A PILOT STUDY- COTTON GIN TRASH TO ETHANOL

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Abstract

Cotton gin trash (CGT) collected from Australian cotton gins was evaluated for bioethanol production. A detailed compositional profiling of CGT reveals variation between ginning samples and a unique profile consisting of elevated extractive fractions (26-28%), lignins (17-22%) and holocellulose (41-51%). Process conditions for converting CGT to fermentable sugars were experimentally optimised using multifactorial experimental designs. Process optimisation revealed CGT fibre required pretreatment at 180˚C in 0.8% H_2SO_4 for 12 min to maximise glucose recoveries by enzymatic cellulose hydrolysis. The highest ethanol productivity by yeast fermentations yielded 147 L ethanol/ metric tonne.

Introduction

Australia's self-sufficiency in crude oil and refined petroleum products is forecast to drop from 48% in 2011 to <20% by 2020. In 2011, this corresponded to trade deficit of $18 billion which is predicted to rise (BP Energy Review, 2012). Ethanol from renewable feedstocks is regarded as an ideal supplement and credible replacement fuel. However, Australia's current ethanol production of 350ML only contributes to < 0.2% of petrol consumption. By 2015, ethanol production capacity is forecast to double to >890ML due to growing demand. Expansion in ethanol currently produced from starches and sugars (1st generation ethanol) is seen as unsustainable because it competes with food and fibre production and does not significantly reduce GHG emissions associated with transport. These shortcomings can be addressed in part by producing 2nd generation ethanol from lignocellulose feedstocks, such as residues/ wastes from agricultural and forestry activities.

Significant research in emerging lignocellulosic technologies is underway in many countries (USA, Brazil, Europe, China & India) in anticipation of approaching commercial reality. These ethanol technologies are principally designed for resident biomass feedstocks at hand (principally sugarcane bagasse, corn and rice trash). Only two small scale commercial ventures, narrowly focusing on sugarcane bagasse and ethanol are being developed in Australia. A viable biobased industry in Australia needs to consider other feedstocks including local agricultural and forestry residues.

Agro-based industries including cotton production generate several million tonnes of waste and for most handling, storage and disposal options add considerable cost to production. Cotton gin trash (CGT) from the ginning process is a centrally stockpiled resource with unique compositional attributes making it ideal as a low-cost biomass feedstock for regional biorefineries. By converting this waste into fuels (ethanol) and higher valued products the cotton industry is positioned to gain benefit in cost reductions associated with disposal practices (including GHG emissions) in addition to gaining access to new markets and opportunities along the cotton processing value chain.

The aim of this study is to investigate the use of CGT as a bioproducts feedstock in order to eliminate traditional disposal management issues in addition to adding value to industry by-products. Specifically, the project aims to provide technical insight and an assessment of the process associated in the conversion of CGT into sugars and subsequently into biofuels (ethanol) via fermentation.

Methodology

The aim of this project is to determine the effectiveness of biochemical pretreatment options for processing CGT into sugars and subsequently fermenting resulting sugar streams into ethanol. Specifically, the research will focus on critical processing stages 2, 3 and 4 (described in Figure 1) and identify key conversion parameters and their relationship to each other throughout the processing stages. The investigation is best summarised by the following objectives:

1. Describe a complete compositional profile of CGT
2. Determining the role of critical processing parameters (acid strength, temperature, residence time and enzyme concentration) and optimise the recovery of sugars.
3. Evaluate fermentation potential of recovered CGT sugar hydrolysates;

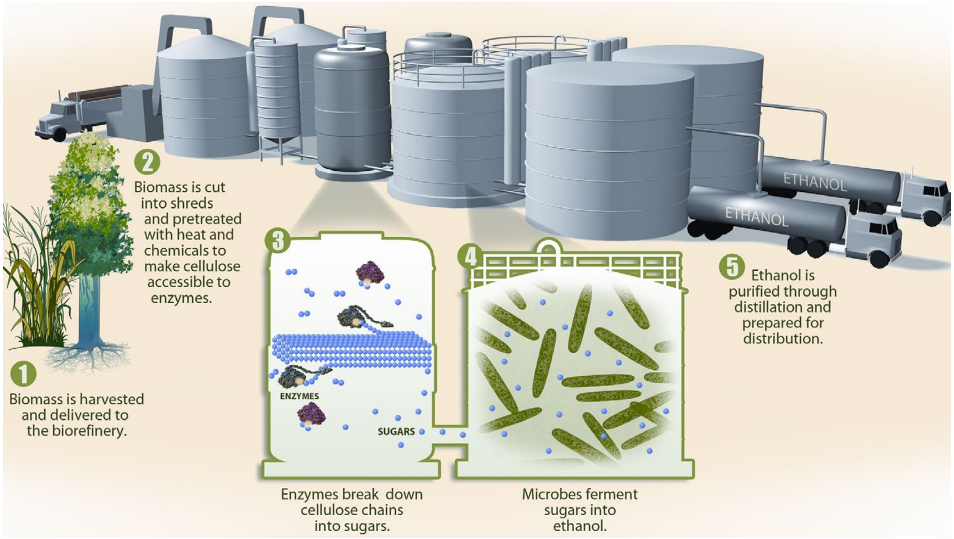

FIGURE 1. Lignocellulose to ethanol conversion steps. (1) Biomass harvesting and delivery. (2) Thermal and/or chemical pretreatment separates cellulose from lignin seal and exposes it to enzymatic digestion. (3) Enzyme mix is added to digest cellulose into simple sugars. (4) Microbes produce ethanol by fermenting recovered sugars. (5) Ethanol is distilled and concentrated. Graphics by U.S. DEG Programs (http://genomics.energy.gov).

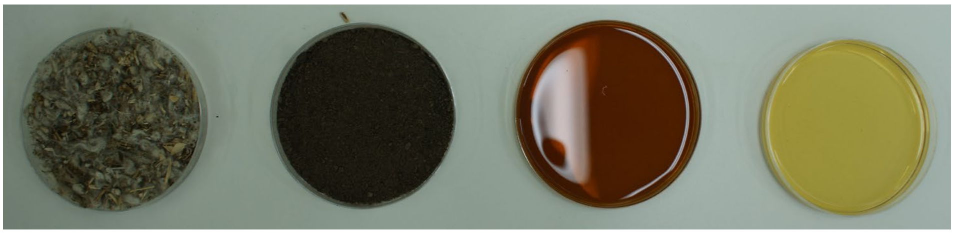

FIGURE 2. Bioprocessing CGT to sugars and ethanol. Panels from L-R are: Raw CGT; Pretreated CGT; Recovered sugar hydrolysate; Post fermentation beer.

Results

Composition of cotton gin trash.

In the first stage of processing it is essential to identify the composition of the CGT biomass. This is crucial to understanding the overall utility of CGT and for specifically tailoring the bioprocessing strategies.

Outcomes:

- CGT is uniquely different in composition to most other agricultural residues in that it consists of a heterogeneous mixture of different plant components mainly, cotton stems, leaves, motes, burrs, lint and seeds. The proportion of these may vary substantially and affect its overall utility.
- The composition of CGT reveals a relatively high extractive content at 26 to 28% compared to other herbaceous crops like wheat straw (18%) and corn stover (10%) (McIntosh et al (2011)). Likewise, the acid-insoluble lignin content (17.9- 22.8%) are more comparable to hardwoods like eucalyptus (McIntosh et al. 2012)). The total carbohydrate content ranged from 41 to 51% with glucan representing about 24 to 36% and correlated well with total cotton fibre content. These compositional estimates reveal that CGT is unique to other biomass feedstocks in that its characteristics are between those of herbaceous crop residues (like cereal straws) and woody type feedstocks.

Bioprocessing CGT to sugars and ethanol

The critical stages in bioprocessing CGT feedstocks are in the recovery of sugars (mainly glucose) and fermentation to ethanol (process streams are shown in Figure 2). To recover composite sugars the CGT must be fractionated by processes of pretreatment followed by further digestion using enzymes. Using dilute acid at elevated temperature is a well documented pretreatment method for fractionating lignocellulosic substrates. Previous processing studies of agroforestry biomass have established that pretreatment variables such as temperature, acid concentration and residence time play a critical role in dictating the efficiency of enzymatic digestion and recovery of fermentable sugars. Furthermore, optimised process conditions must also minimise degradation reactions and production of undesirable toxic compounds. These compounds generally lead to an unfavourable environment for microbial growth resulting in low ethanol titres and productivities, and potentially require removal via an expensive detoxification step.

Outcomes:

- According to the model, the optimal pretreatment conditions are comprised of 0.8% H_2SO_4 at 180°C with a holding time of 12 min.
- A maximum glucose release of 273 mg/g was achieved represents a glucose yield of ~ 60%.
- Further improvements in process configuration and optimisation of enzymatic digestion increased glucose recoveries to about 88% of the theoretical maximum.
- Glucose produced under optimised conditions was rapidly fermented by industrial yeast in about 6-8h with an ethanol yield of approximately 147 L / metric tonne CGT.

- This also demonstrates that the levels of toxic compounds produced during the optimised pretreatment phase are within the yeast's tolerance level and that no expensive detoxification processing steps are required.

Conclusion

Outcomes from this study demonstrate that CGT is a viable resource for producing low cost sugars and subsequently bioethanol. However, further research is required to explore the full potential of CGT and demonstrate the technical and economic viability of commercial scale bioprocessing. The use of CGT as a bioproducts feedstock will eliminate traditional industry issues surrounding disposal costs and potential pollution problems associated with landfilling and composting. Likewise, the development of new processing technologies and establishing new value along the cotton process chain will improve the competitiveness, sustainability and profitability of Australia cotton farming systems.

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References

BP Energy Review, 2011. Statistical Review of World Energy June 2011 – BP. www.bp.com/en/...bp/energy.../statistical-review-of-world-energy.html.

McIntosh S, Vancov T, 2011. *Optimisation of dilute alkaline pretreatment for enzymatic saccharification of wheat straw.* Biomass Bioener. 35:3094-3103.

McIntosh S, Vancov T, Palmer J, Spain M, 2012. *Ethanol production from Eucalyptus plantation thinnings*. Bioresour. Technol. 110:264-272.

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