Kansas Agricultural Experiment Station Research Reports

Volume 5
Issue 8 *Swine Day*

Article 29

2019

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Recommended Citation

Truelock, C. N.; Ward, N. E.; Wilson, J. W.; Stark, C. R.; and Paulk, C. B. (2019) "Effect of Pellet Die Thickness and Conditioning Temperature During the Pelleting Process on Phytase Stability," *Kansas Agricultural Experiment Station Research Reports*: Vol. 5: Iss. 8. https://doi.org/10.4148/2378-5977.7859

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Cover Page Footnote

Appreciation is expressed to DSM Nutritional Products for partial financial support of this project.

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K-STATE Research and Extension

SWINE DAY 2019

KANSAS STATE UNIVERSITY SWINE INDUSTRY DAY 2019

Effect of Pellet Die Thickness and Conditioning Temperature During the Pelleting Process on Phytase Stability[1]

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Summary

This experiment was designed to evaluate the effects of pellet mill die thickness and conditioning temperature on the stability of microbial phytase. Treatments were arranged as a 2 × 3 factorial of die thickness (L:D 5.6 and 8.0) and conditioning temperature (165, 175, and 185°F). Phytase was added to a corn-soybean meal-based diet and mash samples were collected for phytase analysis. The diet was pelleted via steam conditioning (10 × 55 in Wenger twin staff pre-conditioner, Model 150) and using a pellet mill (CPM Model 1012-2) with a 5/32 × 7/8 in (L:D 5.6) or 5/32 × 1 1/4 in (L:D 8.0) pellet die. Conditioner retention time was set at 30 sec and production rate was set at 33 lb/min, approximately 100% of the rated throughput for the pellet mill. All treatments were replicated on 3 separate days. Pellet and conditioned mash samples were collected and immediately placed in an experimental counter-flow cooler for 15 min. For each treatment, pellet and conditioned mash samples were composited such that 2 samples of each were analyzed for phytase activity and pellet durability index (PDI). Conditioning temperature, hot pellet temperature (HPT), and production rate were recorded throughout each processing run. Data were analyzed using the GLIMMIX procedure in SAS (v. 9.4), with pelleting run as the experimental unit and day as the blocking factor.

There was no evidence ($P > 0.14$) for a die thickness × conditioning temperature interaction for any of the pelleting or phytase responses analyzed in this study. Hot pellet temperature was increased when diets were pelleted with a thicker die ($P < 0.01$), and by increasing conditioning temperature from 165 to 185°F (linear, $P < 0.01$). Pellet durability index was greater ($P < 0.01$) for diets pelleted using the thicker die with an 8.0 L:D compared to the die with a 5.6 L:D. Additionally, PDI increased (linear, $P = 0.03$) with increasing conditioning temperature. Increasing conditioning temperature from 165 to 185°F decreased (linear, $P < 0.01$) phytase stability of conditioned mash and cooled pellets, with no difference ($P > 0.72$) in stability due to die thickness.

[1] Appreciation is expressed to DSM Nutritional Products for partial financial support of this project.

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Results of this experiment show that phytase stability in conditioned mash and pellets decreases linearly when conditioning temperature rises above 165°F and HPT rises above 177°F. Although the thicker pellet die increased HPT by an average of 1.9°F and increased PDI by an average of 7.8%, there was no evidence that the additional frictional heat associated with increasing the die L:D from a 5.6 to an 8.0 resulted in lower phytase stability. Finally, increasing conditioning temperature linearly increased HPT and PDI.

Introduction

Due to the growing use of phytase in pelleted diets, it is important to evaluate the effect of thermal processing on phytase stability. Previous research at Kansas State University has shown that phytase activity is inhibited by heat addition, specifically at conditioning temperatures ranging from 170 to 200°F.[4] At the lower end of the temperature range, a large portion of the reduction in stability occurs across the die, likely due to the frictional heat resulting from the pressure of pushing the feed through the die. An optimum pellet die length to diameter ratio (L:D) in commercial feed mills is 8 but can range from 6 to 10. If hole diameter remains constant, pellet dies with a larger L:D are thicker, and thus have greater potential for increased frictional heat. This leads to the objective of this research which was to evaluate the effect of die thickness and conditioning temperature on phytase stability.

Procedures

Treatments were arranged as a 2 × 3 factorial of die thickness (L:D 5.6 and 8.0) and conditioning temperature (165, 175, and 185°F). Phytase was added to a corn-soybean meal-based diet (Table 1) and mash samples were collected for phytase analysis. Diets were mixed in a 1-ton horizontal counterpoise mixer (Hayes & Stolz, Fort Worth, TX), steam conditioned (10 × 55 in twin staff pre-conditioner, Model 150, Wenger, Sabetha, KS) for 30 sec at 165, 175, or 185°F, and subsequently pelleted using a 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill, Crawfordsville, IN) equipped with a 5/32 × 7/8 in (L:D 5.6) or 5/32 × 1 1/4 in (L:D 8.0) pellet die. Conditioner retention time was calculated by adjusting the conditioner screw speed and dividing the amount of feed in the conditioner by the production rate. Production rate was set at 33 lb/min, approximately 100% of the rated throughput for the pellet mill, and steam pressure was 24 psi. All treatments were replicated on 3 separate days, thus achieving 3 replications per treatment. Die thickness was randomized across day to minimize the effects of pelleting order. A conventional corn-soybean meal flush diet was used to warm the mill up to 165°F before each day of pelleting. Six hundred lb of the diet was pelleted using the selected die, according to randomization, at all 3 conditioning temperatures in ascending order. When pelleting was completed, the pellet mill was shut down, and the die was changed. A conventional corn-soybean meal flush was again used to warm the mill up to 165°F before pelleting on the second die, and pelleting procedures followed the pattern previously mentioned. Conditioning temperature, hot pellet temperature (HPT), and production rate were recorded at 3 time points during each run (Table 2).

[4] Truelock, C. N., A. D. Yoder, C. E. Evans, C. R. Stark, S. S. Dritz, J. W. Wilson, N. E. Ward, and C. B. Paulk. 2018. Stability of Four Commercial Microbial Phytase Sources Under Increasing Conditioning Temperatures and Conditioner Retention Times During Pelleting. Kansas Agricultural Experiment Station Research Reports: Vol. 4: Iss. 9.

For each treatment, 3 conditioned mash samples were collected as feed exited the conditioner prior to the pellet die and immediately cooled in an experimental counter-flow cooler for 15 min. Cooled conditioned mash samples were then composited into 2 samples for phytase analysis. Likewise, 3 pellet samples per treatment were collected as feed exited the pellet die, cooled for 15 min, and composited into 3 samples, 2 for phytase analysis and 1 for analysis of pellet durability index (PDI). All samples were sent to DSM Nutritional Products (Parsippany, NJ) for phytase analysis. Samples were analyzed in duplicate for phytase activity according to the official AOAC method[5] by incubation with sodium phytate. Phytase stability was calculated as the percentage of phytase (FYT) remaining in the pelleted diets compared to the analyzed initial mash samples. For analysis of PDI, fines were sifted off from cooled pellets using a U.S. No. 5 (4 mm) sieve. One hundred g of the sifted pellets were placed into a Holmen 100 pellet tester and agitated with air for 60 sec. Following agitation, the sample was again sifted through a No. 5 sieve and the remaining pellets were weighed. Pellet durability index was calculated as the percentage of the initial pellet sample remaining after agitation with air.

Data were analyzed using the GLIMMIX procedure in SAS v. 9.4 (SAS Institute Inc., Cary, NC), with pelleting run as the experimental unit and day as the blocking factor. Main effects included die thickness and conditioning temperature. Linear and quadratic contrasts were used to evaluate the effect of conditioning temperature. Results were considered significant if $P \leq 0.05$ and were considered marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

There was no evidence ($P > 0.14$) for a die thickness × conditioning temperature interaction for any of the pelleting or phytase responses analyzed in this study (Table 2). Production rate and conditioning temperature were as expected for each treatment. Hot pellet temperature was increased by pelleting with a thicker die ($P < 0.01$) and by increasing conditioning temperature from 165 to 185°F (linear, $P < 0.01$). Pellet durability index was greater ($P < 0.01$) for diets pelleted using the thicker die with a L:D of 8.0 compared to the die with a L:D of 5.6. Additionally, PDI increased (linear, $P = 0.03$) with increasing conditioning temperature.

Phytase concentrations of initial mash samples were not different among treatments ($P > 0.74$), averaging 733 FYT/kg. Increasing conditioning temperature decreased (linear, $P < 0.01$) phytase concentrations in conditioned mash and cooled pellets. There was no evidence of difference ($P > 0.54$) in phytase concentrations of conditioned mash or cooled pellets due to die thickness. Phytase concentrations were used to calculate phytase stability and the resulting stability data closely mirrored the data previously mentioned. Increasing conditioning temperature from 165 to 185°F decreased (linear, $P < 0.01$) phytase stability of conditioned mash and cooled pellets, with no difference ($P > 0.72$) in stability due to die thickness.

In conclusion, increasing conditioning temperature linearly increased HPT and PDI. Similar to previous data, results of this experiment show that phytase stability in condi-

[5] AOAC. 2001. AOAC Official Method 2000.12 Phytase Activity in Feed. J. AOAC Int. 84:629.

tioned mash and pellets decreases linearly when conditioning temperature rises above 165°F and HPT rises above 177°F. Although the thicker pellet die increased HPT by an average of 1.9°F and increased PDI by an average of 7.8%, there was no evidence that the additional frictional heat associated with increasing the die L:D from a 5.6 to an 8.0 resulted in lower phytase stability.

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Table 1. Composition of diet[1]

Ingredient	%, as-is
Ground corn	75.88
Soybean meal, 47% crude protein	20.07
Soybean oil	1.50
Monocalcium phosphate	0.50
Limestone	1.10
Salt	0.35
L-Lysine HCl	0.26
DL-Methionine	0.02
L-Threonine	0.05
Trace mineral premix	0.13
Vitamin premix	0.13
Phytase[2]	0.03

[1]Diets were mixed in a 1-ton Hayes & Stolz (Fort Worth, TX) horizontal counterpoise mixer with a 60 sec dry mix time and 120 sec wet mix time.
[2]HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) was added to the experimental diets at 809 FYT/kg.

Table 2. Effect of die thickness and conditioning temperature on pelleting characteristics and phytase stability of a finishing swine diet[1]

Die L:D:	5.6			8.0				Probability, <			
Conditioning temp, °F:	165	175	185	165	175	185	SEM[2]	Die	Linear[3]	Quadratic	Die × temp
Production rate, lb/min	33.8	34.1	33.8	33.9	33.7	34.1	0.13	-	-	-	-
Conditioning temp, °F	165.1	175.3	185.2	165.3	175.5	184.3	0.19	-	-	-	-
Hot pellet temp, °F	176.6	181.8	189.2	178.6	184.1	190.5	0.80	<0.01	<0.01	0.16	0.73
Pellet durability index, %	80.0	80.9	84.7	88.5	88.9	91.7	1.71	<0.01	0.03	0.39	0.91
Phytase, FYT/kg											
Initial mash	772	772	772	743	743	743	141.1	0.74	1.00	1.00	1.00
Conditioned mash	1099	576	267	894	760	275	138.9	0.97	<0.01	0.74	0.28
Cooled pellet	603	329	166	538	292	206	42.6	0.54	<0.01	0.07	0.42
Phytase stability, %											
Conditioned mash	102.8	61.0	35.4	91.4	77.5	36.2	8.14	0.72	<0.01	0.64	0.14
Cooled pellet	63.0	38.1	23.7	58.6	35.6	28.1	7.09	0.85	<0.01	0.19	0.70

[1]Diets were steam-conditioned (10 × 55 in Wenger twin staff pre-conditioner, Model 150) for 30 sec at 165, 175, or 185°F and pelleted (CPM, 1012-2 HD Master Model) using a 5/32 × 7/8 in (L:D 5.6) or 5/32 × 1 1/4 in (L:D 8.0) pellet die.
[2]Pooled standard error of least squares means (n = 3).
[3]Linear and quadratic contrasts were used to evaluate the effect of conditioning temperature.