DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

SWIFT: Single-Pass, Weather Independent Fractionation Technology

April 4th, 2023

Technology Area Session

Dr. Matthew Digman (PI)

Dr. Kevin Shinners (Co-PI, Presenter)

University of Wisconsin

Project Overview

Problem Statement

An estimated 60% of the available corn stover will be collected in excess of 20% moisture resulting in a lack of ability to produce a reliable feedstock with conventional harvest and storage systems.

https://poet.com/bioethanol

CURRENT SOT

SOT Issues

- Inconsistent stover fractions captured.
- Too many non-value-added operations.
- Fall weather challenges.
- Inconsistent & excessive moisture content.
- High ash content.
- Poor transport density.

PROJECT GOALS

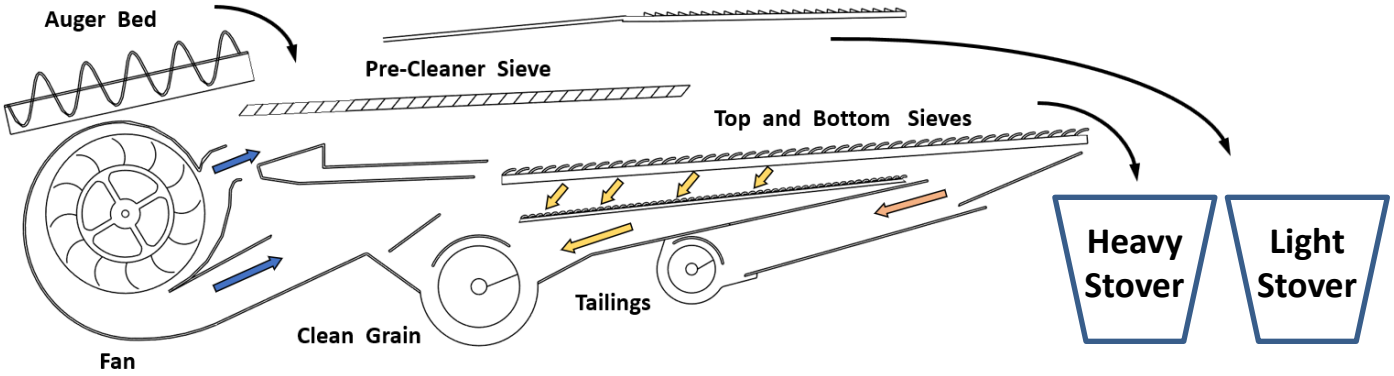
- Overcome issues with current bale-based SOT.
- Develop a single-pass corn stover harvest process with improved chemical and physical property control.
- Reduce corn stover feedstock delivery cost to $70 per dry ton (2016$).

SWIFT INNOVATIONS

- Stover and grain co-harvested, co-stored and co-transported:
  - Target aggregate moisture of ~30% – 45%.
  - Direct harvest increases control of feedstock properties.
  - Stable anerobic storage doesn't require field wilting.
  - Higher transport density to end-utilization.

SWIFT INNOVATIONS

- Separating grain and stover & stover fractions:



SWIFT INNOVATIONS

APPROACH

1. Reduce harvest risk with modified harvesting machines and header configurations.

2. Utilize anaerobic storage to minimize storage loss.

3. Fractionate stover to reduce pretreatment severity.

4. Characterize material properties for scale-up.

5. Evaluate the cost-benefit.

Progress and Outcomes

1ST APPROACH: HARVEST

Note our Weather Independent Harvest

- Modifications:
  - Whole-plant or ear-snapper headers, w/ higher cutting height.
  - To reduce loss of grain integrity:
    - Reduced cutterhead speed.
    - Longer cut length (35 mm)

1ST APPROACH: HARVEST

Modified combine harvester: single-pass co-harvest that maintains grain integrity.

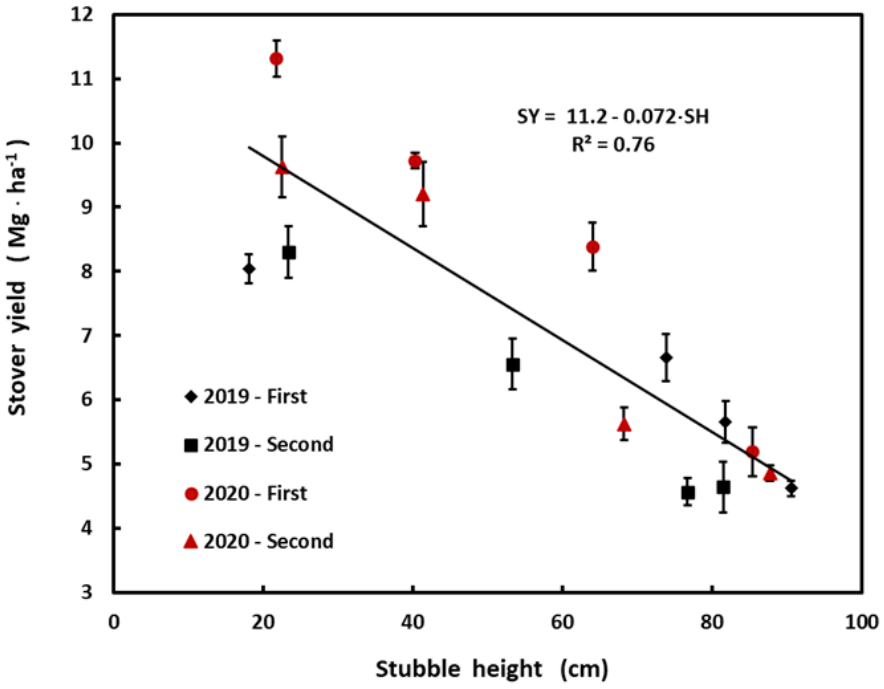
1ST APPROACH: HARVEST

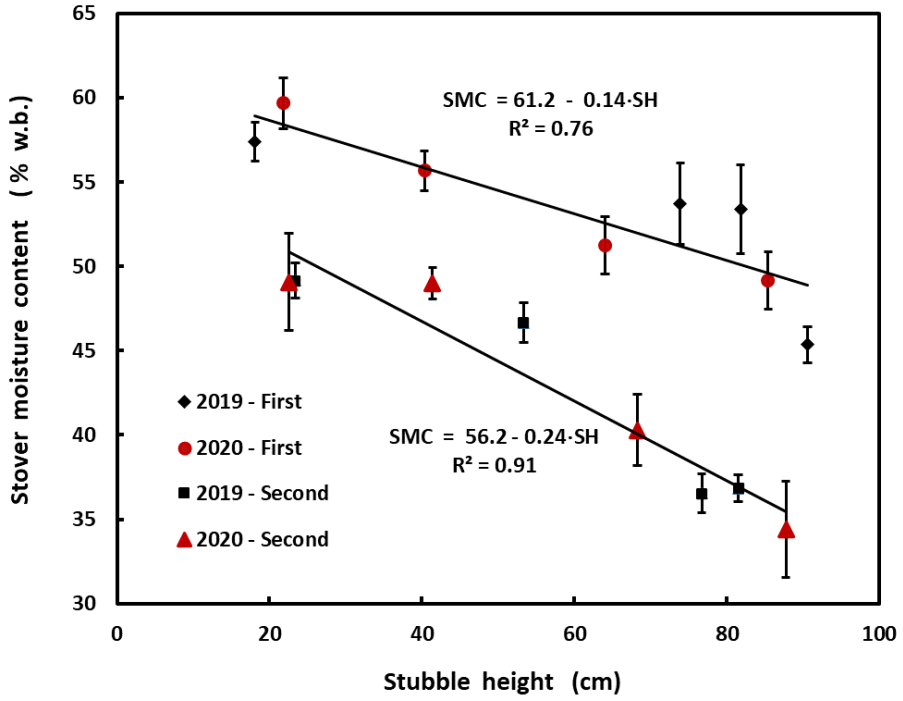
Whole-Plant Header

Modified Ear-Snapper Header

1ST APPROACH: HARVEST

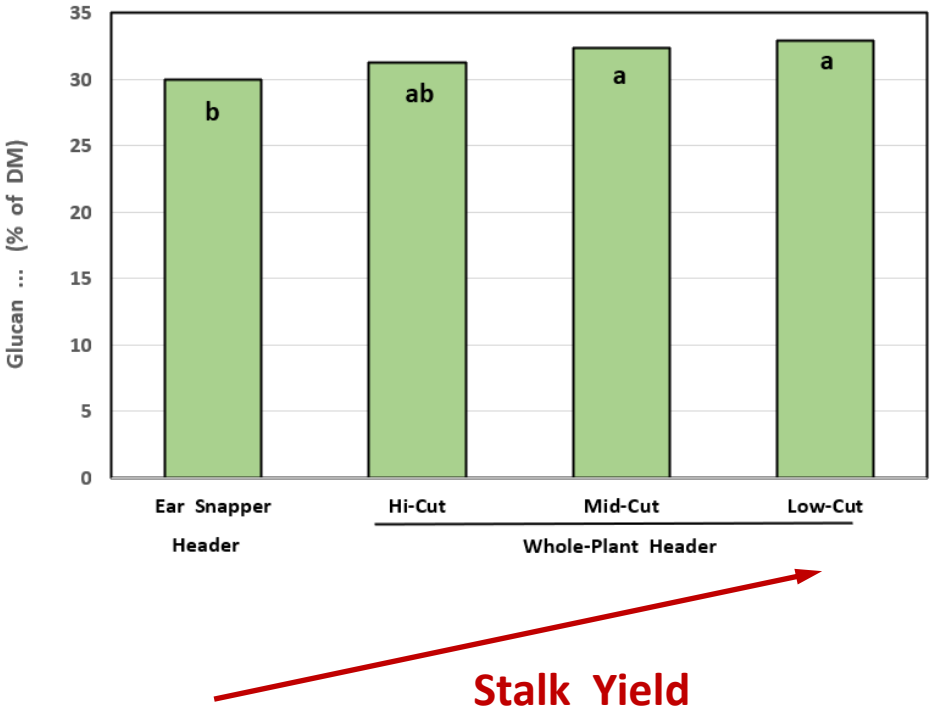
- Yield controlled: 41% to 85% of available stover collected
- Aggregate moisture controlled: 36% to 41% (w.b.)
- Ash content controlled: < 6% of DM

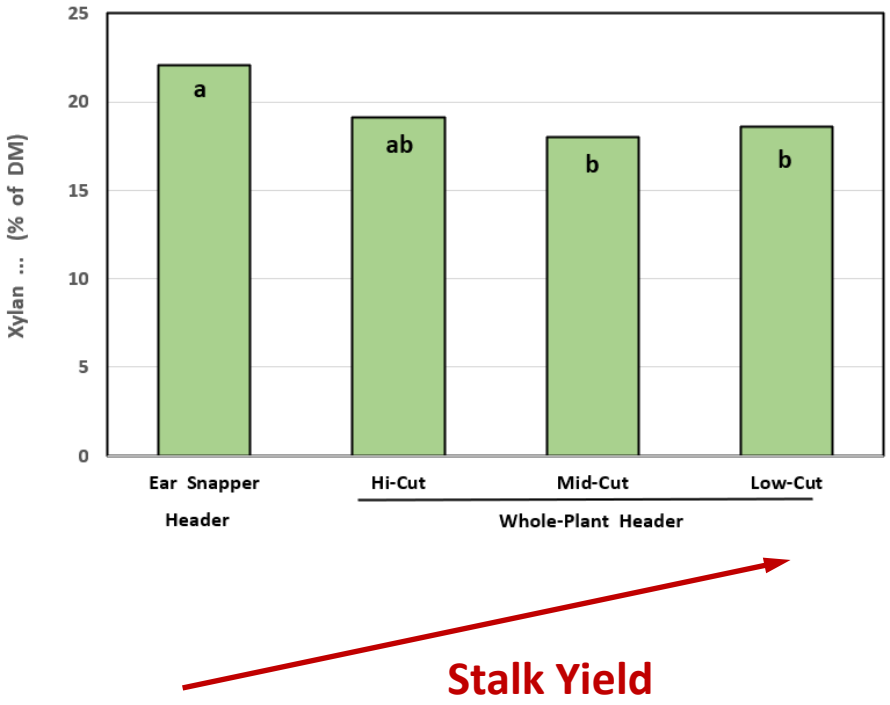




1ST APPROACH: HARVEST

- Glucan and xylan controlled:



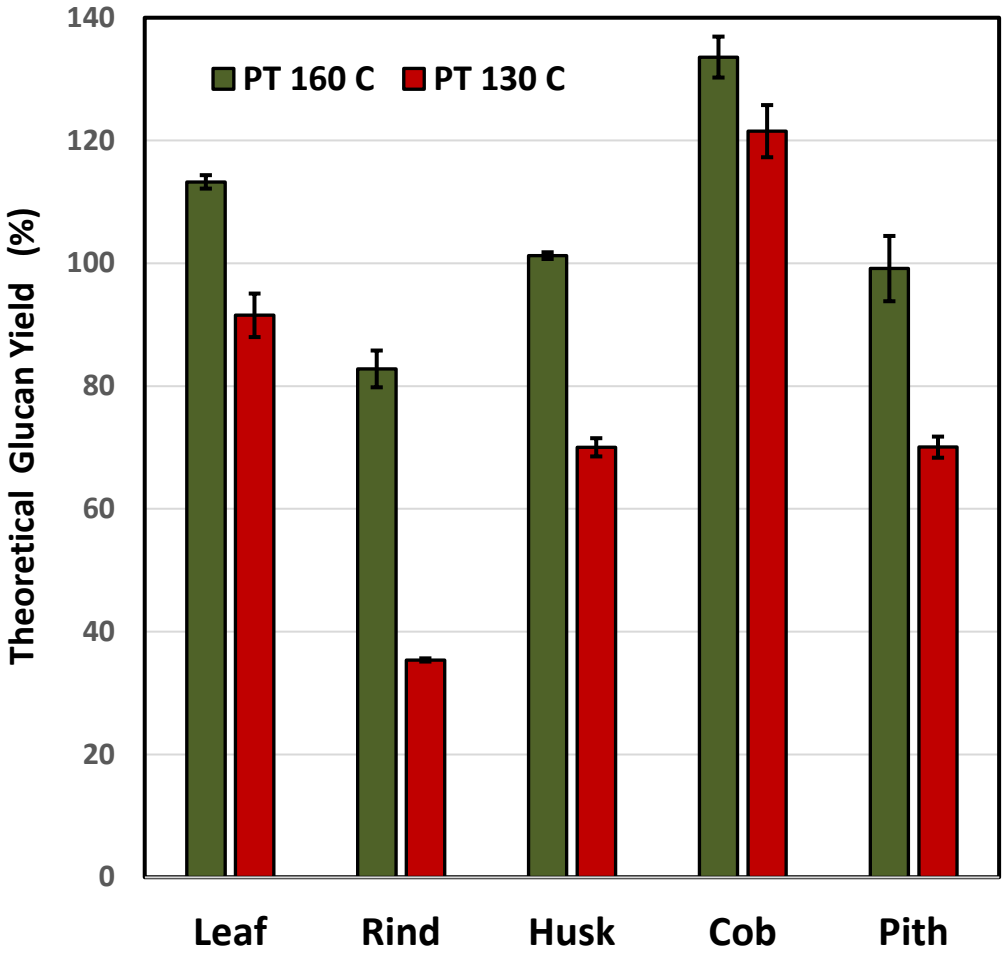


2ND APPROACH: ANAEROBIC STORAGE

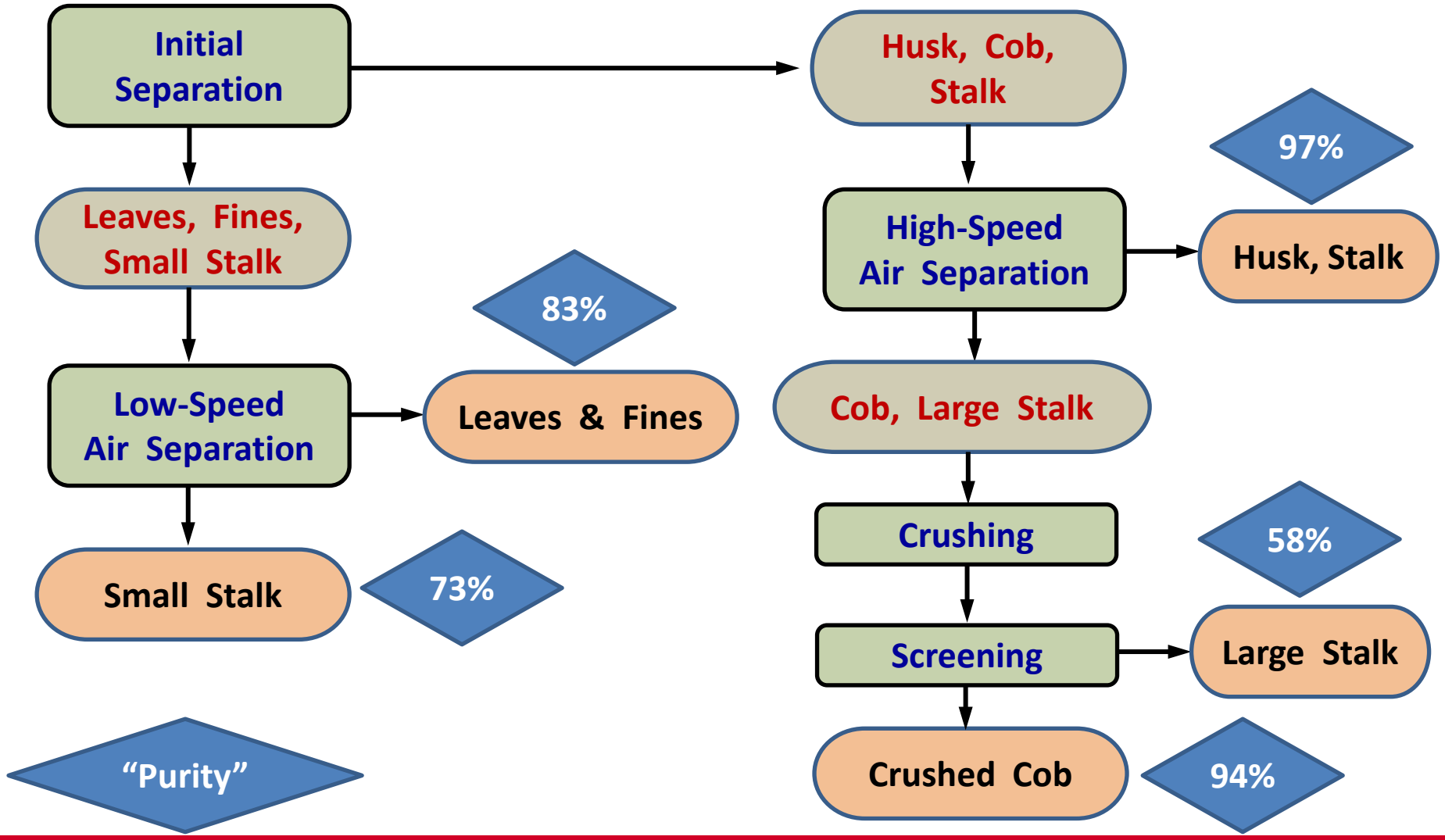
- Harvested and stored:
  - 0.30 tonne DM in 19 L mini-silos
  - 1.7 tonne DM in 200 L pilot-scale silos
  - 22 tonne DM in wrapped bales
  - 30 tonne DM in silo bags
- Losses limited to less than 6% of DM.
- Grain gains moisture during storage.

3RD APPROACH: REDUCED PRETREATMENT COSTS

- Dilute acid pretreatment.
- Leaf & cob fractions:
  - Least recalcitrant at 130°C
  - ~30 to 40% of stover mass.
- ∴ preferred fractions were:
  - Leaves and Cob
  - Husk and Stalk



3RD APPROACH: REDUCED PRETREATMENT COSTS



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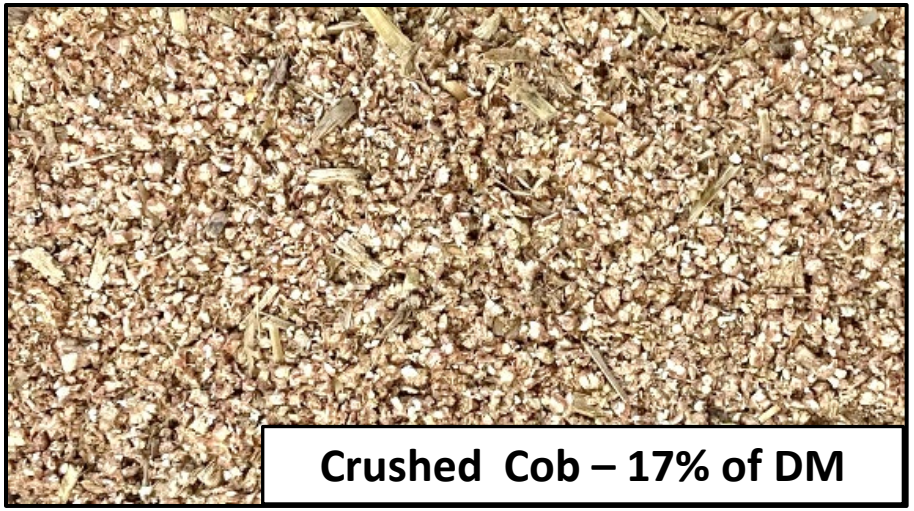
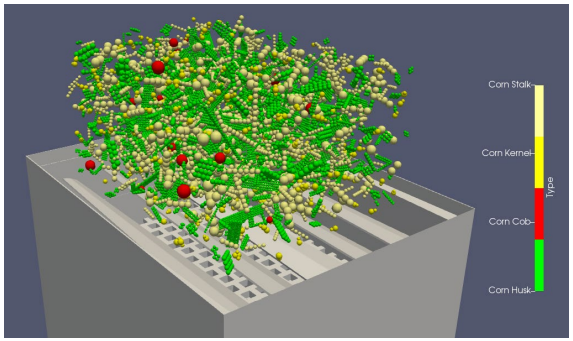
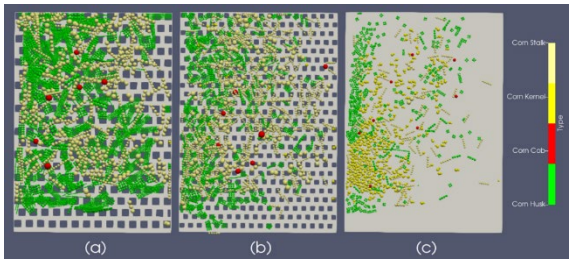
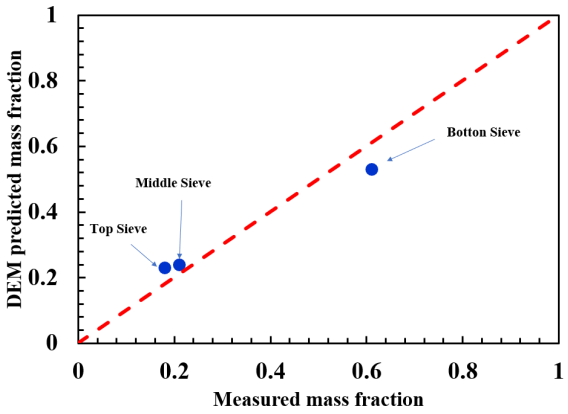


4TH APPROACH: MATERIAL PROPERTIES

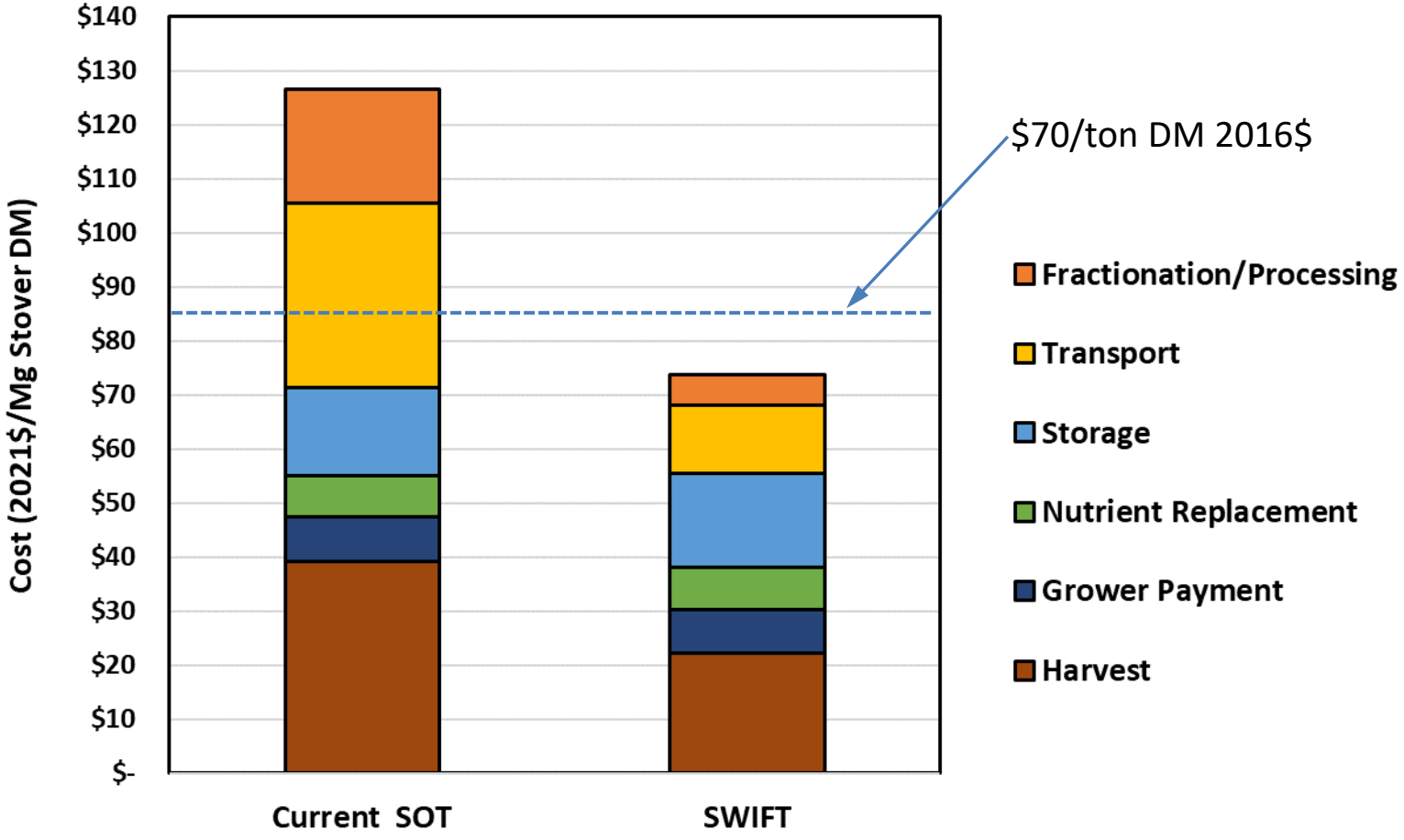
- DEM models developed for each anatomical fraction.
- Material interaction optimized using mechanical sieving.
- Current work focuses on introducing material into a CFD environment.
- Fermented kernel physical properties quantified.







5TH APPROACH: COST – BENEFIT



Hemmelgarn, A. B., Lin, Y., Wendt, L. M., Hartley, D. S., & Digman, M. F. (2022). Techno-economic assessment of single-stream feedstock logistics supply chain for corn stover and grain. Biofuels, Bioproducts and Biorefining. https://doi.org/10.1002/bbb.2459

IMPACT

- A single-pass system with clear demonstration of reduced weather risk will improve grower participation.
- Demonstration of anerobic storage stability reduces on-farm and biorefinery risk.
- Reduction in pretreatment costs and lower ash will reduce conversion costs to biorefineries.
- Material property data will allow further optimization of fractionation, handling, and storage.

SUMMARY

- The single-pass harvest process could be utilized to alter stover yield, moisture, glucan, and xylan while minimizing ash content.
- Combining leaves and cob reduced pretreatment severity by 30% on ~30 – 40% of the biomass.
- A mechanical fractionation process was developed to separate leaves and cob from husk and stalk.
- Virtual material models were developed for stover anatomical fractions.

Quad Chart Overview

Timeline

- *10/01/2019*
- *06/30/2023*

	FY22 Costed	Total Award
DOE Funding	*$337,404*	$1,248,747
Project Cost Share *	$11,518*	$316,653

Project Goal

Develop a corn stover harvest, storage and transportation process that is less weather dependent and produces a corn stover feedstock with defined and measurable characteristics for superior conversion performance,

End of Project Milestone

Establish economic value and sustainability of SWIFT feedstock.

Funding Mechanism

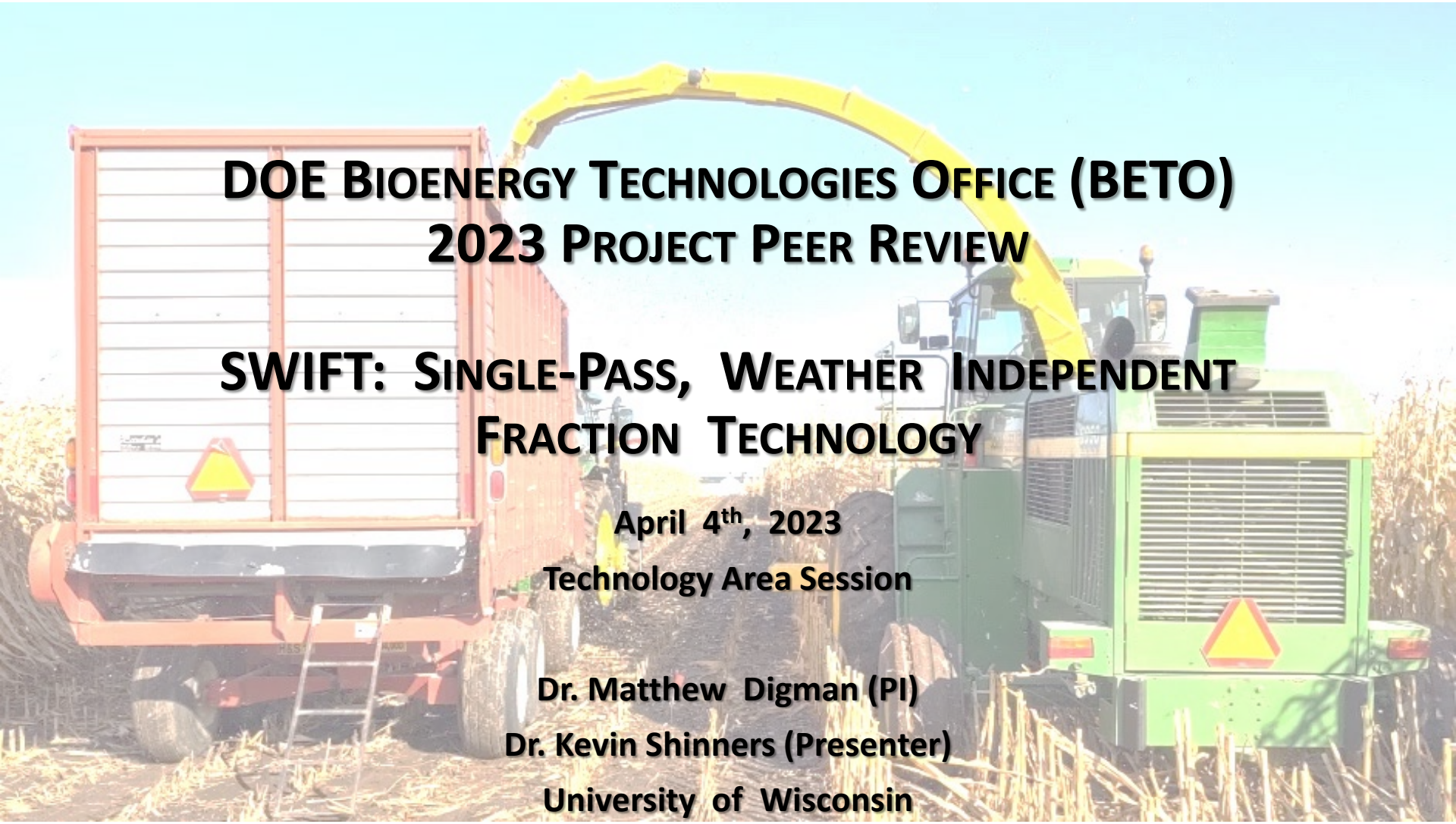
- DE-FOA-0002029, Topic 2a

TRL at Project Start: 2
TRL at Project End: 4

Project Partners

- Idaho National Labs
- Iowa State University

*Cost share was front-loaded in this project via equipment donations.



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PUBLICATIONS

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- Hemmelgarn, A. B., Lin, Y., Wendt, L. M., Hartley, D. S., & Digman, M. F. (2022). Techno-economic assessment of single-stream feedstock logistics supply chain for corn stover and grain. Biofuels, Bioproducts and Biorefining. https://doi.org/10.1002/bbb.2459
- Hemmelgarn, A. B., Shinners, K. J., Timm, A. J., & Digman, M. F. (2023). Anaerobic storage characteristics of whole-ear corn and stover. AgriEngineering, 5(1), 173-181. https://doi.org/10.3390/agriengineering5010012
- Pike, B.C., K.J. Shinners, K.J., Timm, A.J., Friede, J.C. & Digman, M.F.. (2023). Co-harvest and anaerobic co-storage of corn grain and stover as biomass feedstocks. Journal of the ASABE. In Press
- Hemmelgarn, A. B., K.J. Shinners, A.J. Timm, & Digman, M. F. (2023). Single-pass, single-stream harvest of corn grain and stover: a comparison of two harvest methods. BioEnergy Research. Submitted, January 2023.

PUBLICATIONS

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  - Blazer, K.J., Shinners, K.J., Timm, A.J., Tekeste, M. & Digman, M.F. (2023). Physical properties of fermented corn kernels. Processes. Submitted March 2023.

  - Blazer, K.J., Shinners, K.J., Timm, A.J., Tekeste, M. & Digman, M.F. (2022). Physical properties ground fermented corn grain. To be submitted to Materials. In Preparation.

  - Blazer, K.J., Shinners, K.J., Timm & Digman, M.F. (2023). Fractionation of ensiled corn stover and grain. To be submitted to Applied Engineering in Agriculture. In Preparation.

Students Trained

- Theses:

  - Blazer, K.J. (2022). Anatomical Fractionation of Corn Grain and Stover to Produce Biomass Feedstocks. Masters of Science – Biological Systems Engineering. University of Wisconsin.

  - Pike, B.C. (2022). Co-Harvest of Corn Grain and Stover For Improved Property Control of Biomass Feedstocks. Masters of Science – Biological Systems Engineering. University of Wisconsin.

  - Kluge, Z.A. (2024) Separation of Corn Stover into Anatomical Fractions. Masters of Science (Expected) – Biological Systems Engineering. University of Wisconsin.

Technical Presentations

- 2021 ASABE International Meeting:

  - Pike, B.C., K.J. Shinners, and M.F. Digman. Fractional harvest of corn stover for improved property control as part of the Single-pass, Weather Independent Fractionation Technology (SWIFT) process.

  - Blazer, K.J., K.J. Shinners, and M.F. Digman. Anatomical fractionation for improved property control as part of the Single-pass, Weather Independent Fractionation Technology (SWIFT) process.

  - Hemmelgarn, A.B., K.J. Shinners and M.F. Digman. Harvest and storage of ear corn and chopped stover as a biomass feedstock.

Technical Presentations

- 2022 ASABE International Meeting:

  - Zhao, Y., M.Z. Tekeste, M.W. Schramm, and M.F. Digman. Discrete element method simulation of separation of whole-plant corn fractions using mechanical sieving.
  - Hemmelgarn, A.B., L. Yingqian, D.S. Hartley, L.M. Wendt, M.F. Digman. A comparative techno-economic analysis of whole-plant corn to state-of-technology biomass feedstock supply systems.
  - Blazer, K.J., K.J. Shinners, A.J. Timm, M.F. Digman. Grain fractionation as part of the Single-pass, Weather Independent Fractionation Technology (SWIFT) process.
  - Pike, B.C., K.J. Shinners, and M.F. Digman. Fractional harvest of corn stover for improved property control as part of the Single-pass, Weather Independent Fractionation Technology (SWIFT) process.

Technical Presentations

- 2023 ASABE International Meeting:
  - Kluge, Z.A., K.J. Shinners, A.J. Timm, M.F. Digman. Method for anatomically fractionating corn stover to increase biofuel conversion efficiency.