Integrating dry matter losses and direct gas emissions during biomass storage into life cycle inventory models of switchgrass- and Miscanthus-based ethanol production

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Introduction

Switchgrass & Miscanthus are two of the most promising cellulosic feedstocks in the US. Handling, storage, and processing of the two grasses are often assumed to be equivalent despite differences in stalk characteristics. Feedstock storage losses are a major concern, but often not included in life cycle analysis. Prior work shows that losses may have substantial effects on fuel net energy & GHGs. Direct emissions of non-CO\textsubscript{2} greenhouse gases (GHGs) could substantially increase life cycle fuel emissions. Laboratory-scale bales have been shown to approximate large bale storage, a valuable tool to compare storage conditions.

Biomass Storage

Switchgrass & Miscanthus were cut and bagged on 19 November 2011, allowed to air-dry indoors to desired moisture levels before storage. 116 bales pressed and tied by hand; 143 bales stored in insulated boxes indoors at 23° C; 22 bales stored in airtight canisters under 9 temperature & moisture combinations. Bales in boxes were weighed at 30-day intervals, with \( \frac{1}{3} \) bales removed for moisture & dry matter at 30 and 60 days; \( \frac{2}{3} \) removed at 90 days. Airtight canisters contained oversaturated salt solutions to control moisture, and stored at 4°, 24°, or 40° C. Gas samples taken from canisters every 2-8 days over 62 days and re-aerated to prevent oxygen depletion. Gas samples tested for CO\textsubscript{2}, CH\textsubscript{4}, and N\textsubscript{2}O by GC.

Results

Drying rates of switchgrass (orange) and Miscanthus (green) bales in box storage. Miscanthus dried more quickly than switchgrass (\( p < 0.0001 \)), and denser bales dried more slowly (\( p = 0.024 \)). Solid lines indicate higher density bales. Each point \( n = 3 \) or 6.

Net GHG emissions from switchgrass- (orange) and Miscanthus-based (green) ethanol production. Solid lines use default IPCC values for direct N2O emissions from biomass, open lines use measured emissions rates from this study. Modeled using a preliminary draft of the GREET model including biomass harvest & storage losses.

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Conclusions

Stalk breakage during harvest and baling may make Miscanthus faster drying. N\textsubscript{2}O and CH\textsubscript{4} emissions from biomass may be lower than IPCC values for soil and fertilizer emission rates, reducing GHG emissions. Storage losses may have relatively minor effects on cellulose ethanol regulation under the US RFS.

Laboratory-scale bales are a useful tool to study the effects of storage conditions on biomass. However, they are highly labor-intensive and sensitive to local humidity & temperature.

Differences in calibration of the scale used for initial mass and sample mass measurements resulted in the appearance of mass gain (negative DM loss). Trends, correlations, and comparisons between Miscanthus and switchgrass are still valid on a relative basis. However, absolute values of DM loss or predictions of DM loss cannot be made from these data.

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