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The importance of defining the method in particle size analysis by sieving

Abstract

The American Society of Agricultural and Biological Engineers (ASABE) publishes a standard for identifying particle size by sieving (ASABE S319.4). However, this standard includes a number of options that allow the test to be conducted differently, and different laboratories may analyze a single sample with different results. Options include the type of sieve shaker used, the use of sieve agitators, the use of a dispersion agent, and the sieving time. A small study was conducted to examine the effect of varying these methods on the calculated geometric mean diameter by weight (dgw) and geometric standard deviation by weight (sgw). Results indicated that large differences existed depending on the methods used, with dgw varying by as much as 100 microns, and sgw varying by as much as 0.42 simply by altering one option. When compounding the differences in methods, the variations can be even larger. These discrepancies demonstrate that, for particle size analysis by sieving to be used as an effective tool, the same methodology must be used to compare samples. Additionally, the data demonstrate that unless the methods in the current standard are better defined, dgw and sgw should be used only as relative values for comparison.; Swine Day, Manhattan, KS, November 18, 2010

Keywords

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The Importance of Defining the Method in Particle Size Analysis by Sieving

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Summary

The American Society of Agricultural and Biological Engineers (ASABE) publishes a standard for identifying particle size by sieving (ASABE S319.4). However, this standard includes a number of options that allow the test to be conducted differently, and different laboratories may analyze a single sample with different results. Options include the type of sieve shaker used, the use of sieve agitators, the use of a dispersion agent, and the sieving time. A small study was conducted to examine the effect of varying these methods on the calculated geometric mean diameter by weight (d_{gw}) and geometric standard deviation by weight (s_{gw}). Results indicated that large differences existed depending on the methods used, with d_{gw} varying by as much as 100 microns, and s_{gw} varying by as much as 0.42 simply by altering one option. When compounding the differences in methods, the variations can be even larger. These discrepancies demonstrate that, for particle size analysis by sieving to be used as an effective tool, the same methodology must be used to compare samples. Additionally, the data demonstrate that unless the methods in the current standard are better defined, d_{gw} and s_{gw} should be used only as relative values for comparison.

Key words: particle size, sieving, standard

Introduction

Recently, there have been a growing number of questions about defining the exact particle size of ground cereal grains incorporated into animal diets. Additionally, the uniformity of particle size distributions has been suggested as having an important role in animal nutrition. Although measuring particle size and distribution remains an important aspect in quality control, a lack of communication between academia and industry, along with nonuniform interpretation of the standard published by the American Society of Biological and Agricultural Engineers (ASABE S319.4), have led to a divergence in methodologies.

The first step to understanding particle size analysis is to understand the meanings of the resultant values. The geometric mean of particle diameter by weight, or d_{gw}, is also the median particle size. It is important to note that this value is not the same as the arithmetic mean, or what is commonly referred to as the average, though d_{gw} has taken on this misnomer. The geometric standard deviation of particle diameter by weight, or s_{gw}, is similarly different from the arithmetic standard deviation. The geometric standard deviation is a factor, rather than a specific value, and has no unit. It can be used to make observations on the particles that fall within a given range.

The ASABE standard allows considerable latitude in accepted test equipment and sieving methods. The following are the specific sections of the standard reviewed for the purpose of this article: *1.) Section 4.2 - A sieve shaker, such as a Tyler Ro-Tap, Retsch, or equivalent unit, is required; 2.) Section 4.4 - 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 300mm in opening (ISO 3310-1) or US sieve No. 50; 3.) Section 4.5 - A dispersion agent can be used to facilitate sieving of high-fat or other material prone to agglomeration; and 4.) Section 5.2 - Place the charge on one sieve or the top sieve of the nest of test sieves and shake until the mass of material on any on sieve reaches end point. End point is decided by determining the mass on each sieve at 1-minute intervals after an initial sieving time of 10 minutes. If the mass on the smallest sieve containing any material changes by 0.1% or less of the charge mass during a 1-minute period, the sieving is considered complete. For industrial applications, the end-point determination process can be omitted, and the end-point is set to be the sieving time of 15 minutes.*

Procedures

A single sample of freshly ground corn was obtained from the Feed Processing and Research Center in the Department of Grain Science and Industry at Kansas State University. This sample was mixed and split using a Boerner divider before each particle size analysis. Analyses were conducted to determine the effects of using a Tyler Ro-Tap vs. a Retsch sieve shaker, using vs. not using sieving agitators, using vs. not using a dispersion agent, and sieving for 10 vs. 15 minutes. In order to reduce the number of trials, the different methods were mixed in an incomplete factorial design; however, because interactions were not of concern and because of the obviously large differences between the methods, it was determined that statistical analysis was not warranted.

Results

The Tyler Ro-Tap sieve shaker is the most commonly used in the feed industry. However, as the ASABE standard states, a Retsch sieve shaker can also be used. Though both sieve shakers facilitate feed particle passage through the sieve stack, one could argue that particle motion within the sieve stack is different when comparing the two. This difference can be seen in the results shown in Table 1. The use of the Ro-Tap yielded a d_{gw} 93 microns greater than that from the use of the Retsch. The s_{gw} varied by 0.42, with the Retsch yielding the greater value.

It would be uncommon not to use sieve agitators of some kind; however, as the standard neither requires nor provides for a precise method for their use (i.e., specific agitator and sieve designations), it was decided to consider a scenario in which they were not used at all. It would be expected that an intermediate level of use would provide for intermediate results. Not using the agitators led to a 101-micron increase in d_{gw} and a 0.40 decrease in s_{gw}. Concerning the sieving time, it is likely that some labs sieve for a total of 10 minutes, and do not measure the mass on each sieve at 1-minute intervals after 10 minutes to determine an end point, as suggested in the standard. Some others may follow this guideline or use the 15-minute period "for industrial applications." Therefore, a minimum time of 10 minutes and a maximum of 15 minutes were used, with the shorter period generating a d_{gw} of 523 and an s_{gw} of 2.40 vs. 481 and 2.56 respectively for the 15-minute period.

Use of a dispersion agent has become more common in the feed industry over the last few years. A previous study published in this publication[1] showed that the use of a dispersion agent reduces the d_{gw} by approximately 80 microns and produces a greater

[1] Goodband et al., Swine Day 2006, SRP966, p. 163

value for s_{gw}, and this was consistent across the range of particle sizes evaluated. The data from this study appear to confirm these findings, with a reduction in d_{gw} of 74 microns, and an increase in s_{gw} of 0.36.

Discussion

While it is difficult to recommend a procedure as the one correct method for measuring particle size and distribution, it is clear that differences in methodology can lead to large differences in results. In general, it is assumed that lower d_{gw} and higher s_{gw} values are representative of better sifting, as the particles have more likely reached their ideal place in the sieve stack. When the options are compounded in best vs worst sifting scenarios, the range of results can be very large. Figures 1 and 2 show the range of d_{gw} and s_{gw} values from the 25 observations made during this study, using the same sample. In addition to the data shown here, some preliminary data suggest that variations such as sieve age, the way in which the sieve shaker is mounted on the table, and the individual running the analysis can also substantially affect the results.

Feed mills that are being pressured to produce ground grain with a specific d_{gw} and s_{gw} may face challenges if the in-house quality control laboratory is following different procedures compared with an outside lab. Because such large variations can exist, it is important that the methodology be standardized when comparisons are being made, whether for quality control, nutritional analysis, or contractual conditions.

Table 1: Average geometric means (dgw) and standard deviations (s_{gw}) for differing methods

	Geometric mean (d_{gw})	Geometric standard deviation (s_{gw})
Sieve shaker		
Tyler Ro-Tap	589	2.11
Retsch	497	2.53
Sieve agitators		
With	523	2.40
Without	624	2.00
Dispersion agent		
With	486	2.46
Without	560	2.10
Sieving time		
10 minutes	523	2.40
15 minutes	481	2.56

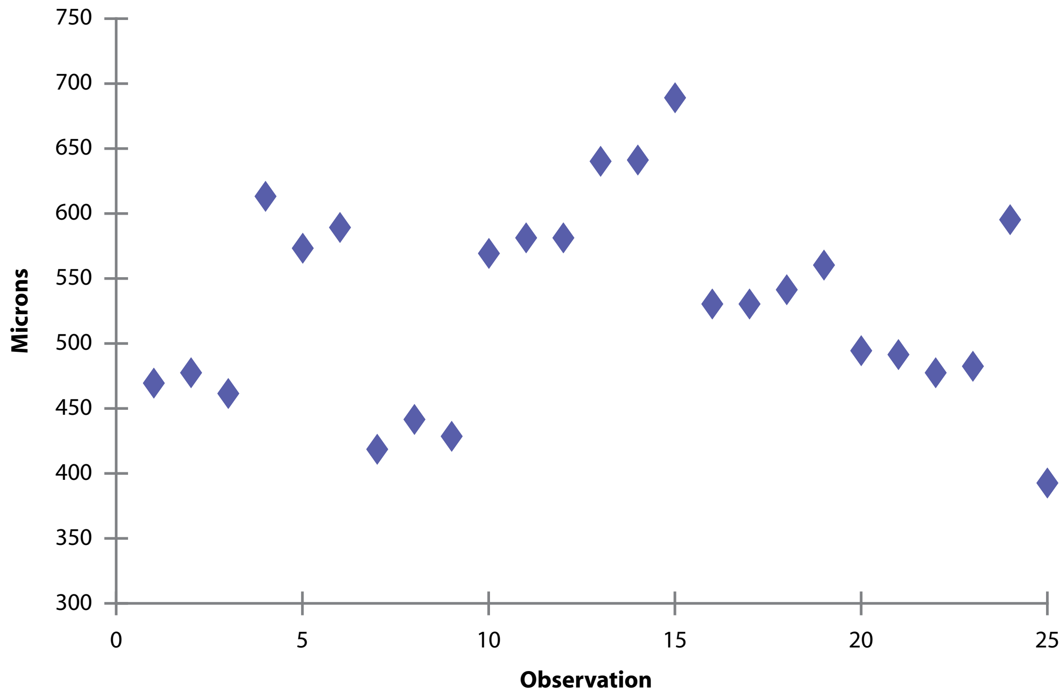

Figure 1: Geometric means (dgw) from 25 observations of a single sample

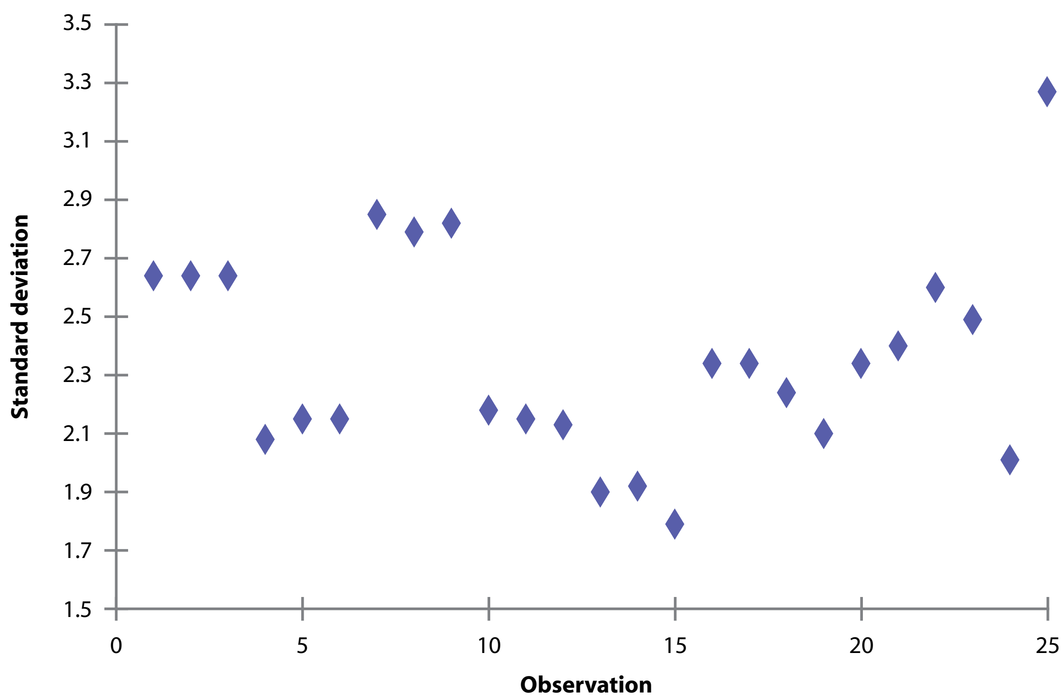

Figure 2: Geometric standard deviations (sgw) from 25 observations of a single sample