PENNSTATE

College of Agricultural Sciences • Cooperative Extension

# Evaluating particle size of forages and TMRs using the Penn State Particle Size Separator

Jud Heinrichs

DAIRY& ANIMAL SCIENCE

Department of Dairy and Animal Science
The Pennsylvania State University
324 Henning Building
University Park, PA 16802
(814) 865-5491 • FAX (814) 865-7442
www.das.psu.edu/teamdairy/

**Topics Include:**

# INTRODUCTION

Having the proper particle size distribution of forages is an important part of a total ration formulation program. Until recently this has been difficult to measure on farms. Many dairy nutritionists have put subjective measures on this aspect of the diet and most have been quite effective in making ration changes in respect to this measure.

The new Penn State Forage Particle Size Separator is currently available to quantitatively determine the forage particle size of various components. The concept of forage particle size analysis and having a standard method for this is not new. The American Society of Agricultural Engineers' standard for particle size analysis and distribution has been available for many years. The objective in developing the easy to handle Penn State separator was to mimic the cumbersome laboratory method for measuring forage and total mixed ration (TMR) particle sizes.

Forage particle size analysis begins with harvesting forages at the proper stage of maturity. Chopping the crop at the proper length allows the forages that can be combined in a total ration to achieve the desired ration particle length.

Measuring the particle length of individual forages is only one part of the solution. In fact, measuring single forages for particle size is similar to analyzing that forage for crude protein. There are recommended ranges for individual forages, but the real use of the measurement is in combining forages to achieve the proper particle size in the total ration, much like combining feeds to achieve the proper protein level in the ration.

The main goal in analyzing the particle size of the total ration is to measure the distribution of feed and forage particles that the cow actually consumes. Examine not only the particles greater than a particular size, but also the overall distribution of feed particles being consumed by the dairy cow. It is recommended that a TMR be measured from fresh samples taken from the feed bunk before the cows eat or sort the feed. Mixing and distribution equipment can reduce particle size of feeds and forages and needs to be accounted for when evaluating the diet.

# GUIDELINES ON PARTICLE SIZE

Achieving adequate ration particle size requires using recommended guidelines for forages and TMRs (Table 1). Particle size guidelines have been obtained from field data consisting of a large number of farms and samples studied over several months. The results of forage and TMR particle size distribution can be a tool in formulating rations, especially for forage neutral detergent fiber (NDF) intake, total NDF intake, and forage dry matter intake.

***Corn silage***

Corn silage can be quite variable and depends largely on the amount fed in the diet. If corn silage is the sole forage, then some longer particle size is suggested. At least 5 to 10 percent of the particles should be in the upper sieve of the separator (> 0.75 inches). When corn silage is not the sole forage, then 2 to 4 percent of the particles in the top sieve may be adequate.

## GUIDELINES ON PARTICLE SIZE (CONTINUED)

It is more critical to chop corn silage so that a good fermentation can occur yet not be pulverized. This means that about 40 to 50 percent of the silage material measured is in both the middle (<0.75 and >0.31 inches) and bottom (<0.31 inches) pans of the separator. As corn silage makes up a greater proportion of the ration, the more that should be in the middle sieve and less in the bottom pan.

The newer systems of harvesting corn silage that includes chopping and rolling in one process can create a silage with 10 percent or more of the forage material having long particles without large pieces of whole cobs or stalks. This forage can still be excellent quality because adequate fermentation can occur in the silo due to packing characteristics.

More conventional choppers that are operated to create such long particle size in corn silage would create a forage material that would be predisposed to mold formation due to poor silo compaction. The material usually has large pieces of cob, dry stalks and leaves that have poor palatability and may often be refused by high producing cows.

### *Haylage*

There is a lot of variability with haylage due to the type and use of machinery, sward type and density, and most of all, the dry matter of the crop harvested. Ten to 25 percent of the crop should be in the top sieve of the particle separator. This means that 10 to 25 percent of the forage particle size is greater than 0.75 inches. If the distribution of forage particles is determined, then the amount of forage particles greater than 1 inch can be approximated.

The type of silo structure may require altering the particle size distribution recommended. Forages stored in upright sealed silos would likely fall at the lower end of the range (10 to 15 percent). Bunker silos can have appreciably longer material ranging from 15 to 25 percent. The middle pan should contain 30 to 40 percent of the material and the bottom pan 40 to 50 percent.

### *TMR*

Field investigations conducted at Penn State have found that there is a high degree of variability in overall rations. Feeding management plays an important role in the particle length needs of the cow. Ideally 10 percent or more of the material should be greater than 0.75 inches (top sieve). It was observed that many rations have only 3 to 8 percent of the TMR particles in the top sieve (> 0.75 inches). This extrapolates to many rations having less than 1 percent of the particles as being greater than 1.5 inches. While this goes against many old thumb rules, there are many farms feeding these types of rations with obvious success.

Feeding management, balanced rations, and attention to total ration NDF and forage NDF levels are likely a large part of their success. Some generally preferred guidelines to follow for TMRs are 6 to 10 percent of the particles in the top sieve, 30 to 50 percent in the middle sieve, and 40 to 60 percent in the bottom pan in rations for high producing dairy cows.

# GUIDELINES ON PARTICLE SIZE (CONTINUED)

**Table 1. Recommended forage and TMR particle sizes for the Penn State Separator.**

| | Corn silage | Haylage | TMR |
|---|---|---|---|
| Upper sieve[1] (> 0.75 ") | 2-4% if not sole forage<br><br>10-15% if chopped and rolled | 10-15% in sealed silo<br><br>15-25% bunker silo, wetter mixture | 6-10% or more<br><br>3-6% focus on TNDF & FNDF |
| Middle sieve[1] (0.75 - 0.31") | 40-50% | 30-40% | 30-50% |
| Bottom pan[1] {< .31") | 40-50% | 40-50% | 40-60% |

[1] Portion remaining on the screen

# PARTICLE SIZE SEPARATOR INSTRUCTIONS

The Penn State Particle Size Separator is currently available from Nasco. For their free phone order service dial 1-800-558-9595. The data sheet and Weibull paper to use with the particle size separator are attached to the back of this publication. An accurate scale is also needed for weighing the samples and the boxes.

***Using the separator***

Stack the three plastic separator boxes on top of each other in the following order: sieves with the large holes (upper sieve) on top, the smaller holes (middle sieve) in the center and the pan on the bottom. Place approximately 3 pints of forage or TMR in the upper sieve.

On a flat surface, shake the sieves in one direction 5 times. There should be no vertical motion during shaking. This process should be repeated 7 times for a total of 8 sets or 40 shakes with the sieves rotated 1/4 turn after each set of 5 shakes. See sieve shaking pattern shown in Figure 1.

Weigh the material on the sieves and on the bottom pan. Note that the material above the upper sieve is greater than 0.75 inches long, the material on the middle sieve is between 0.31 and 0.75 inches, and the material on the bottom pan is less than 0.31 inches. See Table 2 for data entry and how to compute percentages under each sieve.

# PARTICLE SIZE SEPARATOR INSTRUCTIONS (CONTINUED)

***Using Weibull paper***

Weibull paper is used to graph the distribution of forage and TMR particles of the sample using the three weighed fractions from the sieves. The number of forage and TMR particles in a sample do not follow a normal distribution population, however they can be plotted as a straight-line distribution using the unique Weibull graphing paper.

Plotting the sample allows one to extrapolate beyond the measured points (.75 and .31 inches). It should be noted that the accuracy of these values decrease as the line is extended beyond these two points. Therefore the line should not be drawn beyond .2 and 1.5 inches.

Referring to Table 2, value [e] refers to 0.75 inches and value [f] to 0.31 inches. These percentages are plotted on Weibull paper and an appropriate line drawn between the two points (Figure 2).

On Weibull paper, the horizontal axis is for particle size and the vertical axis is for cumulative percent undersized. The axes are not linear. For the example given in Table 2, the following deductions or statements can be made:

- approximately 8% of the feed is > 0.75 inches
- approximately 30% of the feed falls between 0.31 and 0.75 inches
- approximately 62% of the feed are < 0.31 inches

Another interpretation could be:

- approximately 97% of the feed are < 1.0 inch
- approximately 80% of the feed are <0.50 inches
- approximately 48% of the feed are < 0.22 inches

This example would indicate a typical, well cut corn silage. This material can be used as a component of a forage-feeding program where another longer forage material is also used.

**Figure 1. Shaking pattern for particle size separation.**

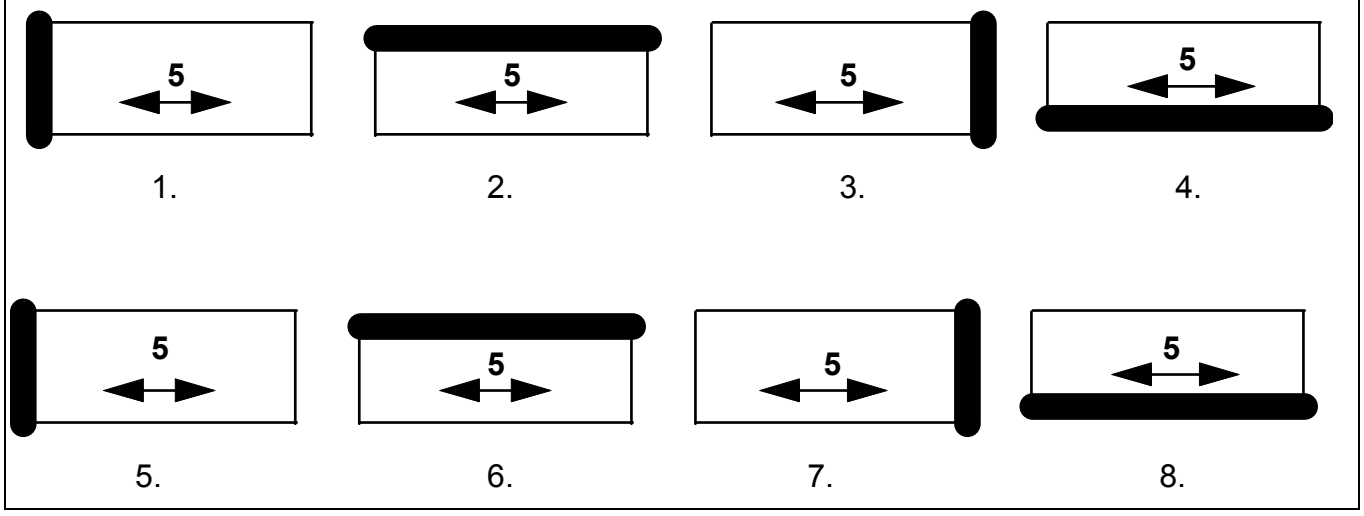
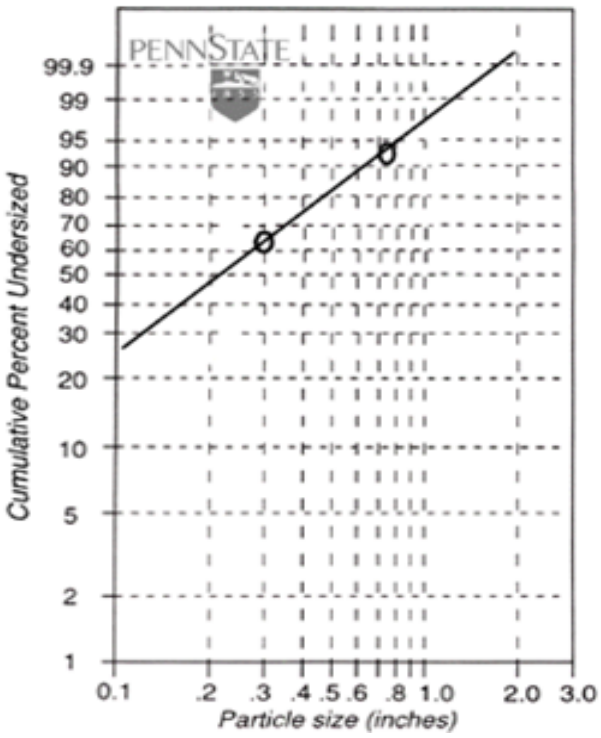


**Table 2. Example on computing the total weight and percentages under each sieve.**

| | Record data | | | |
|---|---|---|---|---|
| Sample | Corn silage | | | |
| Upper sieve | 20 grams | [a] | | |
| Middle sieve | 75 grams | [b] | | |
| Bottom pan | 155 grams | [c] | | |
| Compute total weight and percentages | | | or | Proportion remaining on each pan |
| Total | 250 grams | [d = a+ b+ c] | | upper sieve 8% |
| % under upper sieve | 92% | [e = 100 x (b + c)/d] | | middle sieve 30% |
| % under middle sieve | 62% | [f = (100 x c/d)] | | bottom pan 62% |

[1]The percentages are cumulative percent undersized. For example, on average, 92% of feed is smaller than 0.75 inches and 62% of feed is smaller than 0.31 inches.

**Figure 2. Weibull paper**



# PARTICLE SIZE EFFECTS ON THE DAIRY COW

The dairy cow's need for increasingly higher levels of energy have led to diets relatively high in concentrates. All silage diets have replaced diets high in long hay in today's larger herds and more mechanized farms. However, cows still require adequate fiber in the ration to function properly. When the minimum fiber levels are not met, cows often show one or more of the following metabolic disorders: reduced total dry matter digestibility, reduced milk fat percentage, displaced abomasum, and an increase in the incidence of rumen parakeratosis, laminitis, acidosis, and fat cow syndrome. Cows consuming sufficient NDF with finely chopped forage can also exhibit the same metabolic disorders as a diet deficient in fiber.

Adequate forage particle length is necessary for proper rumen function. Reduced forage particle size has been shown to decrease the time spent chewing and cause a trend toward decreased rumen pH . When cows spend less time chewing, there is a decrease in the volume of saliva produced needed to buffer the rumen.

It has been shown that insufficient particle size will decrease the rumen acetate to propionate ratio and pH, which will lower milk fat percent. When rumen pH falls below 6.0, the growth of the cellulolytic organisms are depressed, allowing for an increase in the propionate producing microbes decreasing the acetate to propionate ratio.

Reduced forage particle size increases dry matter intake, decreases digestibility, and results in less rumen solid retention time. Diets that have a smaller forage particle size enter the rumen at a smaller size after initial chewing and swallowing, and therefore leave the rumen at a faster rate. The result is an increase in the rumen turn over rate allowing for an increase in dry matter intake. Smaller forage particles spend less time in the rumen for microbial digestion, thereby reducing digestibility, particularly fiber digestion.

If rations or forages are too fine in particle size a small amount of long hay or balage can make improvements in achieving some long particles in the ration. Farms feeding 5 or more pounds of long hay per cow daily would not likely have problems with overall particle size. Many farms, however, do not have long hay as an option. In these situations, the distribution of the total ration particle size is likely more important than particles greater than a certain length.

Particle size analysis is not the end all for ration problems. It does give a way to measure this variable and to improve upon the overall nutrition of the dairy cow. Feeding a ration containing extremely fine particle size length with a small amount being greater than 0.75 inches is not recommended. Diets containing very fine particle size can predispose cows to rumen acidosis and other associated problems.

# RECOMMENDED FIBER INTAKES

Adequate NDF intake by the dairy cow is necessary for normal rumen function, production, and health. A majority of the NDF in the ration must be in the form of forage NDF along with sufficient ration particle size to maintain a healthy rumen environment.

Under conditions where particle size is marginal, special attention must be paid to maintaining adequate levels of total NDF and forage NDF intakes (Table 3 and 4).

# RECOMMENDED FIBER INTAKES (CONTINUED)

Suggested ranges for total NDF should be at least 1.10 to 1.20 percent of body weight. Forage NDF intake can range from .75 to 1.10 percent of body weight.

However, if the forage or TMR particle length is too fine, then a higher minimum (> 0.85 percent of body weight) should be used in the ration.

**Table 3. Guidelines for forage NDF intake.**

| Forage NDF as % of body weight[1] | Intake level |
|---|---|
| .75%[2] | Minimum if ration provides 1.30-1.40% total NDF by use of byproduct feeds. |
| .85%[2] | Minimum if ration provides 1.00-1.20% total NDF by use of grains or starchy feeds. |
| .90% | Moderately low |
| .95% | Average |
| 1.00 % | Moderately low |
| 1.10% | Maximum |

[1]Forage dry matter intake should range between 1.40% to 2.40% of body weight regardless of forage NDF intake parameters.

[2]Higher minimum may be necessary if forage is chopped too fine.

**Table 4. Guidelines for total NDF and forage NDF intakes as a percent of the total ration dry matter when using low NDF concentrates.**

| Milk production | Total NDF intake | Forage NDF intake |
|---|---|---|
| High (> 80 pounds) | 28-32% | 21-27% |
| Medium (60-80 pounds) | 33-37% | 25-32% |
| Low (< 60 pounds) | 38-42% | 29-36% |

Penn State **Extension**

**August 26, 2013** extension.psu.edu

# Penn State Particle Separator

## 2-Sieve Model (19 mm and 8 mm)

first available in 1996

**Recommended distribution of particle size (percent remaining on each screen) for corn silage, haylage, and TMR samples**

| Screen | Pore Size (inches) | Particle Size (inches) | Corn Silage | Haylage | TMR |
|---|---|---|---|---|---|
| Upper Sieve (19 mm) | 0.75 | > 0.75 | 2 to 4% if not sole forage<br><br>10 to 15% if chopped and rolled | 10 to 20% in sealed silo<br><br>15 to 25% in bunker silo, wetter | 6 to 10% or more<br><br>3 to 6%, focus on total NDF and forage NDF |
| Middle Sieve (8 mm) | 0.31 | 0.31 to 0.75 | 40 to 50% | 30 to 40% | 30 to 50% |
| Bottom Pan | | < 0.31 | 40 to 50% | 40 to 50% | 30 to 40% |

Note: The recommendations for the percent remaining on the upper sieve vary depending on the conditions described in this table. Graphs on the following pages show boxes that indicate both recommendations. Users should consider their conditions and compare their results to the most appropriate "target" range.

PENNSTATE

Cooperative Extension
*College of Agricultural Sciences*

# Data Sheet For Forage and TMR Particle Size Analysis

| | | | |
|---|---|---|---|
| Sample ID | _____ | _____ | _____ |

Weight of material retained on each sieve

| | | | |
|---|---|---|---|
| Upper (a) | _____ | _____ | _____ |
| Middle (b) | _____ | _____ | _____ |
| Bottom Pan (c) | _____ | _____ | _____ |
| Sum of Weights [d = a+b+c] | _____ | _____ | _____ |

Calculations for percentage retained on each sieve

| | | | |
|---|---|---|---|
| Upper [= a/d *100] | _____ | _____ | _____ |
| Middle [= b/d *100] | _____ | _____ | _____ |
| Bottom Pan [= c/d *100] | _____ | _____ | _____ |

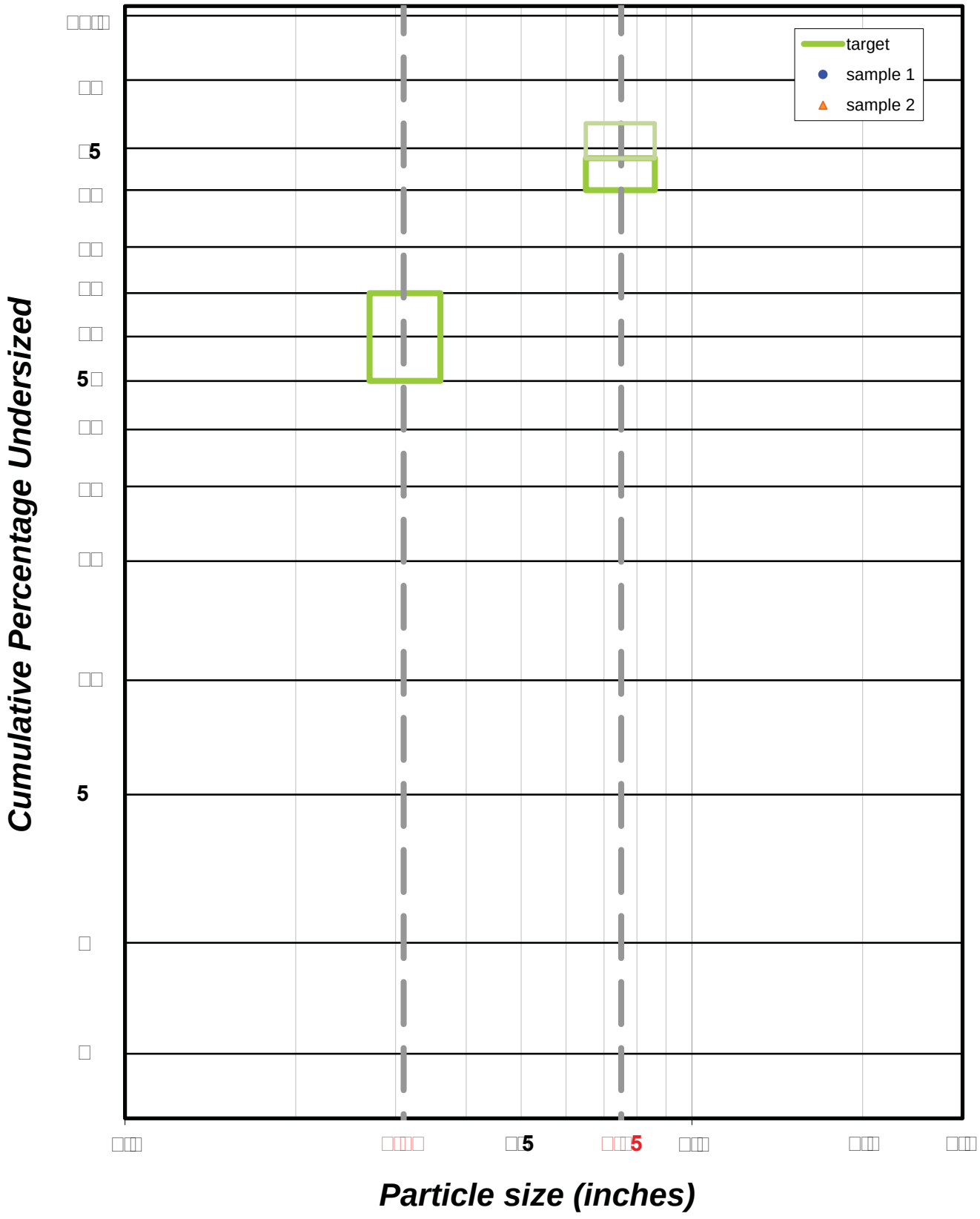
Calculations for percentage under each sieve

| | | | |
|---|---|---|---|
| Upper Sieve [e = 100 – (a/d*100)] | _____ | _____ | _____ |
| Middle Sieve [f = e – (b/d*100)] | _____ | _____ | _____ |

PENNSTATE

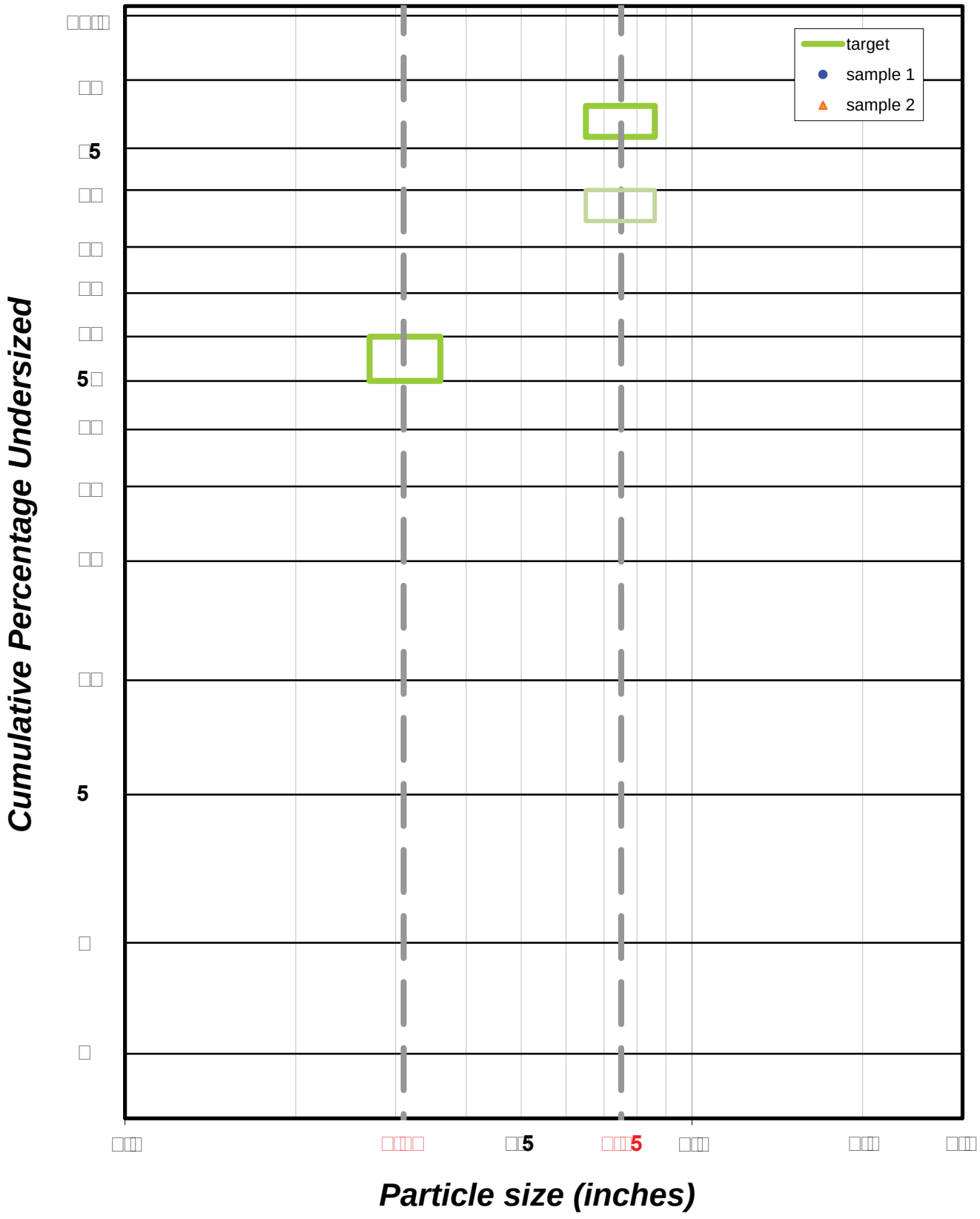
1855

Penn State **Extension**



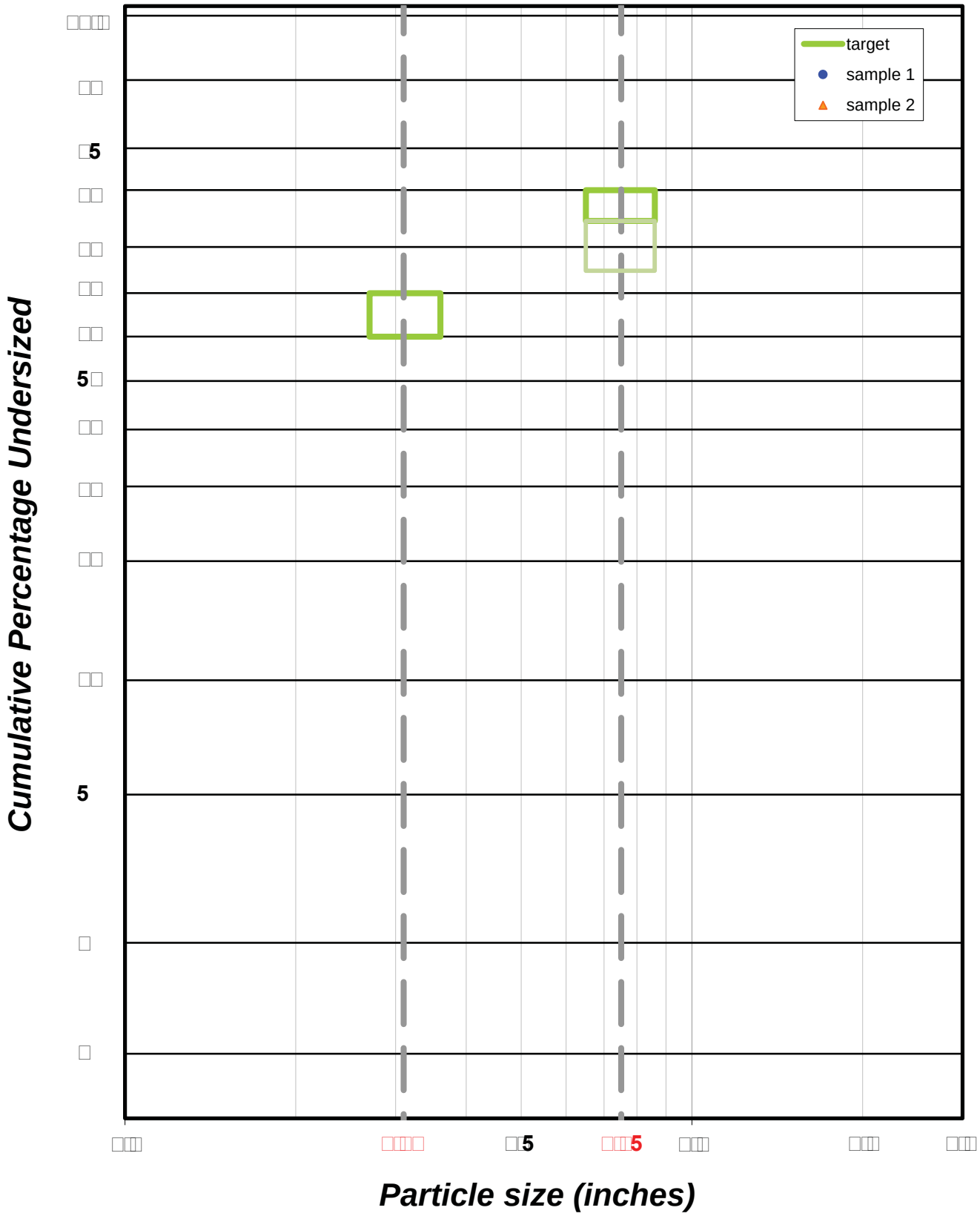
PENNSTATE

Penn State **Extension**



PENNSTATE

Penn State **Extension**



An OUTREACH program of the College of Agricultural Sciences

Visit Penn State's College of Agricultural Sciences on the Web: http://www.agsci.psu.edu/

Penn State College of Agricultural Sciences research, extension, and resident education programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.