




Biological Systems Engineering

UNIVERSITY OF WISCONSIN–MADISON

BADGER AG TECH

# Kernel Processing Score: Determination with SilageSnap

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Badger Crop Connect
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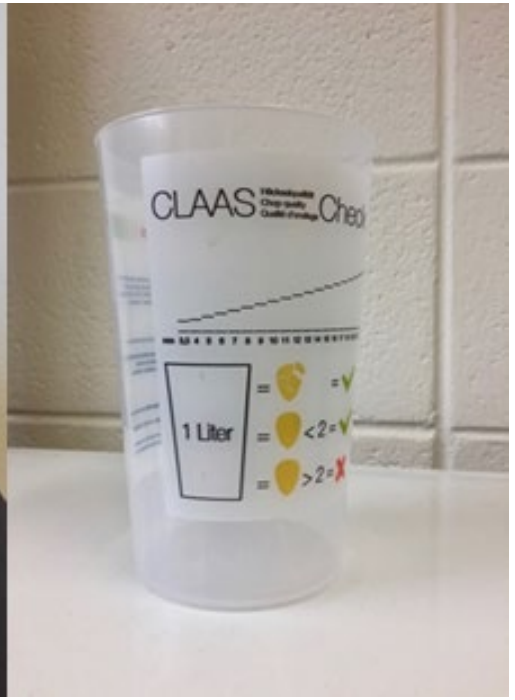
# Corn Silage Particle Size Assessment

- Why is it important?
  - Smaller particle size means increased surface area
  - Increased surface area increases enzymatic hydrolysis potential
  - Increasing digestion of the starch which increases milk production

# Corn Silage Particle Size Assessment





# Image Analysis Methods

- Calibration Images
  - Objects of known size in the image
  - Verified with Mitutoyo Calipers
    - Accuracy of ± 0.025 mm (± 0.001 in)
  - Calibration disc @ 1.5 in used to determine pixel size within image
  - Various camera angles tested for effect of particle size measurement.
  - Camera closer = better results


| Camera Height (m) | Estimate (mm) | Standard Error | Letter Group |
|---|---|---|---|
| 0.4 | 6.01 | 0.04 | A |
| 0.6 | 5.62 | 0.04 | B |
| 0.8 | 5.19 | 0.04 | C |

# Image Analysis Methods

Drewry, J. L., Luck, B. D., Willett, R. M., Rocha, E. M. C., & Harmon, J. D. (2019). Predicting kernel processing score of harvested and processed corn silage via image processing techniques. *Computers and Electronics in Agriculture, 160*, 144-152. https://doi.org/10.1016/j.compag.2019.03.020



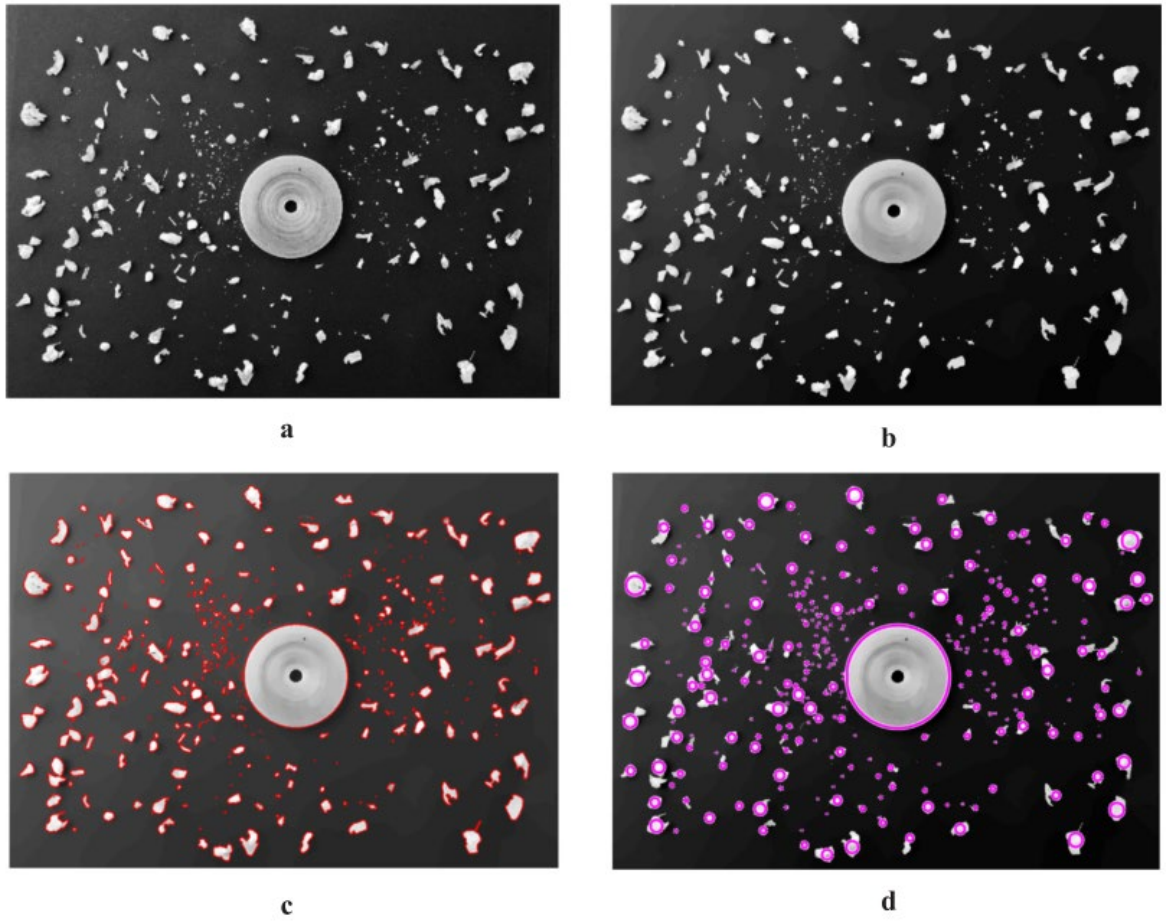



**Fig. 3.** Example of the steps of the image processing algorithm (a) image is imported, (b) image was denoised, (c) contour of each particle was identified, (d) maximum inscribed circle of each particle was identified.

# Image Analysis Methods

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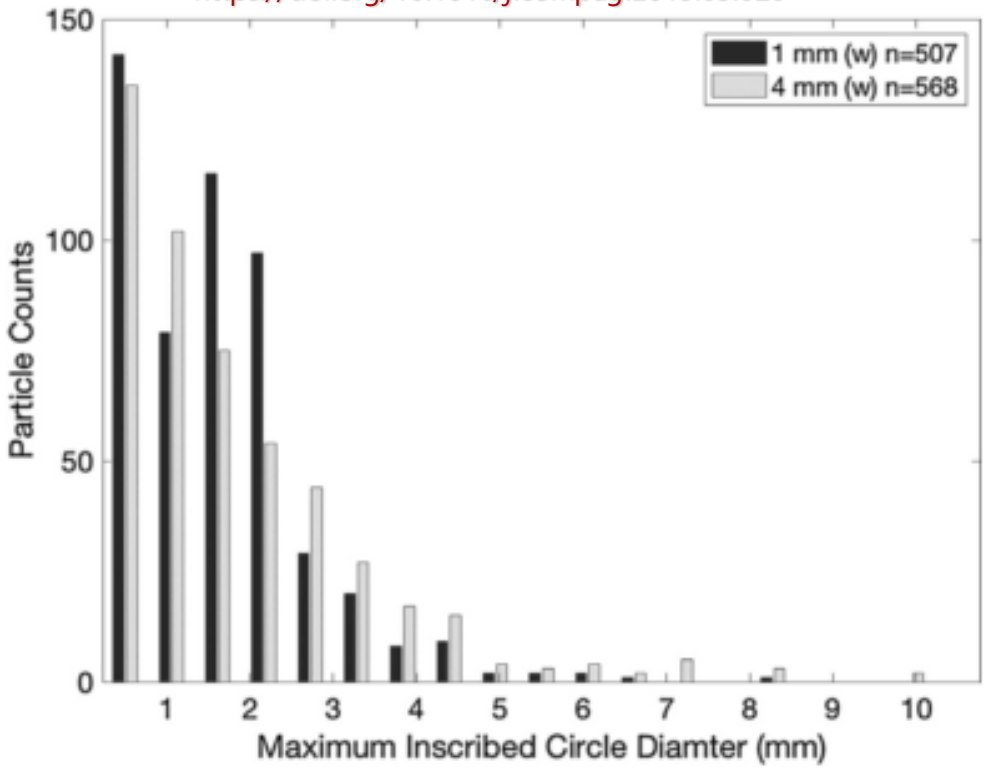


**Fig. 4.** Example of normalized histogram of the distribution of particle diameter for wet (w) samples processed with 1 and 4 mm kernel processer roll gap sizes, n is the number of particles within the image.

# Image Analysis Methods

Drewry, J. L., Luck, B. D., Willett, R. M., Rocha, E. M. C., & Harmon, J. D. (2019). Predicting kernel processing score of harvested and processed corn silage via image processing techniques. *Computers and Electronics in Agriculture, 160*, 144-152. https://doi.org/10.1016/j.compag.2019.03.020



**Table 2**
Percent undersize of 4.75 mm (Kernel Processing Score) by area (image analysis) or by mass (sieve analysis).

| Processing Roll Gap (mm) | Year | Image analysis (by area) | | | | | | Sieve analysis (by weight) | |
|---|---|---|---|---|---|---|---|---|---|
| | | wet sample | | dry sample | | sieved sample | | | |
| | | mean | SD | mean | SD | mean | SD | mean | SD |
| 1 | 2015 | 75.0 | 2.1 | 85.9 | 3.7 | 88.6 | 2.7 | 83.9 | 2.9 |
| 2 | 2015 | 75.0 | 2.5 | 84.7 | 4.1 | 86.7 | 2.4 | 81.4 | 7.0 |
| 3 | 2015 | 69.7 | 5.3 | 84.3 | 3.0 | 88.2 | 0.7 | 79.2 | 3.0 |
| 4 | 2015 | 76.9 | 3.7 | 86.3 | 2.2 | 86.5 | 2.5 | 79.0 | 6.5 |
| 1 | 2016 | 75.7 | 5.4 | 83.4 | 3.0 | 85.1 | 2.3 | 80.3 | 4.1 |
| 2 | 2016 | 71.3 | 2.2 | 81.2 | 2.8 | 82.3 | 3.2 | 75.0 | 6.4 |
| 3 | 2016 | 70.3 | 1.3 | 79.6 | 0.8 | 81.2 | 0.5 | 77.1 | 2.1 |
| 4 | 2016 | 60.5 | 3.8 | 73.6 | 2.4 | 75.2 | 1.3 | 63.0 | 2.1 |

**Table 4**
Mean Kernel Processing Score by crop processing roll gap for by image analysis for wet samples under alpha = 0.05. Means with different letters are significantly different.

| Processing Roll Gap (mm) | Year | Estimate | Standard Error | Letter Group |
|---|---|---|---|---|
| 4 | 2015 | 76.9 | 1.8 | A |
| 1 | 2016 | 75.8 | 2.1 | A |
| 1 | 2015 | 75.0 | 2.1 | A |
| 2 | 2015 | 75.0 | 2.1 | A |
| 2 | 2016 | 71.3 | 2.1 | A |
| 3 | 2016 | 70.3 | 2.1 | AB |
| 3 | 2015 | 69.7 | 2.1 | AB |
| 4 | 2016 | 60.5 | 2.1 | B |

**Table 5**
Percent undersize of 2 mm by crop processing roll gap for by image analysis for wet samples under alpha = 0.05. Means with different letters are significantly different.

| Processing Roll Gap (mm) | Year | Estimate | Standard Error | Letter Group |
|---|---|---|---|---|
| 1 | 2015 | 39.4 | 2.3 | A |
| 4 | 2015 | 38.2 | 2.0 | A |
| 2 | 2015 | 33.5 | 2.3 | AB |
| 1 | 2016 | 30.4 | 2.3 | AB |
| 3 | 2015 | 26.5 | 2.3 | BC |
| 2 | 2016 | 26.2 | 2.3 | BC |
| 3 | 2016 | 26.2 | 2.3 | BC |
| 4 | 2016 | 18.6 | 2.3 | C |

# Image Analysis Methods

Drewry, J. L., Luck, B. D., Willett, R. M., Rocha, E. M. C., & Harmon, J. D. (2019). Predicting kernel processing score of harvested and processed corn silage via image processing techniques. *Computers and Electronics in Agriculture, 160*, 144-152. https://doi.org/10.1016/j.compag.2019.03.020

$$KPS_{sieve} = 5.76 + KPS_{image}$$

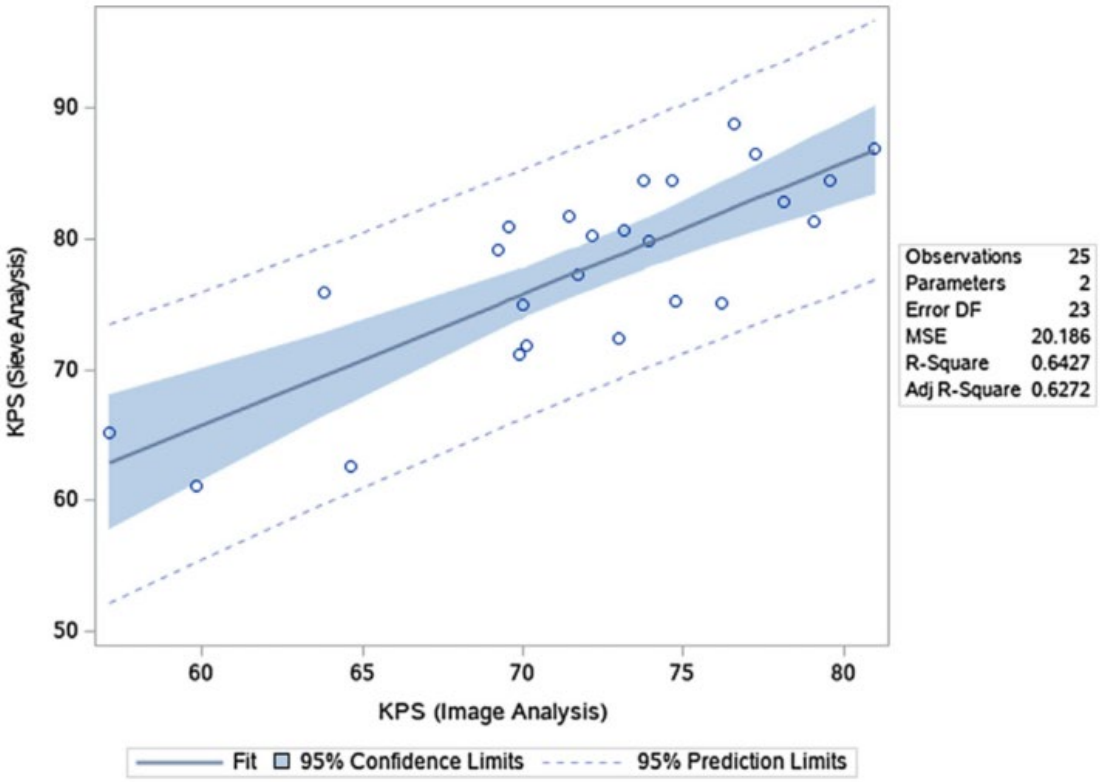


**Fig. 5.** Sieve analysis of dry sample vs image analysis of wet sample of Kernel Processing Score.

# In situ Dry Matter Disappearance

Luck, B. D., Drewry, J. L., Shaver, R. D., Willett, R. M., & Ferraretto, L. F. (2020). Predicting in situ dry matter disappearance of chopped and processed corn kernels using image-analysis techniques. Applied Animal Science, 36(4), 480-488. https://doi.org/10.15232/aas.2020-01993

- Corn Silage harvested at AARS in 2017
  - KP settings at 1-, 2-, 3-, and 4-mm
  - Roller speed differential at 30%
  - TLOC at 26-mm
- Harvested about 50 ft of corn silage and collected samples randomly from a pile on the ground
- Ensiled the samples for 60 d in mini-silos (2 gal buckets)

# In situ Dry Matter Disappearance

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**Table 1.** Corn silage processing score (CSPS) results from the image-processing method on fresh whole-plant corn silage[1]

| Separation method | Processor gap setting (mm) | Silage state | CSPS (%) |
|---|---|---|---|
| Image | 1 | Fresh | 89.2[A] |
| | 2 | Fresh | 83.2[AB] |
| | 3 | Fresh | 80.9[B] |
| | 4 | Fresh | 79.8[B] |

[A,B]Values with different superscripts are statistically significantly different at α = 0.05.

[1]CSPS at the various roll gap settings were statistically different ($P$ = 0.01) at a confidence level of 95%. The pooled SE was 1.6% among these treatments.

**Table 2.** Corn silage processing score (CSPS) results from the sieving method[1]

| Separation method | Processor gap setting (mm) | Silage state | CSPS (%) |
|---|---|---|---|
| Sieve | 1 | Fresh | 87.0[A] |
| | 2 | Fresh | 69.6[B] |
| | 3 | Fresh | 61.8[B] |
| | 4 | Fresh | 70.0[B] |

[A,B]Values with different superscripts are statistically significantly different at α = 0.05.

[1]CSPS at the various roll gap settings were statistically different ($P$ = 0.002) at a confidence level of 95%. The pooled SE was 2.8% among these treatments.

**Table 3.** Corn silage processing score (CSPS) results from the sieving method[1]

| Separation method | Processor gap setting (mm) | Silage state | CSPS (%) |
|---|---|---|---|
| Sieve | 1 | Ensiled | 88.7[A] |
| | 2 | Ensiled | 72.0[AB] |
| | 3 | Ensiled | 61.1[B] |
| | 4 | Ensiled | 75.9[AB] |

[A,B]Values with different superscripts are statistically significantly different at α = 0.05.

[1]CSPS at the various roll gap settings were statistically different ($P$ = 0.005) at a confidence level of 95%. The pooled SE was 4.1% among these treatments.

- Image analysis could not detect CSPS differences after ensiling in this case.

# In situ Dry Matter Disappearance

Luck, B. D., Drewry, J. L., Shaver, R. D., Willett, R. M., & Ferraretto, L. F. (2020). Predicting in situ dry matter disappearance of chopped and processed corn kernels using image-analysis techniques. Applied Animal Science, 36(4), 480-488. https://doi.org/10.15232/aas.2020-01993

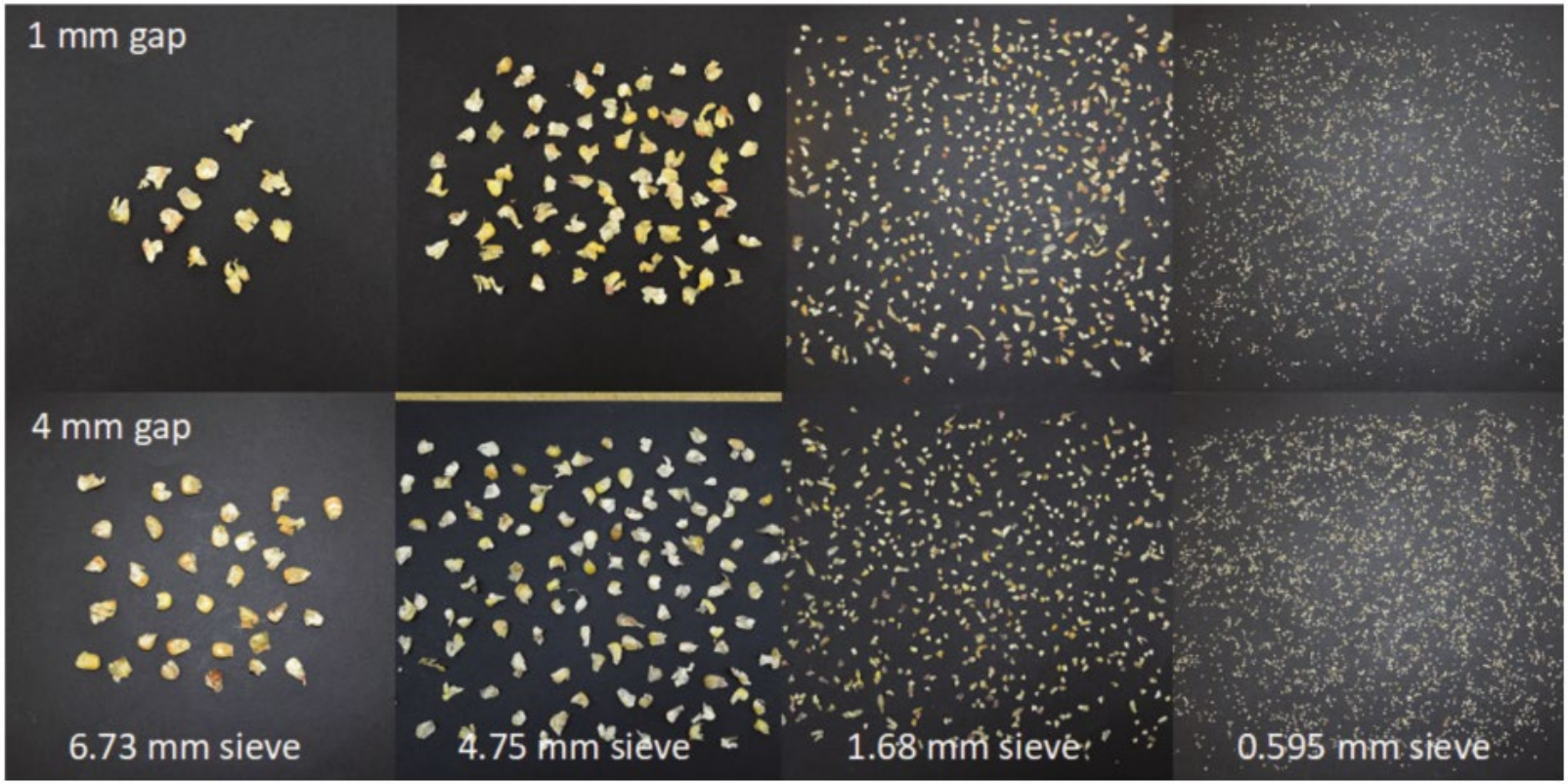


**Figure 2.** Images of the 1-mm (top row) and 4-mm (bottom row) processor gap settings after sieving. Particles collected on the 6.73-, 4.75-, 1.68-, and 0.595-mm sieves are shown.

# In situ Dry Matter Disappearance

Luck, B. D., Drewry, J. L., Shaver, R. D., Willett, R. M., & Ferraretto, L. F. (2020). Predicting in situ dry matter disappearance of chopped and processed corn kernels using image-analysis techniques. Applied Animal Science, 36(4), 480-488. https://doi.org/10.15232/aas.2020-01993

- Incubated the ensiled material in a cannulated cow for 6- and 12-hours and measured dry matter disappearance.

**Table 4.** The 6-h slowly disappearing DM (SDDM) at 1-, 2-, 3-, and 4-mm crop processor roller gap settings[1]

| Processor gap setting (mm) | Incubation time (h) | SDDM (% of DM) |
|---|---|---|
| 1 | 6 | 16.4[A] |
| 2 | 6 | 14.7[AB] |
| 3 | 6 | 8.5[AB] |
| 4 | 6 | 6.7[B] |

[A,B]Values with different superscripts are statistically significantly different at α = 0.05.

[1]Roll gap settings were statistically different for 6-h incubation times ($P$ = 0.02) at a confidence level of 95%. The pooled SE was 3.0 g among these treatments.

**Table 5.** The 12-h slowly disappearing DM (SDDM) at 1-, 2-, 3-, and 4-mm crop processor roller gap settings[1]

| Processor gap setting (mm) | Incubation time (h) | SDDM (% of DM) |
|---|---|---|
| 1 | 12 | 28.4[A] |
| 2 | 12 | 23.6[AB] |
| 3 | 12 | 19.4[BC] |
| 4 | 12 | 16.0[C] |

[A–C]Values with different superscripts are statistically significantly different at α = 0.05.

[1]Roll gap settings were statistically different for 12-h incubation times ($P$ = 0.004) at a confidence level of 95%. The pooled SE was 2.1 g among these treatments.

# In situ Dry Matter Disappearance

Luck, B. D., Drewry, J. L., Shaver, R. D., Willett, R. M., & Ferraretto, L. F. (2020). Predicting in situ dry matter disappearance of chopped and processed corn kernels using image-analysis techniques. Applied Animal Science, 36(4), 480-488. https://doi.org/10.15232/aas.2020-01993

**Table 6.** Pearson r between image-analysis separation, sieve separation, and slowly disappearing DM (SDDM) results[1]

| Variable 1 | Variable 2 | Pearson r(10) | *P*-value |
|---|---|---|---|
| Image CSPS | 12-h SDDM | 0.77 | 0.004 |
| Sieve CSPS | 12-h SDDM | 0.63 | 0.03 |

[1]Image-analysis corn silage processing scores (CSPS) were more highly correlated with the 12-h incubation times than were the sieve CSPS determination methods.

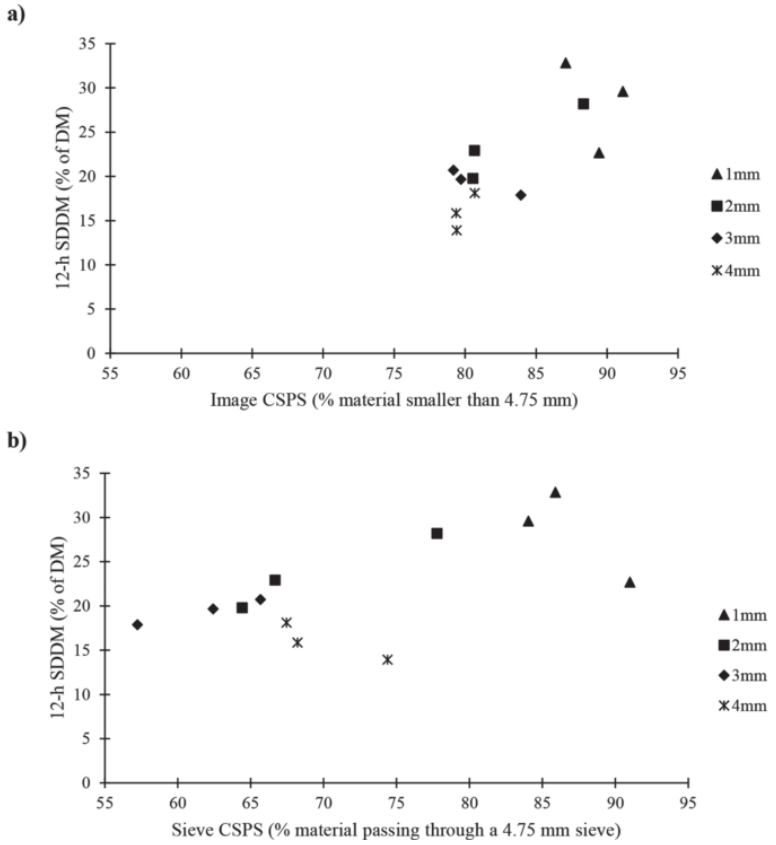


**Figure 3.** Twelve-hour slowly disappearing DM (SDDM) of grain isolated from triplicate ensiled subsamples versus image analysis–based corn silage processing score (CSPS) (a) and sieve-based CSPS (b).

# Research Summary

- Image processing can produce an accurate assessment of KPS!
- Image analysis may provide a better representation due to particle disruption during mechanical sieving.
- Image analysis based KPS was highly correlated to dry-matter disappearance at 12-h incubation times.
- Image analysis will not replace laboratory chemical analysis, but can provide a quantitative check during harvest.

# Corn Silage Particle Size Assessment

- Corn Silage Image Processing App
  - SilageSnap!
  - Released September, 2018!

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Account
Payment methods
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Parent Guide

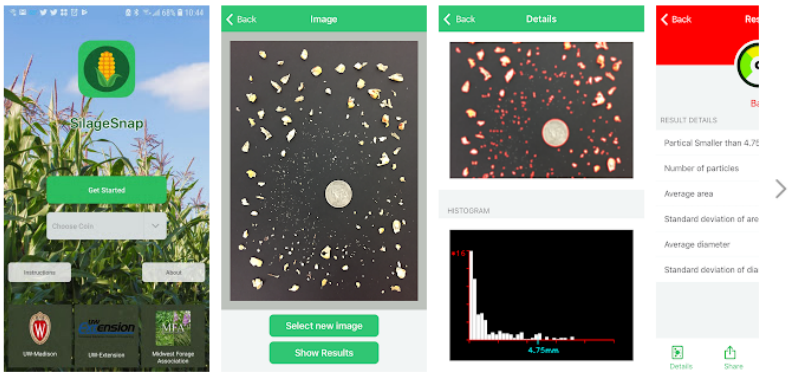
# SilageSnap

University of Wisconsin-Madison Shared Apps Tools

Everyone

This app is compatible with all of your devices.

Installed




Have you ever wondered how well your corn silage kernel processor is working during harvest? SilageSnap allows you to check the particle size of corn kernels in your chopped and processed corn silage during harvest. The app utilizes an image processing algorithm to measure the particle sizes and provide a quantitative assessment of the kernel processing score in-field. This assessment is not meant to replace laboratory analysis of the harvested silage, but will provide a repeatable method for estimating Kernel Processing Score (KPS). Things you will need:

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**App Store** Preview

This app is available only on the App Store for iPhone and iPad.

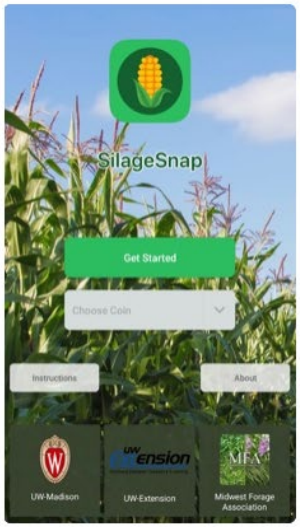
## SilageSnap 4+

University of Wisconsin-Madison Shared Apps

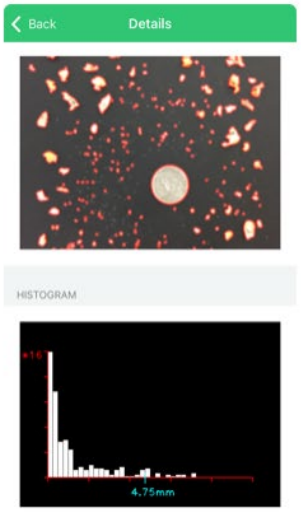
★★★★★ 5.0, 5 Ratings

Free

### Screenshots iPhone iPad









Have you ever wondered how well your corn silage kernel processor is working during harvest? SilageSnap

# SilageSnap!

- Collect a sample (built on 600 ml samples)
- Water separate the sample as best you can
- Spread the kernels out on a dark background
  - Any foreign matter will be considered a kernel, so the cleaner the better
- Place the coin in the center of the image
- Ensure that no kernels are touching (as best you can)
- Take the picture!

# Hydrodynamic Separation

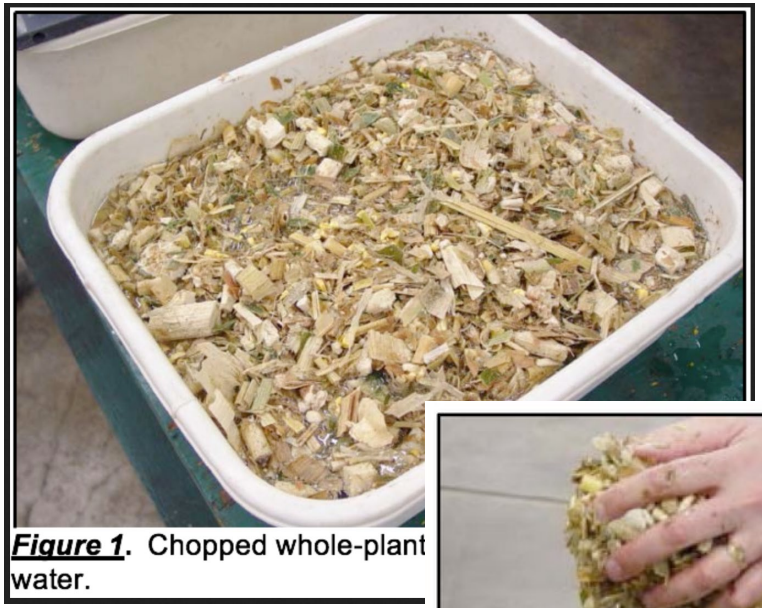


***Figure 1***. Chopped whole-plant
water.

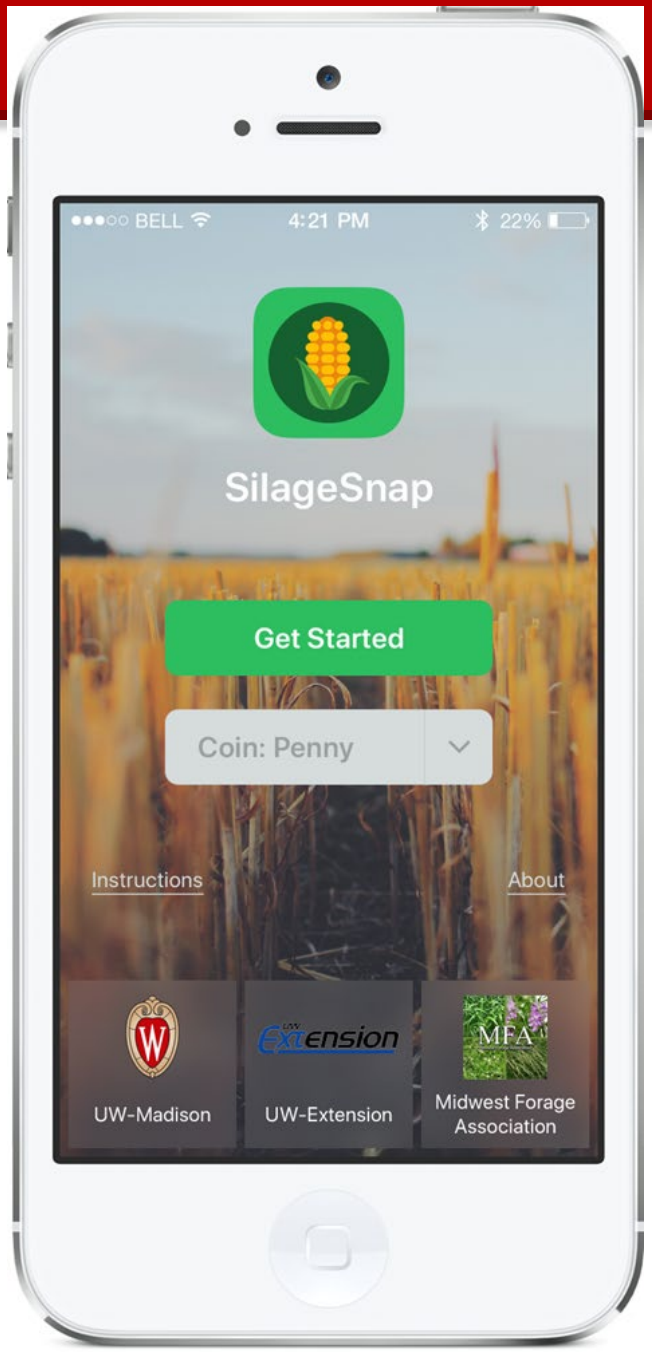
ently agitating material to help the kernels
ottom of the container.

***Figure 3***. Skimming and removing the floating stover.

# Hydrodynamic Separation

***Figure 4***. Carefully draining the water so only the kernels remain in the container.

***Figure 5***. Example of separated stover and kernel fractions using the water separation technique.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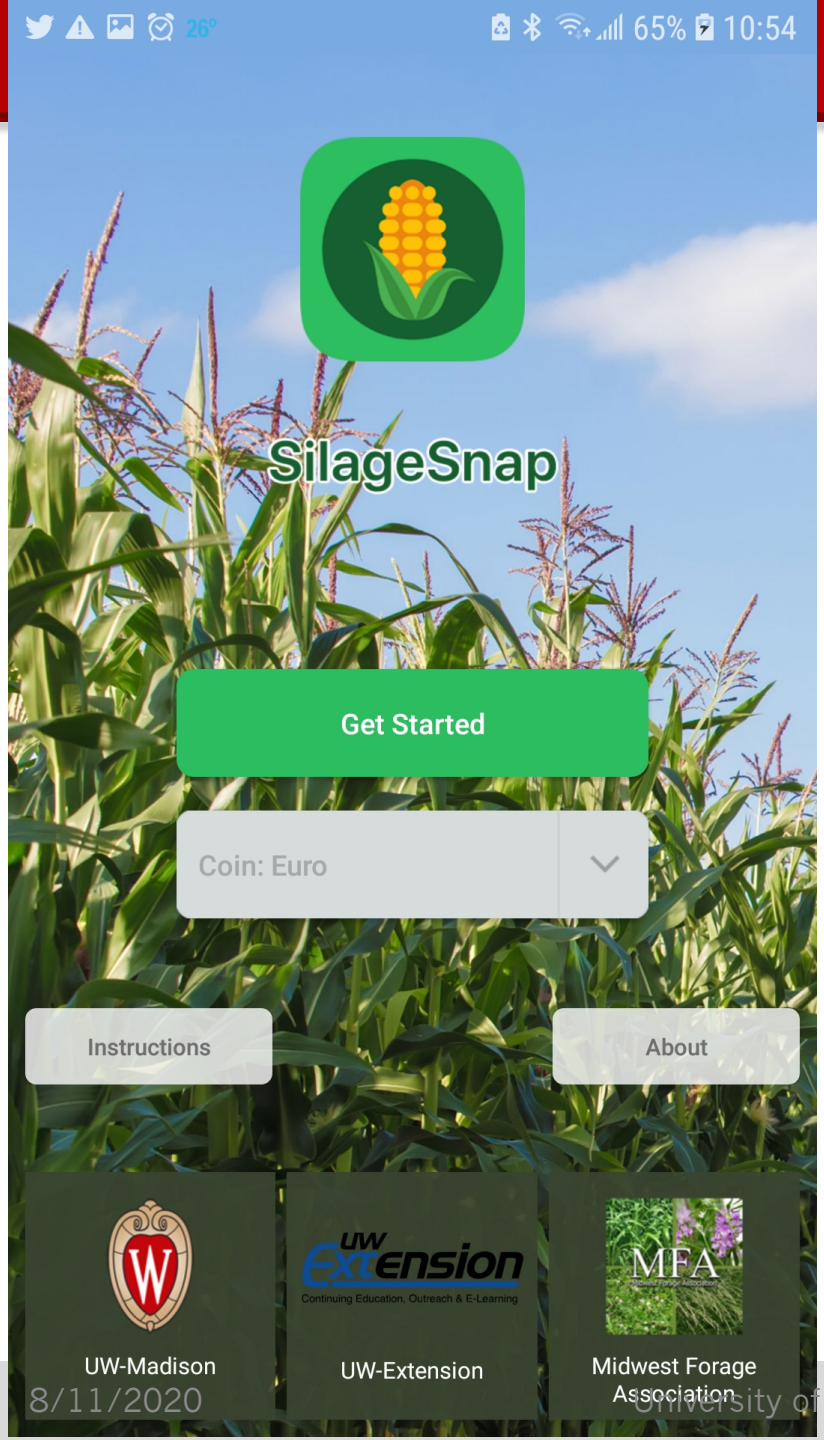
Midwest Forage Association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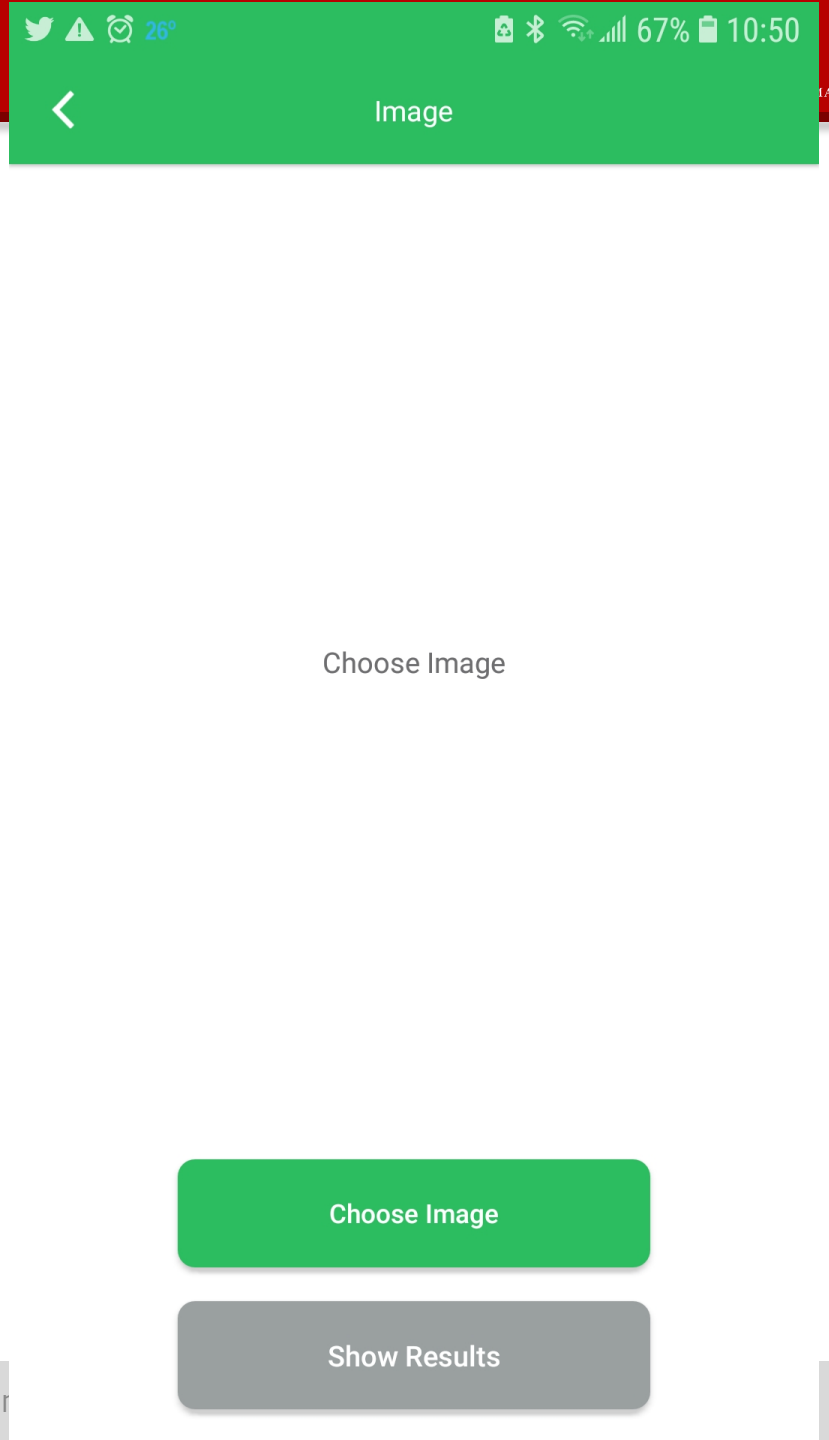
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Choose Image
Choose Image
Show Results

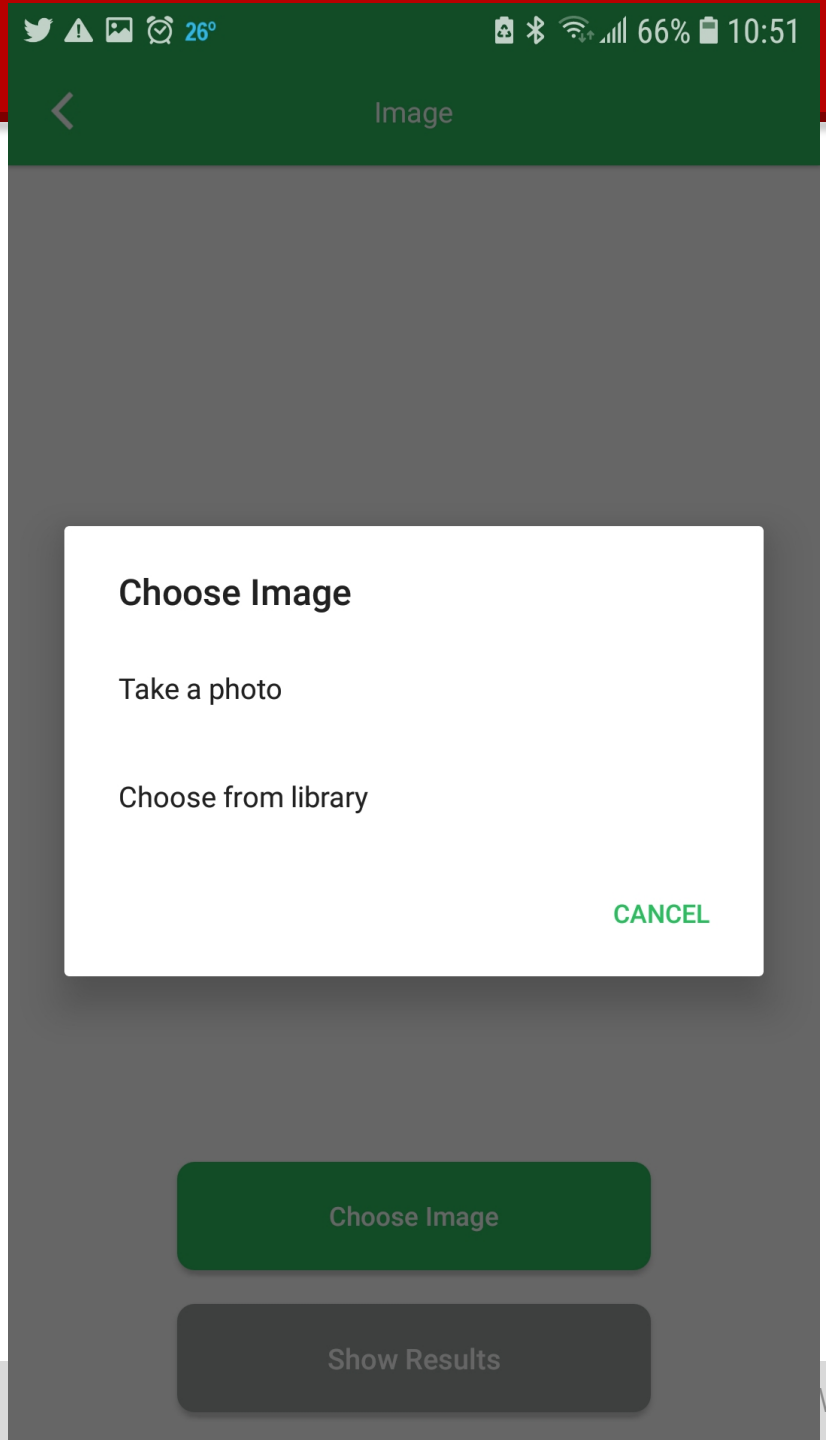
26°
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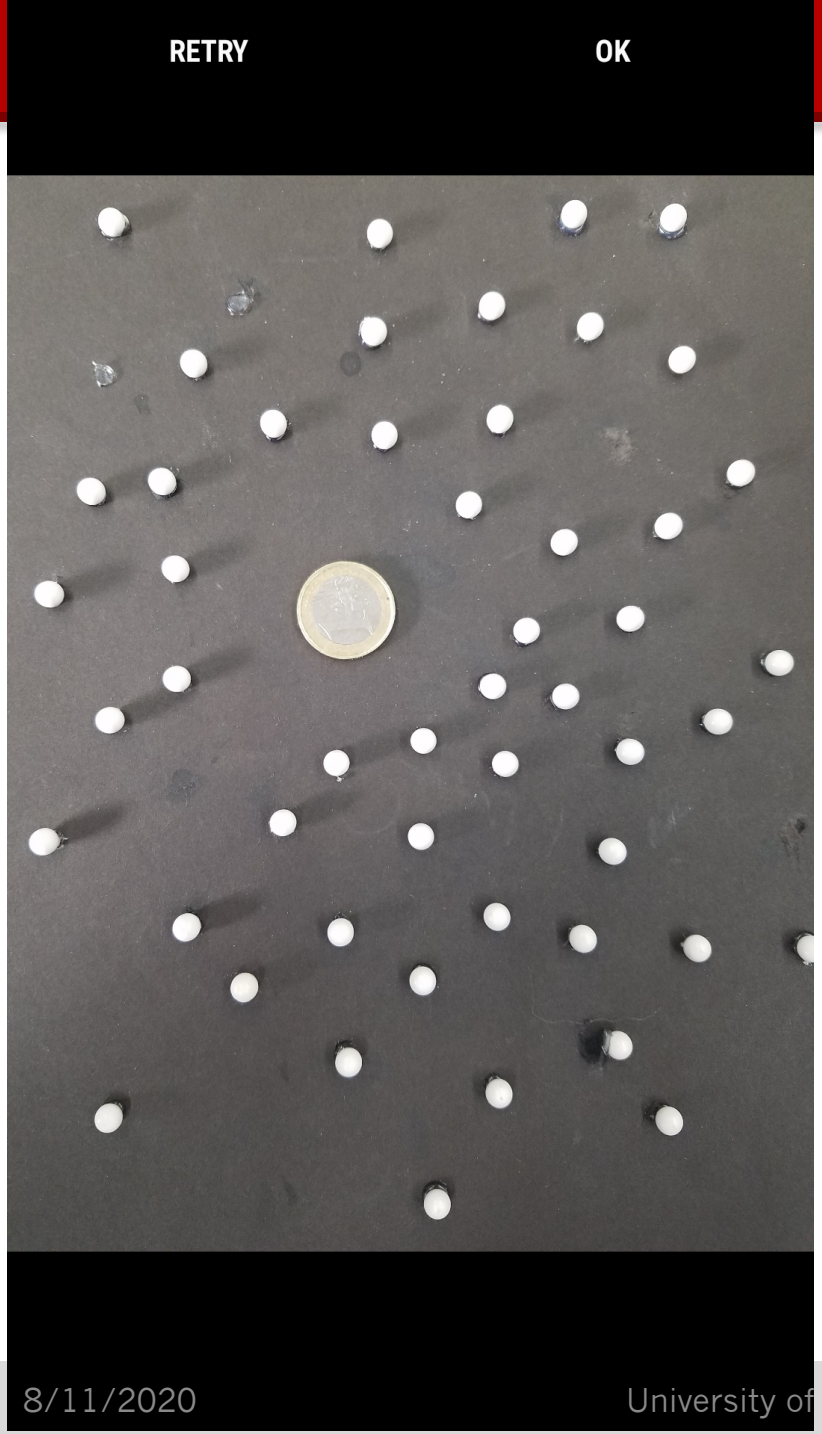
Image
Choose Image
Take a photo
Choose from library
CANCEL
Choose Image
Show Results


STICKERS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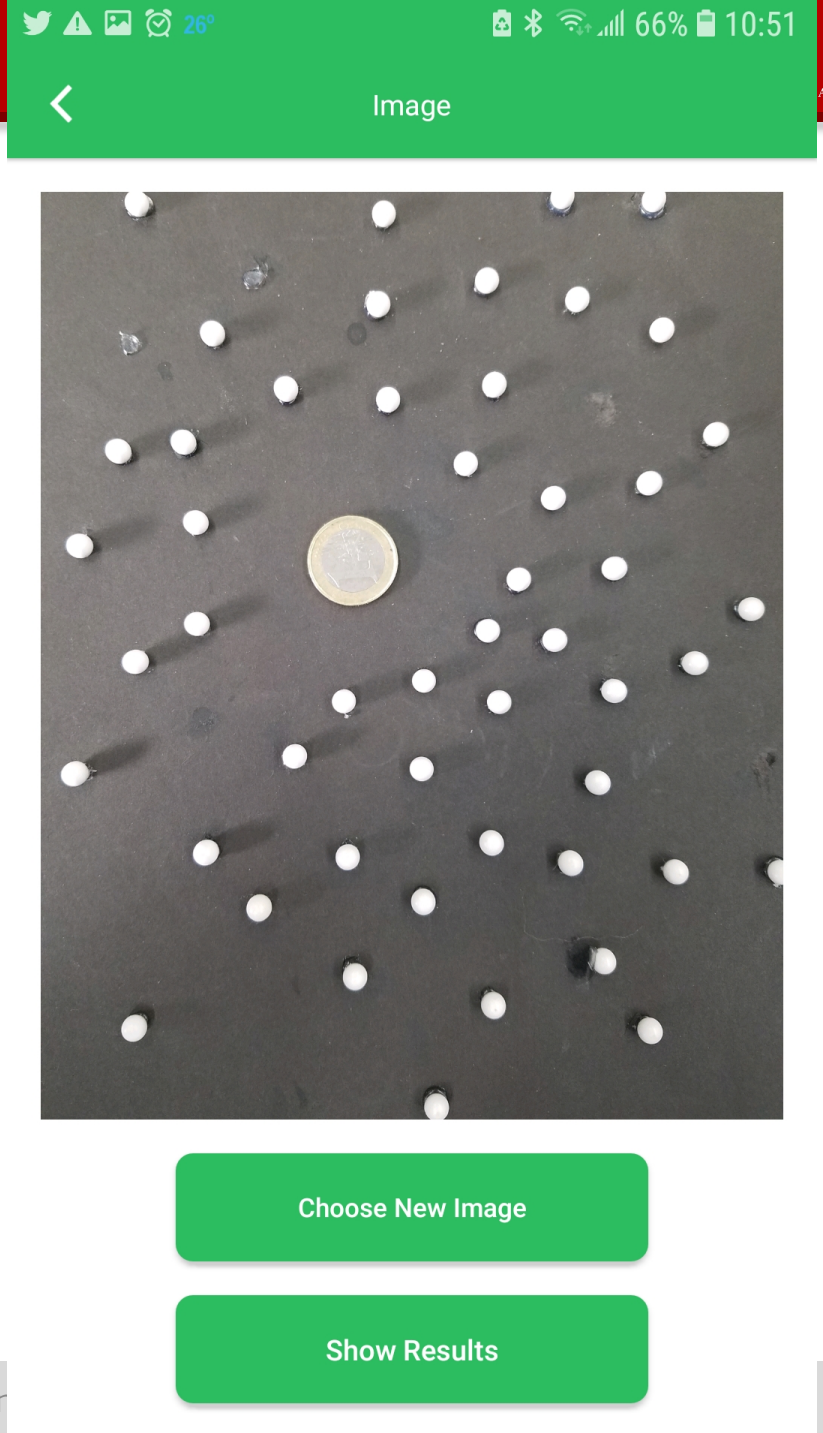
OK


26°
66% 10:51
Image
Choose New Image
Show Results

Results

Bad

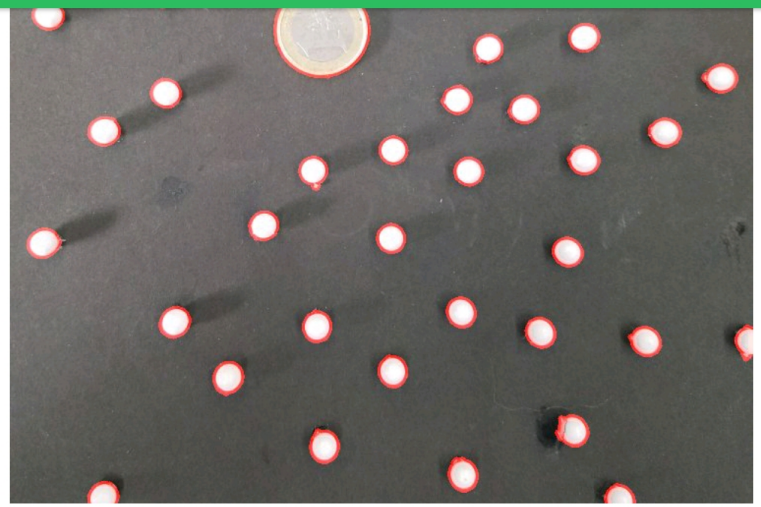
RESULT DETAILS

| | |
|---|---|
| Particle Smaller than 4.75 mm | 1.25% |
| Number of Particles | 54 |
| Average Area | 129.99 mm² |
| Standard Deviation of Area | 38.87 mm² |
| Average Diameter | 5.54 mm |
| Standard Deviation of Diameter | 1.58 mm |

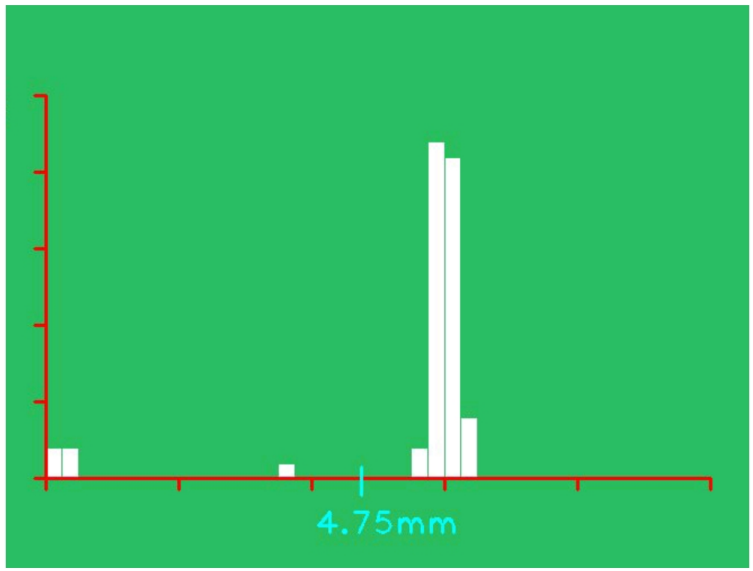
Details Share Save Restart



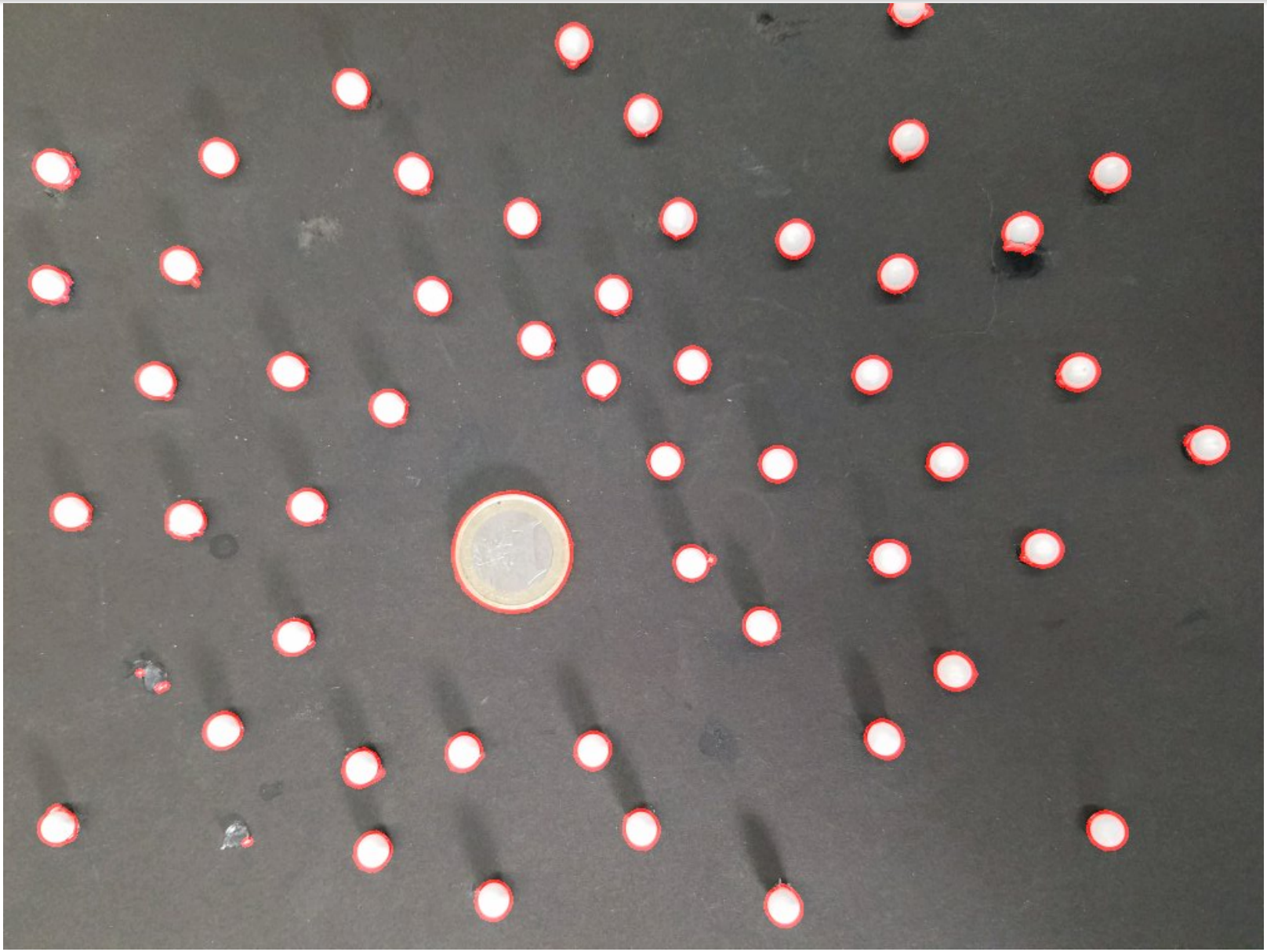
Details



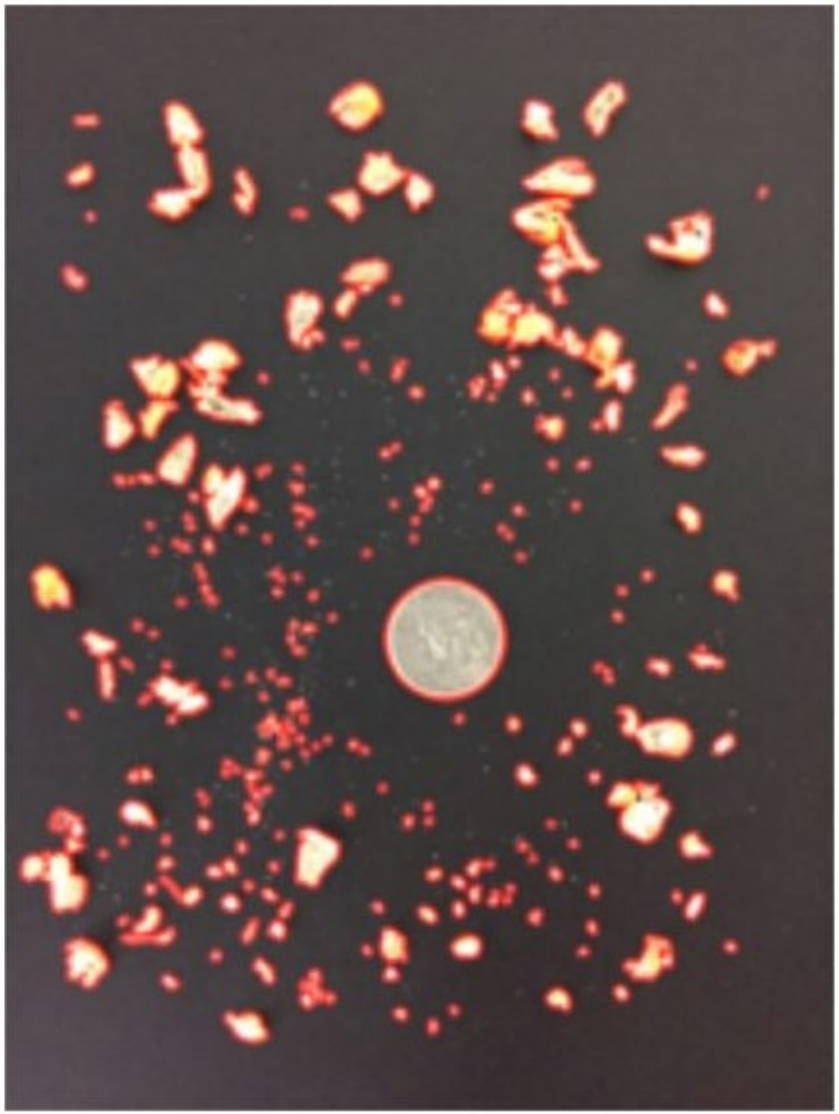
HISTOGRAM




UNITED STATES OF AMERICA
IN GOD WE TRUST
LIBERTY
QUARTER DOLLAR
mm
10
20
0.5 mm



# Poor Images



# Poor Images

# Known SilageSnap Flaws

- The app does not work well on iPad/Tablets
  - Possibly does not work at all.
- The app does not work on Motorola phones (Android)
- Too sensitive
  - Full check vs. quick check
  - Large particles only for measurement
  - Will not provide as much information as full sample.

# KPS Recommendations

- Check often!
  - **Download** and **use** SilageSnap! Please!
- Train all people involved in the harvest process to look for large kernel pieces in the silage.
- Maintenance, Maintenance, Maintenance!
  - Bearings hot, worn rolls, etc
- Adjust often
- Replace worn rolls sooner rather than later to maintain adequate KPS!

# Funding

- Midwest Forage Association
  - Midwest Forage Research Program
- Baldwin Wisconsin Idea Endowment
- More information at:

https://wimachineryextension.bse.wisc.edu/precision-agriculture/silagesnap/

https://wimachineryextension.bse.wisc.edu/2019/09/30/silagesnap-how-to-video/

# AgrAbility of Wisconsin

**Promoting success in agriculture for farmers and farm families affected by disabilities**

AgrAbility of Wisconsin is a cooperative partnership between The University of Wisconsin-Extension and Easter Seals Wisconsin. AgrAbility of Wisconsin exists to assist farm workers and farm families affected by disabilities by providing education, technical assistance, on-site consultation services, and identification of potential funding resources. Since 1991 we have served over 2,000 clients with a 97% success rate- meaning that 97% of our clients continue to farm after our services are provided.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