Australian Government
Department of Agriculture, Water and the Environment

A profitable future for Australian agriculture

Biorefineries for higher-value animal feeds, chemicals, and fuels

Sugar Research Australia Limited

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This summary is an excerpt from the final report, with minor edits made to ensure it meets departmental style and accessibility requirements.

Summary

Australian agriculture is constantly changing to meet the challenge of rising production costs, climate variability, pests and disease, compliance costs, and changing global patterns of production and consumption. Biorefineries turn primary products, off-specification primary products, and low value or waste by-products from agriculture into higher value bioproducts.

The global bioeconomy is creating new markets for agricultural producers and supporting the value of existing crop products and supply chains. Biorefinery development is an important way that Australian agriculture can ensure it remains profitable.

The Biorefineries for Profit project began in 2016 with a goal of establishing profitable bioproduct technologies for the Australian sugar, cotton, forestry, and pork industries. The project has developed technologies to turn agricultural waste into high-value products including animal feeds, chemicals, and advanced fuels. The project has also built the value-chain knowledge and human/organisational capacity needed to capture future biorefinery opportunities for Australian agriculture.

The project consisted of four topics, each with multiple activities, as supported by partners from the sugar, cotton, forestry and wood products and pork industries.

Topic one: Animal feeds for greater profitability

Activity 2.1 Develop technologies for the use of sugarcane products as animal feed ingredients

This activity developed new technologies that increased the nutritional value of sugarcane products (primarily bagasse and trash) in animal feeds and increased the potential use of sugarcane by-products as animal feed ingredients. Key outputs and achievements were:

- development and demonstration of technology to increase digestibility of sugarcane bagasse to the same level as high-quality fodder in cattle rumen fluid trials

- identification of a low cost, commercially available additive to sugarcane bagasse pre-treatment that increased the rate of fibre digestion by cattle
- development and demonstration of technology to produce sugarcane bagasse-based liquid sugar products with a total sugar content like molasses and containing up to 10% prebiotic xylooligosaccharides
- assessment of filamentous fungi and demonstration that they could grow in liquid culture using high-xylose syrup produced from sugarcane bagasse or in solid-state fermentation on raw or pre-treated sugarcane bagasse.

Activity 2.2 Develop feed supplements for enhanced nutritional characteristics of sugarcane-based animal feeds

This activity developed a technology pipeline for the discovery, production and optimisation of animal feed supplements (for example, enzymes and probiotics) that work with sugarcane-based animal feed ingredients to improve their nutritional value in livestock feed applications. Key outputs and achievements were:

- Stored sugarcane bagasse has been demonstrated as a valuable resource for the discovery of novel microbes and enzymes with applications in the industrial biotechnology sector – for example, biofuels, animal feed ingredients, and animal feed supplements.
- The established and characterised microbial collection from sugarcane bagasse created in this project is a novel resource for new and improved enzymes, probiotics, metabolites and nutritional supplements.
- From this collection, Bacillus strains with probiotic characteristics were identified with the five lead candidate strains cultured in scalable fermentation systems. Results from preliminary poultry feed trials suggest the strains are safe and provide nutritional benefits compared to commercial products.
- Thermophilic fungi species with lignin degrading characteristics and other species with xylanase and other industrial enzyme activities have been discovered with potential commercial applications.

Topic two: Specialty chemicals and fuels

Activity 3.1 Develop technologies for the production of chemicals and pharmaceuticals from cotton wastes

This activity developed new technologies to convert cotton residues into an intermediate chemical product (5-chloromethylfurfual; CMF) and subsequent high value molecules with potential application as pharmaceutical precursors, adhesives and other products. Key outputs and achievements were:

- development of a reactor for the continuous production of CMF, from cotton gin trash, mote and other biomass feedstocks and the demonstration and optimisation of this process to reduce operating costs of the technology
- development and demonstration of a novel process for the recovery, purification and crystallisation of CMF for improved stability, storage and transportability of the product
- discovery and development of a new process to produce the valuable product 5-bromo-phalide (a direct pharmaceutical precursor) from CMF

- discovery and demonstration of new pathways to produce commercially relevant plasticisers, adhesives, and flavour and fragrance molecules from CMF

Activity 3.2 Develop technologies for producing fermentable sugars and fuel ethanol from cotton gin trash

This activity developed new technologies for the conversion of cotton gin trash into sugars suitable for fermentation into ethanol and other fermentation products. Key outputs and achievements were:

- development and optimisation of a process for sequential dilute acid two stage pre-treatment of cotton gin trash
- development of a fed-batch simultaneous saccharification and fermentation strategy capable of handling higher steam exploded solid loadings with high conversion efficiency
- demonstration of the process at pilot scale exploiting optimised pre-treatment conditions and fed-batch simultaneous saccharification and fermentation operations.

Topic three: Advanced fuels from sugarcane biomass

Activity 4 Develop technologies for the production of advanced fuels from sugarcane biomass

This activity aimed to develop technology to convert carbohydrates from sugarcane by-products into oils via the use of filamentous fungi fermentation systems and optimise the productivity and yield of oil production for use as fuels. The project demonstrated the production of bio-oils from sugarcane molasses at pilot scale and the upgrading of these oils via hydrothermal liquefaction. Key outputs and achievements were:

- Sugarcane molasses was shown to be a suitable carbon source for the production of microbial oils with only minimal supplementation with inorganic nitrogen and phosphate sources.
- Microbial oil production was successfully scaled-up to 1000 L bioreactor scale at the Mackay Renewable Biocommodities Pilot Plant.
- A hydrothermal liquefaction process was demonstrated to produce high oil yields for processing of the fungal biomass into bio-oils.
- Several novel yeast strains were identified for the production of microbial oils and co-products from molasses.

Topic four: Pathways to biorefinery development

Activity 5.1 Assess factors influencing biorefining innovation and adoption in the Australian sugar milling industry

This activity aimed to assess the factors influencing biorefinery innovation and innovation adoption in enhancing the competitive position of the Australian sugar milling industry within the global value chain. The activity undertook an analysis of the Australian biofuels technological innovation system. The analysis took the form of an historical narrative, grounded in a qualitative event analysis. Key factors influencing the biorefining innovation system were identified and a series of recommendations were made to inform future activities.

Activity 5.2 Develop opportunities for biorefinery innovation in the forest and wood products industries

This activity assessed biorefinery value chain opportunities and feasible technologies for biorefinery innovation in the forest and wood product industries. The activity has identified regions in Australia best suited to the profitable integration of biorefineries based primarily upon forestry and wood product feedstocks. A new database has been developed which contains both historical annual primary production (volume of logs harvested) data as well as projected primary production for 2020, 2030 and 2050. The raw data has been collected and the corresponding biomass availability has been estimated on a state-by-state basis. This state-based data has been aggregated so that national figures are also available. The potential for biorefining technology based on forest and wood product feedstocks to mitigate against increasing production costs, increased competition from imports and variable construction sector activity has been shown in this study to be significant.

Collaboration with project partners has been critical to the success of the project and offered the opportunity to develop, transfer and deliver outcomes. A key project strength was the ability to access pilot scale facilities through project partners enabling rapid demonstration of technologies.

Extension and adoption activities are critical to ensure adoption of technologies resulting from research outcomes. Communication and extension activities included promotion of project achievements at industry-specific conferences and regional seminars for the cotton, sugar, forestry and pork industries, the broader farming community, external partner organisations and the wider community.