Valorising next generation plastic waste using engineering biology

THE UNIVERSITY of EDINBURGH
School of Biological Sciences

Benjamín Armijo G., Dr Joanna C. Sadler

DARWIN TRUST of EDINBURGH

The problem

1.7 billion plastic waste pieces per week from UK households[1]

<17% recycled[1]

56% incinerated, releasing more emissions than burning coal[1]

UK government target: **zero avoidable plastic waste by 2050**

ZERO EMISSION CO_2 2050

Increased use of next generation plastics

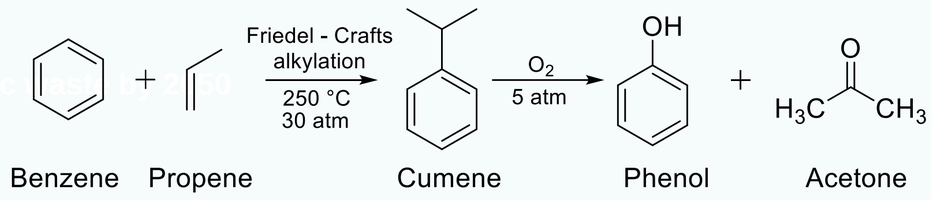
Bioplastics are produced from biobased sources[2]

Biodegradable plastics can be degraded by microbial communities in a short time[2]

Next generation plastics

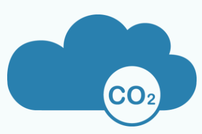
- **Poly(hydroxybutyrate) (PHB)** is a **biodegradable bioplastic**
- Utilised in packaging and single-use food ware
- Fast growing market and production leads to accumulation of PHB waste

Current acetone synthesis



Unmanaged PHB waste is harmful to the environment[2,3]

Microplastics release



Greenhouse gas emissions

Soil toxicity

2.55 kg CO_2e generated per kg acetone produced

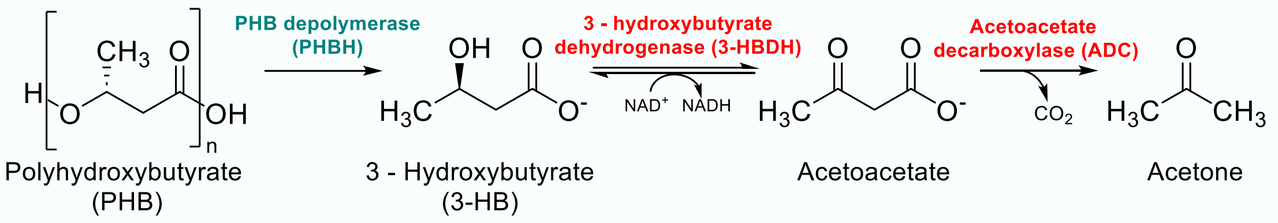
Petrochemically derived

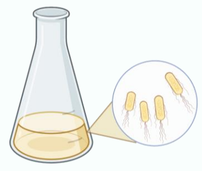
8 millions tonnes per year

Energy intensive

The solution: Engineering biology

PHB waste can be a valuable resource for the bio-economy





Simultaneous degradation and conversion of PHB into acetone

Figure 1: Novel biosynthetic pathway design using enzymes (PHBH, 3-HBDH and ADC) to convert PHB waste into acetone.

PHB degradation

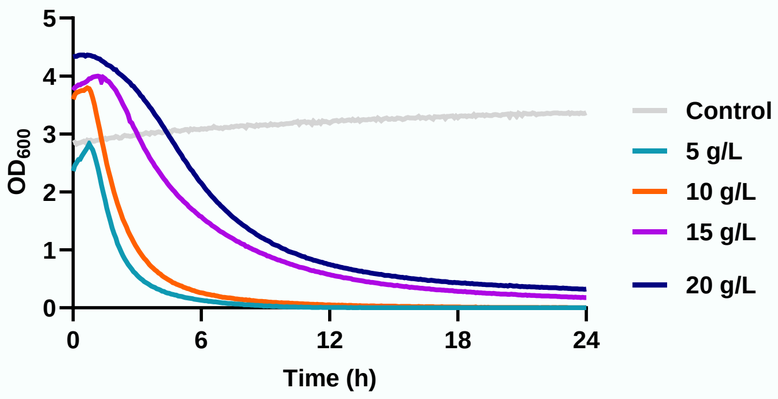
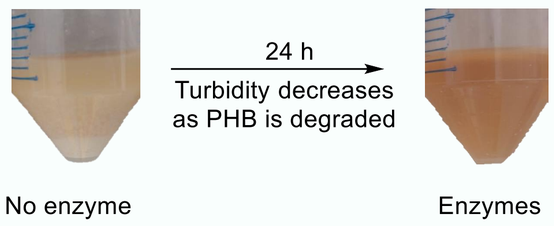


Figure 2: Turbidity PHB degradation assay at different PHB loadings (5 to 20 g/L). An empty vector strain (without pathway) was used as a negative control.



Fast PHB degradation: 97% yield after 8 h

PHB was entirely degraded into 3-HB monomers

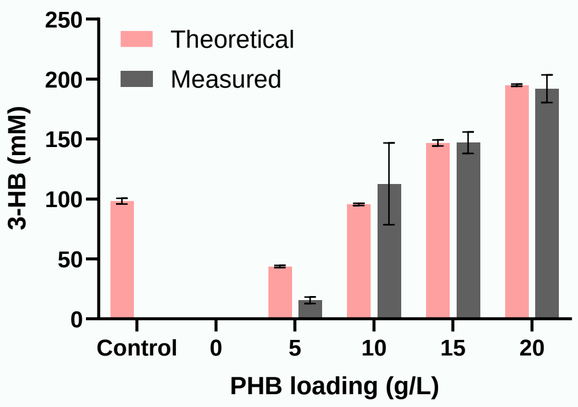
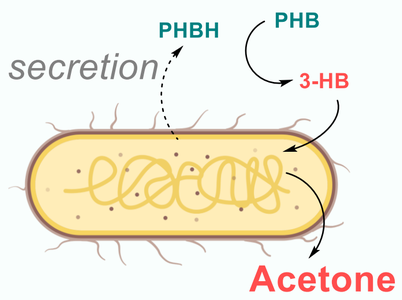


Figure 3: Quantification of 3-HB from PHB degradation (dark grey) compared to theoretical 3-HB yield (pink).

Acetone production



Escherichia coli was engineered with a **novel biosynthetic pathway[3]**

One-pot reaction

mild conditions (30 °C, pH 7, 24 h).

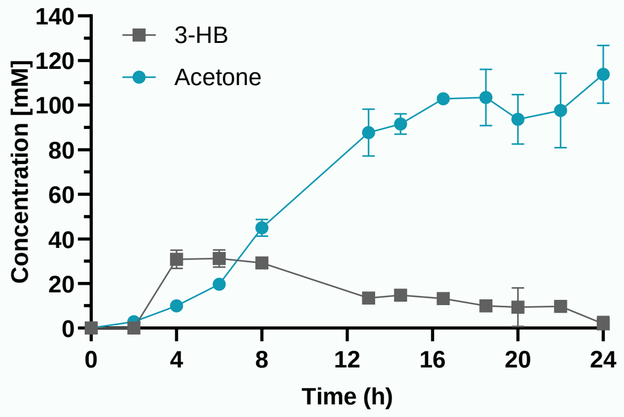
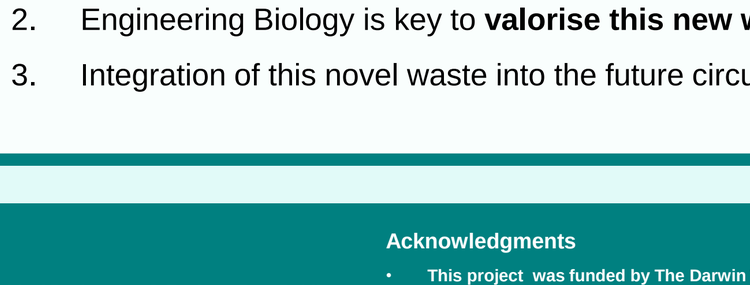
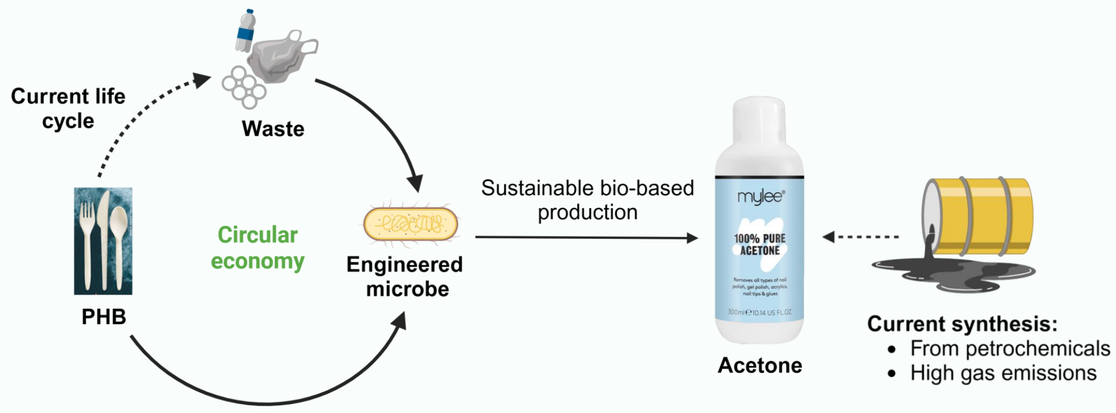


Figure 4: Time course of acetone production and 3-HB quantification.



- **100% conversion** of PHB in 24 h
- Maximum yield of 122 mM acetone (7 g/L)
- 67% yield after extraction from fermentation

Key messages



1. Next-generation plastics are a **novel and valuable feedstock** for sustainable chemical production
2. Engineering Biology is key to **valorise this new waste stream**
3. Integration of this novel waste into the future circular bioeconomy is fundamental

References

1. The Big Plastic Count. Results available at: <https://thebigplasticcount.com/results>
2. Ferreira-Filipe, D.A.; Paço, A.; Duarte, A.C.; Rocha-Santos, T.; Patricio Silva, A.L. Are Biobased Plastics Green Alternatives? A Critical Review. Int. J. Environ. Res. Public Health 2021, 18, 7729.
3. Armijo-Galdames, B.O & Sadler, J.C. One-Pot Biosynthesis of Acetone from Waste Poly(hydroxybutyrate). ACS Sustainable Chemistry & Engineering 2024 12 (20), 7748-7756.

Acknowledgments

- This project was funded by The Darwin Trust of Edinburgh PhD studentship.
- PHB cutlery was kindly provided by Newlight Technologies, Inc.
- Images and illustration created with BioRender.com.

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