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Moisture Content Throughout the Pelleting Process and Subsequent Effects on Pellet Quality

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Summary

This experiment was designed to evaluate the effects of steam addition to the conditioner on moisture content throughout the pelleting process and subsequent effects on pellet quality. Treatments consisted of diets pelleted with no steam and steam added to achieve conditioning temperatures of 145 and 190°F. Conditioner retention time was set at 30 s and diets were pelleted with a ¼ × 2 ½ inch pellet die. Pellet samples were collected and immediately placed in an experimental counterflow cooler for 15 min. All treatments were replicated at 3 separate time points to provide 3 replicates per treatment. Mash, conditioned mash, hot pellets, and cooled pellet samples were collected for moisture content analysis, and cooled pellets for pellet durability index (PDI). Data were analyzed with pelleting run as the experimental unit and time period as the blocking factor. Moisture samples were analyzed as a 3 × 4 factorial of steam-conditioning and sample location. There was a steam-conditioning × sample interaction ($P < 0.01$) for moisture. Moisture in mash samples was similar for all treatments. For the no steam treatment, there was no difference in moisture content between the mash, conditioned mash, and hot pellets; however, moisture decreased in cooled pellets. For the 145°F treatment, there was an increase in moisture from mash to conditioned mash, followed by a decrease in both hot pellets and cooled pellets. For the 190°F treatment, moisture increased from mash to conditioned mash, and decreased in hot pellets and cooled pellets. Increasing conditioning temperature from no steam to 190°F increased ($P < 0.01$) PDI from 3.3, 59.1, to 91.1%, respectively. In conclusion, increasing feed temperature from 97.2 to 190°F via steam addition increased the conditioned mash moisture content by 4.2%, resulting in improved pellet quality.

Introduction

Swine diets are typically pelleted to improve diet handling characteristics, reduce ingredient segregation, decrease feed wastage, and increase bulk density. It is important to produce good quality pellets to maximize the overall growth performance response of pigs fed pelleted diets. The pelleting process begins by feeding dry mash feed into a

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conditioning chamber where heat and moisture are applied via steam. As the feed exits the conditioner, it is compressed through a die to form pellets and then cooled before being stored prior to shipment. While the pelleting process is widely understood, there are many factors that can be manipulated to produce a vastly different final product. These factors include diet formulation, conditioning temperature (i.e. steam addition), die selection, and production rate.

Proper mash feed conditioning is necessary to achieve optimum production rates, pellet quality, energy usage, and die and roll life. Increasing the amount of steam used in the conditioning process will result in increased conditioning temperature and moisture added to the feed. Conditioning the feed is necessary to help lubricate the feed and push it through the die. However, different amounts of heat and moisture are required to adequately pellet different types of feed. Traditionally, it has been determined that conditioned mash moisture should approach 17 or 18% and temperature should reach approximately 180°F when pelleting corn- and soybean meal-based diets. Therefore, the objective of this experiment was to determine the effects of steam addition to the conditioner on moisture content throughout the pelleting process, and subsequent effects on pellet quality.

Procedures

Feed was manufactured in accordance with CGMPs at the Kansas State University O.H. Kruse Feed Technology Innovation Center (Manhattan, KS).

A corn and soybean meal-based diet was manufactured to provide a basal diet for all treatments (Table 1). Corn was ground with a three-high roller mill (RMS Model 924) to approximately 600 microns. Basal diets were mixed in 2,000 lb batches using a 2,000 lb mixer (Hays and Stohlz, Fort Worth, TX). Treatments consisted of diets pelleted with no steam and with steam added to achieve conditioning temperatures of 145 and 190°F. The basal diet had a 30 s retention time in the conditioner and was pelleted using a 3016-4 HD CPM Master Model equipped with a ¼ × 2 ½ inch pellet die (10 length:diameter). Feeder rate was kept constant to achieve a production rate of approximately 6,600 lb/h. After pellets exited the pellet die, pellet samples were collected and placed in an experimental counterflow cooler for 15 min. Treatments were replicated over 6 pelleting runs to provide 6 replicates per treatment. Conditioning temperature, hot pellet temperature (HPT), and production rate were recorded at 3 time points during each run (Table 2). Change in temperature across the die (Δ temperature, °F) was calculated by taking the difference between the hot pellet temperature and conditioned mash temperature. Mash, conditioned mash, hot pellets, and cooled pellet samples were collected throughout each run and analyzed for moisture content. Cooled pellet samples were analyzed for pellet durability index (PDI) using the Holmen NPH100 at 60 bar for 60 s.

Moisture analysis were completed in duplicate for each dry mash, conditioned mash, hot pellet, and cooled pellet sample. Aluminum pans were weighed, and a 2-g sample was placed in the drying oven at 221°F for 24 h (AOAC Method 934.01). Samples were weighed back for moisture calculation (100 – ((dried sample weight / initial sample weight) × 100)).

For analysis of PDI, fines were sifted off from cooled pellets using a U.S. No. 3 ½ sieve. One hundred grams of the sifted pellets were placed into a Holmen 100 pellet tester and agitated with air for 60 s. Following agitation, the sample was again sifted through a No. 3 ½ 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. Moisture data were analyzed as 3 × 4 factorial with conditioning temperature and sample location as the fixed effects and time of processing as a random effect. Sample location also served as the repeated measure with pelleting run as the subject. Pellet quality and Δ temperature data were analyzed using PROC GLIMMIX, SAS 9.4 with conditioning temperature as the fixed effect and time of processing as a random effect. 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

Increasing the conditioning temperature via added steam decreased ($P < 0.01$) Δ temperature across the die. There was a steam-conditioning × sample interaction ($P < 0.01$) for moisture (Table 2). Moisture in mash samples was similar for all treatments. For the no steam treatment, there was no difference in moisture content between the mash, conditioned mash, and hot pellets; however, moisture decreased in cooled pellets. For the 145°F treatment, there was an increase in moisture from mash to conditioned mash, followed by a decrease in both hot pellets and cooled pellets. For the 190°F treatment, moisture increased from mash to conditioned mash, and decreased in hot pellets and cooled pellets. Increasing conditioning temperature from no steam to 190°F increased ($P < 0.01$) PDI from 3.3, 59.1, to 91.1%, respectively.

In conclusion, the data collected herein confirm the traditional components of pelleting feed. Conditioning the diet to 193.8°F via added steam acted as a lubricant to help push the feed through the die, while conditioning the particles to bind together when extruded through the die. This lubrication effect is confirmed by the decrease in change in temperature across the die from 40.9 to -1.3°F as conditioning temperature was increased to 193.8°F. In addition, increasing the feed temperature from 99.3 to 193.8°F, via steam addition, increased conditioned mash moisture content by 4.2%. Feed conditioned to 193.8°F had a moisture content of 17.3% which is in the target range of 17 to 18% moisture. Therefore, conditioned mash moisture content increased by 1.1% for every 25°F increase in conditioning temperature. These increases in feed temperature and moisture content resulted in improved PDI from 3.3 to 91.1%.

Table 1. Diet composition, (as fed-basis)[1]

Ingredient	%
Corn	61.06
Soybean meal, 47% crude protein	34.00
Soybean oil	1.00
Defluorinated phosphate	2.20
Limestone	0.26
Salt	0.23
Sodium bicarbonate	0.23
L-Lysine HCl	0.22
DL-Methionine	0.31
L-Threonine	0.14
Vitamin and trace mineral premix	0.25
Choline chloride	0.10

[1]Diets were mixed in a 1-ton Hayes & Stolz counterpoise mixer with a 60-s dry mix time and 120-s wet mix time.

Table 2. Effect of steam addition during conditions on change in temperature across the die, moisture content, and pellet durability index[1]

		Conditioning temp, °F			
	No Steam	145°F	190°F	SEM	*P*-value
Production rate, lb/h	6,448	6,709	6,682	-	-
Condition temp, °F	99.3	145.7	193.8	-	-
Hot pellet temp, °F	140.2	161.4	192.6	-	-
Δ Temperature, °F	40.9[a]	15.7[b]	-1.3[c]	1.49	0.001
Moisture content, %					
Mash	13.4[ef]	13.2[ef]	13.3[ef]	0.17	0.001
Conditioned mash	13.1[ef]	15.3[c]	17.3[a]		
Hot pellets	12.9[fg]	14.9[d]	16.3[b]		
Cooled pellets	12.0[h]	12.6[g]	13.4[e]		
Pellet durability index, %	3.4[a]	59.1[b]	91.1[c]	1.98	0.001

[1]Diets were pelleted with no steam and with steam added to achieve conditioning temperatures of 145 and 190°F. The basal diet had a 30 s residence time in the conditioner and pelleted using a 3016-4 HD CPM Master Model pellet mill equipped with a ¼ × 2 ½ inch pellet die (10 length:diameter). All treatments were pelleted at 6 separate time points to provide 6 replications per treatment.
[a,b,c]Within a row, means without a common superscript differ ($P < 0.05$).
[a-h]Within all moisture content data, means without a common superscript differ ($P < 0.05$).