Biome Bioplastics: Turning biomass into plastic

BBSRC-funded research is giving waste from the paper pulp industry a new life by turning it into bioplastics. Lignin, a tough structural material from plants, is a waste product of paper manufacturing which is usually burned as fuel. Now, a team of researchers led by the University of Warwick and Biome Bioplastics Ltd have developed a biological method to extract valuable chemicals from lignin and turn them into plastic.

A new target product
Professor Bugg found the gap in the market he needed when he was approached by Paul Law, Managing Director of Biome Bioplastics. Law was interested in making bioplastics from pyridine dicarboxylic acids (PDCAs) due to their potential to build high quality, biodegradable bioplastics. "They were interested in aromatic dicarboxylic acids because having more aromatic content in plastic gives it better thermal properties. That led them to lignin as a raw material," says Bugg. In 2013 they won funding from Innovate UK to demonstrate the commercial feasibility of producing PDCAs, and therefore bioplastics, from lignin.

Together with collaborators at the University of Leeds and the Centre for Process Innovation (CPI), Bugg began engineering R. jostii to break down lignin into PDCAs using IB Catalyst funding, a joint BBSRC, EPSRC and Innovate UK initiative. "Our role was to use metabolic engineering to enhance the PDCA yield, because the challenge is to get to a point where Biome could commercialise this," explains Bugg. "It has proved quite challenging, but we are making progress.

Closing the circle
Plastic production is one of the UK’s biggest industries. It turns over more than £20 billion and exports more than £8 billion of plastic products each year. These existing links to a global market, along with the UK’s world-leading engineering biology sector and the UK Government’s aim to eliminate avoidable plastic waste by the end of 2042, means there are big opportunities in the UK for the bioplastics industry to redefine plastic production. The charity WRAP estimates that 59% of UK plastic is used for packaging, such as trays and films, and their single-use nature makes these a clear product target for bioplastics companies such as Biome Bioplastics.

The term bioplastic refers to plastic made from renewable materials, such as plant biomass, but Biome Bioplastics intend to create bioplastics that are just as eco-friendly at the end of their life. "It’s important to us that the materials we’re developing have both a nice beginning of life story and end of life story, so they’re bio-based and sustainable but also biodegradable and compostable, because that’s how we close the circle," says Krisztina Kovacs-Schreiner, Project and Business Development Manager at Biome Bioplastics.

But Krisztina is also clear that their products need to perform as well as oil-based plastics

IMPACT SUMMARY
BBSRC funding has enabled the production of bioplastics from lignin, a structural material found in plants and a by-product of the paper pulp industry. Waste lignin is usually burned as fuel, but its building blocks have a much wider range of potential uses. However, lignin itself is notoriously difficult to break down into useful chemicals.

Professor Timothy Bugg at the University of Warwick used a BBSRC Integrating Biorefining Research and Technology (IBTI) Club grant to identify a bacterial enzyme which breaks down lignin. The research led to a collaboration with Biome Bioplastics, one of the UK’s leading bioplastic developers, to turn the extracted chemicals into bioplastics. Further support from Innovate UK, EPSRC and BBSRC enabled the company to collaborate with the University of Leeds and the Centre for Process Innovation (CPI). The team are now demonstrating that lignin digestion products can be produced on a commercial scale for bioplastics production.
during their usable life to make them competitive against existing products. “The materials need to be functional and high performance, and we think that aromatic molecules [such as PDCAs] are the key to addressing this challenge,” she says. Biome Bioplastics plan to use their lignin-derived bioplastics to provide a green alternative to single-use plastics, starting with films for food packaging, and moving onto cups, trays and coffee pods.

**From burning to biorefining**

Tough, heavily treated and resistant to degradation, waste lignin from the paper pulp industry is challenging to turn into useful products without using harsh chemicals. Leftover lignin is usually burned as fuel by the paper pulping plant, otherwise it can cause environmental pollution if discarded. This means Biome Bioplastics have an opportunity to reduce pollution at both ends of their production process, by turning a waste product into something useful and eco-friendly.

“Lignin has evolved to be very tough to break down. It is inert and there are not many lignin-degrading bacteria in soil,” says Bugg. Kovacs-Schreiner adds “Lignin on its own would not break down, especially treated lignin from the paper pulping industry, which has gone through very harsh treatments. It would take thousands of years.”

Most paper pulp in Europe is produced in Scandinavia\(^12\), where the harsh environment makes lignin even less likely to biodegrade. But the remote location presents another problem for Biome Bioplastics: the potential carbon footprint of transporting biomass to the UK. Instead, their goal is to develop a process which ties neatly into the lignin production story. This would involve treating waste lignin and producing PDCAs directly at the source, such as by latching onto a paper pulping unit. “That would be our ideal set-up: as close to the biomass as possible, so you don’t have to lift and shift the raw material,” says Kovacs-Schreiner.

**Supporting collaboration with industry**

Bugg’s team are continuing their metabolic engineering work with Biome Bioplastics with support from BBSRC ERA CoBioTech funding\(^13\). Bugg has also been involved in several other BBSRC projects focusing on lignin degradation, and he was previously co-director of BBSRC’s Lignocellulosic Biorefinery Network, now BBNet\(^14\). Bugg believes collaborative projects, such as his own with Biome Bioplastics and others funded through the BBSRC NIBB\(^15\), are key to building the UK’s bio-based chemicals industry. “I appreciate the support I’ve had from BBSRC and their focus on industrial biotechnology as a priority area. I think there is opportunity for a new biotech sector in bio-based chemicals in the UK, and these kinds of projects are the way to do it,” says Bugg.

The benefits of working with a commercial partner are also clear to Bugg. “It’s really nice to have a partnership with a company. I’ve got the support of a company who actually wants to see the research come to fruition. I’ve also learnt quite a bit from them. There are plenty of scientific challenges at our end, but I’ve learnt about the commercial challenges that Biome face, such as finding a market for their products. But from my own interactions with the general public, there’s a lot of interest and appetite for bioplastics.”

**REFERENCES**

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