

Project report: Production of Generation 2 Ethanol, High Nutrition Feed and Green Coal from Sugarcane Bagasse



Lead organisation: Microbiogen Pty Ltd

Project commencement and completion date: November 2009 – April 2012

Project summary

This project addresses the need to develop a cost-effective method of producing second generation ethanol from inedible food crops and materials rather than using the current methods that rely on food crops to produce first generation ethanol. In the near future energy and food security are set to become the major global issues that will need to be addressed in response to population growth and the rapid industrialisation of third world economies.

Inedible plant materials, known as lignocellulosic biomass, are low cost and in plentiful supply. However, the conversion of lignocellulosic materials into biofuels such as ethanol requires more complex technology than that used for first generation ethanol sources.

To facilitate this, the project developed advanced yeast catalysts and a second-generation bio-refinery process. The specialised yeast was created through a 10 year program utilising unique, proprietary breeding technology to maximise the amount of sugar converted from lignocellulosic biomass into valuable co-products

The project's second generation bio-refinery concept, Fuel AND Food, converted the material into fuel ethanol, high nutrition animal feed and an environmentally friendly potential substitute for coal. It was estimated that the process could deliver next generation ethanol at a profit today with a minimum ethanol selling price (MESP) of 52 to 67 cents a litre.

The project was funded through the Second Generation Biofuels Research and Development (Gen 2) Program, which supported the research, development and demonstration of new biofuel technologies and feed-stocks that address the sustainable development of an advanced biofuels industry in Australia.

Project scope

Microbiogen (MBG) has been developing unique yeast catalysts and a bio-refinery process for converting inedible plant material (lignocellulosic biomass) into fuel ethanol, high-nutrition animal feed, and a product that is an environmentally friendly substitute for coal. By producing these three saleable materials, the majority of the material is converted into income-generating products, and the bio-refinery produces both liquid and solid fuels. In addition, by producing sustainable renewable fuels and high nutrition animal feed from inedible plant biomass, the production of renewable fuels using this technology can help strengthen food security rather than diminish it.

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A challenge to affordable production of yeast is the cost of molasses (the main ingredient used by the yeast industry) with its price tripling over the past six years. MBG's patented yeasts can grow on the biomass derived sugar xylose instead of the food sugars derived from molasses. This can open up global markets, with the new yeasts competing in the established feed yeast market (worth approximately \$500 million) and also potentially competing in soymeal and fishmeal markets worth over \$80 billion/year globally.

The project included a US National Renewable Energy Laboratory (NREL) assessment of Microbiogen's technical and economic feasibility analysis of its own Feed AND Fuel concept.

Outcomes

Key findings

- Technical feasibility of Fuel AND Food concept

The model shows that for a facility processing 2,000 dry tonnes of bagasse per day, the Fuel AND Food Biorefinery will produce more than 131 million litres of ethanol and 117,000 tonnes of dried high nutrition feed yeast at 50% crude protein, along with 152,000 tonnes of green coal.

- Economic feasibility of Fuel AND Food concept

The fixed capital investment was \$374 million, and the annual operating cost was estimated to be \$186 million. The major production cost after feedstock is the cost of purchasing enzymes, with 22 million litres required per annum. The next major component is the cost of aeration during propagation. Reducing the aeration or enzyme usage by half would equate to a 12-15% reduction in operating costs, respectively. MBG's enzyme partner has recently released a new product that significantly reduces cost in use for second generation biomass hydrolysis. Meanwhile advances in MBG's strain development program have resulted in yeast strains with higher yields and productivities than those modelled in the Gen 2 project. Once validated, these recent developments should translate into even lower process costs.

The minimum ethanol selling price (MESP) is the value per litre at which ethanol from the facility can be sold at a 10% return on investment, obtained over the 30 year life of the project. This includes income taxes but excludes any subsidies. Based on observed yields and productivities the MESP for the Fuel AND Food base case is \$0.67/litre. When optimisation of yields and the aeration requirements are taken into account next generation ethanol can be made profitably for an MESP of \$0.52 – \$0.67c per litre.

Just as the viability of current starch or sugarcane ethanol is very much reliant on the sale of the distiller's grains or export of co-generation power, the MESP for Fuel AND Food is reliant on the cost of selling the green coal at \$90/tonne and feed yeast at \$700/tonne. These by-products make up 7% and 42% respectively of the revenue with the remaining income attributed to the sale of the ethanol itself. Assuming a Fuel AND Food Biorefinery was in operation since January 2010 and its ethanol sold at market value, this venture would have been profitable if the feed yeast was sold at US\$700 – \$1,200 per tonne. This value sits comfortably between two large established feed markets, those being soymeal (48% crude protein) at 178 million tonnes per annum and fishmeal (65% crude protein) at five million tonnes per annum. In the current market aerobically propagated high nutrition feed yeast sells at a significant premium to both soymeal and fishmeal.

Products, patents (applied/granted) and publications produced as part of the project

The yeasts of the species *Saccharomyces cerevisiae* evolved and developed by Microbiogen that can utilise the wood sugar xylose are covered by a broad ranging patent. To date the patent has been granted in 31 jurisdictions (PCT/AU 2009/00527). No genetic engineering technology was used in their generation and they have retained their non-GMO status.

MBG's robust non-GM yeasts are also attracting interest from other industrial biotechnology companies engaged in genetic engineering yeast for the production of advanced fuels and value added chemicals. To date MBG has executed a license and research agreement with US firm Amyris with respect to

engineering MBG base strains for the production of Biofene. The new yeast strains developed by Microbiogen also open the potential of adding value to current generation biofuel waste streams by growing on the non-sugar wastes and significantly upgrading average unit values of the biorefinery products. MBG is working with companies in the US, Europe and Japan.

Effectiveness

Primarily, Microbiogen has demonstrated that its technology is able to produce second generation ethanol in a cost-effective manner which does not impact upon food security and world food prices. In addition, the co-products of Microbiogen's Fuel AND Food bio-refinery concept respond to the challenges of supplying feed yeast as a supplement for livestock (Australia imports 550,000 tonnes of soymeal per annum with a majority used by the poultry, swine and dairy industries) and reducing the impacts of coal-based energy generation.

The Fuel AND Food model is attractive for areas such as the Mackay region which is home to 1% of Queensland's 12 million head of beef cattle, as well as three active sugar cane mills. As shown by Kollaras et al. (2011) if 80% of Mackay's bagasse was diverted from co-gen power production and into a Fuel AND Food process, where green coal would still be used within existing power production, the proposed facility would produce 110ML of ethanol and enough feed yeast to nourish the entire cattle herd in the Mackay region. Therefore, this would significantly increase the value per hectare of land harvested, than if the bagasse was used for power generation alone. As well, *Saccharomyces* provides a more nutritional feed additive in comparison to soymeal alone. Based on UN Food and Agriculture Organisation estimates of human population growth and associated protein requirements for 2050, over 20,000 of the modelled bio-refineries would be needed to provide the yeast needed to meet projected increase in demand for animal feed.

In terms of the benefits of green coal, Australia is the largest exporter of black coal in the world, accounting for one-third of the world's exports with sales of \$36 billion in 2010. A single Fuel AND Food Biorefinery would only produce enough solid fuel to substitute less than 0.05% of current Australian coal exports. In order to substitute 5% of these exports we would need over a hundred Fuel AND Food bio-refineries in operation, which in turn would produce 13.1 billion litres of ethanol and 12 million tonnes of feed yeast.

Transferability

MBG is already collaborating with a range of domestic and international groups to determine the efficacy of MBG technology. In Australia, with respect to eucalypt biomass in areas such as Northern NSW where significant forestry resources are available for exploitation, a project is being explored. If successful the project will demonstrate the flexibility, robustness and transferability MBG technology to other biomass resources and pre-treatment processes. In other areas, MBG is working with the Japanese to determine its effectiveness in lifting yields of ethanol and yeast from waste rice straw. The technology is also transferrable to first generation ethanol and biodiesel production enabling the yeast to "clean" the waste streams of otherwise low value non-sugar by-products and lift overall yields, sustainability and economics.

Conclusion and next steps

MBG is planning a demonstration scale trial of its Fuel AND Food Biorefinery, where possible, leveraging existing infrastructure and collaborating with a range of domestic and international partners. The project will address techno-economic modelling, pre-engineering, site selection and partner identification in terms of resources suppliers and off take partners. If successful the deployment of a knowledge based, value added industry will be one step closer to being realised.

Contact information

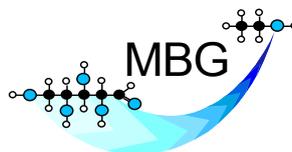
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