Kansas Agricultural Experiment Station Research Reports

Volume 6
Issue 10 *Swine Day*

Article 27

2020

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Recommended Citation

Nichols, G. E.; Stark, C. R.; Ogles, A. M.; Truelock, C. N.; Beckman, N. M.; Winowiski, T. S.; and Paulk, C. B. (2020) "Effect of Dietary Formic Acid and Lignosulfonate on Pellet Quality," *Kansas Agricultural Experiment Station Research Reports*: Vol. 6: Iss. 10. https://doi.org/10.4148/2378-5977.8008

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Abstract

Nursery pig diets are pelleted to improve handling characteristics and pig performance. Feeding good quality pellets is important to achieve the maximum improvements in growth performance. Therefore, it is important to determine how feed additives included in nursery pig diets influence pellet quality. The objective of this study was to determine the effect of formic acid and lignosulfonate (LignoTech USA) inclusion in nursery pig diets on pelleting characteristics, pellet quality, and diet pH. The 5 treatments consisted of a control, or the control plus 2 concentrations of added formic acid (0.36% or 0.60%), or the control plus two combinations of 60% formic acid and 40% lignosulfonate (0.60% or 1.0%). Diets were steam conditioned (10 × 55 in, Wenger twin shaft pre-conditioner, Model 150) for approximately 30 s and pelleted on a 1-ton 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) with a 3/16 × 1 ¼ in pellet die (length:diameter ratio of 6.67). The production rate was set at 1,984 lb/h. Treatments were pelleted at 3 separate time points to provide 3 replicates per treatment. Samples were collected directly after discharging from the pellet mill and cooled in an experimental counterflow cooler. Pellet samples were analyzed for pellet durability index using the Holmen NHP 100 (TekPro Ltd, Norfolk, UK) and standard and modified tumble box methods. Pellet hardness was determined by evaluating the peak amount of force applied before the first signs of fracture. Pellets were crushed perpendicular to their longitudinal axis using a texture analyzer (Model TA-XT2, Stable Micro Systems Godalming, UK). Pellet samples were analyzed for pH via potentiometer and electrodes (AACC Method 02-52.01). Voltage and amperage data was collected via Supco DVCV Logger (Supco, Allenwood, NJ) and used to calculate pellet mill energy consumption (kWh/ton). Data were analyzed using the MIXED procedure in SAS v. 9.4, with pelleting run as the experimental unit. Increasing formic acid in the diet decreased pH ($P < 0.001$) by 0.6 to 0.8 in low formic acid diets and by 1 point in the high formic acid diets. When adding formic acid or lignosulfonate to the diet, no evidence for differences was observed for pellet mill energy consumption, production rate, hot pellet temperature, or pellet durability regardless of testing method or pellet hardness. In conclusion, pellet quality was not influenced by formic acid or lignosulfonate, and as expected pH decreased as the level of formic acid increased.

Keywords

formic acid, lignosulfonate, pellet quality

Authors

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Effect of Dietary Formic Acid and Lignosulfonate on Pellet Quality

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Summary

Nursery pig diets are pelleted to improve handling characteristics and pig performance. Feeding good quality pellets is important to achieve the maximum improvements in growth performance. Therefore, it is important to determine how feed additives included in nursery pig diets influence pellet quality. The objective of this study was to determine the effect of formic acid and lignosulfonate (LignoTech USA) inclusion in nursery pig diets on pelleting characteristics, pellet quality, and diet pH. The 5 treatments consisted of a control, or the control plus 2 concentrations of added formic acid (0.36% or 0.60%), or the control plus two combinations of 60% formic acid and 40% lignosulfonate (0.60% or 1.0%). Diets were steam conditioned (10 × 55 in, Wenger twin shaft pre-conditioner, Model 150) for approximately 30 s and pelleted on a 1-ton 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) with a 3/16 × 1 ¼ in pellet die (length:diameter ratio of 6.67). The production rate was set at 1,984 lb/h. Treatments were pelleted at 3 separate time points to provide 3 replicates per treatment. Samples were collected directly after discharging from the pellet mill and cooled in an experimental counterflow cooler. Pellet samples were analyzed for pellet durability index using the Holmen NHP 100 (TekPro Ltd, Norfolk, UK) and standard and modified tumble box methods. Pellet hardness was determined by evaluating the peak amount of force applied before the first signs of fracture. Pellets were crushed perpendicular to their longitudinal axis using a texture analyzer (Model TA-XT2, Stable Micro Systems Godalming, UK). Pellet samples were analyzed for pH via potentiometer and electrodes (AACC Method 02-52.01). Voltage and amperage data was collected via Supco DVCV Logger (Supco, Allenwood, NJ) and used to calculate pellet mill energy consumption (kWh/ton). Data were analyzed using the MIXED procedure in SAS v. 9.4, with pelleting run as the experimental unit. Increasing formic acid in the diet decreased pH ($P < 0.001$) by 0.6 to 0.8 in low formic acid diets and by 1 point in the high formic acid diets. When adding formic acid or lignosulfonate to the diet, no evidence for differences was observed for pellet mill energy consumption, production rate, hot pellet temperature, or pellet durability regardless of testing method or pellet hardness. In conclusion, pellet quality was not influenced by formic acid or lignosulfonate, and as expected pH decreased as the level of formic acid increased.

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[2] LignoTech USA Inc., Rothschild, WI.

Introduction

Feed for nursery pig diets may be pelleted to improve pig performance, reduce feed wastage, and improve handling characteristics. Pig performance improvements are dependent on pellet quality. Therefore, it is important to determine how diet formulation influences pellet quality. Along with proper pellet mill operation, the inclusion of a pellet binder in diets can help to increase pellet quality. Lignosulfonate is a byproduct of the paper milling industry and has been shown to improve pellet quality between 1 and 2% especially in diets containing high levels of fat.[3]

In addition to pelleting diets, feed additives may be included in nursery pig diets to improve performance. Organic acids are types of acidifier that have been demonstrated to improve growth performance in nursery pigs. Although the mechanism for this improvement is not clearly defined, it is hypothesized that the improvement stems from improved gut health through reduction of pH and buffering capacity of diets, increased pancreatic enzyme secretions, or promotion of beneficial bacterial growth while inhibiting growth of pathogenic microbes.[4] In addition, organic acids can be included as a preservative agent to prevent the growth of mold and bacteria. Common examples of organic acids are carboxylic acid, citric acid, lactic acid, and formic acid. However, to our knowledge, there are very limited data determining the effect of organic acids on pellet quality. Therefore, the objective of this study was to determine the effect of formic acid and liquid lignosulfonate 50% dry matter (LignoTech USA) on pellet quality.

Procedures

This study was conducted at the Kansas State University O.H. Kruse Feed Technology and Innovation Center. A total of 5 diets were pelleted to determine the effects of formic acid and lignosulfonate inclusion on pellet quality, pellet mill performance, and feed acidity. The 5 treatments (Table 1) consisted of a control; or the control with 2 concentrations of 95% formic acid (FA) (0.36% or 0.60%; Douda Diesel, Decatur, AL); or the control plus two concentrations (0.60% or 1.0%) of a 60% formic acid and 40% lignosulfonate product (50% dry matter; LignoTech USA, Rothschild WI). This resulted in the 5 dietary treatments: Control, 0.36% FA, 0.60% FA, 0.60% formic acid lignosulfate (FALS), and 1.0% FALS. The FALS concentrations were chosen to include the same levels of FA as the two FA-only treatments. Basal diets were mixed in a 1-ton Hayes and Stolz double ribbon mixer (Burleson, TX). Basal diets were equally divided, and the test products were added and individually mixed using a Davis Paddle Mixer (Model S-3, Bonner Springs, KS) immediately prior to pelleting. Pellets were produced from the mash diets via steam conditioning (10 in × 55 in Model 150, Wegner twin staff pre-conditioner, Sabetha, KS) and subsequently pelleted using a 1-ton 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill Co., Crawfordsville, IN) equipped with a 3/16 × 1 ¼ in pellet die (length:diameter ratio of 6.67). The feeder rate was set at a constant speed to achieve approximately 1,984 lb/h. The target conditioning temperature and time were held at 178 to 182°F for 30

[3] Wamsley, K.G.S., J.S. Moritz. 2013. Resolving poor pellet quality and maintaining amino acid digestibility in commercial turkey diet feed manufacture, Journal of Applied Poultry Research. 22:439-446.
[4] Jacela, J. J., J. M. DeRouchey, M. D. Tokach, R. D. Goodband, J. L. Nelssen, D. G. Renter, S. S. Dritz. 2009. Feed additives for swine: Fact sheets – acidifiers and antibiotics. J. Swine Health and Prod. 17:270-275.

seconds, the temperature was achieved by adjusting steam addition using 25 to 30 PSI steam pressure. Each treatment was pelleted in 3 separate 500-lb batches in order to provide 3 replicates per treatment. Time of processing served as a blocking factor, and treatment pelleting order was randomized within each block. Three 20-lb pellet samples were collected from the cooler during each replication for analysis of pellet durability index and pellet hardness testing. Hot pellet temperature and production rate measurements were collected to correspond to each sample. Pellet mill energy consumption was measured using a Supco DVCV Logger (Supco, Allenwood, NJ).

Samples were analyzed for pellet durability index (PDI) with a Holmen NHP100 (60 s, 70 mbar) (TekPro Ltd, Norfolk, UK), standard tumble box (ASAE Standard S269.5), and modified tumble box methods (STD and MOD, respectively). For pellet hardness, 25 pellets between 0.39 and 0.47 in length were randomly chosen from the cooled pellet samples for each replication to be analyzed. Pellets were crushed perpendicular to the longitudinal axis and the peak force (lb) required to cause the first fracture was recorded according to the methods described by Fahrenholz.[5] Pellet pH was determined by grinding 0.03 lb of pellet samples for each replicate. Ground samples were placed in a flask and mixed with 3.38 fl. oz of distilled water. The mixture was agitated until feed was suspended in the water and was free of clumps for 30 minutes using a mechanical stirrer, or shaker. The sample was allowed to rest for 10 min before the liquid was decanted into the electrode vessel and the pH was determined via potentiometer and electrodes (AACC Method 02-52.01). Moisture analysis was completed in duplicate for each mash, conditioned mash, and cooled pellet sample. Aluminum pans were weighed, and the 0.004 g sample were placed in the drying oven at 221°F for 24 h. Samples were weighed back for moisture calculation (100 – ((dried sample weight / initial sample weight) × 100)) (AOAC Method 934.01).

Data were analyzed using the PROC MIXED procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC). Experimental unit was pelleting run with a random effect of pelleting period. Results were considered significant if $P \leq 0.05$ and marginally significant if $P \leq 0.10$.

Results and Discussion

There was no evidence of overall treatment effects on pellet mill production rate, energy consumption, or hot pellet temperature (Table 2). There was no evidence of overall dietary treatment effects on PDI for the standard tumble box, modified tumble box, Holman 100, or pellet hardness (Table 3). Therefore, the data reported herein indicate that formic acid may be included in the diet without negatively impacting pellet quality. As lignosulfonate was included in the diet (up to 0.40%) there were no differences in PDI regardless of PDI testing method used. Future research should investigate the concentration of lignosulfonate needed to improve pellet quality and its ability to improve pellet quality with and without formic acid.

As the formic acid levels in the diet increased there was a decrease ($P < 0.001$) in diet pH, with the diets containing 0.60% formic acid being the most acidic. Increasing

[5] Fahrenholz. 2012. Evaluating Factors Affecting Pellet Durability and Energy Consumption in a Pilot Feed Mill and Comparing Methods for Evaluating Pellet Durability. Kansas State University. Ph.D. Dissertation. KREX.KSU.edu.

formic acid inclusion from 0 to 0.60% dropped pH by approximately 1 point regardless of lignosulfonate inclusion. This pH drop was expected as the formic acid would reduce the pH of the feed. More research is needed to evaluate the effects of other organic acids, their salts, binder inclusion rates, and to better understand their effect on pellet quality.

Overall, the inclusion of formic acid and lignosulfonate had no effect on pellet quality, pellet mill performance, or pellet mill energy consumption. Increasing formic acid inclusion in feed ($P < 0.001$) decreased the pH of the feed.

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Table 1. Diet composition, as-is basis

Ingredients, %	Control	0.36% FA[1]	0.60% FA	0.60% FA+LS[2]	1.00% FA+LS
Corn	66.10	65.74	65.50	65.50	65.10
Soybean meal, 46.5%	28.25	28.25	28.25	28.25	28.25
Soy oil	1.50	1.50	1.50	1.50	1.50
L-lysine HCl	0.55	0.55	0.55	0.55	0.55
DL-methionine	0.21	0.21	0.21	0.21	0.21
L-threonine	0.23	0.23	0.23	0.23	0.23
L-tryptophan	0.05	0.05	0.05	0.05	0.05
L-valine	0.16	0.16	0.16	0.16	0.16
Monocalcium phosphate 21%	1.10	1.10	1.10	1.10	1.10
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.60	0.60	0.60	0.60	0.60
Trace mineral premix[3]	0.15	0.15	0.15	0.15	0.15
Vitamin premix[4]	0.25	0.25	0.25	0.25	0.25
Phytase[5]	0.03	0.03	0.03	0.03	0.03
Formic acid[6]	-	0.36	0.6	-	-
Formic acid + lignosulfonate	-	-	-	0.6	1
Total	2000.00	2000.00	2000.00	2000.00	2000.00

[1] Formic acid (Douda Diesel, Decatur, AL).
[2] FA+LS contained 60% formic acid and 40% lignosulfonate.
[3] Provided 1.36 g Cu from copper sulfate; 72.72 mg Ca from calcium iodate; 14.09 mg Fe from ferrous sulfate; 1.36 g Mn from manganese sulfate; 54.54 mg Se from sodium selenite; and 14.09 g Zn from zinc sulfate per lb of premix.
[4] Provided 750,000 IU vitamin A from vitamin A acetate; 300,000 IU vitamin D from vitamin D3; 8,000 IU vitamin E from dl-α-tocopheryl acetate; 600 mg menadione from menadione nicotinamide bisulfite; 6 mg B12 from cyanocobalamin; 9000 mg niacin from niacinamide; 5000 pantothenic acid from d-calcium panthothenate; 1,500 mg riboflavin from crystalline riboflavin per lb of premix.
[5] Ronozyme HiPhos (GT) 2700 (DSM Nutritional Products, Parsippany, NJ) provided 1,102,300 phytase units (FTU)/kg of product with a release of 0.10% available P.
[6] Formic acid and formic acid+lignosulfonate were added once basal batches were split directly prior to the pelleting period.

Table 2. Effect of formic acid and lignosulfonate on pellet mill performance[1,2]

Item	Control	0.36% FA[3]	0.60% FA	0.60% FA+LS[4]	1.00% FA+LS	SEM	*P*-value
Conditioning temperature, °F	180.63	180.34	180.61	180.30	180.27	-	-
Hot pellet temperature, °F	187.6	187.8	187.9	187.4	187.7	0.35	0.167
Production rate, lb/h	2055	2039	2043	2063	2069	11.6	0.361
kWh/ton	13.07	13.03	12.80	13.06	12.82	0.221	0.826

[1] Corn, soybean meal-based nursery pig diets were steam pelleted for approximately 30 s at 180°F targeted conditioning temperature with a production rate target of 1984 lb/h on a 30-horsepower pellet mill with a 3/16 in × 1 ¼ in pellet die (length:diameter 6.67).
[2] Diets were pelleted at 3 separate time points to achieve 3 replicates per treatment.
[3] Formic acid (Douda Diesel, Decatur, AL).
[4] FA+LS contained 60% formic acid and 40% lignosulfonate.
[5] Kilowatt hour per ton.

Table 3. Effect of formic acid and lignosulfonate on pellet quality and feed pH[1,2]

Item[3,4]	Control	0.36% FA[5]	0.60% FA	0.60% FA+LS[6]	1.00% FA+LS	SEM	*P*-value
Holman 100 with filter, %[7]	88.0	89.3	89.6	89.0	88.7	1.69	0.947
Standard tumble box, %[8]	85.3	86.9	86.4	87.2	86.3	1.34	0.786
Modified tumble box, %[9]	75.2	77.9	76.9	78.7	77.7	2.23	0.762
Pellet hardness, lb[10]	14.4	14.5	13.8	15.0	14.7	0.33	0.813
pH	5.9[a]	5.1[b]	4.9[c]	5.3[b]	4.9[c]	0.06	0.001

[1] Corn, soybean meal-based nursery pig diets were steam pelleted for approximately 30 s at 180°F targeted conditioning temperature with a production rate target of 1,984 lb/h on a 30-horsepower pellet mill with a 3/16 in × 1 ¼ in pellet die (length:diameter 6.67).
[2] Diets were pelleted at 3 separate time points to achieve 3 replicates per treatment.
[3] All PDI analyses and pH analyses were completed in duplicate on the 3 samples collected for each treatment per replication.
[4] Superscripts ([a,b,c]) denote significant differences ($P < 0.05$).
[5] Formic acid (Douda Diesel, Decatur, AL).
[6] FA+LS contained 60% formic acid and 40% lignosulfonate.
[7] Holmen NHP Pellet Tester 100 ran for 60 seconds at 70 mbar with a Holmen filter. A No. 5 screen was used to sift pellets.
[8] KSU Standard Tumble Box ran for 600 seconds with no added abrasive. A No. 5 screen was used to sift pellets.
[9] KSU Modified Tumble Box ran for 600 seconds with three ¾-inch hex nuts as the abrasive. A No. 5 screen was used to sift pellets.
[10] 25 pellets between 0.39 and 0.47 in length were chosen at random, pellets were crushed perpendicular to the longitudinal axis and the peak force (lb) was recorded.