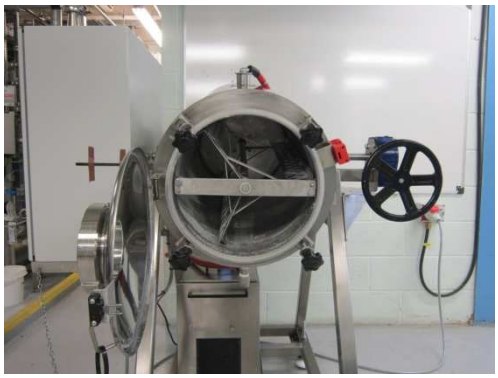
A novel biomixer design to aid efficient enzymatic hydrolysis of diverse feedstocks

Transforming household waste into an environmentally and financially valuable resource is the aim of the EU funded Waste2Go project, which seeks to valorise municipal solid waste (MSW) for social and economic benefit. The Project's main objective is the innovative transformation of the biogenic fraction of MSW, which accounts for over 55%, into chemicals with an economic value greater than its use as an energy source.

At the beginning of the project a series of trials took place, which pre-treated various waste streams in an autoclave. This produced a partially hydrolysed feedstock for the enzyme digestion. To further process the waste generated by the autoclave process, a novel engineering system for handling the viscous materials produced by the pre-treatment process have been developed to produce sufficient amounts of enzyme for small-scale digestion trials. This process and the novel biomixer design is introduced further below.

The economic viability of Industrial Biotechnology (IB) processes based on sustainable biomass feedstocks is, to a large extent, reliant on the enzymatic hydrolysis of diverse substrates (e.g. lignocellulosic biomass, paper pulp, forestry waste, cardboard, food waste) at high solids loadings (>20% w/v); which poses operational challenges. Efficient feedstock hydrolysis requires turbulent mixing which, in general, cannot be achieved with impellors in conventional stirred tank reactors, leading to sub-optimal process operations and economics.



The Biomixer developed at the Centre for Process Innovation (CPI), with a fill volume of 100 litres, overcomes many of these limitations through the application of a stainless steel horizontal drum containing a central shaft running along its length from which three radial paddles are attached. The paddles are powered by a 0.4 kW motor with an inline step down gearbox providing high torque even at low rotation speeds. This produces a lift and drop, tumbling action which ensures mixing to homogeneity for high percentage solids materials. Furthermore, the paddles, which can be easily interchanged to test new mixing strategies, have been designed for excellent performance in the presence of solids in the substrate but continue to efficiently mix the product after liquefaction has occurred.

Temperature control is essential in order to achieve optimal reaction conditions for enzymatic feedstock hydrolysis. Conventionally, mixing of high solids slurries is achieved through rotation of

the entire vessel (e.g. cement mixer) resulting in limited mechanisms for temperature adjustment, such as steam injection. In the CPI design, a water jacket capable of ramping the contents' temperature at 40°C $hour^{-1}$ is employed and can maintain isothermal conditions up to 90°C. Despite its ability to operate at high temperatures, the Biomixer is a non pressurised vessel with a range of features which permit safe operation. These include emergency stops, an interlock which prevents operation unless the hinged door is securely closed and gearing that allows the entire vessel to be tilted forwards and backwards, allowing facile loading/unloading, reducing risks involved with manual handling.

Crucially for process development and pilot work, a data recorder charts a range of Biomixer parameters including power consumption, pH, temperature and shaft rotation speed. This inline monitoring provides invaluable information for process optimisation in relation to substrate characteristics over time and overall energy efficiency. Moreover, the plug and play nature of the Biomixer design allows for new probes to be installed and their outputs recorded with a minimum of down time.

The Biomixer was taken from concept to delivery in six months enabling the Waste2Go project to process a range of substrates at high solids loadings in excess of 20% dry weight (w/v) which would not have been feasible in conventional stirred tank reactors. As such it has expedited the scale up of novel feedstock hydrolysis protocols producing C5 and C6 mono/oligosaccharides which are of significant commercial interest.

For more information on the project please visit www.waste2go.eu or contact the project coordinator, Dr Jonathan Kearney at CPI.