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The Ohio State University, Department of Food, Agricultural, and Biological Engineering, BioSystems Analysis Lab

# Co-pelletization of corn stover and plastic waste as an alternative fuel for cement industry

**Haley Stockham, Asmita Khanal, Ajay Shah***

## INTRODUCTION

### Alternative fuel use in cement industry

- The US cement industry substitutes 19% of fuel with solid wastes[1] (Fig 1).
- Residual ash becomes part of the cement.
- Emission of dioxins and furans is minimal due to high kiln temperature and long residence times.[1]


*Figure 1. Common alternative fuels for cement manufacture*

### Underutilized wastes

Plastic

- 75% of plastic municipal solid waste generated in 2018 was landfilled.[2]
- Plastic film, including high density polyethylene (HDPE) film used for retail shopping bags, are rejected by recyclers due to processing issues.
- However, plastics are energy dense and contain little to no ash.

Corn stover

- 360 million metric ton of corn stover was produced in 2020 in the US.[3]
- More than 90% of stover goes unused.[4]
- Combustion of stover is limited due to high ash content, low heating value, and low bulk density.

### Co-Pelletization of stover and plastic waste

- Improves combustion and material handling properties of biomass and plastic films
- CS contains lignin, which acts as a binder when pelletized.[5,6]

## OBJECTIVES

- Evaluate the co-pelletization characteristics of HDPE film and stover
- Conduct techno-economic analysis (TEA) for a pelletization plant

## METHODS

### Pelletization Parameters

- Flat die pellet mill (Fig. 2)
- Feedstocks: stover and HDPE retail bags
- Particle size: 3 mm stover, 1 mm HDPE
- HDPE content: 0-25% dry basis (denoted by P)
- Die diameter: 6- and 8-mm
- Feedstock moisture content: 20%
- Feedstock temperature: 105-125 ºC
- Specific energy consumption[6] (SEC): instantaneous load was monitored with a submeter and averaged to determine full load power.

$$\text{SEC (kWh/t)} = \frac{(\text{Full load power (kW)} - \text{No load power(kW)})^{*} \text{ time (h)}}{\text{Mass of biomass (t)}}$$

### Phyisco-thermal properties characterization:

- Durability[7]**:** ratio of pellet mass before and after tumbling
- Bulk Density[6] (kg/m$^3$): Dry mass that fills 250 ml container

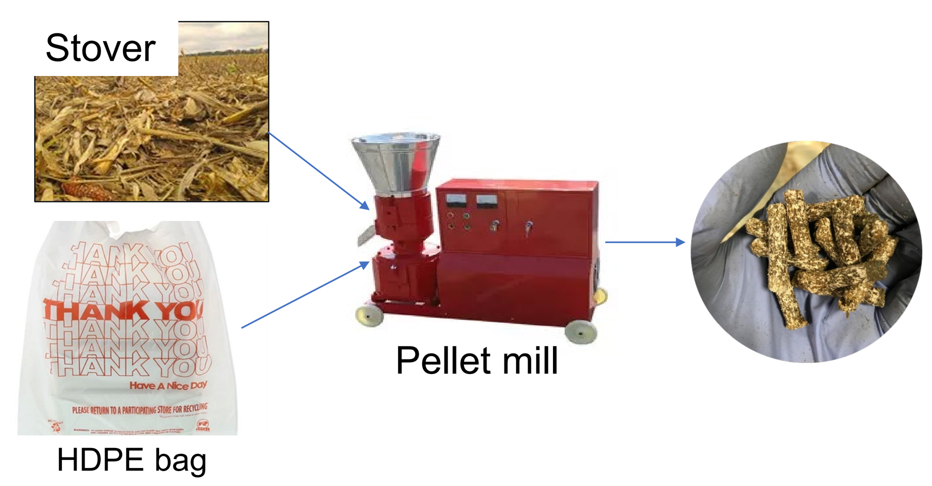


*Figure 2. Feedstocks, pellet mill and CS-HDPE pellets*

### TEA

- Literature and experimental data was used to model a pelletization plant (Fig. 3).
- Manufacturer data was used to estimate cost and energy requirement for equipment.
- Sensitivity analysis was conducted with Oracle Crystal Ball

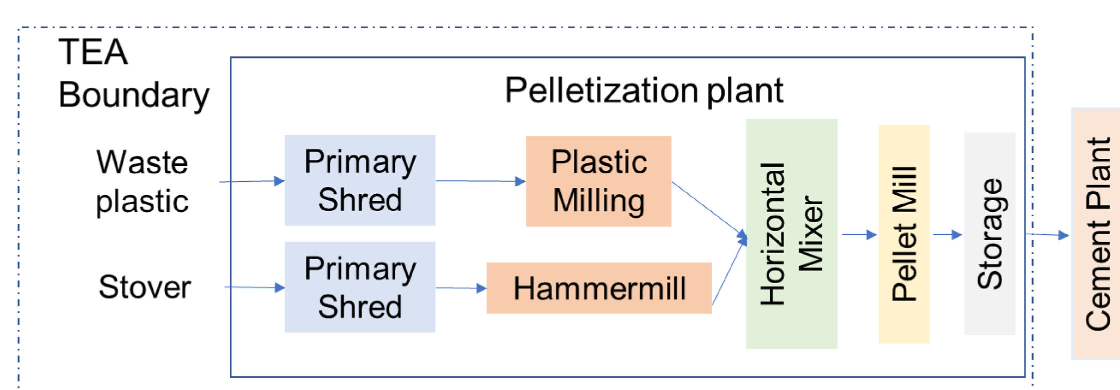


*Figure 3. System diagram*

**Key TEA assumptions:**

- Capacity of 200,000 t pellets/y
- Pellet plastic content of 25%

## RESULTS

### PELLETIZATION

- 6-mm pellets were more durable than 8-mm pellets (Fig. 3) due to increased compaction because of the decrease in die size.
- Durability decreased as plastic content increased because HDPE interfered with lignin binding.
- Moisture content stabilized at 3-5% after a week of curing.
- Bulk density for 8-mm pellets was generally lower than 6 mm due to larger pellet size (Fig. 4).
- SEC was found to vary in the range of 38-120 kWh/t.

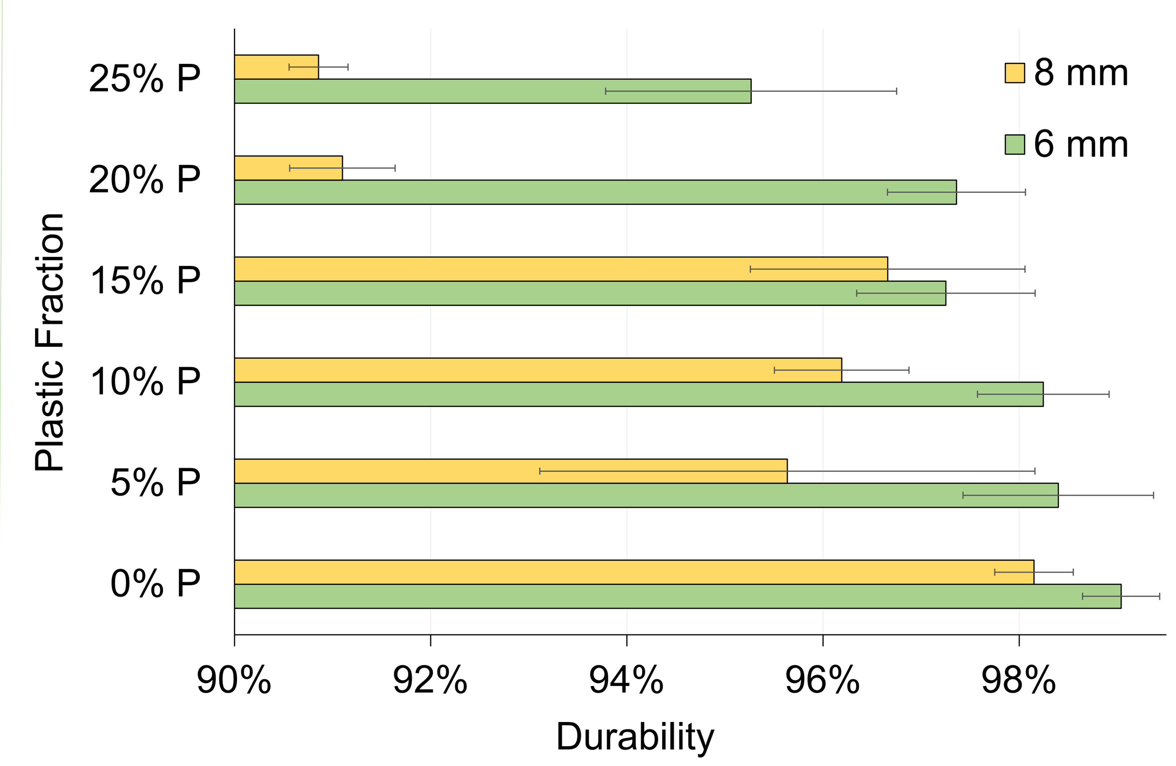


*Figure 3. Durability of different blends. Error bars represent standard deviation*

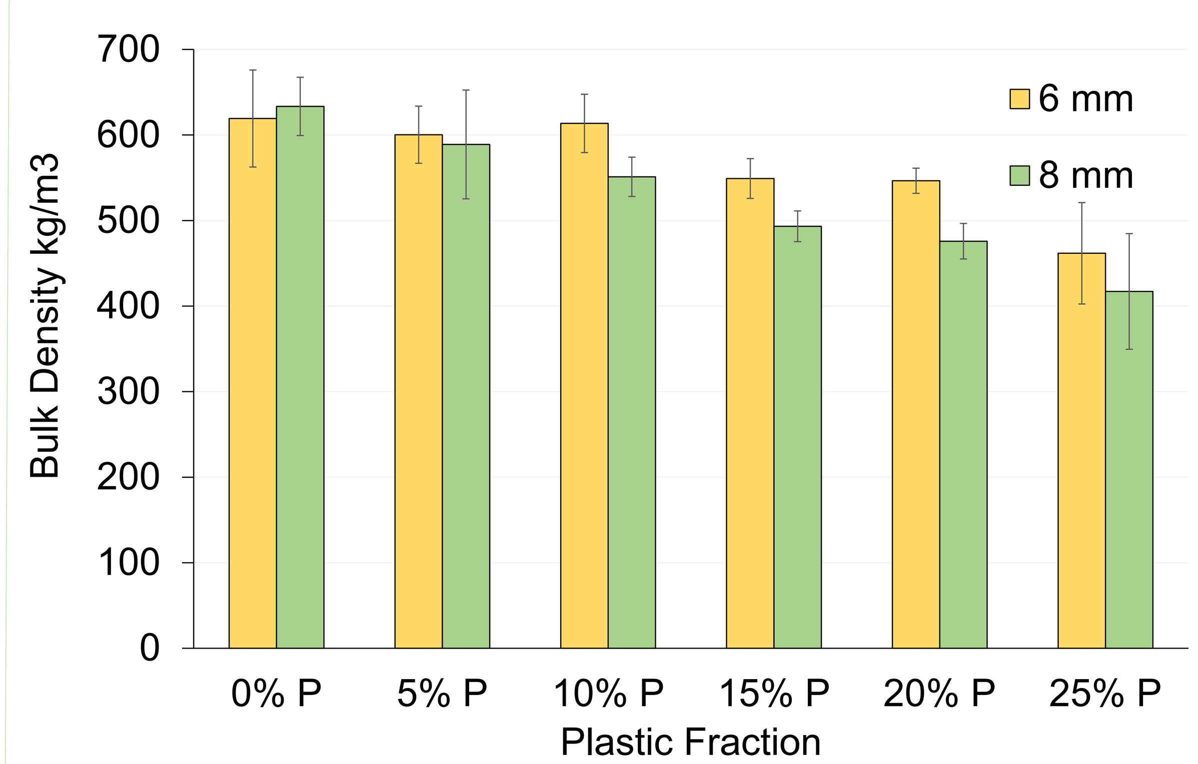


*Figure 4. Bulk density of different blends. Error bars represent standard deviation*

### TECHNO-ECONOMIC ANALYSIS

- Operating cost ($/t pellets) was found to be $72-105/t
- Stover delivered cost accounted for 85% of operating costs (Fig. 5).
- Operating cost is most affected by stover delivered cost (Fig. 6).

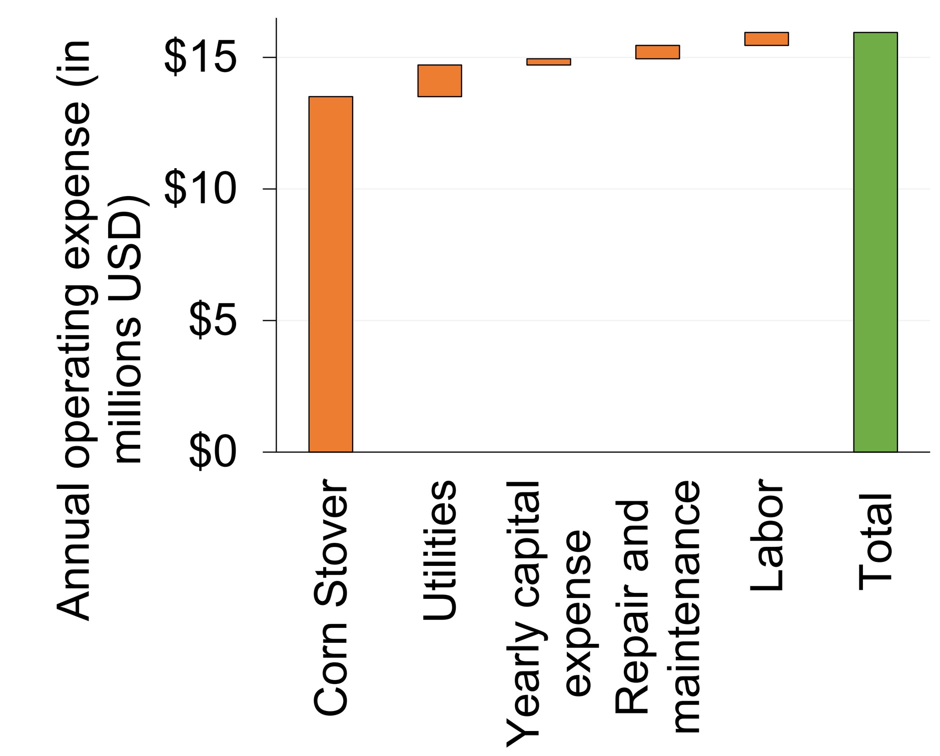


*Figure 5. Annual operating expenses*

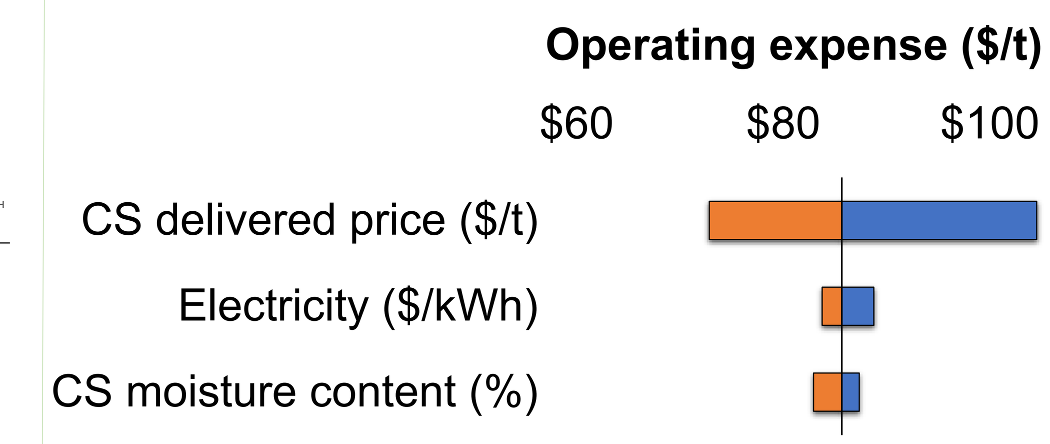


*Figure 6. Sensitivity analysis*

## CONCLUSIONS AND FUTURE WORK

- Co-pelletization of stover and HDPE for 6mm 5-20% P pellets met durability standards >96.5%[8]
- Stover-plastic pellets have potential to be used as an alternative fuel.
- Environmental impact of stover-plastic pellets will be evaluated for use in the cement sector.

## BROADER IMPACTS

- Valorization for corn stover and plastic waste
- Diversion 48,000 t/y of non-recyclable plastic from landfills
- Reduced environmental impact for the cement industry

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THE OHIO STATE UNIVERSITY

COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

[1]Department of Food, Agricultural, and Biological Engineering

*Corresponding author: shah.971@osu.edu; stockham.7@osu.edu