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Corn Stover Degradation in Field-Edge Storage and Implications for Feedstock Cost to Lignocellulosic Biorefineries

Introduction

- The feedstock contribution to ethanol production cost (FCEPC) is 33% for cellulosic refineries using ag residues or energy crops that require aggregation (Jacques, 2016).
- Beyond equipment and operations optimization, field edge (FE) storage has potential to reduce feedstock supply chain cost, roughly $21/ton. Storing bales on the same field as harvested eliminates storage site prep and transportation to storage. (Darr, 2014).

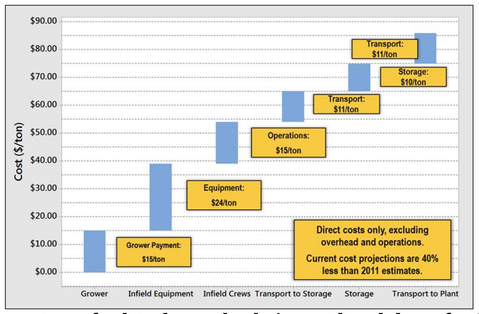

Figure 1: Corn stover feedstock supply chain cost breakdown for 2014 harvest (Darr, 2014)

- The influence of FE storage on material degradation and biomass quality is unknown. This research evaluates the level of degradation with lessened protection and assesses the tradeoff in FCEPC (1) between reduced storage cost and increased cost with material degradation for FE storage.

$$FCEPC = \frac{\$Cost_{HST}}{1\ Ton_{DM_i}} * \frac{1\ Ton_{DM_i}}{Ton_{DM_f}} * \frac{1\ Ton_{DM_f}}{Ton_{carbohydrate}} * \frac{1\ Ton_{carbohydrate}}{Gal_{Etoh}} = \frac{\$}{Gal_{Etoh}} \quad (1)$$

Results – Measured Degradation and Cost Comparison

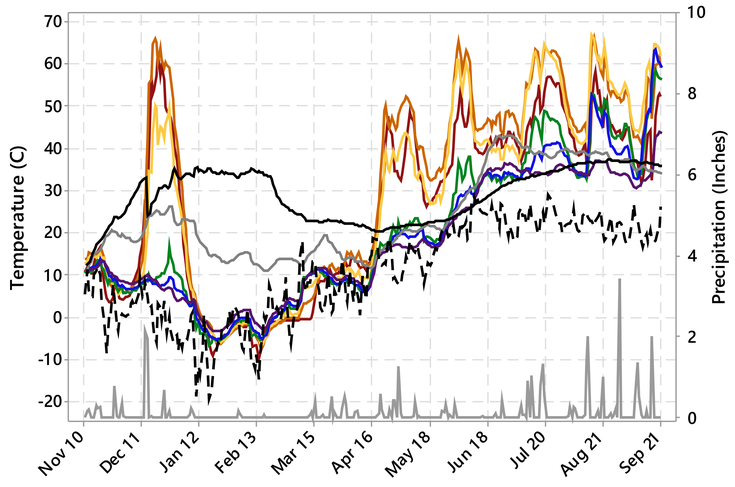

Figure 3: Vertical temperature profile for uncovered FE storage, one year

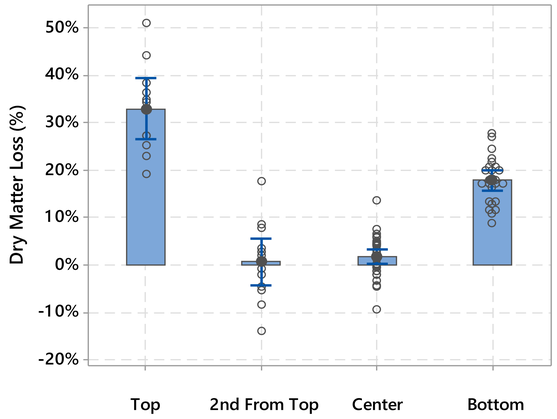

Figure 4: Dry matter loss by vertical bale location for uncovered FE storage, one year

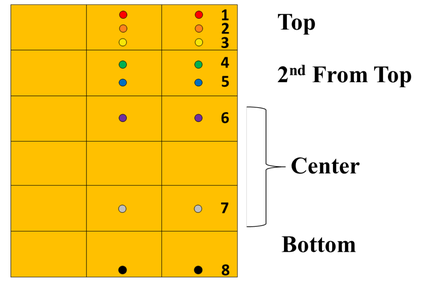

Figure 5: Vertical locations of bales & thermistors

$$FCEPC = \frac{Cost_{HST}}{300\ (BCC_i - DML)(Yield_{Etoh})}$$

where

FCEPC = feedstock contribution to ethanol production cost ($ gal-1)

$Cost_{HST}$ = cost to harvest, store, and transport one ton of biomass ($ ton^{-1})

BCC_i = initial biomass carbohydrate concentration (fractional)

DML = dry matter loss (fractional)

$Yield_{Etoh}$= reaction product yield ratio (fractional)

*300 represents a constant conversion of volume to mass (gal ton^{-1})

Table 1: FCEPC cost comparison for uncovered FE storage to protected storage

FCEPC Parameters	Protected Storage (Transported to satellite location)	FE Uncovered (All bales make to plant)	FE Uncovered (Loose top bales)	FE Uncovered (Loose top and bottom bales)
	Input Assumptions	Input Assumptions	Input Assumptions	Input Assumptions
$Cost_{HST}$	$86	$65	$65	$65
BCC_i	70%	70%	70%	70%
DML	2.0%	9.5%	21.0%	35.0%
$Yield_{Etoh}$	35%	35%	35%	35%
Mass to volume	300	300	300	300
$/gal	$ 1.20	$ 1.02	$ 1.26	$ 1.77
Annual FCEPC *	$ 36,100,000	$ 30,700,000	$ 37,900,000	$ 53,100,000

Methods

- Commercial scale field-edge stacks were assembled with large square bales harvested in 2015.
- To monitor real-time response to environmental conditions, stacks were instrumented with thermistor logging systems, used to develop vertical temperature profiles.
- Average bale moisture contents and bale weights were captured during stack assembly and deconstruction to assess moisture migration and determine the percent dry matter loss (DML) in all vertical locations of the stack.
- All dry matter loss is assumed to be loss of carbohydrate components of lignocellulose and the FCEPC was used to monetarily compare uncovered FE storage to protected storage

Figure 2: Stack assembly with commercial stacker

Conclusions

- Exposed top and bottom bales absorb significant moisture, experience large amounts of dry matter loss, and loose bale integrity.
- Center bales are relatively stable in storage and should be maximized in number.
- If all material is transported and processed at a biorefinery, uncovered field-edge storage has potential to reduce the FCEPC by $0.18/ gal, saving a plant $5.4M annually.
- Limitations in handling and processing of degraded bales at a biorefinery increases the FCEPC of field-edge storage, and makes it more costly than protected storage.

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References

Darr, M. J. (2014). Corn Stover Feedstock Supply Chain Cost Reduction Report to DuPont Cellulosic Ethanol.

Jacques, C. (2016, February 24). Raizen Has Lowest Price as Cellulosic Ethanol Hinges on Feedstock Cost. Lux Research, Inc. Boston, MA.