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Effects of High Phytase Supplementation in Lactation Diets on Sow and Litter Performance

K. L. Batson
Kansas State University, kelsey72@k-state.edu

H. Calderon Cartagena
Kansas State University, hilda1@k-state.edu

R. D. Goodband
Department of Animal Science and Industry, Kansas State University, goodband@ksu.edu

See next page for additional authors

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Abstract

A total of 109 sows (Line 241; DNA, Columbus, NE) were used in a study to evaluate the effect of increasing phytase concentration in lactating sow diets on farrowing duration, and sow and litter performance. On d 107 of gestation, sows were blocked by body weight and parity and allotted to 1 of 3 dietary treatments of increasing phytase concentration (0, 1,000, or 3,000 FTU/kg; Ronozyme HiPhos 2700; DSM Nutritional Products, Inc., Parsippany, NJ). The control diet contained no phytase and was formulated to contain 0.50% standardized total tract digestible phosphorus (STTD P; 0.45% available P) and 0.62% STTD calcium (0.90% total Ca). The phytase diets contained 1,000 or 3,000 FTU/kg also formulated to 0.50% STTD P and 0.62% STTD Ca including the release of 0.132 STTD P and 0.094 STTD Ca in both phytase diets. Diets were balanced for net energy by altering choice white grease. Diets were fed from d 107 of gestation until weaning (d 17 ± 2) and all farrowings were monitored with farrowing duration measured starting at the time the first pig was born until the first dispersal of placental tissues with no subsequent pigs born. Litters were cross-fostered within treatment until 48 h post-farrowing to equalize litter size. There were no differences among treatments in body weight at d 107 of gestation, 24 h after farrowing, or at weaning. Sow average daily feed intake (ADFI) from farrowing to weaning tended to increase (linear, $P = 0.093$) as phytase units increased. There was no evidence for difference in farrowing performance, wean-to-estrus interval, or litter size among dietary treatments. Although not significant (linear, $P = 0.226$), farrowing duration decreased for sows fed 3,000 FTU/kg. Litter weaning weight increased (quadratic, $P = 0.039$) and overall litter gain increased (quadratic, $P = 0.047$) with 1,000 FTU of phytase. In summary, sow feed intake tended to increase linearly with increasing phytase; however, feeding 1,000 FTU/kg maximized overall litter gain and weaning weight. Farrowing duration was numerically decreased with increasing units of phytase. This small-scale study presents interesting impacts on sow and litter performance due to high inclusions of dietary phytase; however, a commercial trial with more sows is warranted.

Keywords

farrowing duration, lactation, phytase, sow

Cover Page Footnote

Appreciation is expressed to Jon Bergstrom, DSM Nutritional Products (Parsippany, NJ) for the phytase analysis of experimental diets.

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K. L. Batson, H. Calderon Cartagena, R. D. Goodband, J. C. Woodworth, M. D. Tokach, S. S. Dritz, and J. M. DeRouchey

Effects of High Phytase Supplementation in Lactation Diets on Sow and Litter Performance[1]

Kelsey L. Batson, Hilda Calderon Cartagena,[2] Robert D. Goodband, Jason C. Woodworth, Mike D. Tokach, Steve S. Dritz,[3] and Joel M. DeRouchey

Summary

A total of 109 sows (Line 241; DNA, Columbus, NE) were used in a study to evaluate the effect of increasing phytase concentration in lactating sow diets on farrowing duration, and sow and litter performance. On d 107 of gestation, sows were blocked by body weight and parity and allotted to 1 of 3 dietary treatments of increasing phytase concentration (0, 1,000, or 3,000 FTU/kg; Ronozyme HiPhos 2700; DSM Nutritional Products, Inc., Parsippany, NJ). The control diet contained no phytase and was formulated to contain 0.50% standardized total tract digestible phosphorus (STTD P; 0.45% available P) and 0.62% STTD calcium (0.90% total Ca). The phytase diets contained 1,000 or 3,000 FTU/kg also formulated to 0.50% STTD P and 0.62% STTD Ca including the release of 0.132 STTD P and 0.094 STTD Ca in both phytase diets. Diets were balanced for net energy by altering choice white grease. Diets were fed from d 107 of gestation until weaning (d 17 ± 2) and all farrowings were monitored with farrowing duration measured starting at the time the first pig was born until the first dispersal of placental tissues with no subsequent pigs born. Litters were cross-fostered within treatment until 48 h post-farrowing to equalize litter size. There were no differences among treatments in body weight at d 107 of gestation, 24 h after farrowing, or at weaning. Sow average daily feed intake (ADFI) from farrowing to weaning tended to increase (linear, $P = 0.093$) as phytase units increased. There was no evidence for difference in farrowing performance, wean-to-estrus interval, or litter size among dietary treatments. Although not significant (linear, $P = 0.226$), farrowing duration decreased for sows fed 3,000 FTU/kg. Litter weaning weight increased (quadratic, $P = 0.039$) and overall litter gain increased (quadratic, $P = 0.047$) with 1,000 FTU of phytase. In summary, sow feed intake tended to increase linearly with increasing phytase; however, feeding 1,000 FTU/kg maximized overall litter gain and weaning weight. Farrowing duration was numerically decreased with increasing units of phytase. This small-scale study presents interesting impacts on sow and litter performance due to high inclusions of dietary phytase; however, a commercial trial with more sows is warranted.

[1] Appreciation is expressed to Jon Bergstrom, DSM Nutritional Products (Parsippany, NJ) for the phytase analysis of experimental diets.

[2] Department of Statistics, College of Arts and Sciences, Kansas State University.

[3] Department of Diagnostic Medicine/Pathology, College of Veterinary Medicine, Kansas State University.

Introduction

Phytic acid is the main storage form of phosphorus in grains and oil seeds; however, pigs are unable to utilize P bound to this complex structure. The enzyme phytase dephosphorylates phytate, ultimately reducing supplementation of inorganic P in swine diets by improving digestibility of dietary phosphorus. The inclusion of phytase at high levels above that needed for P-release has shown improvements in growth performance in nursery pigs. This suggests that phytase possesses extra-phosphoric effects by freeing other molecules bound to phytate and increasing the digestibility of energy, amino acids, and minerals. While the exact mechanisms are unknown, it is hypothesized that the destruction of phytate, release of phosphate, and myo-inositol liberation combined with extra-phosphoric effects, are synergistic components responsible for improvements in performance experienced in the literature.[4] Sows commonly experience a negative energy balance in lactation due to reduced feed intake while supporting sufficient milk production and meeting maintenance requirements, which can result in the mobilization of body reserves. Due to this reason, high levels of phytase may offer some benefit to lactating sows. Manu et al. (2018)[5] found that high levels of phytase in lactation diets had no effect on sow performance but they did observe a reduction in farrowing duration and a decrease in the number of stillborns present. Another study observed a decrease in sow body weight loss with increasing phytase dosage up to 2,000 FTU/kg in older parity sows.[6] Therefore the objective of this study was to determine the effect of high levels of phytase fed to lactating sows on feed intake, farrowing duration, and sow and litter performance.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment.

A total of 109 sows (Line 241; DNA, Columbus, NE) were used across four batch farrowing groups from November 2018 to March 2019 at the Kansas State University Swine Teaching and Research Center. On d 107 of gestation, sows were weighed and moved into the farrowing house. Females were blocked by initial body weight and parity, then allotted to 1 of 3 dietary treatments (Table 1). Dietary treatments were corn-soybean meal-based and consisted of three concentrations of phytase (0, 1,000, or 3,000 FTU/kg). The control diet containing no phytase was formulated to 0.50% STTD P (0.45% available P) and 0.62% STTD Ca (0.90% total Ca). The phytase diets contained 1,000 or 3,000 FTU/kg and were also formulated to 0.50% STTD P and 0.62% STTD Ca including the release of 0.132 STTD P and 0.094 STTD Ca in both diets. Diets were balanced for net energy (NE) by altering choice white grease.

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[4] Boyd, R.D., C.E. Zier-Rush, A. J. Elsbernd, P. Wilcock, and E. van Heugten. 2018. Effects of superdosing phytase and inositol supplementation on growth performance and blood metabolites of weaned pigs housed under commercial conditions. J. Anim. Sci. 96(suppl.2):164. (Abstr.). https://doi.org/10.1093/jas/sky073.302.

[5] Manu, H., D. Pangeni, P. Wilcock, and S. K. Baidoo. 2018. The effect of superdosing phytase from 109 days of gestation through lactation on farrowing duration, piglet and sow performance. J. Anim. Sci. 96(suppl.2): 148. (Abstr.). https://doi.org/10.1093/jas/sky073.273.

[6] Wealleans, A.L., R.M. Bold, Y. Desjant-Li, and A. Awati. 2015. The addition of a buttiauxella sp. phytase to lactating sow diets deficient in phosphorus and calcium reduces weight loss and improves nutrient digestibility. J. Anim. Sci. 93(11):5283-90. doi:10.2527/jas.2015-9317.

Diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center in Manhattan, KS. A new batch of each treatment diet was manufactured for each farrowing group and packaged in 50-lb bags. During bagging, feed samples were collected from every fifth bag, pooled, and stored at -20°C and later homogenized for nutrient analysis.

From d 107 of gestation until farrowing (approximately d 115-116), sows were offered up to 6 lb/d of their respective treatment diets. Postpartum, sows were allowed *ad libitum* access to feed distributed by an electronic feeding system (Gestal Solo Feeders Jyga Technologies, Quebec City, Quebec, Canada). Sow feed intake was recorded by weighing the amount of feed placed in the feeder and the amount remaining every 7 d until weaning. Farrowing duration was monitored by 24-h care for 101 sows, where the initiation of farrowing was classified as the birth of the first piglet and the completion of farrowing was determined by the first dispersal of placental tissues with no subsequent pigs born. From the onset of farrowing, sows were checked in 15 minute intervals and were sleeved if the time in between births reached 30 to 45 minutes. Oxytocin was administered to sows who produced no piglets when sleeved and the time in between births was greater than approximately 2 hours. Sows were excluded from the study if retained fetuses were expelled 24 h after a sow's respective initial farrowing time and if initial farrowing time could not be determined. Sow body weight was measured 24 h after farrowing and at weaning (d 17 ± 2). Cross fostering occurred within dietary treatment until 48 h postpartum in an attempt to equalize litter size (minimum of 10 pigs per litter). Litters were weighed on d 2, 7, 14, and at weaning. Piglet survivability was calculated as the number of pigs per weaned per sow divided by the number of pigs on d 2 after cross fostering was completed.

At weaning, sows were moved to a breeding barn, individually housed, and checked daily for signs of estrus using a boar. The wean-to-estrus interval (WEI) was determined as the number of days between weaning and when sows were first observed to show a positive response to the back-pressure test.

Chemical Analysis

Four samples (1 per batch) per dietary treatment from the pooled feed samples were sent for phytase analysis (DSM Nutritional Products, Inc., Belvidere, NJ) and analysis of CP, Ca, and P (Ward Laboratories, Inc., Kearney, NE).

Statistical Analysis

Data were analyzed using the lmer function from the lme4 package in R (version 3.5.2 (2018-12-20)) where sow was the experimental unit, dietary treatment was a fixed effect, and sow group and block were the random effects. Statistical models were fitted using RStudio[7] (Version 3.5.2, R Core Team. Vienna, Austria). Pre-planned linear and quadratic contrast statements were used to evaluate increasing phytase concentrations.

Sow ADFI, body weight, backfat depth, litter weight, litter gain, pig gain, and lactation length were fitted assuming a normal distribution. Litter weight on d 2 was used as a

[7] R Core Team. 2018. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. https://www.R-project.org/.

covariate for d 7, 14, and weaning litter weights and litter weight gain to improve the fit of the model. In these cases, residual assumptions were checked using standardized residuals and were found to be reasonably met.

Litter counts, wean to estrus interval, and the duration of farrowing were fitted using a negative binomial distribution. Total born, born alive, stillborn, mummy, and piglet survivability were fitted using a binomial distribution. All results were considered significant at $P \leq 0.05$, and marginally significant at $0.05 \leq P \leq 0.10$.

Results and Discussion

Chemical analysis of diets was similar to formulated values with phytase being slightly higher than formulated, but still within expected analytical variation (Table 2). There were no differences among treatments in body weight at d 107 of gestation, 24 h after farrowing, or at weaning. Sow average daily feed intake from d 107 of gestation to farrowing increased (quadratic, $P = 0.009$) as added phytase increased, with those fed 1,000 FTU having the greatest ADFI. From d 0 to 7 and 7 to 14 of lactation, ADFI was similar across treatments; however, from d 14 to weaning, ADFI increased (linear, $P = 0.020$) with increasing dietary phytase and overall ADFI tended to increase (linear, $P = 0.093$) as phytase dosage increased. There was no statistical difference (linear, $P = 0.226$) for phytase to impact farrowing duration; however, the duration numerically decreased with increasing phytase dose, similar to our hypothesis, which supports the need for additional research with more sows to properly determine the phytase impact on farrowing duration.

Similarly, there was no evidence for difference in total born, percentage of pigs born alive, stillborn, or mummies, litter count at d 2 and at weaning, piglet survivability or pig weight gain. No evidence for differences were found for litter weight at d 2 or 7; however, litter weaning weight increased (quadratic, $P = 0.039$) and overall litter gain increased (quadratic, $P = 0.047$) with sows fed 1,000 FTU/kg exhibiting the best performance. There was marginal evidence for differences in litter weight at d 14 (quadratic, $P = 0.053$) and litter average daily gain (quadratic, $P = 0.0053$) to increase with increasing added phytase, but appeared to be maximized for sows fed 1,000 FTU/kg.

In summary, increasing phytase to 3,000 FTU/kg increased feed intake in lactating sows from d 14 of lactation to weaning and tended to increase overall ADFI, while pre-farrow intake was maximized at 1,000 FTU of phytase. Sows fed diets with 1,000 FTU had increased overall litter gain and weaning weight. Although not significant, farrowing duration numerically decreased for sows fed 3,000 FTU/kg. This small-scale study presents interesting impacts on sow and litter performance due to high inclusions of dietary phytase; however, a commercial trial with more sows is warranted.

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Table 1. Diet composition (as-fed basis)

	Phytase concentrations, FTU/kg	
Item	0	1,000/3,000
Ingredient, %		
Corn	63.30	64.40
Soybean meal, 46.5% CP	30.0	30.0
Choice white grease	2.40	2.00
Limestone	0.95	0.88
Monocalcium phosphate, 21%	1.78	1.10
Salt	0.50	0.50
L-Lysine-HCL	0.18	0.18
DL-Methionine	0.05	0.05
L-Threonine	0.10	0.10
L-Valine	0.12	0.12
Sow add pack	0.25	0.25
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Phytase[1]	---	0.04 / 0.11
Total	100	100
Calculated analysis		
Standardized ileal digestible (SID) amino acids, %		
Lysine	1.05	1.05
Isoleucine:lysine	68	68
Leucine:lysine	141	142
Methionine:lysine	30	30
Methionine and cysteine:lysine	56	56
Threonine:lysine	67	67
Tryptophan:lysine	20.1	20.1
Valine:lysine	85	85
Total lysine, %	1.19	1.19
Net energy, kcal/lb	1,136	1,136
SID Lys:ME, g/Mcal	4.19	4.19
Crude protein, %	19.9	20.0
Ca, %	0.90	0.75
P, %	0.76	0.62
STTD P, %	0.50	0.50

[1]Ronozyme HiPhos 2700, DSM Nutritional Products Inc., Parsippany, NJ.
Lys = lysine. ME = metabolizable energy. STTD = standardized total tract digestible.

Table 2. Chemical analysis of the diets (as-fed basis)[1]

	Phytase concentration, FTU/kg		
Item, %	0	1,000	3,000
Dry matter	88.43	88.03	87.94
Crude protein	19.7	20.2	20.4
Ca	0.94	0.79	0.76
P	0.66	0.54	0.54
Phytase[2]	17	1,261	3,744

[1]Diet samples were collected from each batch of feed at manufacturing from every fifth bag. Nutrient analysis was conducted on composite samples (Ward Laboratories Inc., Kearney, NE).
[2]Ronozyme HiPhos 2700 analyzed at DSM Nutritional Products Inc. (Belvidere, NJ).

Table 3. Effect of high phytase supplementation in lactation diets on sow performance[1]

	Phytase concentration, FTU/kg				Probability, $P =$	
	0	1,000	3,000	SEM	Linear	Quadratic
Number of sows, n	36	36	37	--	--	--
Parity	2.1	2.1	2.1	1.13	0.990	0.924
Sow body weight, lb						
d 107[2]	528.5	536.5	519.6	10.77	0.452	0.418
Farrow	506.1	511.9	511.8	10.10	0.424	0.475
Wean	483.0	488.2	488.1	9.46	0.507	0.551
Change (farrow to wean)	-23.0	-23.4	-23.4	3.61	0.943	0.943
Sow ADFI, lb						
d 107 to farrow	4.8	5.4	5.2	0.14	0.112	0.009
d 0 to 7	9.6	10.3	10.2	0.30	0.140	0.144
d 7 to 14	13.7	14.0	14.2	0.41	0.367	0.793
d 14 to wean	14.9	15.9	16.3	0.45	0.020	0.264
Farrow to wean	12.4	13.0	13.1	0.30	0.093	0.285
Farrowing duration, min[3]	399	376	350	1.08	0.226	0.873
Lactation length, d	18.1	18.3	18.1	0.18	0.586	0.366
Wean to estrus, d	4.8	4.6	4.6	1.08	0.707	0.710

[1]A total of 109 sows and their litters were used in a 21-d study. There were 36 or 37 sows per treatment.
[2]Sows were loaded into the farrowing room at d 107 of gestation.
[3]Farrowing duration was determined for a total of 101 sows and excludes any sow that expelled a retained fetus 24-hours past the parturition of the initial piglet or initial time of farrowing could not be confirmed. The initiation of farrowing was classified as the birth of the first piglet and the completion of farrowing was determined by the first dispersal of placental tissues with no subsequent pigs born.

Table 4. Effect of high phytase supplementation in lactation diets on litter performance[1]

	Phytase concentration, FTU/kg				Probability, P =	
	0	1,000	3,000	SEM	Linear	Quadratic
Number of sows	36	36	37	--	--	--
Farrowing performance						
Total born	17.4	17.8	16.2	1.04	0.135	0.316
Born alive,[2] %	92.0	91.0	91.0	1.18	0.839	0.478
Stillborn,[2] %	6.0	7.0	6.0	1.20	0.995	0.541
Mummy,[2] %	2.0	2.0	2.0	1.35	0.710	0.729
Litter count, n						
d 2[3]	14.7	15.0	13.9	1.04	0.252	0.428
Wean	12.9	13.7	13.1	1.05	0.961	0.337
Piglet survivability,[4] %	96.0	97.0	97.0	1.28	0.387	0.714
Litter weight, lb						
d 2[5]	46.2	46.0	46.6	1.33	0.760	0.816
d 7[6]	72.1	74.4	74.5	1.00	0.278	0.108
d 14[6]	121.4	126.8	124.7	2.19	0.551	0.053
Wean[6]	148.2	156.6	152.5	3.09	0.613	0.039
Litter average daily gain, lb[6]	6.32	6.82	6.59	0.18	0.427	0.053
Overall litter gain, lb	102.0	110.7	106.0	3.42	0.543	0.047
Pig weight, lb						
d 2	3.2	3.3	3.2	0.09	0.794	0.346
d 7[7]	5.4	5.3	5.5	0.07	0.210	0.119
d 14[7]	9.3	9.2	9.6	0.17	0.154	0.302
Wean[7]	11.5	11.4	11.9	0.25	0.281	0.457
Pig weight gain, lb[8]	8.3	8.3	8.6	0.28	0.351	0.771

[1]A total of 109 sows and their litters were used in a 21-d study. There were 36 to 37 sows per treatment.
[2]Percent of total born.
[3]Cross-fostering occurred within treatment in an attempt to equalize litter size.
[4]Piglet survivability = litter count at weaning/litter count on d 2.
[5]Litters were weighed at 48 h after cross-fostering.
[6]Litter weight on d 2 was used as a covariate to improve the fit of the model.
[7]Pig weight on d 2 was used as a covariate to improve the fit of the model.
[8]Pig weight gain = pig weight at weaning minus pig weight at d 2.