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The Impact of Fines Inclusion Level and Conditioning Temperature on Pellet Quality and Energy Consumption

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Summary

The advantages of pelleted feed can include improved handling, palatability, and nutrient availability. Poor pellet quality, however, can diminish these positive returns and lead to customer complaints. Thus, commercial feed mills may remove fines with a screener after cooling in order to provide a consistent product to customers. There are limited data on the effect of returning pellet fines back to the pellet mill on pellet quality and pellet mill efficiency. The objective of the following 2 experiments was to determine the effect of fines inclusion level and conditioning temperature on pellet quality and energy consumption. Experiment 1 treatments were arranged in a 3 × 2 factorial design of fines inclusion level (0, 10, and 20%) and conditioning temperature (170 and 180°F). Experiment 2 treatments were arranged in a 3 × 2 factorial design of fines inclusion level (0, 10, and 20%) and conditioning temperature (175 and 185°F). The results of Experiment 1 demonstrated there was no interaction between fines inclusion level and conditioning temperature on pellet durability index (PDI) ($P > 0.348$). Increasing conditioning temperature from 170 to 180°F increased ($P < 0.003$) PDI by 0.6 and 4.3% for both the standard and modified methods, respectively. There was a linear increase ($P < 0.032$) in standard and modified PDI as the fines inclusion level increased. The results of Experiment 2 demonstrated that there was an interaction between fines inclusion level and conditioning temperature for modified PDI ($P < 0.001$). When the diets were pelleted at 185°F, increasing the fines inclusion level increased the modified PDI. However, there was no significant difference for modified PDI of the diets with 0, 10, and 20% fines inclusion level when they were pelleted at 175°F. For starch analysis, there was no interaction between fines inclusion level and conditioning temperature on total starch. There was no evidence of difference in total starch between the diets that were pelleted at 175 and 185°F. The total starch was the lowest in the diet with 0% fines (54.11%) followed by the diet with 20% and 10% fines (56.42% and 57.90%), respectively ($P = 0.013$). For gelatinized starch and cooked starch, there was no interaction between the fines inclusion level and conditioning temperature. Both fines inclusion level and conditioning temperature did not affect gelatinized starch. For energy consumption, there was an interaction ($P < 0.0001$) between fines inclusion level and conditioning temperature. When the diets were pelleted at 185°F conditioning temperature, the diet with 20% fines required significantly more energy during the pelleting process as compared to the diets with 0 and 10%. However, there was no significant difference in energy consumption for diets containing 0, 10, and 20% fines when the diets were pelleted at 175°F conditioning

temperature. Therefore, increasing conditioning temperature increased pellet quality. When a diet contained less than 1.5% oil, recirculating fines through the conditioner and pellet die improved pellet quality. However, the 20% inclusion of fines led to occasional roll slips, decreased pellet mill stability, and increased energy usage when the diet was pelleted.

Introduction

Pelletizing animal feed can improve both the handling characteristics and animal performance. Ensuring optimal pellet quality or low pellet fines can ensure that these benefits are fully realized and the cost of production is justified. Pellet quality, however, is often difficult to control as it can be influenced by many things including formulation, ingredient quality, and production parameters. Thus, many commercial feed mills typically use a mechanical screener after pelleting and cooling to separate quality pellets from broken pellet fines. This ensures only quality pellets reach the customer. The screened pellet fines are then returned to the pellet mill and re-integrated into the mash diets and subsequently re-pelleted. There are limited data on the effect of returning pellet fines back to the pellet mill and their optimum inclusion level on pellet quality and pellet mill efficiency. It is possible that pellet fines that are returned to the pellet mill may have some starch granules that are pre-gelatinized, which may improve pellet quality. Therefore, the objective of this experiment was to determine the effect of pellet fines inclusion level and conditioning temperature on pellet quality and energy consumption.

Materials and Methods

Experiment 1

Treatments were arranged in a 3 × 2 factorial design of fines inclusion level (0, 10, and 20%) and conditioning temperature (170 and 180°F) to determine the effect on pellet quality. A swine grower feed was used for Experiment 1 (Table1). The ingredients were added to a 58 ft^3 counterpoise mixer (Hayes & Stolz model TRDB63-0152, Fort Worth, TX) and were mixed for 1 min dry mix and 2 min wet mix time. Mash feed was steam conditioned for approximately 30 s at 170 or 180°F and pelleted (CPM, model CL-5, Crawfordsville, IN) with a 5/32 in. × 1 1/4 in. die. The feeder setting was held constant at approximately 2.2 lb/min. The diets pelleted at each temperature were ground using a single pair crumble roll (Colorado Mill Equipment model EcoRoll 7, Canon City, CO) with a 0.04 in. gap to produce the fines. The mash feed and pellet fines were mixed in a 6-ft^3 paddle mixer (Davis model 2014197-SS-S1, Bonner Springs, KS) for 5 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 and analyzed for pellet durability index (PDI).

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 and pellet mill energy consumption. A swine finishing feed was used for Experiment 2 (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 175 or 185°F and pelleted (CPM, model CL-5, Crawfordsville, IN) with a 5/32 in. × 7/8 in. die. 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 and analyzed for PDI.

Pellet durability index
The PDI was determined by ASAE 269.5.[1] The sample was sifted with a U.S. No. 5 (3/16 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. The PDI procedure was modified by adding three ¾ in. hex nuts to the tumble box and tumbling for 10 min.

Energy consumption
Specific energy consumption (SEC) was calculated by dividing energy used (kW) by production rate (ton/h). The energy consumption was recorded with a Data View Current and Voltage Data Logger (Supco model DVCV, Allenwood, NJ).

Starch analysis
Total starch was determined by the amount of D-glucose that was released from a mixture of 0.5 g sample and 25 mL distilled water after boiling for 20 min followed by 70 min of incubation at 104°F with glucoamylase. Gelatinized starch was determined by the amount of D-glucose that was released from a mixture of 0.5-g sample and 25 mL distilled water after resting for 20 min followed by 70 min incubation at 104°F with glucoamylase. Cooked starch was determined by dividing gelatinized starch by total starch then multiplying by 100.

Statistical analysis
Data were analyzed as a completely randomized design. In Experiment 1, treatments were arranged in 3 × 2 factorial design of fines inclusion level (0, 10, and 20%) and conditioning temperature (170 and 180°F) to determine the effect on pellet quality. In Experiment 2, treatments were arranged in 3 × 2 factorial design of fines inclusion level (0, 10, and 20%) and conditioning temperature (175 and 185°F) to determine the effect on pellet quality, gelatinized starch, and pellet mill energy consumption. 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
There were similar PDI responses for the standard and modified methods. For both methods, there was no interaction between fines inclusion level and conditioning temperature ($P > 0.348$) (Table 2). Both fines inclusion level and conditioning temperature had an effect on PDI ($P < 0.028$). Increasing conditioning temperature from 170 to 180°F significantly increased PDI by 0.6 and 4.3% for standard and modified methods, respectively. There was a linear increase ($P < 0.032$) in standard

[1] 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.

and modified PDI as the fines inclusion level increased. Increasing the conditioning temperature and percentage of fines improved pellet quality.

Experiment 2

The PDI of the six treatments was between 86 and to 93% for the standard method and between 68 and 85% for the modified method (Table 3). There were different PDI responses for the standard and modified methods. Differences between treatments were not observed when the standard method was used to measure PDI due to the high PDI results for all treatments. The modified PDI provided a better explanation of the effect of fines inclusion level and conditioning temperature on pellet quality for this experiment. There was an interaction ($P < 0.001$) between fines inclusion level and conditioning temperature for modified PDI. There was an increase in the modified PDI when the diets were pelleted at 185°F conditioning temperature and the fines inclusion level was increased. However, there was no evidence of difference for modified PDI of the diets with 0, 10, and 20% fines inclusion level when all diets were pelleted at 175°F conditioning temperature. Both fines inclusion level and conditioning temperature impacted modified PDI ($P < 0.0001$). Increasing conditioning temperature or fines inclusion level improved pellet quality. There was no interaction between fines inclusion level and conditioning temperature on total starch (Table 4) ($P = 0.562$). There was no evidence of difference ($P = 0.715$) in the total starch between the diets that were pelleted at 175 and 185°F conditioning temperatures. The total starch was the lowest in the diet with 0% fines (54.11%) followed by the diet with 20% and 10% fines (56.42 and 57.90%, respectively) ($P = 0.013$). There was no interaction between fines inclusion level and conditioning temperature ($P > 0.276$) for gelatinized and cooked starch results. Both the fines inclusion level and conditioning temperature did not affect gelatinized and cooked starch results ($P > 0.067$). However, the cooked starch tended ($P = 0.067$) to be greater when the diets were pelleted at 185°F versus 175°F conditioning temperature. Recirculated fines that passed through the conditioner and pellet die had a marginally higher percentage of cooked starch.

For energy consumption (Table 4), there was an interaction between fines inclusion level and conditioning temperature ($P < 0.001$). When the diets were pelleted at 185°F conditioning temperature, the diet with 20% fines (25.2 kWh/ton) required more energy during the pelleting process as compared to the diets with 0 and 10% (17.0 and 16.6 kWh/ton, respectively). However, there was no difference in energy consumption for the diets that contained 0, 10, and 20% fines (16.7, 16.8, and 16.5 kWh/ton, respectively) when the diets were pelleted at 175°F conditioning temperature. The pellet mill required more energy per ton when the diet was pelleted at 185°F versus 175°F conditioning temperature ($P < 0.001$). The results of the current experiment demonstrated that when the diet was steam conditioned above an optimum temperature, more energy was required to produce the pellets. There was a quadratic increase in energy consumption per ton as the fines inclusion level increased ($P < 0.001$). There was no interaction between fines inclusion level and conditioning temperature ($P = 0.075$) for variation in energy consumption, as measured by the standard deviation of the specific energy consumption (SEC). There was a linear increase in variation of energy consumption as the fines inclusion level increased ($P = 0.021$). The pellet mill was less consistent when the diets were pelleted at 185°F conditioning temperature as compared to 175°F conditioning temperature ($P = 0.019$).

The results of these experiments suggest that increasing conditioning temperature increases pellet quality. When a diet contained less than 1.5% oil, recirculating fines through the conditioner and pellet die improved the pellet quality. However, 20% fines inclusion led to occasional roll slips, decreased pellet mill stability, and increased energy usage when the diet was pelleted.

Table 1. Diet composition Experiment 1 and Experiment 2

Ingredients, %	Exp. 1	Exp. 2
Corn	69.19	76.06
Soybean meal (46.5% CP)	26.50	20.05
Soy oil	1.50	1.50
Monocalcium P (21% P)	0.55	0.32
Calcium carbonate	1.13	1.10
Vitamin premix[1]	0.15	0.12
Trace mineral premix[2]	0.15	0.12
L-Lys-HCl	0.31	0.26
DL-Met	0.07	0.02
L-Thr	0.09	0.05
Phytase[3]	0.02	0.02
Salt	0.35	0.35
Total	100.00	100.00

[1] Composition per pound: 33 g iron, 33 g zinc, 10 g manganese, 5 g copper, 0.09 g iodine, and 0.09 g selenium.
[2] Composition per pound: 751,563 IU vitamin A, 300,625 IU vitamin D_3, 8,017 IU vitamin E, 6 mg vitamin B_{12}, 601 mg menadione, 1,503 mg riboflavin, 5,010 mg d-pantothenic acid, and 9,019 mg niacin.
[3] 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. The effect of pellet fines inclusion level and conditioning temperature on pellet durability index (PDI) in Experiment 1

			PDI, %	
Pellet fines, %	**Cond temp, °F**	**n**	**Standard**	**Modified**
Interaction effects				
0	170	3	94.5	77.1
0	180	3	94.9	80.1
10	170	3	94.4	76.2
10	180	3	95.0	79.9
20	170	3	94.9	78.2
20	180	3	95.8	84.5
SEM			0.21	1.13
Main effects				
0		6	94.7	78.6
10		6	94.7	78.0
20		6	95.3	81.3
SEM			0.15	0.80
	170	9	94.6	77.2
	180	9	95.2	81.5
	SEM		0.12	0.65
Source of variation			------------ Probability, *P* < ------------	
Fines × temperature			0.419	0.348
Pellet fines				
Linear			0.011	0.032
Quadratic			0.119	0.072
Conditioning temp			0.003	0.001

Table 3. The effect of pellet fines inclusion level and conditioning temperature on pellet durability index (PDI) and starch in Experiment 2

			PDI, %		Starch, %		
Pellet fines, %	**Cond temp, °F**	**n**	**Standard**	**Modified**	**Total**	**Gelatinized**	**Cooked**
Interaction effects							
0	175	3	86.2	68.1[d]	53.60	12.66	23.63
0	185	3	89.3	74.7[c]	54.62	13.56	24.80
10	175	3	87.3	69.7[d]	58.49	13.61	23.27
10	185	3	90.2	78.1[b]	57.31	14.28	24.93
20	175	3	87.1	69.0[d]	56.83	13.11	23.10
20	185	3	93.2	85.3[a]	56.00	17.32	30.73
SEM			1.14	1.18	1.07	1.40	2.12
Main effects							
0		6	87.8	71.4	54.11[y]	13.11	24.22
10		6	88.8	73.9	57.90[x]	13.95	24.10
20		6	90.1	77.1	56.42[xy]	15.22	26.92
SEM			0.81	0.83	0.76	0.99	1.50
	175	9	86.9	68.9	56.31	13.13	23.33
	185	9	90.9	79.4	55.98	15.05	26.82
	SEM		0.12	0.68	0.62	0.81	1.22
Source of variation			---------------------------- Probability, P < ----------------------------				
Fines × temperature			0.329	0.001	0.562	0.396	0.276
Pellet fines							
Linear			0.058	0.001	0.052	0.158	0.228
Quadratic			0.857	0.718	0.015	0.861	0.440
Conditioning temp			0.001	0.001	0.715	0.118	0.067

[a-d] Means in column within the interaction effect of pellet fines inclusion level and conditioning temperature followed by a different letter are significantly different ($P < 0.05$).
[x-z] Means in column within main effect of pellet fines inclusion level followed by a different letter are significantly different ($P < 0.05$).

Table 4. The effect of pellet fines inclusion level and conditioning temperature on pellet mill specific energy consumption (SEC) in Experiment 2

Pellet fines, %	Cond temp, °F	n	SEC, kWh/ton	Std dev of SEC, kWh/ton
Interaction effects				
0	175	2	16.65[b]	1.99
0	185	2	17.00[b]	2.23
10	175	3	16.82[b]	1.98
10	185	3	16.63[b]	2.23
20	175	3	16.49[b]	2.18
20	185	3	25.19[a]	3.79
SEM			1.93	0.41
Main effects				
0		4	16.83	2.11
10		6	16.72	2.10
20		6	20.84	2.99
SEM			0.96	0.29
	175	8	16.65	2.05
	185	8	19.61	2.75
	SEM		0.64	0.21
Source of variation			------------ Probability, *P* < ------------	
Fines × temperature			0.001	0.075
Pellet fines				
Linear			0.001	0.021
Quadratic			0.007	0.139
Conditioning temp			0.001	0.019

[a,b]Means in column within the interaction effect of pellet fines inclusion level and conditioning temperature followed by a different letter are significantly different ($P < 0.05$).