 and days 22 to 28 ($P < 0.01$; Table 4).

The ADFI tended to decrease with increased ergot level on days 0 to 7, days 15 to 21 (linear, $P < 0.071$) and decreased quadratically from days 22 to 28 and days 0 to 28 ($P < 0.02$; Table 4). However, ergot inclusion in the diet did not affect ADFI from days 8 to 14.

Feed efficiency decreased quadratically with increased ergot level ($P < 0.05$) from days 0 to 7 and days 22 to 28, linearly from days 8 to 14 and days 0 to 28 ($P < 0.05$; Table 4). Dietary ergot did not affect feed efficiency from days 15 to 21.

Body weight, which was similar across treatments on day 0, decreased quadratically with increased ergot level by day 7 ($P < 0.01$; Table 5) and throughout the remainder of the experimental period.

Serum Prolactin, Urea Nitrogen Concentration and Dry Matter Digestibility

Serum prolactin and SUN concentration, measured on day 28, had decreased quadratically with increasing ergot level ($P < 0.05$; Table 6). Dry matter digestibility increased linearly with increased ergot level ($P < 0.01$; Table 6).

DISCUSSION

The present study was designed to define the ergot quantity that may be tolerated in the diet without any adverse effect on growth or feed intake and to clarify clinical symptoms associated with ergo-toxicity in the weaned pig. The total alkaloid content of the ergot used in the present study was lower than previously reported for wheat ergot (3080 mg kg^{-1}, Rotter et al. 1985). Ergocristine and ergotamine were the major alkaloids determined in our sample, constituting over 76% of the total; this is in contrast to the 48% reported by Rotter et al. (1985). Total alkaloid content of sclerotia varies from 0 to 5 000 mg kg^{-1} (Lorenz 1979) and ergo-toxicity is related to the total alkaloid content and profile of the individual alkaloids present in a given sample (Rotter et al. 1985). Clearly, variability in alkaloid content and profile among samples is an important variable that would need to be recognized in applying this research in the field.

Ergotism is a widespread disease that develops in humans and animals following the consumption of ergot contaminated food and feed (Janssen et al. 2000a). Several syndromes are associated with ergotism in animals. The nervous syndrome is characterized by staggers and paralysis of the posterior limbs and may be followed by bouts of drowsiness and convulsion (Selby 1999). Gangrenous ergotism results from the vasoconstrictive properties of the alkaloids (Bennett and Bentley 1999). The resulting reduction in blood flow in capillary beds causes degeneration of the affected tissues, progressing to gangrene, and eventual sloughing of the affected areas, primarily the extremities. Whittemore et al. (1977) and Blaney et al. (2000) did not observe signs of ergotism in growing pigs fed diets containing up to 5% ergot sclerotia. None of the classical cutaneous or neural signs of ergotism were observed in the present study. This confirms that pigs are relatively resistant to ergot poisoning (Lorenz 1979) and clinical signs of ergotism in cattle and other species are not effective models for tolerance in young pigs.

Effect on Feed Intake

A dose response reduction in ADFI was observed in the last week of the present study. Reduced feed intake due to poor

Table 4. Effects of dietary ergot level on pig performance[z]

	Dietary ergot (%)						Pooled	*P* values	
	Control	0.05	0.10	0.25	0.50	1.00	SEM	Linear	Quadratic
ADG ($g\ d^{-1}$)[y]									
Days 0 to 7	211	239	227	130	80	39	13	0.0001	0.0025
Days 8 to 14	432	429	384	363	323	269	11	0.0001	0.0563
Days 15 to 21	573	608	534	493	465	362	14	0.0007	0.3085
Days 22 to 28	671	680	689	619	574	519	13	0.0067	0.3658
Days 0 to 28	472	489	459	401	362	298	11	0.0001	0.0061
ADFI ($g\ d^{-1}$)									
Days 0 to 7	384	343	336	292	314	316	13	0.0705	0.1221
Days 8 to 14	678	622	561	642	678	809	30	0.8425	0.3845
Days 15 to 21	890	877	778	792	788	733	15	0.0522	0.2609
Days 22 to 28	1130	1066	1032	976	934	931	17	0.0001	0.0028
Days 0 to 28[x]	768	727	673	675	674	694	13	0.0187	0.0355
Feed efficiency									
Days 0 to 7	0.57	0.71	0.68	0.46	0.23	0.14	0.04	0.0002	0.0482
Days 8 to 14	0.64	0.69	0.69	0.60	0.49	0.37	0.02	0.0147	0.6366
Days 15 to 21	0.65	0.69	0.69	0.63	0.60	0.49	0.01	0.2077	0.4221
Days 22 to 28	0.60	0.63	0.67	0.63	0.62	0.55	0.01	0.1331	0.0105
Days 0 to 28[w]	0.62	0.67	0.69	0.60	0.55	0.44	0.01	0.0344	0.6444

[z] $n = 8$ per treatment.
[y] 0.25% dietary ergot and above differ from the control ($P < 0.05$).
[x] 0.10% dietary ergot and above differ from the control ($P < 0.05$).
[w] 0.05, 0.10, 0.50 and 1.00% dietary ergot differ from the control ($P < 0.05$).

Table 5. Effects of dietary ergot level on pig body weight[z]

	Dietary ergot (%)						Pooled	*P* values	
	Control	0.05	0.10	0.25	0.50	1.00	SEM	Linear	Quadratic
Body weight (*kg*)									
Day 0	7.06	7.16	7.08	7.16	7.04	7.12	0.09		
Day 7	8.58	8.78	8.69	8.01	7.66	7.38	0.12	0.0001	0.0005
Day 14	11.59	11.77	11.39	10.54	9.95	9.28	0.16	0.0001	0.0005
Day 21	15.62	16.01	15.12	13.98	13.20	11.81	0.22	0.0001	0.0046
Day 28	20.31	20.77	19.94	18.31	17.22	15.43	0.27	0.0001	0.0054

[z] $n = 8$ per treatment (four pigs/pen).

Table 6. Effects of dietary ergot level on serum prolactin and urea N concentration and DM digestibility[z]

	Dietary ergot (%)						Pooled	*P* values	
	Control	0.05	0.10	0.25	0.50	1.00	SEM	Linear	Quadratic
Prolactin ($ng\ mL^{-1}$)[y]	1.90	1.00	1.08	1.09	1.12	1.11	0.04	0.0003	0.0018
Urea N ($mg\ dL^{-1}$)[x]	15.12	14.26	15.14	13.80	12.62	13.77	0.29	0.0286	0.0475
DM digestibility (%)	77.3	78.4	77.2	81.1	79.7	80.9	0.69	0.0084	0.0724

[z] $n = 16$ (8 barrows and 8 gilts per treatment), prolactin and urea N concentration; $n = 8$, DM digestibility.
[y] Gender, $P > 0.30$; all levels of dietary ergot differ from the control ($P < 0.05$).
[x] Gender, $P > 0.80$.

palatability has been attributed to the aromatic properties of ergot alkaloids (Whittemore et al. 1977). Whittemore et al. (1977) observed a negative reaction to the gustatory and aromatic properties of ergot alkaloids in 17-kg pigs. However, this reduction was observed only when dietary ergot content reached 10% (Whittemore et al. 1976). The observed reduction in feed intake in the present study cannot be attributed to poor palatability arising from the aromatic properties of ergot because ADFI was not affected in the first 2 wk ($P > 0.20$). Furthermore, much lower levels of ergot are reported herein. Whittemore et al (1977) found a 38% reduction in the feed intake of weaned pigs fed 2.5% ergot (77.5 mg alkaloid kg^{-1} diet). A reduction in feed intake was also observed in growing pigs fed 0.5% of the same ergot. Blaney et al. (2000) reported a 30% reduction in the feed intake of 20-kg growing pigs fed diets containing 0.6% ergot (9 mg alkaloid kg^{-1}diet). It is likely that in the present study, the reduction in feed consumption in the last week was probably due to an overall increase in the intake of alkaloids as a proportion of body weight. For example, feed intake, averaged across treatments, represented 4.7% of BW in week 1 and 7.1% in week 4. Thus, it is reasonable to

anticipate an increasing effect of ergot alkaloids on metabolic activity and feeding behaviour as the experiment progressed.

Depression of feed intake may be related to the pharmacological properties of ergot alkaloids. By acting as partial agonists or antagonists at adrenergic, dopaminergic, and trypaminergic receptors, ergot alkaloids exhibit wide and complex pharmacological properties (Peroutka 1995). Both serotonin and dopamine have been associated with a decrease in food intake (Halford and Blundell 2000). Ergotoxines (ergocryptine, ergoristine, and ergocornine) are known dopamine agonists (Melmed 1990) and therefore may inhibit feed intake by activating the satiety mechanisms in the lateral hypothalamic area and/or produce effects incompatible with feeding behaviour in the forebrain (Evans and Eikelboom 1987; Opara et al. 1996). The stimulation of dopaminergic receptors with low doses of selective agonists in rats reduced food intake (Terry et al. 1995) and, α-ergobromocryptine (ergoset), a dopamine agonist, is being considered as a potential drug for the treatment of obesity in humans (Halford and Blundell 2000).

Dopamine exerts a direct effect on levels of physical activity that may account for some of its hypophagic effects (Halford and Blundell 2000). Sedation was produced in rodents treated with dihydroergosine (Manev et al. 1989), and other alkaloids such as bromocriptine cause nausea, vomiting and dizziness (Ascoli and Segaloff 1995).

Effects on Growth and Feed Efficiency

The results from the present study indicate that decreased feed intake is not the primary cause of reduced growth resulting from ergot alkaloid consumption in swine. Although feed intake was unchanged in weeks 1 and 2, ADG declined to 82 and 38% of the control for pigs fed 1.00% ergot, in weeks 1 and 2, respectively. This indicates that the growth of these young pigs was severely affected by a toxic effect of alkaloids regardless of the effects on feed intake. However, feed intake decreased by 18% in weeks 3 and 4 at which time ADG declined by 37 and 23%, respectively for pigs fed 1.00% ergot. This suggests that the effect on growth may become attenuated as exposure continues, probably due to a reduction in the amount of alkaloid consumed as feed intake declines. Similarly, Whittemore et al. (1976) reported a 77 and 24% decrease in ADG in the early and late period, respectively, in growing pigs fed ergot. However, this decline in ADG was not associated with feed intake, because pigs were restricted to a similar daily intake.

Whittemore et al. (1977) concluded that reduced feed intake did not fully explain poor growth performance in pigs fed 2.5% ergot. Similarly, Janssen et al. (2000a) found that poor growth and feed efficiency in rats fed diets containing up to 500 mg ergocryptine kg^{-1} were not solely due to reduced feed intake. In the present study, reduced feed intake may have contributed to the poor growth performance observed in the second half, but not during the initial 2 wk of the experiment.

The results from this and other studies (e.g., Whittemore et al. 1976, 1977; Sawosz 1996; Blaney et al. 2000) indicate that ergo-toxicity in pigs may go undiagnosed due to a lack of cutaneous or nervous signs. This may have serious economic implications. Although pigs appear normal, severe impairment in growth rate will result in more days to reach market weight. For instance, pigs that were fed the 1.00% ergot level weighed 15.4 kg on day 28, similar to the weight of the control pigs at day 21 (15.5 kg). Assuming the use of the ergoty wheat in the diet is terminated and that there are no residual toxic effects (e.g. internal injuries) that may result in a poorer nutrient utilization and growth, pigs fed diets containing 1.00% ergot for 28 d would require an additional 7 d to reach market weight. Similarly, pigs that were fed the 0.25% ergot diet had a 15% lower ADG than the control (Table 6) and may require 4 extra days to reach market weight compared to the control. This translates into inefficiency in the use of facilities, and a negative impact on productivity.

The primary cause of poor growth may be related to the effects of alkaloids on the central nervous and cardiovascular systems. Alkaloids, especially ergotamine, ergocryptine and ergocornine, are known to be potent vasoconstrictors (Janssen et al. 2000b). Additionally, alkaloids may either increase peristalsis (Nickerson 1970) or may decrease motility due to an agonistic action at serotonin receptors inhibiting electrically stimulated acetycholine release from cholinergic neurons (Pfeuffer-Friederich and Kilbinger 1985). Increased vasoconstrictive activity in the gastrointestinal tract (GIT) will result in reduced blood flow in the capillaries and a reduction in digestive and absorptive capacity and a decrease in DM digestibility. An increase in peristaltic activity increases the rate of passage of digesta in the GIT (Nickerson 1970) and may result in diarrhoea.

Whittemore et al. (1976) observed no effect on DM digestibility in growing pigs fed 4% ergot, or in piglets fed 0.5% ergot (Whittemore et al. 1977). In contrast, Blaney et al. (2000) reported an increase in DM digestibility in growing pigs fed 0.6% ergot. Rotter and Phillips (1991) observed no increase in mean transit time in the small intestine of sheep fed increasing levels of ergot. However, Whittemore et al. (1977) observed toxic assaults characterized by gastritis, ulceration, enteritis and hepatic fibrosis in the GIT of pigs fed 2.5% ergot. In the present study, ergot actually increased DM digestibility ($P < 0.05$) suggesting no increased vasoconstrictive or peristaltic activities. This suggests that the major effect of ergot ingestion and alkaloid toxicity in this experiment was not elicited in the GIT and may be metabolic in nature, exerted perhaps via effects on hormones. Alternatively, apparent DM digestibility might reasonably be expected to rise with declining daily feed intake, so the effect could be explained as secondary to the primary action of ergot alkaloids.

Alkaloids may affect the secretion of hormones that regulate nutrient metabolism (Janssen et al. 2000b). Janssen et al. (2000b) observed an increase in plasma glucagon in fed rats suggesting increased conversion of glycogen and amino acids into glucose. Increased use of protein for gluconeogenesis led to high plasma urea concentration. In the present study, SUN decreased with increasing ergot level. Whittemore et al. (1977) reported a 22% increase in daily N retention in growing pigs fed 0.50% ergot compared with the control.

In the present study, and similar to previous studies (Sawosz 1996), the inclusion of 0.05% ergot numerically increased ADG (4%) compared to the control. Sawosz (1996) observed a 3% increase in ADG in growing-finishing pigs fed 0.05% ergot compared with the control and suggested a stimulating action of a small amount of ergot alkaloids on growth. Burfening (1994) reported a 2.4% increase in ADG in heifers fed 0.10% ergot compared with the control. It may be hypothesized that at low levels, ergot alkaloids may exert a positive influence on N retention and increase growth performance. Further research will be necessary to evaluate the response in ADG to ergot at several graded levels between 0 and 0.10% to clarify the growth promoting potential of ergot alkaloids in the weaned pig.

Effects on Serum Prolactin

Prolactin is a hormone that is essential for mammogenesis and lactogenesis in mammalian species (Farmer 2001). A certain threshold is necessary for normal mammary gland development in gilts and the expression of maximum milk potential in lactating sows (Farmer 2001). Dopaminergic agonists inhibit the secretion of pituitary hormones such as prolactin, growth hormone and adrenocorticotropic hormone (Kren 1999) and bromocryptine has been used to treat pathological disorders caused by the overproduction of these hormones e.g., hyperprolactinaemia and acromegaly (Melmed 1990; Kren 1999). Prolactin secretion in the pituitary gland is regulated by the hypothalamus and is subjected to inhibition by dopamine agonists and serotoninergic antagonists (Lipham et al. 1987).

Dopamine is believed to suppress all aspects of prolactin secretion including cell division of prolactin producing cells (Sbarbati et al. 1989). Ergotoxine (ergocryptine, ergocornine and ergocristine) have the greatest prolactin suppression potency (Fluckiger et al. 1976). These alkaloids constituted 53% of the total alkaloid content of the ergot used in the present study. A decrease in serum prolactin concentration was observed at all levels of ergot fed and suggests that ingestion of ergot alkaloid could impair mammary development in gilts and/or lactation in lactating sows. Blaney et al. (2000) reported a depression of plasma prolactin at all levels of ergot fed to growing pigs. Janssen et al. (2000b) observed a dose-dependent decrease in serum prolactin in rats fed up to 500 mg ergocryptine kg^{-1} diet.

A depression in prolactin synthesis or secretion may have severe consequences. One possibility is that at the termination of feeding the ergoty wheat, prolactin secretion returns to normal, a reversible suppression. However, if damage to prolactin secreting cells of the pituitary is severe, secretion of the hormone in pigs previously exposed to ergot alkaloid in the nursery period may be permanently lower than those unexposed. A consequence of this would be reduced reproductive performance through impaired mammogenesis, lactation insufficiency and poor litter performance.

Janssen et al. (2000a) found no decrease in the level of prolactin positive cells in spite of an observed dose-dependent decrease in prolactin in rats (Jansen et al. 2000b). It was suggested that the pathogenesis of prolactin suppression from ergot alkaloid may be complex and not fully understood. Currently, there is a paucity of information on the impact of exposure to alkaloid in the nursery or growing pigs on mammogenesis and subsequent reproductive performance. Until such information becomes available, even low levels of ergot should not be included in the diet of pigs destined for the breeding herd and in the diet of gestating or lactating sows.

Tolerable Ergot Level

Tolerable ergot levels from the responses in ADG, ADFI and serum prolactin were determined using the Dunnett *t*-like test. The ADFI and serum prolactin were more sensitive indicators of the toxic effect of ergot alkaloids than ADG. The ADFI was significantly reduced at 0.10% and above (days 0 to 28; Table 4). At the 0.05% ergot level pigs were consuming 0.76 ± 0.04 mg alkaloid d^{-1}. Alternatively, this is equivalent to 1.6 mg alkaloid consumed per kilogram of body weight gain by pigs at the 0.05% ergot level (approximately 60 µg alkaloid kg^{-1} liveweight). Thus, when the alkaloid content of ergot is known and the feed intake of the weaned pig can be predicted accurately, the amount of ergoty wheat to be included in the diet to ensure consumption of not more than 0.76 mg alkaloid d^{-1} can be calculated. For example, if wheat is known to contain 0.50% ergot, not more than 10% may be incorporated in the weaned pig diet.

However, these calculations assume that the alkaloid profile and content of the ergot is comparable to that used in the present study. The response to serum prolactin may suggest that no level of alkaloid-containing ergot sclerotia is desirable in the diet of breeding stock (Table 6).

Although ADFI was more sensitive to ergot than ADG, there was a delayed response to ADFI such that in the first 2 wk (Table 4) no effect was observed on ADFI and ADG was decreased at the 0.25% inclusion level and above. Thus, ADFI may not be a good response criterion for low-level ergo-toxicity in the early nursery period. The ADG was significantly reduced at 0.25% and above (Table 4). Pigs on the 0.10% ergot level consumed 1.39 ± 0.12 mg alkaloid d^{-1} compared with 3.54 ± 0.55 mg alkaloid d^{-1} for those on 0.25%.

CONCLUSION

Consumption of up to 1.00% ergot by piglets did not produce cutaneous or nervous manifestations. Reduced feed intake may not be apparent during low-level ergo-toxicity in the weaned pig. Increased intake of ergot alkaloid caused a severe reduction in the growth performance of weaned pigs with or without an effect on feed intake. Also, ergot alkaloid consumption caused severe reduction of serum prolactin concentration. At 1800 mg alkaloid kg^{-1}ergot, piglets cannot tolerate more than 0.10% ergot sclerotia in their diet. A safer level would be 0.05% based on feed intake. Furthermore, due to the impact on serum prolactin, until data become available on the effect of ergot consumption in nursery pigs and future reproductive performance, ergoty grain may not be suitable in the diet of pigs destined for the breeding herd.

ACKNOWLEDGEMENTS

The authors acknowledge with gratitude funding of this project from the Alberta Agricultural Research Institute and the program funding received by the Prairie Swine Centre from

Sask Pork, the Saskatchewan Agriculture Development Fund, Alberta Pork and the Manitoba Pork Council. The authors gratefully acknowledge Drs. B. Thompson and R. Baker for discussing the statistical analysis; Dr. T. J. Evans, Veterinary Medical Diagnostic Laboratory, University of Missouri, Columbia, MO, for ergot alkaloid assay; and Susan Cook, Prairie Diagnostic Services, Endocrinology, Saskatoon, SK, for the prolactin assay.

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