The Effect of Particle Size on Methane Potential of Sugarcane Bagasse

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Abstract

Agricultural residues can be used to produce second-generation biofuels. However, their woody texture presents challenges to biodegradation. Sugarcane bagasse is a lignocellulosic residue that can be converted into bioethanol, but requires extensive pretreatment with high temperature, pressure and chemical additions for effective fermentation. Anaerobic digestion is an alternative conversion technology that produces methane gas, but also has limitations with lignocellulosics. The initial conversion of complex biomass into simple sugars (i.e. hydrolysis) is considered the rate-limiting step because the lignin component prevents microbial access to the degradable fractions of the feedstock. The objective of this research was to determine the impact of particle size on methane production from sugarcane bagasse. Sugarcane bagasse was dried and milled to two particle sizes (2mm and 0.85mm). Methane index potential batch assays were conducted at mesophilic (35ºC) temperature, in triplicate. Positive controls with glucose and cellulose reached 98% and 91%, respectively, of the theoretical methane yield, demonstrating the efficacy of the inoculum. The average methane production from sugarcane bagasse only reached 57% of the theoretical yield, emphasizing restricted hydrolysis from the presence of lignin. However, minimal pretreatment, 2mm to 0.85mm particle-size reduction, increased methane production from sugarcane bagasse by 9% over a 20-day digestion period.

Introduction

Agricultural waste from the sugar cane industry is widely available and can be used as a renewable resource. Sugarcane bagasse (SCB) can be converted to electricity by recovering heat through incineration, but cleaner and more efficient energy recovery processes are being sought. Anaerobic digestion is a viable option but the lignocellulosic challenge must be overcome. SCB consists of approximately 50% cellulose, 25% hemicellulose and 25% lignin (Pandey et al., 2012). The lignin content creates a barrier for microbial conversion, and particle size reduction is one way to break this barrier and expose more degradable components such as cellulose to the microbes. This research investigates the impact of particle size reduction, a physical pretreatment, as a means to improve degradation and enhance methane production from SCB.

Objectives

- Determine how much methane can be produced from SCB using methane index potential (MIP) assays.
- Determine if particle size can improve the rate and yield of methane production.

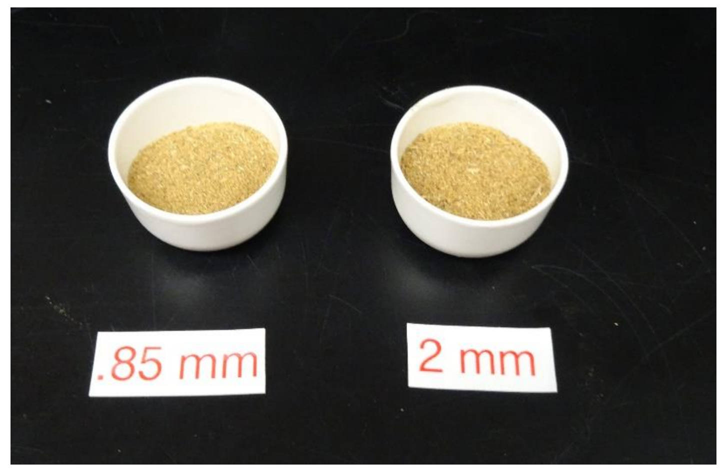

Figure 1. SCB particle sizes

Figure 2. MIP set-up

Methods

- Feedstock preparation
  - Harvested cane, extracted juice, shredded and dried residual bagasse, milled to 2mm and 0.85mm.
- Feedstock characterization
  - Measured pH, brix, chemical oxygen demand (COD), total solids (TS), and volatile solids (VS).
- MIP batch assays
  - lab-scale (in triplicates)
  - mesophilic (35°C) conditions
  - 20-day digestion period
  - Inoculum was mixture of digested flush dairy manure and anaerobic granules from a pulp and paper mill facility

Figure 3. Grinding Samples with Wiley Mill

Figure 4. Ground SCB

Results

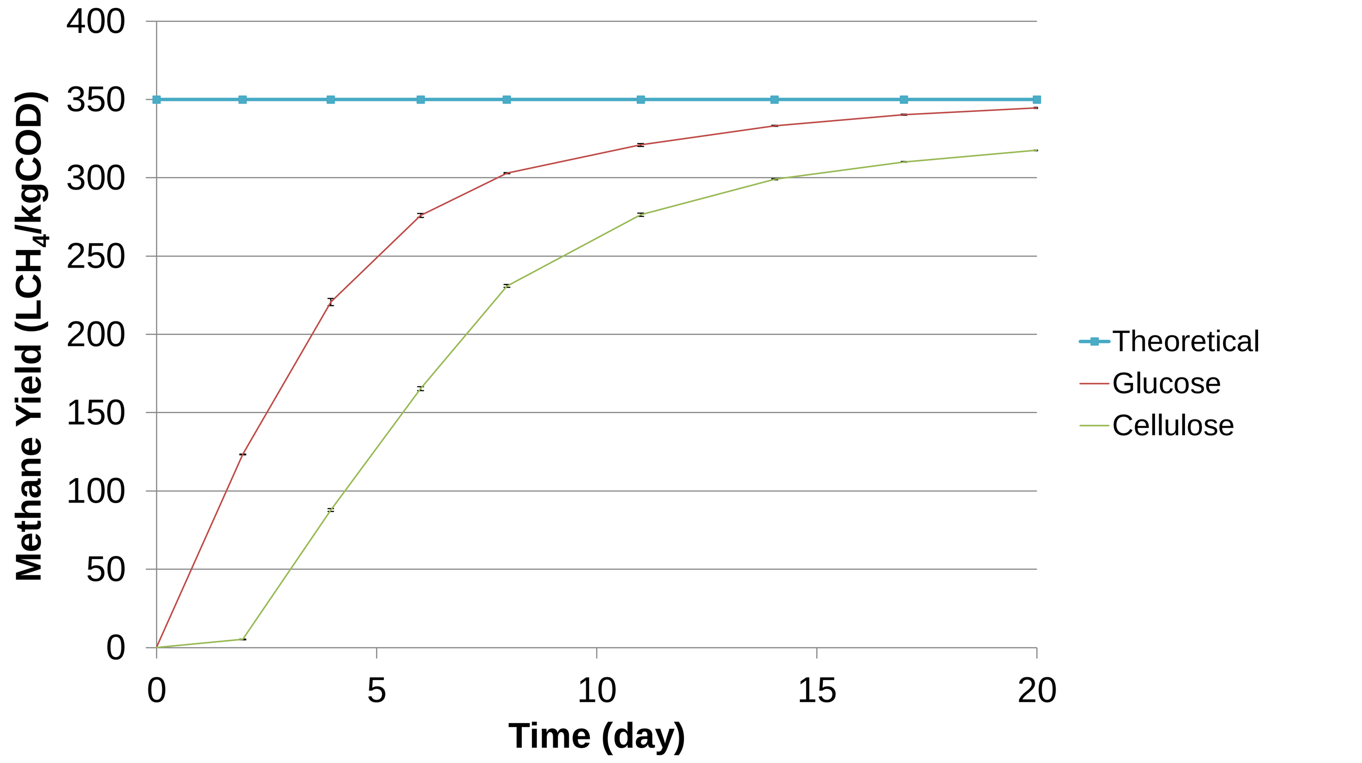

Figure 5. Methane yield for Control Assays

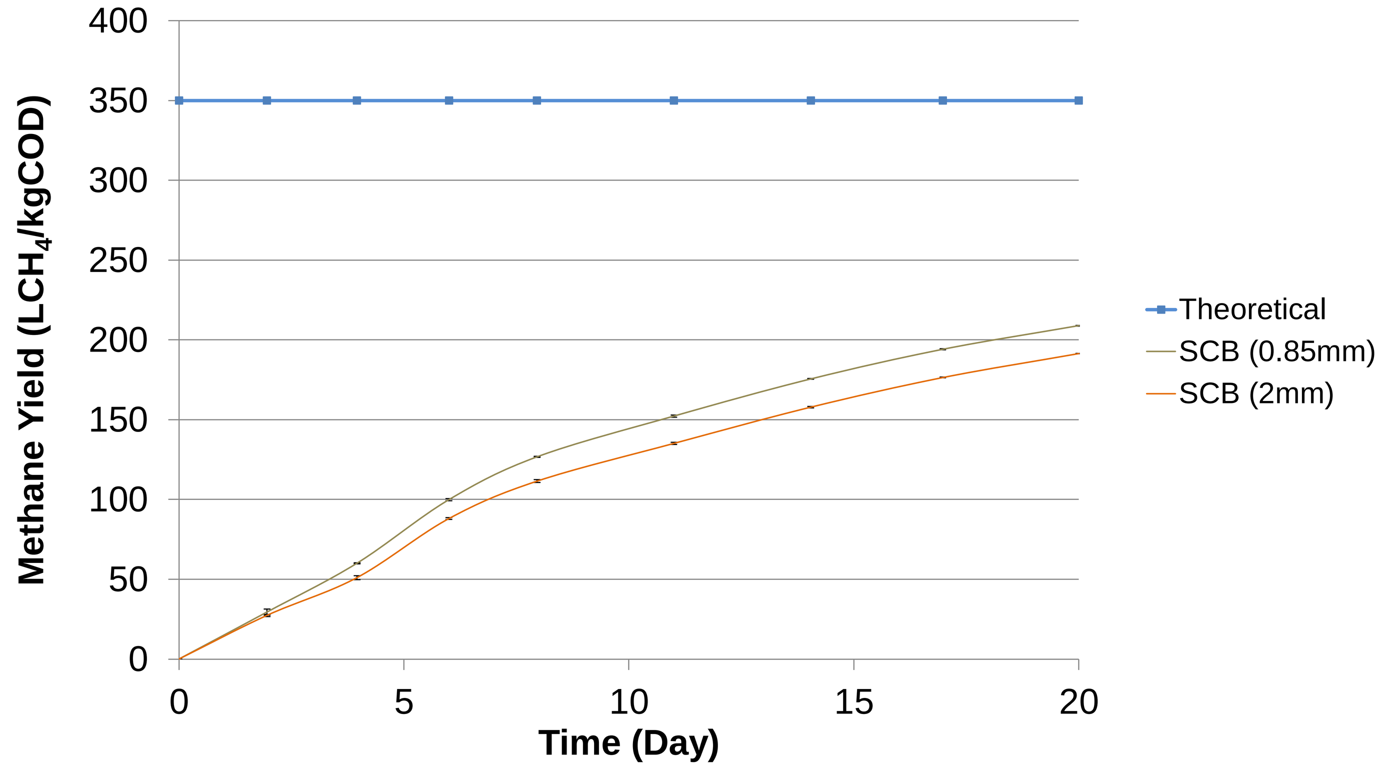

Figure 6. Methane yield for SCB

Results

Glucose and cellulose were used as positive controls to confirm the efficacy of the chosen inoculum. Glucose and cellulose reached 98% and 91%, respectively, of their theoretical methane yields in 20 days. On the contrary, the SCB only reached between 55 and 60% of the theoretical yield, thus emphasizing the restricted hydrolysis associated with the lignocellulosic material. The results showed that by reducing the particle size of SCB from 2mm to 0.85mm, the overall methane yield increased from 191 to 209 LCH_4/kgCOD (9.4% increase) after 20 days. Similar results were obtained for barley straw, another lignocellulosic feedstock. When particle size of barley straw was reduced from 20mm to 5mm, overall methane yield increased from 339 to 370 LCH_4/kgVS (9.1% increase) after 60 days (Menardo et al., 2012). In addition, the energy required to reduce the particle size of the straw was less than the energy gained from the higher methane production, so size reduction was recommended for large scale applications (Menardo et al., 2012). Particle size reduction is a practical approach for farm-scale operations to increase methane production from agricultural residues since shredders are often available for other agricultural operations on a farm.

Conclusions

- While positive controls of glucose and cellulose reached well over 90% of the theoretical methane yield in 20 days, the SCB reached between 55 and 60% of the theoretical yield, thus emphasizing the restricted hydrolysis associated with the lignocellulosic material.
- Reducing the particle size of SCB by 58% increases the overall methane production by nearly 10%.
- The net gain in methane production can offset the energy required for particle size reduction.

Future Work

Future work could involve more MIP assays that evaluate SCB at larger sizes, such as 4mm and 8mm, in order to establish whether or not there is a specific correlation coefficient that can be applied to determine methane yield from various particle sizes of SCB.

References

1. Pandey, V. K., M. P. Singh, et al. (2012). "Biodegradation of sugarcane bagasse by Pleurotus citrinopileatus." Cell Mol Biol (Noisy-le-grand) 58(1): 8-14.
2. Menardo, S., G. Airoldi, et al. (2012). "The effect of particle size and thermal pre-treatment on the methane yield of four agricultural by-products." Bioresour Technol 104: 708-714.

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