Kansas Agricultural Experiment Station Research Reports

Volume 7
Issue 10 *Animal Feed and Pet Food Research Report* Article 5

2021

The Effect of Different Inclusion Levels of Corn Starch and Fine Ground Corn With Different Conditioning Temperature or Die Thickness on Pellet Quality

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Recommended Citation

Saensukjaroenphon, Marut; Evans, Caitlin E.; Jones, Cassandra K.; Stark, Charles R.; and Paulk, Chad B. (2021) "The Effect of Different Inclusion Levels of Corn Starch and Fine Ground Corn With Different Conditioning Temperature or Die Thickness on Pellet Quality," *Kansas Agricultural Experiment Station Research Reports*: Vol. 7: Iss. 10. https://doi.org/10.4148/2378-5977.8143

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Abstract

Feeding a greater percentage of whole pellets to poultry and swine provides a greater return on investment for producers. Pellet binders are commonly used in commercial feed mills, but the added cost has limited their use in poultry and swine feed mills. Corn starch could be a potential natural binder for feed as it is for biomass pellet operations. Therefore, the objective of these experiments was to determine the effect of different inclusion levels of corn starch and fine ground corn with different conditioning temperature or die thickness on pellet quality. In, Experiment 1, treatments were arranged in 3 × 2 factorial design of corn starch inclusion level (0%, 5%, and 10%) and die thickness (1/2 in. and 7/8 in.). In Experiment 2, treatments were arranged in 3 × 2 factorial design of fine ground corn inclusion level (0%, 10%, and 20%) and conditioning temperature (175 and 185°F). For Exp. 1, there was a corn starch by die thickness interaction ($P = 0.033$; Table 3) on pellet durability index (PDI). Increasing concentration of corn starch from 0 to 10% in the diet decreased PDI when diets were pelleted using the ½ in. thick die. However, there was no evidence of difference in PDI when corn starch was increased from 0 to 10% and diets were pelleted using the 7/8 in. die. There was no evidence of an interaction between corn starch inclusion level and die thickness on modified PDI. Increasing die thickness from 1/2 in. to 7/8 in. increased ($P = 0.001$) modified PDI. There was a linear decrease ($P < 0.001$) in modified PDI as the corn starch inclusion level increased. For Exp. 2, there was no evidence for interaction between fine ground corn inclusion level and conditioning temperature on PDI ($P > 0.541$). There was no evidence of difference in PDI with increasing fine ground corn inclusion. Increasing conditioning temperature from 175 to 185°F increased ($P < 0.0001$) standard and modified PDI. In conclusion, the use of pure corn starch was not an effective binding agent in the feed when the diet contained at least 60% ground corn. The ratio of small corn particles to large corn particles in the diet did not impact pellet quality when the diets were conditioned above 175°F for 35 s and then pelleted with a 5.6 L:D die. Increasing die thickness and conditioning temperature improved pellet quality.

Keywords

conditioning temperature, corn starch, fine corn particles, pellet die, pellet quality, poultry

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The Effect of Different Inclusion Levels of Corn Starch and Fine Ground Corn With Different Conditioning Temperature or Die Thickness on Pellet Quality

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Summary

Feeding a greater percentage of whole pellets to poultry and swine provides a greater return on investment for producers. Pellet binders are commonly used in commercial feed mills, but the added cost has limited their use in poultry and swine feed mills. Corn starch could be a potential natural binder for feed as it is for biomass pellet operations. Therefore, the objective of these experiments was to determine the effect of different inclusion levels of corn starch and fine ground corn with different conditioning temperature or die thickness on pellet quality. In, Experiment 1, treatments were arranged in 3 × 2 factorial design of corn starch inclusion level (0%, 5%, and 10%) and die thickness (½ in. and ⅞ in.). In Experiment 2, treatments were arranged in 3 × 2 factorial design of fine ground corn inclusion level (0%, 10%, and 20%) and conditioning temperature (175 and 185°F). For Exp. 1, there was a corn starch by die thickness interaction ($P = 0.033$; Table 3) on pellet durability index (PDI). Increasing concentration of corn starch from 0 to 10% in the diet decreased PDI when diets were pelleted using the ½ in. thick die. However, there was no evidence of difference in PDI when corn starch was increased from 0 to 10% and diets were pelleted using the ⅞ in. die. There was no evidence of an interaction between corn starch inclusion level and die thickness on modified PDI. Increasing die thickness from ½ in. to ⅞ in. increased ($P = 0.001$) modified PDI. There was a linear decrease ($P < 0.001$) in modified PDI as the corn starch inclusion level increased. For Exp. 2, there was no evidence for interaction between fine ground corn inclusion level and conditioning temperature on PDI ($P > 0.541$). There was no evidence of difference in PDI with increasing fine ground corn inclusion. Increasing conditioning temperature from 175 to 185°F increased ($P < 0.0001$) standard and modified PDI. In conclusion, the use of pure corn starch was not an effective binding agent in the feed when the diet contained at least 60% ground corn. The ratio of small corn particles to large corn particles in the diet did not impact pellet quality when the diets were conditioned above 175°F for 35 s and then pelleted with a 5.6 L:D die. Increasing die thickness and conditioning temperature improved pellet quality.

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Introduction

Pelleted feed is commonly fed to swine and poultry. The advantages of feeding pelleted feed compared to mash are improvements of feed flowability, animal performance, and storage capacity. Factors that influence pellet quality include ingredient characteristics, grinding, process uniformity, and pellet mill parameters. The commercial feed industry uses a pellet binder in diets that contain ingredients that are difficult to pellet, or contain a high percentage of oils or large particles. Previous researchers have observed pre-gelatinized tapioca starch improved pellet quality as compared to native starch.[2] Researchers have also reported that adding 2 to 4% pure corn starch acted as a binder in ground corn stover to increase pellet durability when the mixture was pelleted with a flat die pellet mill.[3] In addition, research at Kansas State University reported that decreasing corn particle size in a swine finishing diet from 1,000 μm to 400 μm increased pellet durability index (PDI) from 78.8 to 86.4%.[4] Small particles have more surface area to absorb steam during pelleting and more potential contact points with other particles. Increasing the percentage of very fine corn particles may improve the pellet quality of the pelleted feed. However, there are limited data on the impact of replacing a portion of the ground corn in a diet with corn starch and fine ground corn on pellet quality in corn-soybean meal diet. Therefore, the objective of this experiment was to determine the effect of different inclusion levels of corn starch and fine ground corn with different conditioning temperature or die thickness on pellet quality.

Materials and Methods

Experiment 1

Treatments were arranged in 3 × 2 factorial design of corn starch inclusion level (0%, 5%, and 10%) and die thickness (½ in. and ⅞ in.) to determine the effect on pellet quality. A swine finishing feed was used for the experiment (Table 1). The ingredients were added to a 6 ft^3 paddle mixer (Davis model 2014197-SS-S1, Bonner Springs, KS) and were mixed for 5 min. The mixtures were steam conditioned for approximately 30 s at 185°F and pelleted using a pellet mill (California Pellet Mill, CPM, model CL-5, Crawfordsville, IN) equipped with 2 different pellet dies (5⁄32 × ½ in. and 5⁄32 × ⅞ in.). The feeder setting was held constant at approximately 2.2 lb/min. The pellet mill was run 3 separate times to provide 3 replicates for each treatment. The pelleted samples were cooled for 10 min. using a counterflow cooler. The PDI of the cooled pellets was determined according to the ASAE 269.5[5] standard and modified methods.

Experiment 2

Treatments were arranged in 3 × 2 factorial design of fine ground corn inclusion level (0%, 10% and 20%) and conditioning temperature (175 and 185°F) to determine the effect on pellet quality. A swine finishing feed was used for the experiment

[2] Wood, J.F. 1987. The functional properties of feed raw materials and their effect on the production and quality of feed pellets. Animal Feed Science and Technology, 18(1), pp. 1–17.

[3] Tumuluru JS, Conner CC, Hoover AN. Method to Produce Durable Pellets at Lower Energy Consumption Using High Moisture Corn Stover and a Corn Starch Binder in a Flat Die Pellet Mill. J Vis Exp. 2016;(112):54092. Published 2016 Jun 15. doi:10.3791/54092.

[4] Wondra, K., Hancock, J., Behnke, K., Hines, R., & Stark, C. (1995). Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. Journal of Animal Science, 73(3), 757-63.

[5] ASAE S269.5 Pellets, and crumbles-definitions and methods for determining density, durability, and moisture content. Am. Soc. Agric. Eng., Oct. 2012 (2016). St. Joseph, MI.

(Table 2). Corn was ground using a Fitz Mill (Fitzpatrick, model DAS06, Elmhust, IL) equipped with screen no. 1532-0050 (0.05 in), which was used as fine ground corn. The ingredients were added to a 6 ft^3 paddle mixer (Davis model 2014197-SS-S1, Bonner Springs, KS) and were mixed for 5 min. The mixtures were steam conditioned for approximately 30 s at 175 or 185°F and pelleted using a pellet mill (CPM, model CL-5, Crawfordsville, IN) equipped with 5⁄32 × 7⁄8 in. die (length to die diameter, L:D of 5.6). The feeder setting was held constant at approximately 2.2 lb/min. The pellet mill was run 3 separate times to provide 3 replicates for each treatment. The pelleted samples were cooled for 10 min. using a counterflow cooler. The PDI of the cooled pellets was determined according to the ASAE 269.5 standard and modified methods.

Data collection

Pellet durability index

The PDI was determined by ASAE 269.5. The sample was sifted with a U.S. No. 6 (5⁄32 in.) sieve. A 1.1 lb sample of sifted pellets was placed in the tumble box for 10 min. The sample was sifted again with the same sieve. The PDI was calculated by dividing the whole pellets after tumbling by the initial sample weight and then multiplying by 100.[5] The PDI procedure was modified by adding three ¾ in. hex nuts to the tumble box and tumbling for the 10 min.

Particle size

Particle size was determined with a Ro-Tap model RX-29 (W.S. Tyler Industrial Group, Mentor, OH) using the method of determining and expressing fineness of feed materials by sieving (ASAE S319.2[6]) with 0.5 g of flow agent (Model SSA-58, Gilson Company, Inc., Lewis Center, OH) for 10 min.

Statistical analysis

Data were analyzed as a completely randomized design. In Exp. 1, treatments were arranged in 3 × 2 factorial design of corn starch inclusion level (0%, 5%, and 10%) and die thickness (½ in. and 7⁄8 in.) to determine the effect on pellet quality. In Exp. 2, treatments were arranged in 3 × 2 factorial design of fine ground corn inclusion level (0%, 10%, and 20%) and conditioning temperature (175 and 185°F) to determine the effect on pellet quality. There were 3 replicates per treatment. Data were analyzed using the GLIMMIX procedure of SAS (v. 9.4, SAS Institute, Inc., Cary, NC). Means were separated by least squares means. Results were considered significant at $P \leq 0.05$.

Result and Discussion

Experiment 1

The pelleting parameters were similar across treatments. For PDI, there was a corn starch by die thickness interaction ($P = 0.033$; Table 3). Increasing concentration of corn starch from 0 to 10% in the diet decreased PDI when diets were pelleted using the ½ in. thick die. However, there was no evidence of difference in PDI when corn starch was increased from 0 to 10% and diets were pelleted using the 7⁄8 in. die. There was no evidence of interaction between corn starch inclusion concentration and die thickness ($P = 0.636$) for modified PDI. Both corn starch inclusion level and die

[6] ASAE S319.2: Method of determining and expressing fineness of feed materials by sieving. Am. Soc. Agric. Biol. Eng., 1995. St. Joseph, MI.

thickness affected modified PDI ($P < 0.001$). Increasing die thickness from ½ in. to ⅞ in. increased ($P < 0.001$) modified PDI. Increasing corn starch in the diet from 0 to 10% decreased (linear, $P < 0.001$) modified PDI. Therefore, increasing corn starch in the place of corn did not improve pellet quality. It is important to note that diets were not balanced for crude protein. Therefore, as corn starch increased in the diet, the calculated crude protein decreased from 18.3 to 17.5%. Previous research has reported that protein content in the diet had greater impact on pellet quality than starch.[2] The decrease in protein could potentially explain the observed reduction in pellet quality when increasing corn starch in the diet. In addition, increasing the die thickness increased the temperature of feed on the surface of the pellet. The friction between the die and feed that is generated while forming the pellet may also enhance the interaction of melted materials, resulting in stronger bonds between natural polymers. The results of the current experiment demonstrated that increasing die thickness from ½ in. to ⅞ in. increased modified PDI by 27%.

Experiment 2

The particles sizes of diets were 574, 557, and 544 μm for diets with 0, 10, and 20% fine ground corn (209 μm), respectively. For both PDI methods (Table 4), there was no evidence of interaction ($P > 0.541$) between fine ground corn inclusion level and conditioning temperature. When the diets were conditioned above 175°F for approximately 35 s, increasing the fine ground corn from 0 to 20% did not increase the PDI ($P > 0.238$). Moreover, increasing conditioning temperature from 175 to 185°F increased ($P < 0.0001$) PDI by 0.4% and 9.4% for the standard and modified methods, respectively.

The results of these experiments suggest that pure corn starch was not an effective binding agent in the feed when the diet contained at least 60% ground corn and was not balanced for crude protein. In addition, the ratio of small corn particles to large corn particles in the diet did not impact pellet quality when the diets were conditioned above 175°F for 35 s and then pelleted with 5.6 L:D die. Increasing die thickness and conditioning temperature improved pellet quality.

Table 1. Diet composition Exp. 1 (as-is)

	Corn starch, %		
Ingredients	**0%**	**5%**	**10%**
Corn	69.19	64.19	59.19
Corn starch	0.00	5.00	10.00
Soybean meal	26.50	26.50	26.50
Soy oil	1.50	1.50	1.50
Monocalcium phosphate, 21% P	0.55	0.55	0.55
Limestone	1.13	1.13	1.13
Swine vitamin premix	0.15	0.15	0.15
Swine trace mineral premix	0.15	0.15	0.15
L-Lysine HCl	0.31	0.31	0.31
DL-Methionine	0.07	0.07	0.07
L-Threonine	0.09	0.09	0.09
Phytase[1]	0.02	0.02	0.02
Salt	0.35	0.35	0.35
Total	100.00	100.00	100.00

[1]Ronozyme HiPhos (GT) 2700 (DSM Nutritional Products, Parsippany, NJ) provided 216.5 phytase units (FTU)/lb with a release of 0.10% available P.

Table 2. Diet composition Exp. 2 (as-is)

	Fine ground corn, %		
Ingredients	**0%**	**10%**	**20%**
Corn	69.18	59.18	49.18
Fine ground corn[1]	0.00	10.00	20.00
Soybean meal (SBM)	26.50	26.50	26.50
Soy oil	1.50	1.50	1.50
Monocalcium phosphate, 21% P	0.55	0.55	0.55
Limestone	1.13	1.13	1.13
Swine vitamin premix	0.15	0.15	0.15
Swine trace mineral premix	0.15	0.15	0.15
L-Lysine HCl	0.31	0.31	0.31
DL-Methionine	0.07	0.07	0.07
L-Threonine	0.09	0.09	0.09
Phytase[2]	0.02	0.02	0.02
Salt	0.35	0.35	0.35
Total	100.00	100.00	100.00

[1]The fine ground corn particle was 209 μm.
[2]Ronozyme HiPhos (GT) 2700 (DSM Nutritional Products, Parsippany, NJ) provided 216.5 phytase units (FTU)/lb with a release of 0.10% available P.

Table 3. The effect of corn starch inclusion level and die thickness on pellet durability index (PDI) as determined by PDI and modified PDI (Exp 1)[1]

	Corn starch, %				Probability, *P* <			
Die thickness	**0**	**5**	**10**	**SEM**	**Corn starch × die thickness**	**Die thickness**	**Linear**	**Quadratic**
PDI, %								
½ in.	76.1[b]	72.9[b]	58.3[c]	2.24	0.033	0.001	0.001	0.119
⅞ in.	92.5[a]	90.6[a]	87.1[a]					
Modified PDI, %								
½ in.	50.6	47.0	30.2	3.64	0.636	0.001	0.001	0.159
⅞ in.	76.7	72.2	61.9					

[1] Treatments were arranged in 3 × 2 factorial design of corn starch inclusion level (0%, 5%, and 10%) and die thickness (½ in. and ⅞ in.) to determine the effect on pellet quality. Diets were steam conditioned for approximately 30 s at 185°F and pelleted using a pellet mill (California Pellet Mill, CPM, model CL-5, Crawfordsville, IN) equipped with 2 different pellet dies (5/32 × ½ in. and 5/32 × ⅞ in.). The pellet mill was run 3 separate times to provide 3 replicates for each treatment.
[a-c]Means in a row and column within an interaction effect followed by different letter are significantly different ($P \leq 0.05$).

Table 4. The effect of fine ground corn inclusion level and conditioning temperature on pellet durability index (PDI) as determined by the PDI and modified PDI (Exp. 2)[1]

	Fine ground corn, %				Probability, *P* <		
Conditioning temperature	0	10	20	SEM	Fine ground corn × temperature	Temperature	Fine ground corn
PDI, %							
175°F	94.5	94.5	94.7	0.18	0.879	0.001	0.238
185°F	95.9	96.0	96.1				
Modified PDI, %							
175°F	74.5	75.4	76.8	1.53	0.541	0.001	0.298
185°F	84.6	85.1	85.1				

[1]Treatments were arranged in 3 × 2 factorial design of fine ground corn inclusion level (0%, 10%, and 20%) and conditioning temperature (175 and 185°F). Diets were steam conditioned for approximately 30 s at 175 or 185°F and pelleted using a pellet mill (CPM, model CL-5, Crawfordsville, IN) equipped with 5⁄32 in. × 7⁄8 in. (length to die diameter, L:D of 5.6). The pellet mill was run 3 separate times to provide 3 replicates for each treatment.