DEMONSTRATION OF CELLULOSIC ETHANOL PRODUCTION FROM SUGARCANE BAGASSE IN AUSTRALIA: THE MACKAY RENEWABLE BIOCOMMODITIES PILOT PLANT

By

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Abstract

The ready availability of sugarcane bagasse at an existing industrial facility and the potential availability of extra fibre through trash collection make sugarcane fibre the best candidate for early stage commercialisation of cellulosic ethanol technologies. The commercialisation of cellulosic ethanol technologies in the sugar industry requires both development of novel technologies and the assessment of these technologies at a pre-commercial scale.

In 2007, the Queensland University of Technology (QUT) received funding from the Australian and Queensland Governments to construct a pilot research and development facility for the production of bioethanol and other renewable biocommodities from biomass including sugarcane bagasse. This facility has been built on the site of the Racecourse Sugar Mill in Mackay, Queensland and is known as the Mackay Renewable Biocommodities Pilot Plant (MRBPP). This research facility is capable of processing cellulosic biomass by a variety of pretreatment technologies and includes equipment for enzymatic saccharification, fermentation and distillation to produce ethanol. Lignin and fermentation co-products can also be produced in the pilot facility.

Introduction

As a result of the increasing scarcity of crude oil, rising oil prices and concerns about the geopolitical concentration of remaining oil reserves, many countries are now seeking alternative energy sources for transport fuels. The need for transport fuels that are renewable and sustainable and have low greenhouse gas emissions is also underpinning the development of new fuel production technologies.

Second generation biofuels utilise non-food feedstocks for bioethanol production. Materials considered for second generation biofuel production are generally lower value feedstocks, including crops grown on marginal agricultural land or underutilised biomass residues of existing agricultural crops such as sugarcane bagasse.

Sugarcane bagasse is a complex mixture of cellulose, hemicellulose and lignin with minor amounts of ash, proteins, lipids and extractives. The cellulose and hemicellulose components of sugarcane bagasse can be pretreated, hydrolysed and fermented with varying efficiencies into ethanol (IEA, 2004; Olsson *et al.*, 2005).

Pilot plants are an essential tool for the development of new technologies, bridging the gap between laboratory research and commercial application. Pilot plants are used to optimise key process parameters such as yield, rate and efficiency at a scale much larger than that used for laboratory development and in equipment that mimics large scale industrial facilities. These plants allow key process economics to be evaluated and provide information on both the robustness of the process and scale-up data for the design of the commercial facility. Pilot plants also provide the opportunity to produce a significant amount of product for pre-commercial testing.

In Australia, the Queensland University of Technology (QUT) has constructed a pilot research and development biorefinery for the production of biofuels and other renewable biocommodities from biomass including sugarcane bagasse. In a biorefinery, bagasse is typically fractionated into its major component streams and value is added to each component through the production of multiple co-products, such as bioethanol, compounds derived from lignin, specialty sugars, organic acids, fermentation products and energy products including biodiesel, hydrogen and methane (Figure 1).

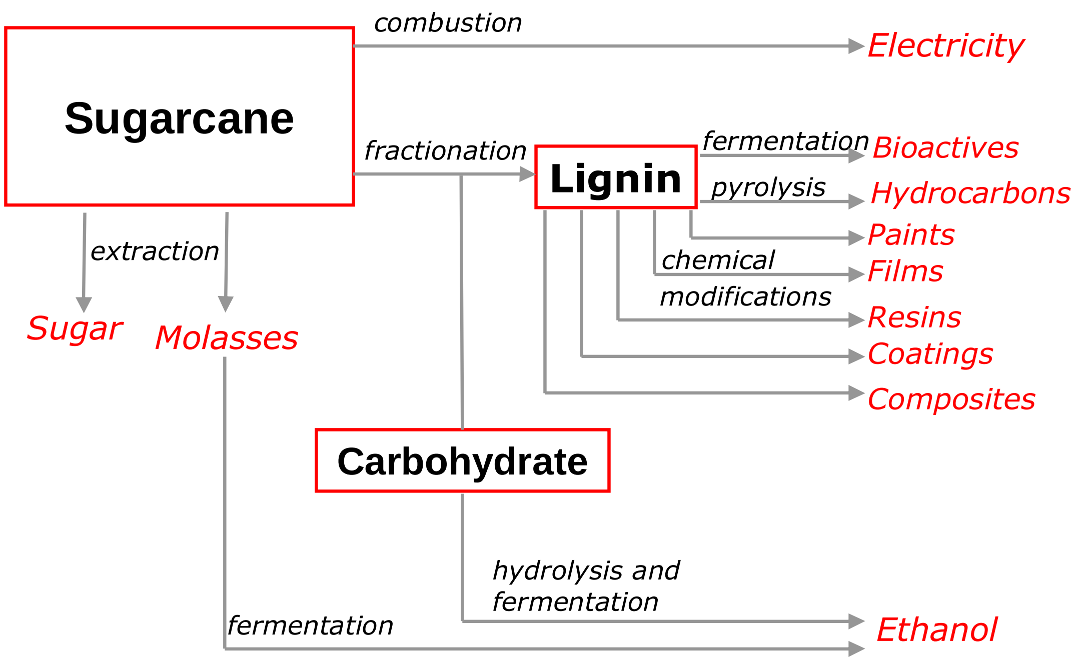

Fig. 1 – A typical concept drawing for a sugarcane biorefinery

The Mackay Renewable Biocommodities Pilot Plant

The Mackay Renewable Biocommodities Pilot Plant (MRBPP) has been funded jointly by the Queensland Government, the Australian Government and QUT. Queensland Government funding was provided through the Innovation Building Fund which was established to promote the development of research infrastructure for science and technology in Queensland. Under the Australian Government National Collaborative Research Infrastructure Strategy funding conditions, facilities are made available by the host organisations for both public and private sector research. The priority and cost of access is determined in accordance with an Access and Pricing Code, and access for meritorious, eligible research is provided at a subsidised rate to enhance facility usage.

The MRBPP has been built at the Mackay Sugar Limited (MSL) Racecourse Mill in Mackay, Queensland. Mackay is a major sugarcane producing region in Australia, with this region producing around 10 million tonnes of sugarcane per annum. Co-location on the site of a sugar factory allows the facility ready access to feedstocks for the process (bagasse, juice and molasses) and enables the utilisation of essential services from the Racecourse Mill site.

Key elements of the facility include site infrastructure consisting of the main factory building, office and laboratory facilities, plant and equipment and facility labour. Plant and equipment includes bagasse handling, pretreatment, saccharification, fermentation and ethanol purification and concentration. Laboratory process development units are available including a Mettler Toledo RCe1 reaction calorimeter with on-line infra-red detection. This unit enables the development of comprehensive chemical reaction kinetic information.

Plant and equipment for the MRBPP facility has been selected to be capable of demonstrating a range of biorefinery processes (such as that shown in Figure 2). The major pretreatment reactor has been designed and manufactured by Andritz Inc and is a Hastelloy two-stage batch reactor capable of processing a range of biomass feedstocks, and demonstrating several pretreatment processes. These processes include pretreatment using both alkaline and dilute acid processes at temperatures up to 230^{o}C and pressures to 26 bar. Further, the equipment will enable the fibrous material to be "exploded" out of the reactor in the rapid depressurisation process known as steam explosion. Providing the flexibility to simulate a range of pretreatment processes maximises the value of the facility both to the research community and to potential industry partners.

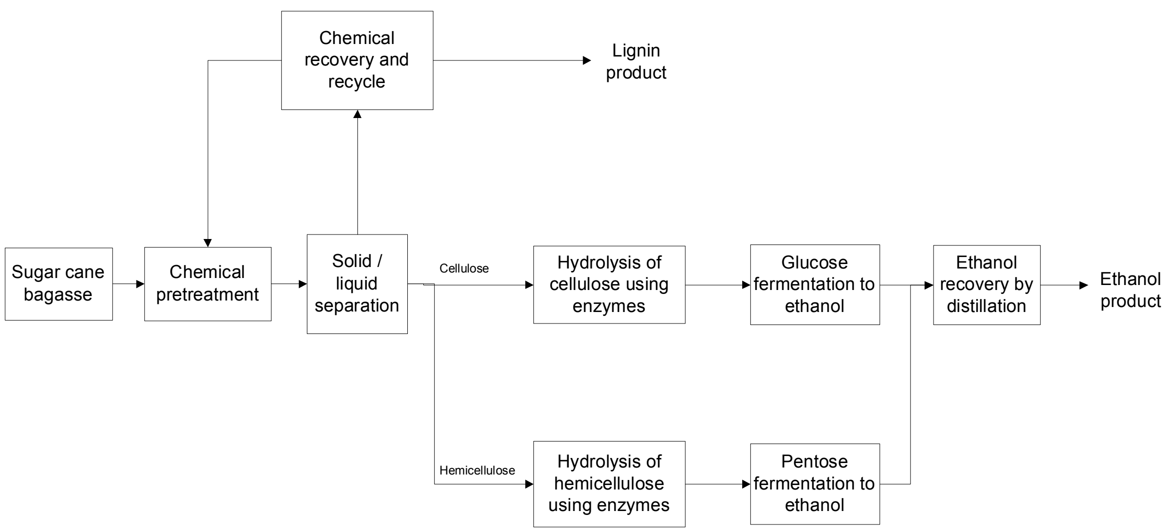

Fig. 2 - Typical biorefinery process diagram

Glucose and pentose fermentation to ethanol will be undertaken in a range of fermenters of varying scales up to 10 000 L. The MRBPP facility has been designed with an enclosed fermentation facility, capable of being certified to physical containment level 2 (PC2). This containment level will enable the facility to trial a range of fermentation organisms, including recombinant organisms that have been modified for enhanced pentose fermentation capability. Ethanol produced in the pilot plant will be concentrated using a distillation column to produce a hydrous ethanol product.

One of the key co-products from the biorefinery is lignin – an aromatic polymer with many valuable properties. Research work at QUT and through the Cooperative Research Centre for Sugar Industry Innovation through Biotechnology (CRC-SIIB) has investigated a range of potential uses for lignin including as a phenol substitute in phenol-formaldehyde resins, as a water-borne barrier coating and as a component of lignin-PF films and biocomposite materials (Doherty *et al.*, 2007). The pilot plant includes equipment for both the delignification of biomass and the subsequent recovery and purification of lignin. The purified lignin is able to be produced in significant quantities to enable further product development and testing.

Conclusion

The MRBPP is valuable research and development infrastructure for both the international sugarcane research community and future biomass-based industries. This facility provides unique infrastructure for biomass utilisation research, particularly focussed upon the enzymatic conversion of cellulose into ethanol in an integrated biorefinery. Additionally, the ability to produce novel co-products such as lignin allows opportunities for large scale product development and testing.

The MRBPP has sufficient flexibility to undertake trials on fermentation technologies based on sugar, molasses and bioethanol process streams to manufacture organic acids and other products. Further chemical derivatisation and transformations are also possible dependent upon process conditions.

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REFERENCES

Doherty W., Halley P., Edye L., Rogers D., Cardona F., Park Y. and Woo T. (2007). Studies on polymers and composites from lignin and fiber derived from sugar cane. Polymers for Advanced Technologies, 18: 673-678.

IEA (2004). Biofuels for transport - an international perspective. (OECD / IEA: Paris).

Olsson L., Jorgensen H., Krogh K.B.R. and Roca C. (2005). Bioethanol production from lignocellulosic material. In: Dimitriu, S. (eds). Polysaccharides: Structural diversity and functional versatility. 957-994. Marcel Dekkar: New York.