SRA Research Project Final Report

Biomass characterisation facility for extended stockpile model accuracy and capability: final report project 2011/049

SRA Project Code	**QUT049 (2011/049)**
Project Title	Biomass characterisation facility for extended stockpile model accuracy and capability
Key Focus Area in SRA Strategic Plan	Milling Efficiency and Technology, Product Diversification and Value Addition
Research Organisation(s)	Queensland University of Technology
Chief Investigator(s)	Dr Phil Hobson, Dr Floren Plaza
Project Objectives	This project aimed at significantly enhancing both the capabilities and accuracy of an existing computer model of bagasse stockpile behaviour as a unique predictive tool for managing the two most critical issues in any bioenergy project, namely retention of fuel quality (heating value) and avoidance of spontaneous combustion.
Milestone Number	8

Milestone Due Date	04/05/2015	**Date submitted**	01/06/2015

Reason for delay (if relevant)	There have been competing demands on key staff with the necessary skills to modify and run the model. The main stockpile model has undergone more development than had originally been anticipated and resources have had to be directed at producing error free operation rather making it more user-friendly. Opportunities to allocate alternative staff with the skills to run the model in its present form have therefore been limited. The project has involved six staff with diverse skills to carry out, analyse and document the experimental work with equipment created specially for the project, in order to provide improved data to the stockpile model. A significant amount of staff liaison has been required.
Milestone Title	Final Report
Success in achieving the objectives	☐ Completely Achieved ☒ Partly Achieved (Mostly achieved)

	☐ Not Achieved
SRA measures of success for Key Focus Area (from SRA Strategic Plan)	Adoption of improved or novel milling processes and technology.

Please cite as: Hobson P, Plaza F. 2015. Biomass characterisation facility for extended stockpile model accuracy and capability: final report project 2011/049. Sugar Research Australia Limited, Brisbane.

PART A

Section 1: Executive Summary

Two issues critical to the design and operation of stockpiles are prevention of spontaneous combustion and minimisation of loss of heating value due to deterioration. There are currently few tools available to the industry to ensure optimum management of stockpiles. The project has delivered experimental means, data and model refinements necessary to advance the capabilities of an existing model towards being a practical stockpile design and management tool for the industry.

The project has developed, from scratch, three sets of equipment to measure four important bagasse material behaviours relevant to bagasse degradation and spontaneous combustion. They are:

1. A permeability and diffusivity measuring test rig that reproduces the layered bagasse structure formed when a stockpile is built and compacted by the tracks of a bulldozer in a co-generation scenario. It has been shown that the permeability of the bagasse in the vertical direction is quite different to that along the horizontal direction. This is important since the ability of oxygen to move into the stockpile has a significant effect in the reactions occurring in the bagasse and its subsequent deterioration.
2. A large sample size calorimeter that is likely to be more representative of the behaviour of a bagasse stockpile compared to previously available equipment (many kg versus less than 20 g) to measure the heating behaviour of bagasse.
3. A degradation measuring rig was built in an incubator with the capability of measuring the behaviour of six bagasse samples simultaneously. By measuring for example the quantity of carbon dioxide given off, the percentage loss of combustible matter and fuel heating value were determined.

Some of the measurements have required the development of methods to incorporate the newly measured bagasse deterioration behaviour into the existing stockpile model, in order to improve its predictive capabilities. The model has then been exercised in different conditions to develop guidelines on reducing deterioration. For example, it has quantified the effect of bagasse compaction on deterioration. Four detailed recommendations were made.

The outputs of this project will assist in the improved design and management of large stockpiles thereby enabling year-round reliable delivery of high quality bagasse feedstock to sugar industry power and biofuel projects. A final report entitled 'Biomass characterisation facility for extended stockpile model accuracy and capability' was submitted in June 2015. The SRA key area of adoption of improved milling processes and technology has been addressed.

Section 2: Background

Understanding the behaviour of large biomass stockpiles in order to minimize degradation and the risk of spontaneous combustion is important. A previous investigation to develop a computer model that simulates the complex processes in a stockpile identified significant deficiencies in the availability of the following:

- Porosity, gas diffusivity and permeability measurements as a function of local compaction, moisture and fibre characteristics
- Reliable measurements of bagasse exothermicity as a function of oxygen concentration, moisture, temperature, fibre type and time
- Elucidation of the chemistry of low temperature bagasse oxidation processes to quantitatively determine and implement within the model factors and mechanisms influencing both oxidative reactivity and loss of fuel heating value within stockpiles.

An important objective of the work reported in this document was to find and/or develop testing equipment and methods to measure gas diffusivity and permeability as well as the exothermicity in a representative sample of bagasse. As a starting point the progress made in different industries in measuring and understanding the behaviour of stored materials was identified. The issues of bagasse degradation and spontaneous combustion have been investigated through a significant number of studies, while a large amount of research has been carried out on other materials. One of the primary aims of this project was to identify the storage conditions that impact on the loss of bagasse heating potential and to quantify the impact over time of these conditions on fuel quality and quantity. Heating potential in this context refers to the energy available from combustion due to both the quantity of dry matter in the bagasse and its associated heating value. Changes to the quantity and heating value of dry matter can be caused by either microbial activity (biotic effects) or chemical oxidation unassisted by microbial activity (abiotic effects). Further key considerations for a range of biomass types and storage scenarios were:

- aspects of biomass composition that predisposes it to decomposition;

- the nature and mechanisms of decomposition;

- the way in which decomposition is manifest in loss of dry matter and heating value and;

- methods used to characterise biomass degradation

Section 3: Outputs and Achievement of Project Objectives
Project objectives, methodology, results and discussion

See Section 7 – Conclusions of the attached (confidential) report 'Biomass characterisation facility for extended stockpile model accuracy and capability'

Section 4: Outputs and Outcomes

- Test equipment, procedures and trained staff for the measurement of four key parameters relevant to bagasse stockpile deterioration (permeability, diffusivity, exothermicity and degradation). They can be used to investigate aspects of bagasse storage for a particular sugar cane factory's circumstances and/or bagasse properties.
- An improved predictive tool that will result in changes to the design and management of large stockpiles thereby enabling improved year-round reliable delivery of high quality bagasse feedstock to sugar industry power and biofuel projects.

Section 5: Intellectual Property (IP) and Confidentiality

The IP from the project belongs to Queensland University of Technology. The outputs will remain confidential in accordance with the Research and Development Project Agreement between QUT, the syndicate of member mills and SRA.

Section 6: Industry Communication and Adoption of Outputs

The results of this project were communicated to the syndicate members at the 2012, 2013, 2014 and 2015 Regional Research Seminars. The final report includes four recommendations regarding ways in which bagasse degradation and the risk of spontaneous combustion of bagasse stockpiles can be minimised. These recommendations have already been circulated to the syndicate members in a recent report dated 31/04/2015. Further reporting to the syndicate members will be carried out at the 2016 Regional Research Seminars to be presented by QUT staff. Further communications will occur with individual sugar mill staff in an informal manner.

Section 7: Environmental Impact

There are no environment impacts associated with this final stage of the project.

It is expected that the use of the tools, findings and recommendations from this project will, in the future, result in reduced degradation of bagasse in stockpiles and a reduced likelihood of spontaneous combustion events. This is expected to result in a reduced quantity of by-products being produced from the storage of bagasse, such as acetic acid with the potential to leach into the ground or smoke that could be released into the atmosphere. Therefore the main outcomes from an environmental view will be beneficial.

Section 8: Recommendations and Future Industry Needs

An issue was found during the project during the transfer of the exothermicity data to the bagasse stockpile program in order to calibrate the model: the form and solution method of the current bagasse stockpile model was found to result in a problematic definition of the boundary conditions required. This problem proved to be particularly intractable and as yet has not been resolved despite the best efforts of senior staff members in the mathematics department and a number of postdoctoral mathematicians employed by the project to work on the problem.

A potential option is to transfer the bagasse behaviour code into open source Computational Fluid Dynamics (CFD) software, such as Openfoam, which has an inbuilt capability to solve the relevant physical behaviour as well as the capability to easily define boundary conditions for the calorimeter model. An additional advantage is that the CFD option will provide the capability of modelling a three dimensional stockpile of varying geometry with relatively easy definition of boundary conditions. For example, the CFD model could be applied to conditions where a stockpile is tarped and/or has only some surfaces covered, greatly enhancing the capability, flexibility and user friendliness of the predictive bagasse stockpile model.

It is proposed that the resolution to the boundary condition problem and the calibration of the model using the exothermicity experimental data be put forward as a QUT mathematics Honours project.

The bagasse stockpile should continue to be exercised in collaboration with factory staff in order to extract the maximum benefits from the current project.

Section 9: Publications

The below reports are confidential to the Mill syndicate, SRA and SRL:

Plaza, F. and Hobson, P. (2012). 'Biomass characterisation facility for extended stockpile model accuracy and capability -literature review and test equipment design'. QUT syndicated report.

Hobson, P., Moghaddam, L., Plaza F., and McKenzie, N. (2013). 'Biomass characterisation facility for extended stockpile model accuracy and capability'. QUT interim syndicated report.

Hobson, P. and Plaza, F. (2014). 'Summary of bagasse stockpile scenario simulation results and request for feedback'. QUT syndicated report.

Hobson, P., McKenzie, N., Plaza, F., Moghaddam, L., Baker, A. and East, C. (2015). 'Biomass characterisation facility for extended stockpile model accuracy and capability'. QUT syndicated report.