A4174

Monitoring Kernel Processing During Harvest

Brian Luck, Rebecca Willett, Jessica Drewry, Luiz Ferraretto

Adjusting and optimizing machinery settings on a forage harvester is critical to improving silage quality. The cutter head and kernel processor roll clearance on the forage harvester affect the level of kernel processing which, along with other factors, determines the quality of the silage. Research has shown that smaller kernel size can make starch utilization in dairy cows more efficient, which can lead to increases in milk production (Ferraretto et al. 2013). Many steps can be taken during the harvest process to ensure that the corn silage is being optimally processed.

It is recommended the gap between the kernel processor rollers should be set to 1 to 3 mm (about the thickness of a dime) and the theoretical cut length set to 19 mm (Shinners et al. 2000). Researchers at the University of Wisconsin–Madison found that these settings resulted in improved dairy cow lactation without placing undue power requirements on the forage harvester. However, monitoring the kernel processing score (KPS) (Mertens 2005) and recording actionable data in the field is the best way to determine if the harvester settings are appropriate and to identify any trends. Making adjustments to the settings each day can help to ensure uniform quality throughout the harvest.

Advantages of greater kernel processing to dairy cows

A unique characteristic of corn silage is the presence of adequate concentrations of various carbohydrates (i.e., fiber and starch) whereas most forages only provide fiber. Starch is located in the endosperm of corn kernels and may constitute up to half of the energy provided to cows by corn silage.

However, the presence of starch in the corn plant does not guarantee its availability for digestion and utilization by cows. Kernels are primarily seeds. The endosperm is surrounded by a hard coat, the pericarp, which protects the embryo and the starch endosperm from external threats so the seed can germinate and become a new plant. The seed coat inhibits the fermentation and digestion of corn kernels by bacteria in the rumen or enzymes in the small intestine of cows. As previously mentioned, smaller kernel particle size is a key component in this process as maximum starch and energy availability will only occur with the breakdown of the pericarp which allows for the exposure of the starch endosperm. Thus, breaking more kernels should be the primary objective at harvesting to maximize energy availability. Greater kernel breakage enhances starch digestibility which is associated with greater feed efficiency, milk, and milk protein yields by high-producing dairy cows.

Factors influencing kernel breakage

Many factors influence kernel processing efficiency, including the aforementioned roll gap settings of kernel processor rollers and theoretical length of cut. A review from University of Wisconsin (Ferraretto and Shaver 2012) reported no benefits of using kernel processors set with gap settings between 4 to 8 mm; but greater starch digestibility was observed with roll gap of 1 to 3 mm. The same review underscored that increasing theoretical length of cut with the aim of achieving greater proportion of coarse fiber particles could inhibit kernel breakage during passage through rollers.

Maturity at harvest is another factor that plays a major role on kernel breakage. As maturity progresses, an increased proportion of vitreous endosperm accumulates in the kernel thereby increasing kernel hardness. Harder kernels of very mature corn silage (> 40% of dry matter (DM)) are less susceptible to breakage.

References


Ferraretto, L. F., and R. D. Shaver. 2012. Meta-analysis: Effect of corn silage harvest processing during harvest on the forage harvester affect the level of kernel processing which, along with other factors, determines the quality of the silage. Research has shown that smaller kernel size can make starch utilization in dairy cows more efficient, which can lead to increases in milk production (Ferraretto et al. 2013). Many steps can be taken during the harvest process to ensure that the corn silage is being optimally processed.

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To maximize kernel breakdown requires continuous monitoring of plant maturity within and across fields, proper roll gap and theoretical length of cut settings, regular processor maintenance, and continuous monitoring of kernel breakage during harvest.

**Laboratory methods to determine the level of kernel processing**

The Ro-Tap sieving system is the standard laboratory method for determining the KPS, which is a measure of the level of kernel processing (figure 1). The sample is dried and passed through progressive sieves to determine the percentage of starch that can pass through a 0.187-in. (4.75-mm) screen:

- **Optimally processed corn silage**: 70% of kernel starch passes through the screen
- **Adequately processed corn silage**: 50% to 69% of kernel starch passes through the screen
- **Inadequately processed corn silage**: Less than 50% of kernel starch passes through the screen

Particles of starch passing through this sieve are thought to be from kernels broken in at least four pieces. Laboratory analysis is key for ensuring a balanced Total Mixed Ration. Although this method led to considerable improvements in the dairy industry, sending off samples for analysis does not allow for adjustments to the harvester in the field.

**Field methods to determine the level of kernel processing**

Some of the most well know methods for assessing kernel processing in the field are the Penn State Particle Separator (Heinrichs 2013), the water separation method (Shinners and Holmes 2013), and the visual inspection method.

The Penn State Particle Separator (PSPS; figure 2), along with an accurate scale, is typically used to determine the particle size in silage before feeding (for more information [http://extension.psu.edu/animals/dairy/nutrition/forages/forage-quality-physical/separator](http://extension.psu.edu/animals/dairy/nutrition/forages/forage-quality-physical/separator)). Three or four stacked trays are used to separate the particles in the sample based on their size. The sample is placed in the top box, with all boxes stacked, then the box stack is shaken by hand 40 times at a rate of approximately one shake per second. The amount of silage in each tray, by weight, is then used to determine the distribution of particles in the sample. This is similar to the laboratory method, making it a powerful metric in the field. It is important to note, however, that this method can be sensitive to the rate of shaking and moisture content of the sample.

The visual inspection and water separation methods use the number of whole kernels within a 1-quart sample as an indication of the level of kernel processing (figure 3). If more than two whole or half kernels are found per quart sample, the kernel processing is not optimal. This method is useful in spot-checking the forage harvester settings between more thorough analyses to determine the kernel size distribution. The steps for the water separation method are as follows (see the following link for a more detailed description and photographs of the process: [http://fyi.uwex.edu/forage/making-sure-your-kernel-processor-is-doing-its-job/](http://fyi.uwex.edu/forage/making-sure-your-kernel-processor-is-doing-its-job/)):

1. Fill a dishpan (or similarly sized container) about ¾ full with water.
2. Place the representative forage sample in the container.
3. Gently stir the material, for about a minute, to separate the stover from the kernel. The stover will float while the kernel will sink.
4. Skim the stover from the surface using your hands or a strainer.
5. Slowly pour the water from the dishpan to ensure the kernels remain in the pan.
Image processing to determine the level of kernel processing (SilageSnap)

With a smart phone, dishpan, coin, and sheet of black construction paper, you can determine the kernel processing score in the field or at the storage site (Drewry et al. 2019). The kernels must first be separated from the stover and then an image is taken of the kernels along with a coin. The software in the newly developed mobile application SilageSnap filters the photo to make the kernels stand out, detects the edge of each kernel, finds the coin at the center of the photo to serve as a scale, and determines the size of each kernel in the image (figure 4). This method results in recordable data that can be used to gain insight into trends between fields and to potentially spot kernel processor maintenance and wear issues.

1. Collect representative forage sample (about 1-2 handfuls), at least once per field. It would be best to collect several handfuls, mix them, and then collect 1-2 handfuls from the larger sample.

2. Use water separation method described previously to separate stover and kernel in the sample.

3. Place a coin (penny, nickel, dime, or quarter) at the center of a dark, matte background such as a sheet of construction paper (figure 5a). This will be the coin you select on the SilageSnap home screen.

4. Pat kernels dry gently then lay kernels out in a single layer around the coin, forming a rough rectangle. Make some effort to ensure particles are not touching (figure 5a). You can use a paint brush to separate particles.

5. Take a picture using the application. Align the camera directly over the kernels, parallel to the black surface. Avoid any shadows or bright spots in the image.

Let the application determine kernel size distribution

To determine the appropriate height from which to take the image, follow steps 3-5. Except, in step 4 lay several smaller coins, such as pennies or dimes, on the dark, matte background. Take images from lower heights until the results match the known diameter of the coin used. (Note: on the SilageSnap home screen (figure 4) select the single, large coin used). Taking images from too high will result in inaccurate results. Make any needed adjustments to the kernel processing attachments based on the KPS.

Sometimes it may be necessary to take multiple image to capture all the kernels in a single sample. If multiple images are required use the worksheet at the end of the article to determine a weighted average of the KPS from each image.

Detailed instructions and troubleshooting techniques can be found online at: https://wimachineryextension.bse.wisc.edu/precision-agriculture/silagesnap/

Experimental methods and results

Forage samples were collected in 2015 and 2016 from a production corn silage field at the University of Wisconsin–Madison Arlington Agricultural Research Station (Arlington, WI) with a self-propelled forage harvester (SPFH) equipped with an 8-row gather head and Shredlage™ crop processing rolls. The crop processor rolls were set at 1, 2, 3, and 4 mm roll gap clearances. Triplicate samples were analyzed using the image processing and sieve method to determine KPS and the results found to be well correlated and consistent over the range of KPS scores analyzed. To obtain a value of KPS, similar to that of the sieve method, add 5 to the KPS determined using the image processing method on fresh kernels immediately after water separation. This image processing method can decrease the time to determine KPS, as compared with standard laboratory methods, and allow for adjustment of kernel processing rolls during harvest. Sample collection, preprocessing, imaging, and determination of KPS can be completed in minutes, as compared to a turnaround time of days with the standard laboratory sieve method.
How to interpret results

Results of the image processing application and the PSPS method can be used, each morning, to determine if the forage harvester settings are appropriate. A worksheet can be used to analyze the results of the PSPS to determine the particle size distribution. The image processing application will display the KPS and a histogram of particle size and information about the KPS and average particle size. If 70% of the kernels are smaller than 0.187 in. (4.75 mm) in diameter, the kernel processing rolls are set to an appropriate gap and the app will display the result as good (figure 6). If fewer than 70% of the kernels are smaller than 0.187 in. in diameter, the kernel processing roll gap should be reduced. The roll gap should be between 1-3 mm (0.04-0.12 in.) and the app will display the result as bad (figure 6). This can be measured using a dime, nickel, or pocketknife, which are all about 1-3 mm in thickness. The setting can then be spot-checked using the visual inspection or water separation method throughout the day. Also, keep in mind that processing kernels too finely can cause wear on equipment and increased fuel usage.

Best practices to determine the level of kernel processing

All of the methods presented can be used in conjunction to optimize kernel processing. The Penn State Particle Separator and the image processing method could be used each morning to provide actionable data about particle size distribution of the whole forage and kernels, respectively. Visual inspection or water separation can then be conducted one or more times per day, especially if field conditions change, to spot-check the settings. In addition to field methods, samples should be sent for laboratory analysis. The time invested in ensuring optimal kernel processing will yield benefits in the digestibility of the resulting silage.

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Authors: Brian Luck is assistant professor and extension specialist, Biological Systems Engineering, University of Wisconsin-Madison; Rebecca Willett is professor, Department of Statistics and Computer Science, University of Chicago; Jessica Drewry is assistant faculty associate, Biological Systems Engineering, University of Wisconsin-Madison and Luiz Ferraretto is assistant professor of livestock nutrition, Department of Animal Sciences, University of Florida. Division of Extension publications are subject to peer review.

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Determining Kernel Processing Score (KPS) from multiple SilageSnap results

<table>
<thead>
<tr>
<th>Image</th>
<th>Particles smaller than 4.75 mm (in %)</th>
<th>Number of particles</th>
<th>Particles smaller than 4.75 mm * Number of particles (column B*C)</th>
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Sum of Column C
Sum of Column D
KPS of sample (Sum of Column D/ Sum of Column C)

Instructions:
Multiple images may be required to capture all the corn kernels within a sample. Use this worksheet to record the particles smaller than 4.75 mm and number of particles for each image in the sample. For each image, multiply the particles smaller than 4.75 mm (column B) by the number of particles (column C) and record the value in column D. Then, sum all the values of column C and column D. Finally, divide the sum of column D by column C to determine the Kernel Processing Score of the entire sample.

Record value directly from the SilageSnap Application under Column B: Particles smaller than 4.75 mm
Record value directly from the SilageSnap Application under Column C: Number of Particles