Bioenergy Recovery Scheme for Industrial Starch Crop and Associated Co-products

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Abstract

Strategic and sustainable agricultural practices not only require innovative crop selection that will produce maximum yields with minimal resources, but also a zero-waste mentality. In order to maximize both soil and land potential, every ounce of biomass within a crop should contribute to food, fuel or restoration of soil fertility. The sweetpotato crop produces starchy roots and nutritious green tops that are both valuable end-products in regards to food or fuel. From a bioenergy perspective, even damaged or diseased roots have significant value through methane recovery. The objectives of this research were to evaluate the bioenergy potential of the products/co-products associated with an industrial sweetpotato crop (CX-1) and develop a bioenergy recovery scheme based on agronomic yields. The ethanol yield was determined for the roots and methane yields were determined for three co-products, namely the aerial vines, culls, and stillage (byproduct of ethanol production). Methanogenic batch assays conducted in triplicate at 35˚C for 40 days revealed methane yields (L of methane per kg of volatile solids added) of 305 ± 9 (vines), 364 ± 7 (culls), and 446 ± 6 (stillage). Results showed that one acre of CX-1 sweetpotatoes has the potential to produce nearly 250 gallons of ethanol and nearly 50,000 MJ from methane gas. While 20-40% of the energy would be necessary for the cultivation, transport and conversion of sweetpotato into ethanol (range dependent on conversion efficiencies), the remaining 60-80% represents excess energy that could be used for other purposes such as direct heat and/or electricity.

Introduction

- Sweetpotatoes are a promising feedstock for bioethanol production in Florida because they have high productivity in tropical/subtropical climates and require minimal irrigation and fertilization
- Industrial sweetpotatoes, such as CX-1, have higher starch and dry matter content than table varieties [1]
- Co-products associated with the sweetpotato crop include:
  - Aerial vines
  - Culls (rotten or diseased roots)
  - Stillage (when roots are utilized for ethanol production)

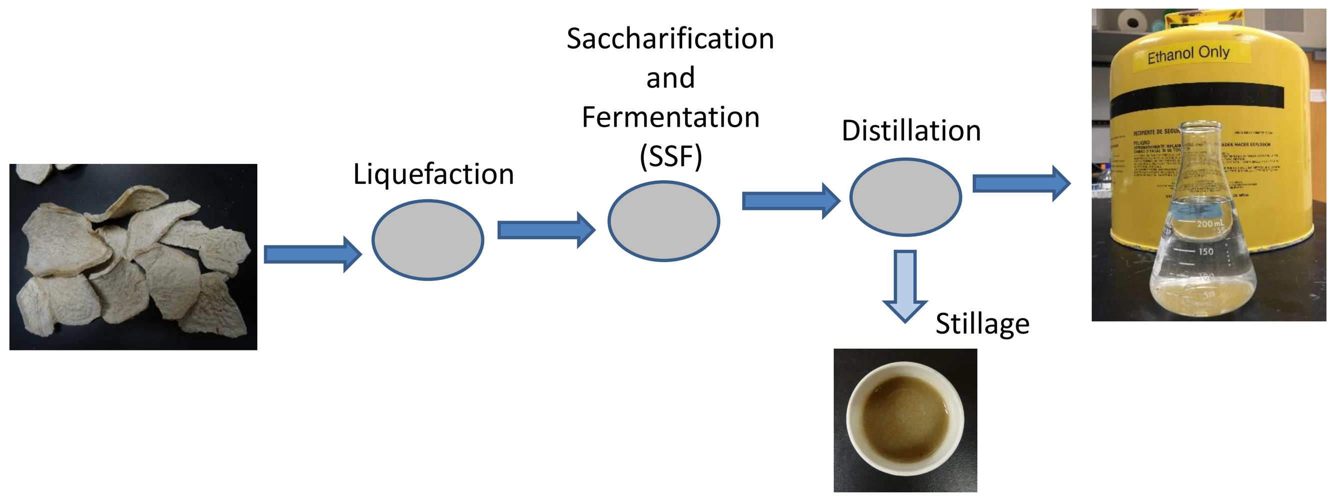


Figure 1. Bioethanol Production from Sweetpotato

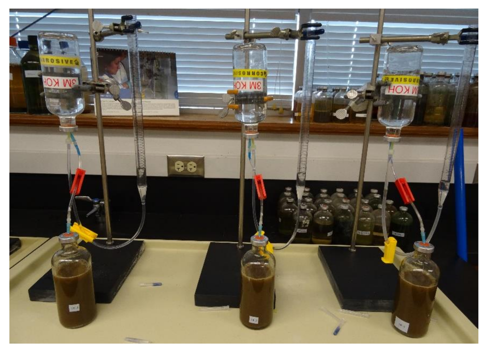
Objective

Incorporate agronomic yields from the CX-1 sweetpotato crop with methane yields from associated co-products to determine the overall net energy balance when utilizing this crop for bioethanol production

Methods

- Conducted two-year field trial to determine agronomic yields of CX-1 roots, culls and vines
- Determined bioethanol yield through conversion of dry CX-1 roots into ethanol (conducted at the National Corn to Ethanol Research Center)
- Conducted methane index potential assays on associated co-products including the stillage, culls and vines to determine methane yields
  - Triplicate batch assays
  - 40 days at 35˚C
- Assimilated results into net energy balance to determine overall bioenergy recovery opportunity from both ethanol and methane production

Cultivation and Harvest of CX-1 Sweetpotato



Methane Index Potential Assays

Results

Table 1. Average Agronomic Yields from Two-Year Field Trial

Feedstock	Agronomic yield (t/ac)	Agronomic yield (dry t/ac)
Roots + Culls	13.3	3.3
Culls	5.1	1.1
Vines [2]	20.8	2.9

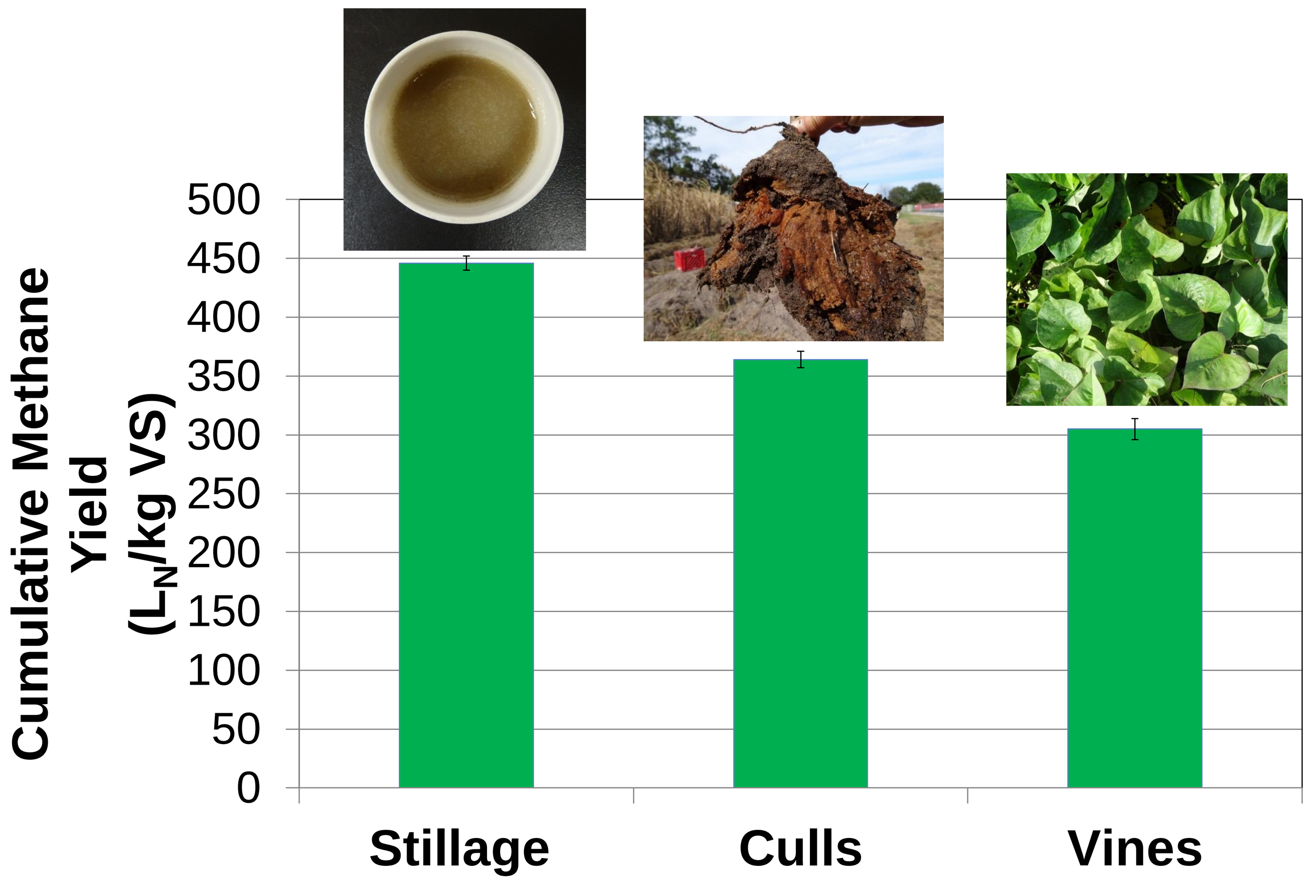


Figure 2. Cumulative Methane Yields from CX-1 Sweetpotato Co-Products

Stillage generated from the fermentation/distillation process consists of intermediary products (i.e. volatile fatty acids) for anaerobic digestion and is thus easily converted into methane. The fresh vines have a higher proportion of structural carbohydrates such as fiber and lignin than culls and stillage, and these are less easily digested than non-structural carbohydrates such as sugar and starch.

Results

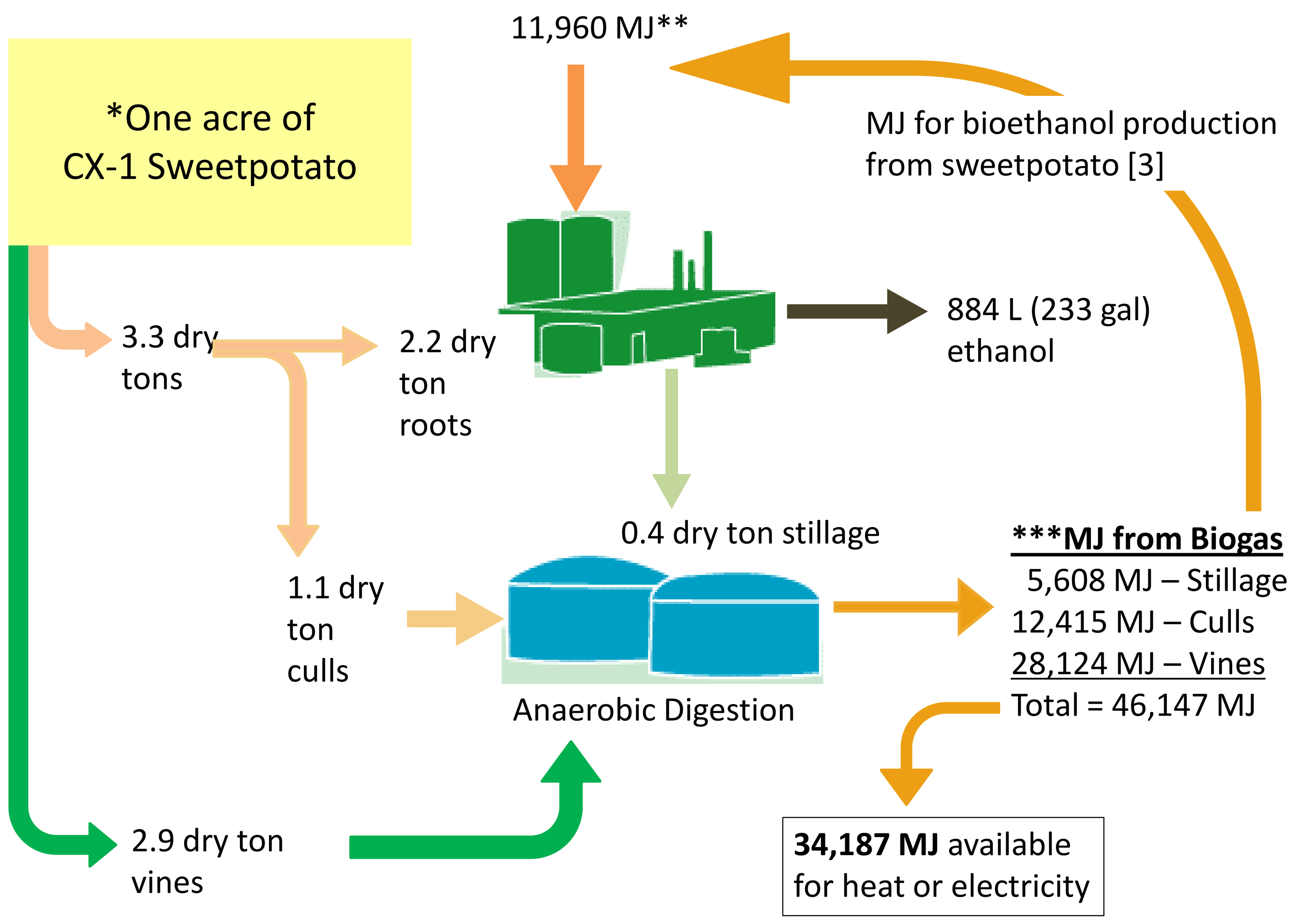


Figure 3. Bioenergy Recovery Scheme for CX-1 Sweetpotato and Associated Co-Products

* Agronomic data based on two-year average from UF Field Trial (2014-2016)

** This energy value incorporates all aspects of using sweetpotato for ethanol production including cultivation/harvest, transport and conversion

***Energy conversion from measured methane yields ($50.1 kJ/gCH_4 \times 16 g/mol \times 1 mol/22.4 LCH_4 \times LCH_4/dry\ ton$)

Based on the agronomic productivity and bioethanol conversion efficiency of the CX-1 crop, an estimated 233 gallons of ethanol could be produced from one acre. The vines contribute the most significant fraction (61%) of bioenergy recovery from the three co-products, despite their lower methane yield. Wang et al. (2013) reported that 13.53 MJ/L were required for the production of sweetpotato bioethanol, which includes energy for cultivation, harvest, transportation and conversion to ethanol [3]. This amounts to approximately 25% of the total energy that could be recovered from the associated co-products via anaerobic digestion.

Conclusions

- Complete utilization of the CX-1 sweetpotato crop is possible through ethanol production from the starchy roots (233 gal/acre) and methane recovery from stillage, culls and aerial vines (46 GJ/acre).
- Although the vines have a slightly lower methane yield than the other co-products, they contribute over 60% of the energy that can be recovered from co-products because of their high agronomic yields.
- A net positive energy balance is feasible when co-products are used for methane recovery.

References

[1] Mussoline, W.A., Wilkie, A.C. (2015). Anaerobic digestion potential of coproducts associated with ethanol production from sweetpotato: A review. *Industrial Biotechnology, 11(2), 113-126.*

[2] Mussoline, W.A., Wilkie, A.C. (2016). Feed and fuel: the dual-purpose advantage of an industrial sweetpotato. *Journal of the Science of Food and Agriculture*, epub. DOI: 10.1002/jsfa.7902

[3] Wang, M., Shi, Y., Xia, X., Li, D., Chen, Q. (2013). Life-cycle energy efficiency and environmental impacts of bioethanol production from sweet potato. *Bioresource Technology*, 133, 285-292.

Acknowledgements

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