Effect of sieving methodology on determining particle size of ground corn, sorghum, and wheat by sieving

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Goals:
- Evaluate four sieving methods to determine which method best estimates the average particle size of a corn, wheat, and sorghum sample at three different grind sizes (coarse, medium, and fine) ground on a hammermill and roller mill creating a 4 x 3 x 2 factorial arrangement.
- Determine the analytical variation of the particle size method.
- Determine if results from method S391.2 are linear to results S319.4 across multiple particle sizes.
- Conduct a growth assay in nursery pigs to determine if a 50 µm increment results in different average daily feed intake (ADFI), average daily gain (ADG), and feed to gain (F/G).

Recent Publications:
- ANSI/ASAE S319.4

Statement of Problem:
The feed industry currently uses multiple sieving methods to determine the particle size of feed ingredients, primarily ground cereal grains. The most recent version of the standard is ANSI/ASAE S319.4 FEB2008 (R2012) but it is not readily used by the feed industry. The first two versions (S319.1 and S319.2) of the standard recommended a sieving time of 10 minutes, which became and still remains the industry standard for most of the feed industry. Additionally, most of the animal research was conducted based on either S319.1 or S319.2. However, between standards S319.2 and S319.3 there was a major revision in which the words “For industrial applications, the end-point determination process can be omitted, and the end-point is set to be the sieving time of 15 min” were added to the standard. This major change in the standard in addition to the research of Fahrenholz (2010) and Stark and Chewning (2012) who demonstrated that sieve agitators and sieving agents significantly change the average particle size of a ground sample of corn has raised many questions as to what is the appropriate method for determining particle size in the feed industry.

The objectives of this study are to evaluate the effect of sieving time, sieve agitators, and sieving agents on the geometric mean diameter and geometric standard deviation of ground cereal grains using the procedures outlined in ANSI/ASAE S319.4 FEB2008 (R2012)

Current Activities:
- Determine roll settings on RMS 3-high roller mill (Model 924; roll set up of top: 6 corrugations/inch, middle: 12 and 14 corrugations/inch, and bottom: 16 and 18 corrugations/inch) to achieve desired particle sizes.
- Determine particle size produced by hammermill screens (model 22115, Bliss) to achieve desire particle sizes.
- Collect samples to be analyzed
- Split and divide samples using a riffle divider
- Procure cereal grains to be ground and associated resources being used
Introduction
The particle size of grain and feed has been shown to be directly correlated with animal performance. For example, in swine as particle size decreases, feed efficiency improves, whereas in poultry as particle size increases so does performance. Reducing the particle size of grain in swine diets increases the surface area, which improves digestion in the lower GI tract where the particles come in contact with enzymes. However, as particle size decreases, energy consumption required for particle size reduction increases. Additionally there are increased problems with flowability and dust control throughout the feed manufacturing system will also result with finer particle size.

Method of grinding affects the particle size and the standard deviation of a sample. Samples ground using a hammermill versus those ground using a roller mill have a higher standard deviation because of an increased range in the particle size of the individual particles.

Brief Description of Research and Significance of Project
The feed industry currently uses multiple sieving methods to determine the particle size of feed ingredients, primarily ground cereal grains. The most recent version of the standard is ANSI/ASAE S319.4 FEB2008 (R2012) but it is not readily used by the feed industry. The first two versions (S319.1 and S319.2) of the standard recommended a sieving time of 10 minutes, which became and still remains the industry standard for most of the feed industry. Additionally, most of the animal research was conducted based on either S319.1 or S319.2. However, between standards S319.2 and S319.3 there was a major revision in which the words “For industrial applications, the end-point determination process can be omitted, and the end-point is set to be the sieving time of 15 min” were added to the standard. This major change in the standard in addition to the research of Fahrenholz (2010) and Stark and Chewning (2012) who demonstrated that sieve agitators and sieving agents significantly change the average particle size of a ground sample of corn has raised many questions as to what is the appropriate method for determining particle size in the feed industry.

The goals of this project are to: 1) Evaluate four sieving methods to determine which method best estimates the average particle size of a corn, wheat, and sorghum sample at three different grind sizes (coarse, medium, and fine) ground on a hammermill (Model 22115, Bliss) and roller mill (Model 924, RMS) creating a 4 x 3 x 2 factorial arrangement; 2) Determine the analytical variation of the particle size method; 3) Determine if results from method S391.2 are linear to results S319.4 across multiple particle sizes; 4) Conduct a growth assay in nursery pigs to determine if a 50 µm increment results in different average daily feed intake (ADFI), average daily gain (ADG), and feed to gain (F/G).

Background and Justification
The purpose of the ANSI/ASAE S319.4 (ASABE, 2012) standard is to define a test procedure to determine the fineness of feed ingredients and to define a method of expressing the particle size of the material. Surface area and number of particles per unit mass can be calculated from the determined particle size.

The current method, ANSI/ASAE S319.4 (ASABE, 2012) stipulates a sample of 100 g is placed on the top sieve of the stack. The sample is then shaken for a specified amount of time. For industrial applications, the sieving time is 15 minutes. Mass of the material on all sieves should then be determined and recorded (ASABE, 2006). If a dispersing agent is required, it should be added at 0.5% of the sample mass. Point 4.4 states, “sieve agitators such as plastic or leather rings, or small
rubber balls may be required to break up agglomerates on finer sieves, usually those smaller than US sieve No. 50” (ASABE, 2012). Continuing with point 4.5, “A dispersion agent can be used to facilitate sieving of high-fat or other materials prone to agglomeration”.

Recently, (A. C. Fahrenholz, 2010) found the lowest geometric mean ($d_{gw}$) (particle size) in a sample that was sieved for 15 minutes rather than for 10 minutes. It was not specified whether or not a dispersion agent was also used for this sample. However, this sample also had the highest geometric standard deviation ($s_{gw}$). Samples of a smaller particle size have more variation in their geometric mean and geometric standard deviation than do larger particle size samples.

As was reported in a 2006 Swine Day report (R. D. Goodband, et al., 2006) found a bias in both the particle size and standard deviation using a flow agent and not using a flow agent. “Results of this study indicate that there are differences in results between the two procedures”. Just like with (A. C. Fahrenholz, 2010), it was found that using a dispersion agent increased the standard deviation but decreased the particle size.

Materials and Methods

Material Preparation

Samples will be prepared at the O.H. Kruse Feed Technology Innovation Center at Kansas State University. Grain will be produced using a hammermill (Model 22115, Bliss) and roller mill (Model 924, RMS) to achieve the desired grind sizes (course, medium, and fine). The roll gap settings and hammermill screen sizes will be the same for each cereal grain. For example, corn, wheat, and sorghum will all be ground using a 4/64 mm hammermill screen to provide the fine ground size, while an 8/64 mm screen will be used to provide the medium ground size.

Particle Size Analysis

Samples will be divided using a riffle divider to approximately 100 g ± 5 g. The individually weighed samples will then be analyzed in the swine laboratory. The analysis will be conducted with two sieve stacks (13 sieves + pan). Stack C, a stainless steel sieve stack, will be used for the samples that involve a dispersing agent and stack B, a brass sieve stack, will be used to analysis samples that do not involve a dispersing agent. Both sieve sets will contain sieve agitator(s) (Table 1). Each sieve will be cleaned using compressed air and a stiff bristle sieve cleaning brush.

Each sieve will be individually weighed with the sieve agitator(s) to obtain a tare weight. The 100 g sample will be placed on the top sieve. If a dispersing agent is required, (0.5 g) it will be mixed into the sample prior to placing the mixture on the top sieve. The sieve stack will be placed in the Ro-Tap machine (Model RX-29) and run for the specified amount of time. Once completed, each sieve will once again be individually weighed with the sieve agitator(s) to obtain the weight of the sample on each sieve. The amount of material on each sieve will then be entered into a particle size spreadsheet in order to calculate the geometric mean ($d_{gw}$) and geometric standard deviation ($s_{gw}$). Each sample will have five replications.
Table 1. Sieves and sieve agitator arrangement

<table>
<thead>
<tr>
<th>U.S. Sieve Number</th>
<th>Sieve Opening (µm)</th>
<th>Sieve Agitator(s)</th>
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<tbody>
<tr>
<td>6</td>
<td>3360</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>2380</td>
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<tr>
<td>12</td>
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<td>Three Screwballs</td>
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<td>1190</td>
<td>Three Screwballs</td>
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<tr>
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<td>841</td>
<td>Three Screwballs</td>
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<tr>
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<td>595</td>
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</tr>
<tr>
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<td>420</td>
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</tr>
<tr>
<td>Pan</td>
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</table>

**Experimental Design**

Experiment 1 will evaluate four sieving methods to determine which method best estimates the average particle size of a corn, wheat, and sorghum sample at three different grind sizes (coarse, medium, and fine) ground on a hammermill (Model 22115, Bliss) and roller mill (Model 924, RMS) creating a 4 x 3 x 2 factorial arrangement. The four sieving methods will be: 1) 10 minutes with sieve agitators (10S), 2) 15 minutes with no sieve agitators (15NS), 3) 15 minutes with sieve agitators (15S), and 4) 15 minutes with sieve agitators and dispersing agent (fumed silica) (15SA). Samples will be blocked by day for evaluation.

Experiment 2 will determine the analytical variation the 10S method (currently used by the industry) compared to the method that resulted in lowest average particle size from experiment 1. The experiment will also evaluate potential difference between technicians. Four technicians will perform particle size analysis on a 500 µm corn sample from a roller mill and a 350 µm corn sample from a hammermill using the ANSI/ASAE S319.4 FEB2008 (R2012) method.

Experiment 3 will compare the results of the 10S (currently used by the industry) and the method that resulted in the lowest average particle size from experiment 1 and determine if the methods are linear across multiple particle sizes. Corn samples ranging from 200 µm to 1000 µm, ground with a hammermill will be evaluated using the ANSI/ASAE S319.4 FEB2008 (R2012) and the method with the lowest particle size from experiment 1. Using a roller mill, the corn samples ranging from 400 µm to 1000 µm will also be ground. The samples will be evaluated at 200 µm increments.

Experiment 4

A growth assay study will be conducted in nursery pigs to determine if a 50 µm increment results in different average daily feed intake (ADFI), average daily gain (ADG), and feed to gain (F/G).

**Statistical Analysis**

Collected data will be analyzed using PROC GLIMMIX (SAS, 2006). Statements of statistical differences will be based upon $P<0.05$. 
Time Schedule

January 22, 2014 – Experiment 1 begins; Obtain corn, wheat, and sorghum samples to be analyzed. Divide samples using a riffle divider and individually weigh 100 g ± 5 g of each sample.

February 15, 2014 – Analyze and obtain the particle size of the individually weighed corn, wheat, and sorghum samples using the Tyler Ro-Tap sieve stack.

March 1, 2014 - Determine a method that most accurately demonstrated the micron size of the corn samples using statistical analysis.

April 1, 2014 – Experiment 1 ends; experiment 2 begins; obtain corn samples to be analyzed for experiment 2; divide samples using a riffle divider and individually weigh 100 g ± 5 g of each sample.

April 15, 2014 – Four technicians perform particle size analysis on corn samples using 10S and method that resulted in lowest particle size from experiment 1.

May 15, 2014 - Determine the analytical variation the 10S method (currently used by the industry) compared to the method that resulted in lowest average particle size from experiment 1 and the potential difference between technicians using statistical analysis.

July 15, 2014 – Experiment 2 ends; experiment 3 begins; obtain corn samples to be analyzed. Divide samples using a riffle divider and individually weigh 100 g ± 5 g of each sample.

August 1, 2014 - Determine if the methods are linear across multiple particle sizes using statistical analysis.

September 1, 2014 – Experiment 3 ends; experiment 4 begins; process feed using specified micron size of corn; process, weigh, and allot weaned pigs to begin phase 1

September 8, 2014 – Weigh pigs and record performance data for end of phase 1; begin phase 2

September 18, 2014 – Weigh pigs and record performance data for end of phase 2; begin phase 3

October 12, 2014 – Weigh pigs and record performance data for end of phase 3; determine if there is a difference in the performance data collected using statistical analysis.

November 12, 2014 – End experiment 4
References


