Kansas Agricultural Experiment Station Research Reports

Volume 5
Issue 8 *Swine Day*

Article 38

2019

Effects of Grinding Corn with Different Moisture Concentrations on Subsequent Particle Size and Flowability Characteristics

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Recommended Citation
Braun, M. B.; Dunmire, K. M.; Evans, C. E.; Stark, C. R.; and Paulk, C. B. (2019) "Effects of Grinding Corn with Different Moisture Concentrations on Subsequent Particle Size and Flowability Characteristics," *Kansas Agricultural Experiment Station Research Reports*: Vol. 5: Iss. 8. https://doi.org/10.4148/2378-5977.7868

Effects of Grinding Corn with Different Moisture Concentrations on Subsequent Particle Size and Flowability Characteristics

Abstract

The objective of this study was to determine the effects of whole corn moisture and hammermill screen size on subsequent ground corn moisture, particle size, and flow- ability. Whole yellow dent #2 corn was used for this experiment. Treatments were arranged as a 2 × 2 factorial design with two moisture concentrations (as-received and high) each ground using 2 hammermill screen sizes (1/8 and 1/4 in). Corn was ground using a laboratory scale 1.5 HP Bliss Hammermill (Model 6K630B) at 3 separate time points to create 3 replications per treatment. Increasing initial whole corn moisture was accomplished by adding 5% water and heating at 55°C for 3 hours in sealed glass jars using a Fisherbrand Isotemp Oven (Model 15-103-051). Ground corn flowability was calculated using angle of repose (AOR), percent compressibility, and critical orifice diameter (COD) measurements to determine the composite flow index (CFI).

There was no evidence for a screen size × corn moisture interaction for moisture content, particle size, standard deviation, or flowability metrics. Grinding corn using a 1/8 in screen resulted in decreased ($P <$ 0.041) moisture content compared to corn ground using the 1/4 in screen. There was a decrease in particle size from the 1/4 in screen to the 1/8 in but no evidence of difference was observed for the standard deviation. There was a decrease ($P < 0.03$) in percent compressibility as screen size increased from 1/8 to 1/4 in. Angle of repose tended to decrease ($P <$ 0 .056) when corn was ground using a 1/4 in screen compared to a 1/8 in screen. For the main effects of moisture content, high moisture corn had increased ($P < 0.0001$) ground corn moisture content compared to as-received corn. As-received corn resulted in decreased ($P < 0.029$) particle size and an increased standard deviation compared to the high moisture corn. Increased moisture content of corn increased ($P < 0.038$) CFI and tended to decrease ($P <$ 0.056) AOR and COD. In conclusion, decreasing hammermill screen size increased moisture loss by 0.55%, corn particle size by 126 µm, and resulted in poorer flowability as measured by percent compressibility and AOR. High moisture corn increased subsequent particle size by 89 µm, therefore improving flowability as measured by CFI.

Keywords

corn, grind, moisture, flowability, particle size

Authors

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Effects of Grinding Corn with Different Moisture Concentrations on Subsequent Particle Size and Flowability Characteristics

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Summary
The objective of this study was to determine the effects of whole corn moisture and hammermill screen size on subsequent ground corn moisture, particle size, and flowability. Whole yellow dent #2 corn was used for this experiment. Treatments were arranged as a 2 × 2 factorial design with two moisture concentrations (as-received and high) each ground using 2 hammermill screen sizes (1/8 and 1/4 in). Corn was ground using a laboratory scale 1.5 HP Bliss Hammermill (Model 6K630B) at 3 separate time points to create 3 replications per treatment. Increasing initial whole corn moisture was accomplished by adding 5% water and heating at 55°C for 3 hours in sealed glass jars using a Fisherbrand Isotemp Oven (Model 15-103-051). Ground corn flowability was calculated using angle of repose (AOR), percent compressibility, and critical orifice diameter (COD) measurements to determine the composite flow index (CFI).

There was no evidence for a screen size × corn moisture interaction for moisture content, particle size, standard deviation, or flowability metrics. Grinding corn using a 1/8 in screen resulted in decreased ($P < 0.041$) moisture content compared to corn ground using the 1/4 in screen. There was a decrease in particle size from the 1/4 in screen to the 1/8 in but no evidence of difference was observed for the standard deviation. There was a decrease ($P < 0.03$) in percent compressibility as screen size increased from 1/8 to 1/4 in. Angle of repose tended to decrease ($P < 0 .056$) when corn was ground using a 1/4 in screen compared to a 1/8 in screen. For the main effects of moisture content, high moisture corn had increased ($P < 0.0001$) ground corn moisture content compared to as-received corn. As-received corn resulted in decreased ($P < 0.029$) particle size and an increased standard deviation compared to the high moisture corn. Increased moisture content of corn increased ($P < 0.038$) CFI and tended to decrease ($P < 0.056$) AOR and COD. In conclusion, decreasing hammermill screen size increased moisture loss by 0.55%, corn particle size by 126 μm, and resulted in poorer flowability as measured by percent compressibility and AOR. High moisture corn increased subsequent particle size by 89 μm, therefore improving flowability as measured by CFI.

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Introduction

Reducing the particle size of cereal grains is the first step in the feed production process. This reduction could improve growth performance in all phases of swine production by increasing the surface area-to-volume ratio of grain particles. Hammermills are commonly used to reduce particle size because of their versatility and ease of use for grinding various grains and materials. The characteristics of the incoming grains can vary greatly from the region of origin, weather patterns, and variety of grain harvested. A major characteristic that is tested routinely is the moisture content. Changes in the whole grain moisture content can greatly affect the overall throughput of mill equipment, as well as change the ground materials characteristics. Moisture content, particle size, and the standard deviation of the grind can all significantly impact the ability of materials to flow easily. Therefore, the objective of this study was to determine the effects of whole corn moisture on the subsequent particle size and flowability of ground corn.

Procedures

Whole yellow dent #2 corn with an initial moisture content of 14.6% was used in this experiment. Treatments were arranged as a 2 × 2 factorial design with two moisture levels (as-received and high) and ground using 2 hammermill screen sizes (1/8 and 1/4 in). Increasing initial whole corn moisture was accomplished by adding 5% water and heating at 55°C for 3 hours in sealed glass jars using a Fisherbrand Isotemp Oven (Model 15-103-051). Whole corn moisture was analyzed using a Dickey-John GAC 2500-UGMA. Whole corn samples' initial moisture content analyzed as 14.5% for as-received and 16.7% for high. Corn was then ground using a laboratory scale 1.5 HP Bliss Hammermill (Model 6K630B) at 3 separate time points to create 3 replications per treatment.

Samples of each treatment were collected and analyzed for moisture, particle size, and flowability characteristics. Ground corn samples were analyzed for moisture according to AOAC 930.15. Particle size analysis was completed according to ANSI/ASAE S319.4 using a 13 sieve stack with the inclusion of sieve agitators and flow agent. The flowability characteristics of finished diets were evaluated using a composite flow index (CFI), which includes tests such as percent compressibility, angle of repose, and critical orifice diameter.[4]

Data were analyzed using the PROC GLIMMIX procedure in SAS version 9.4 (SAS Institute Inc., Cary, NC). Results were considered significant if $P \leq 0.05$, and a trend if $0.05 < P \leq 0.10$.

Results and Discussion

There was no evidence for a screen size × corn moisture interaction for moisture content, particle size, standard deviation, or flowability metrics (Table 1). Grinding corn using a 1/8 in screen resulted in decreased ($P < 0.041$) moisture content compared to corn ground using the 1/4 in screen. There was a decrease in particle size from the 1/4 in screen to the 1/8 in, but no evidence of difference was observed for the standard deviation. There was a decrease ($P < 0.03$) in percent compressibility as screen size increased from 1/8 in to 1/4 in. Angle of repose tended to decrease ($P < 0.056$)

when corn was ground using a 1/4 in screen compared to a 1/8 in screen. For the main effects of moisture content, high moisture corn had increased ($P < 0.0001$) ground corn moisture content compared to as-received corn. As-received corn resulted in decreased ($P < 0.029$) particle size and an increase in standard deviation compared to the high moisture corn. The higher moisture content corn increased ($P < 0.038$) CFI and tended to decrease ($P < 0.056$) AOR and COD. In conclusion, decreasing hammermill screen size increased moisture loss by 0.55%, corn particle size by 126 µm, and led to poorer flowability as measured by percent compressibility and AOR. High moisture corn increased subsequent particle size by 89 µm, therefore improving flowability as measured by CFI.

Ground ingredient quality is a key concern when manufacturing feed. This experiment shows corn samples of different initial moisture content, ground using two different screen sizes on a hammermill, will have different physical characteristics post-grinding. Decreasing screen size decreased particle size and increased standard deviation which resulted in poorer flowability. Flowability was determined using the composite flow index (CFI), which includes angle of repose, percent compressibility, and critical orifice diameter. A CFI greater than 45 is considered passable. All treatments met this standard except corn that was ground using the 1/8 in screen and as-received moisture content. When corn was ground using the 1/8 in screen, a 0.55% moisture loss was observed compared to the 1/4 in screen, regardless of the initial corn moisture. Increasing the initial corn moisture resulted in increased particle size and an improved standard deviation, which created improved flow characteristics.

Table 1. Physical analysis

	1/8 in		1/4 in			Probability, *P* <		
Item	Normal	High	Normal	High	SEM	Screen Size	Moisture	Interaction
Moisture, %	11.4	15.7	11.9	16.3	0.002	0.041	0.001	0.805
Particle size,[1] µm	348	401	438	563	44.58	0.031	0.029	0.240
Standard deviation	2.49	2.39	2.75	2.41	0.03	0.240	0.038	0.189
Angle of repose,[2] °	52.07	47.21	47.24	46.00	1.35	0.056	0.055	0.219
Critical orifice diameter[3]	30.0	26.0	27.3	23.3	1.79	0.175	0.056	1.00
Compressibility,[4] %	26.8	26.1	25.4	23.0	0.85	0.030	0.112	0.344
Composite flow index[5]	38.5	46.6	45.6	52.4	3.02	0.063	0.038	0.839

[1]Particle size and standard deviation (Sgw) are determined according to ASABE 319.4 methods.
[2]Angle of repose was determined by measuring the height and radius of the cone formed by the material and using the following equation: Tan θ = height of cone (mm)/radius of cone (mm).
[3]Critical orifice diameter was determined using a Flodex device to determine product mass flow characteristics through varying discharge outlet sizes.
[4]Percent compressibility is calculated by using the Hausner ratio (PTapped/PBulk).
[5]The composite flow index is calculated by the following equation CFI = (-0.667(AoR Result) + 50) + (-0.667(%C Result) + 36.667) + (-1.778(COD Result) + 37.778).