Biomass Biorefinery Network

4th BBNet Conference

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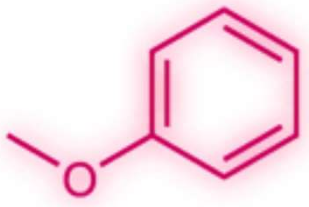
Developing a biological route towards the green solvent anisole using *Pseudomonas putida*

Micaela Chacón



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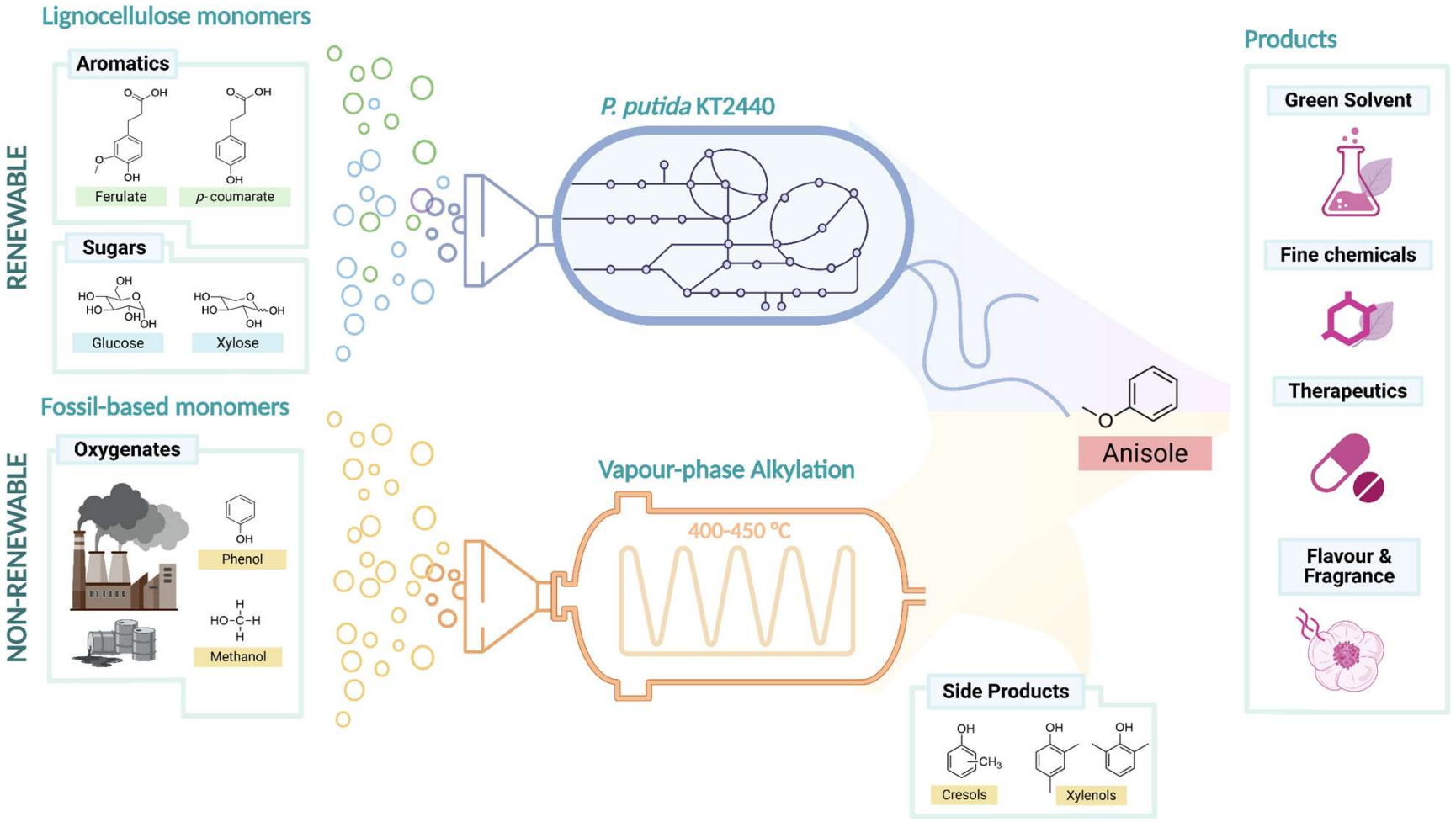
Renewable vs Petrochemical Routes to Anisole



Establishing a *P. putida* Chassis and Biosynthetic Pathway for Anisole Production

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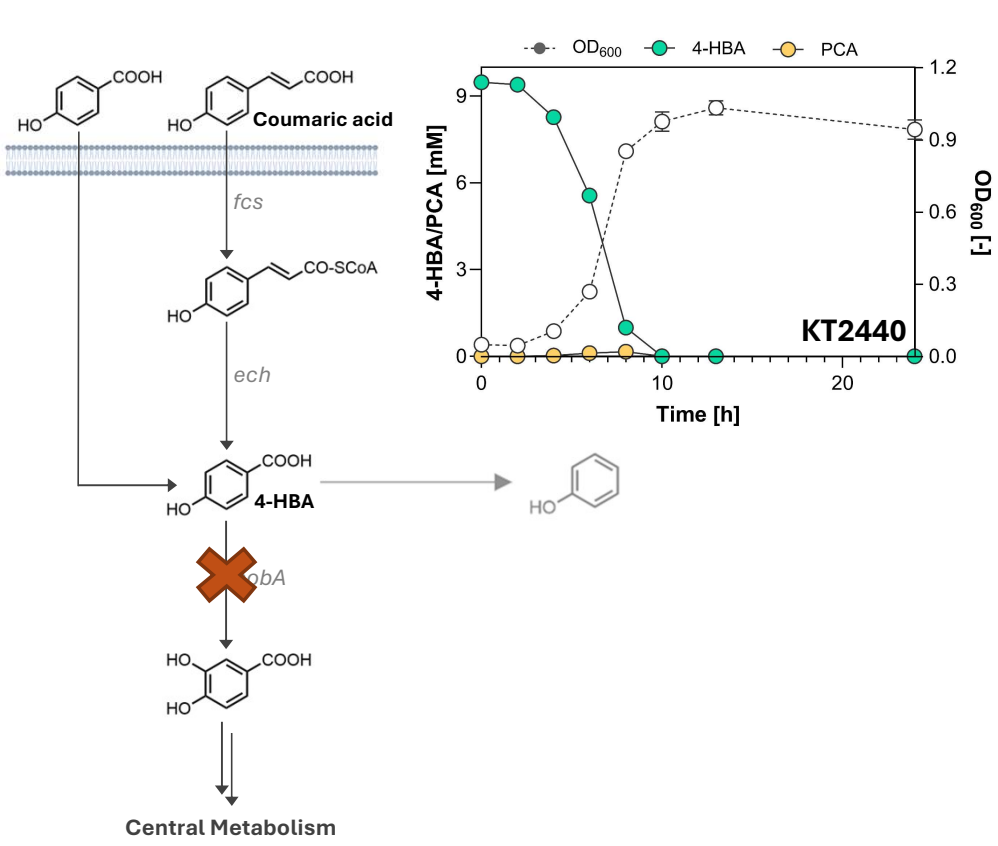

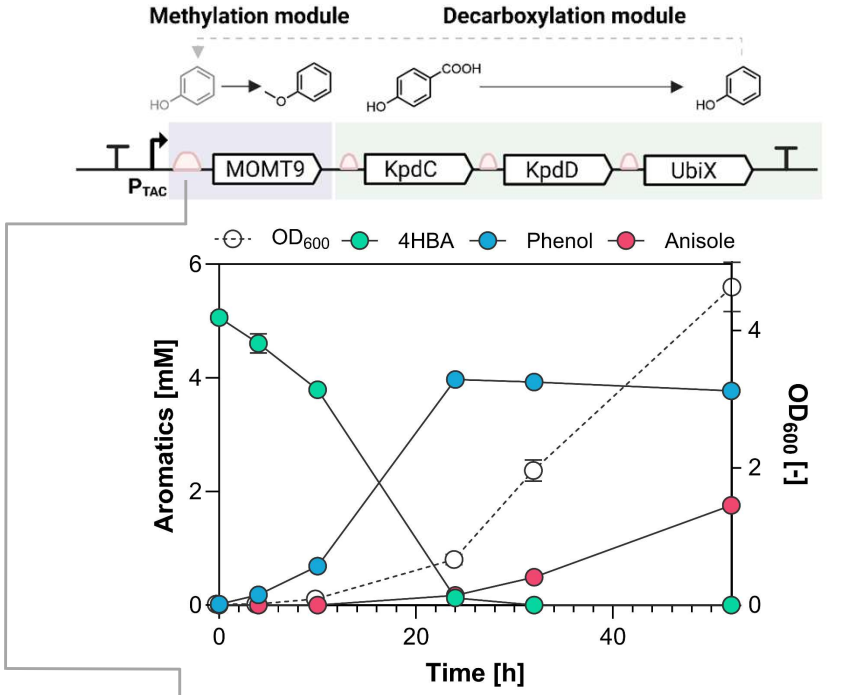

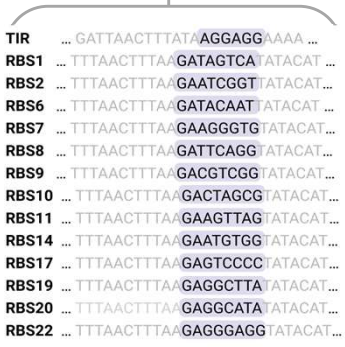

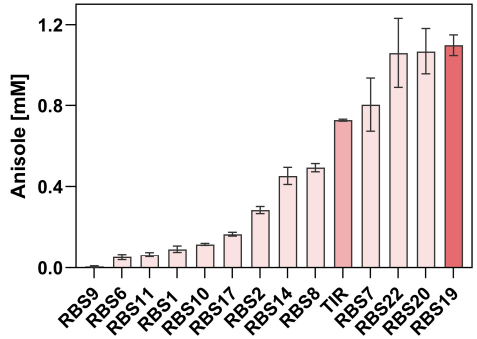

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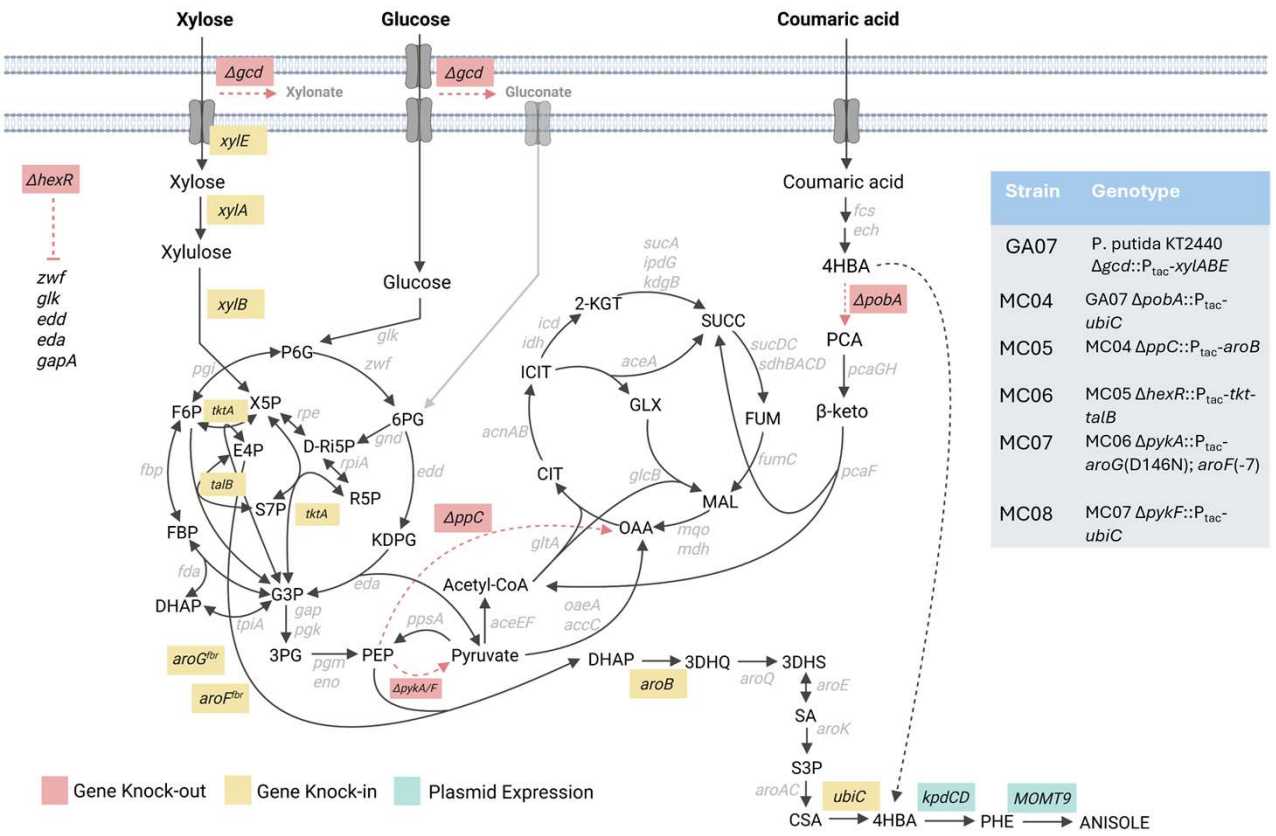
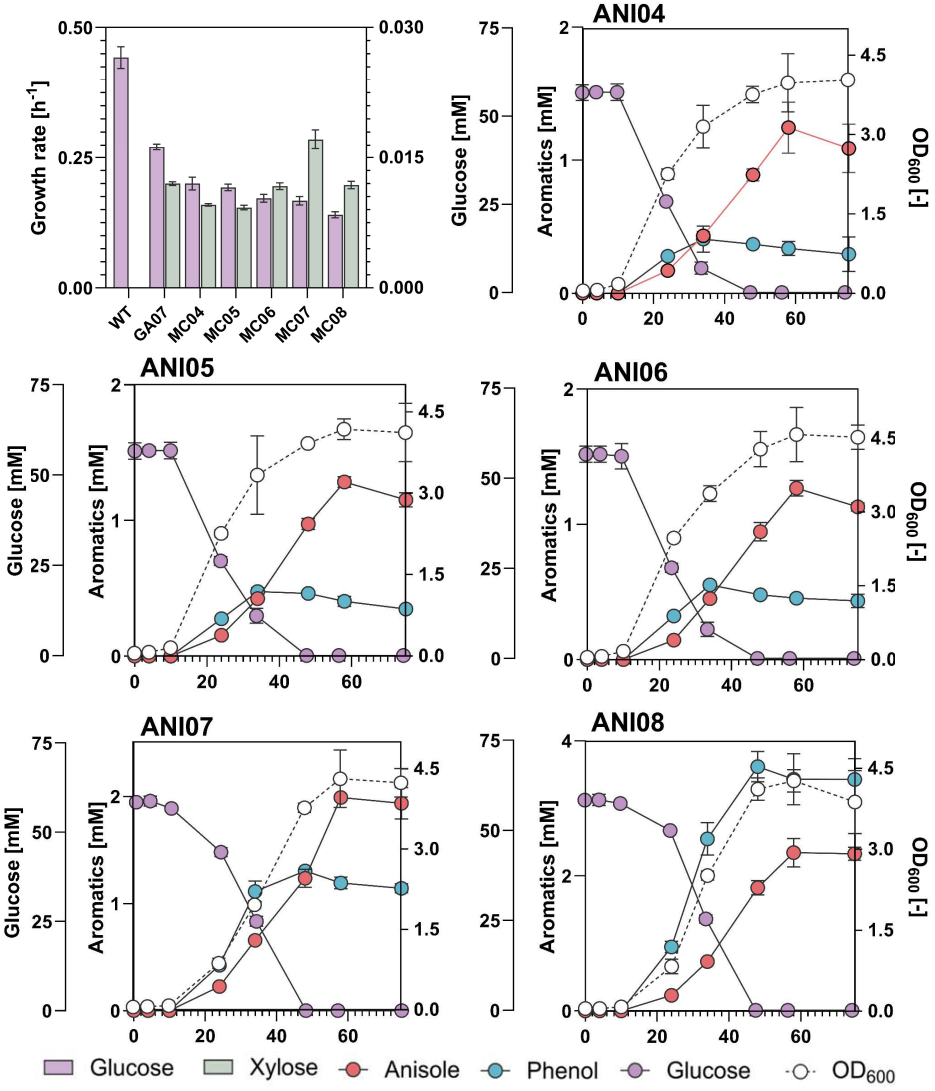
Redirecting Glycolytic Flux to Drive Shikimate-Pathway Precursors



Strain	Genotype
GA07	P. putida KT2440 Δ*gcd*::P_{tac}-*xylABE*
MC04	GA07 Δ*pobA*::P_{tac}-*ubiC*
MC05	MC04 Δ*ppC*::P_{tac}-*aroB*
MC06	MC05 Δ*hexR*::P_{tac}-*tkt-talB*
MC07	MC06 Δ*pykA*::P_{tac}-*aroG*(D146N); *aroF*(-7)
MC08	MC07 Δ*pykF*::P_{tac}-*ubiC*



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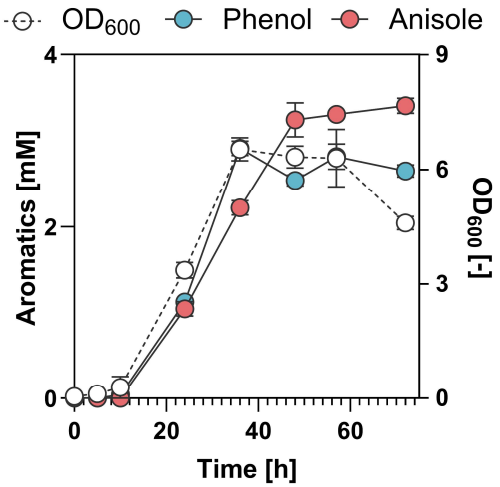
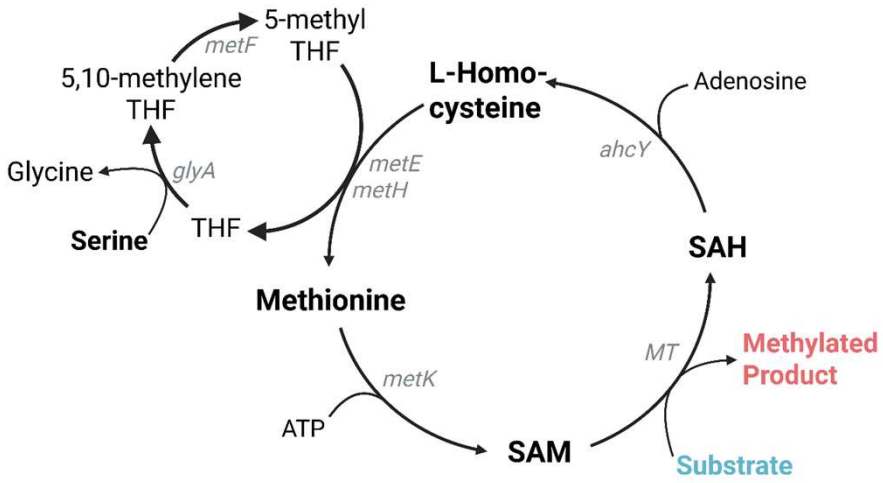
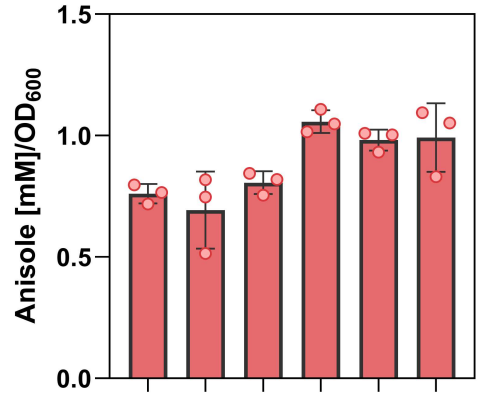
Identifying an Improved *O*-Methyltransferase and Enhancing SAM-Dependent Methylation

Methyltransferase	Conversion [%]
MOMT9	16.6 ± 0.1
*Cr*SMT	12.1 ± 0.2
*Ej*OMT	-
*Cv*OMT	2.1 ± 0.8
*Mt*OMT	-
***Rh*OMT**	**64.8 ± 7.6**

1 mg/mL methyltransferase in 50 mM sodium phosphate buffer pH 7.4 with 1 mM phenol, 2 mM SAM and 20% dodecane for 18 hours at 30°C.







Methionine		+	+			+
Homocysteine				+	+	+
Serine			+		+	+

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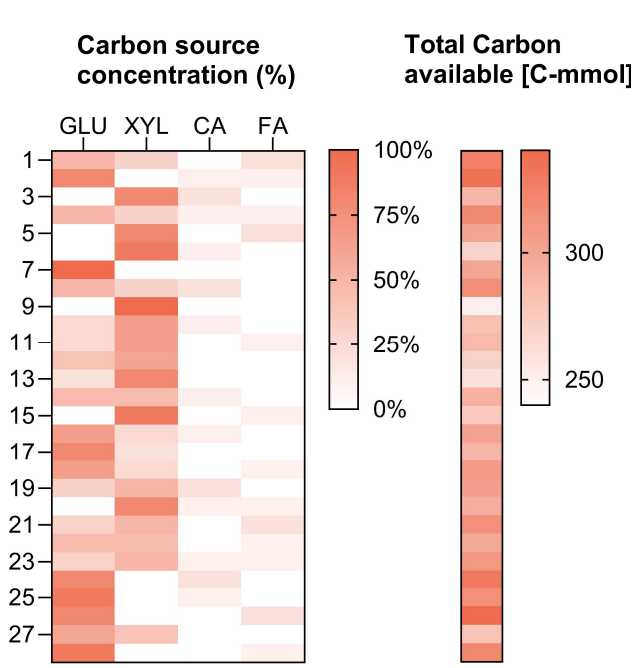
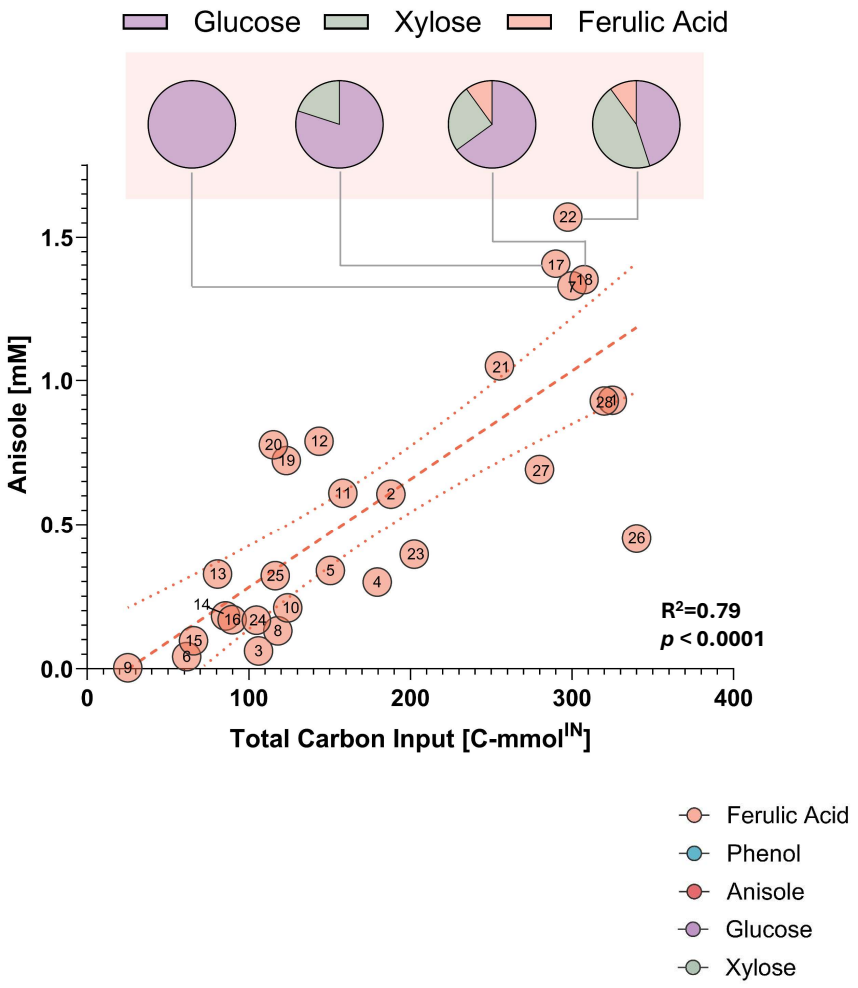
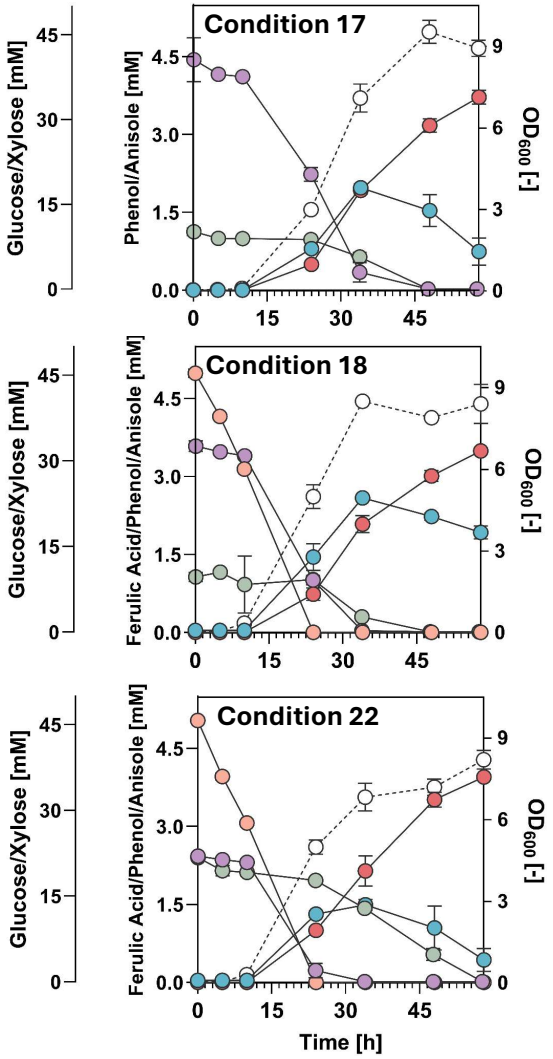
Production Performance across Lignocellulose-Derived Substrate Mixtures







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Neil Dixon
Ruth Lopez-Perez
Phil Leroy
Karl Fisher
James Winterburn

Federico Visinoni
Rosa Cuellar-Franca
Piya Gosalvitr
Will Goundry

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Synthetic organelles to convert lignocellulosic biomass into chemical wealth

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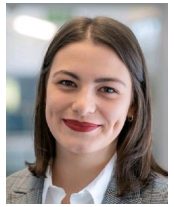
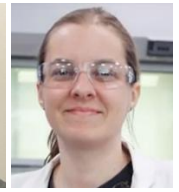
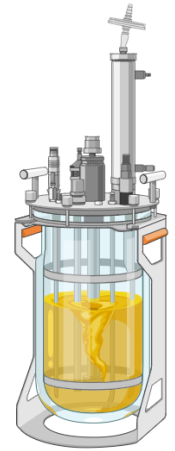


Circular bioeconomy





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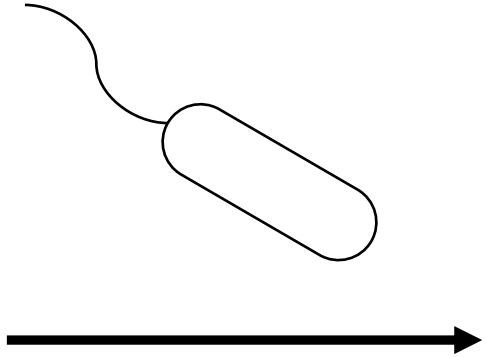
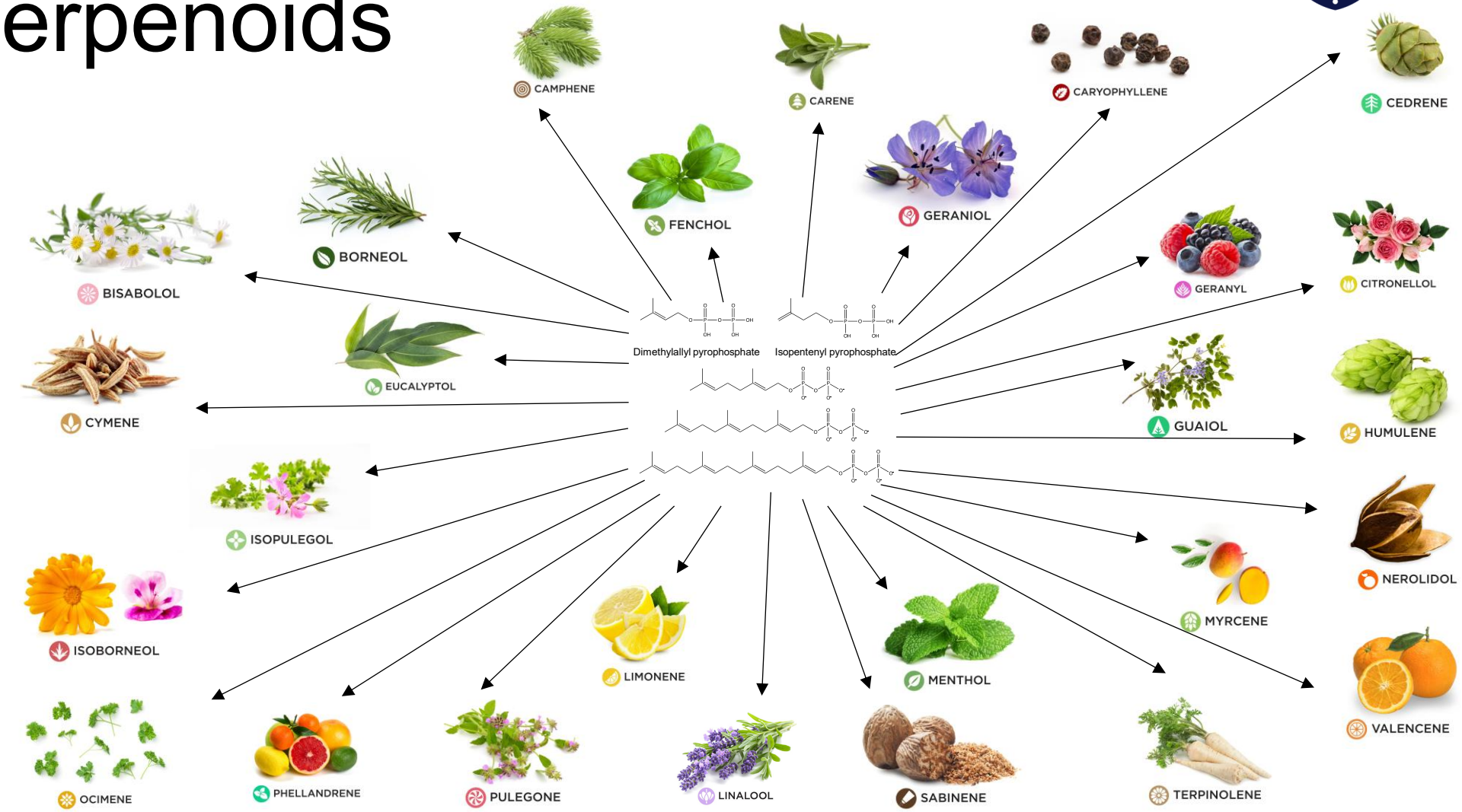
Terpenoid Biomanufacturing from Cellulose



Cellulose

Terpenoids

Terpenoids



WeedMaps

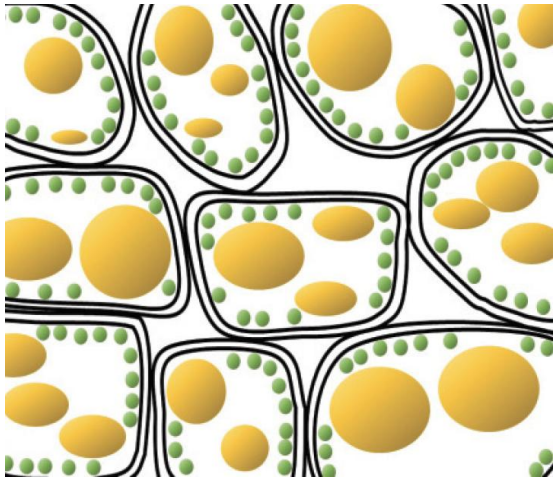
Terpenoid titres might be limited by toxicity

- Highest titres in *E. coli* are between 1-60 g/L
- TEA suggests titre improvements will lead to cost-competitive processes
- Previously explored terpenoid tolerance strategies improve titres 4-fold at most
- 2019 BBSRC Report: “Greater understanding of mechanisms for dealing with toxicity“

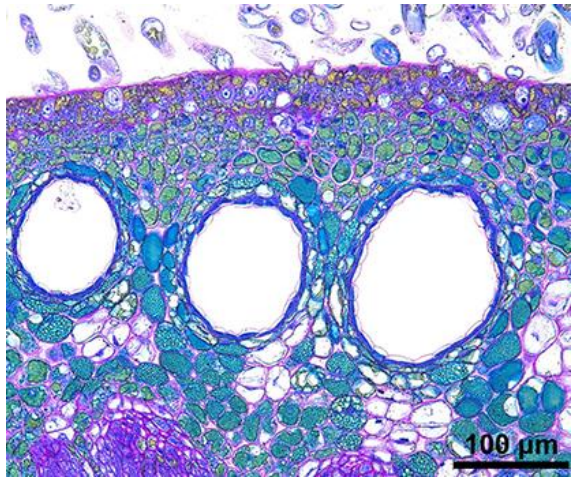
Terpenoid	Highest reported titre (g/L culture)
Hemiterpenoids	
Isoprene	60
Isoprenol	10.8
Monoterpenoids	
Limonene	3.65*
Sabinene	2.65
Geraniol	2.124
Linalool	1.523
a-Pinene	0.97
1,8-Cineole	0.653
Sesquiterpenoids	
Amorphadiene	30
Viridiflorol	25.7
b-Farnesene	10 .67
(-)-a-Bisabolol	9.1
Diterpenoids	
Sclareol	1.46
Taxadiene	1.02
Triterpenoids	
Squalene	0.612
Tetraterpenoids	
Lycopene	448 mg/g DCW
b-Carotene	3.6
Astaxanthin	1.18
Zeaxanthin	0.722

Reviewed in Rinaldi *et al*., 2022 Nat Prod Rep

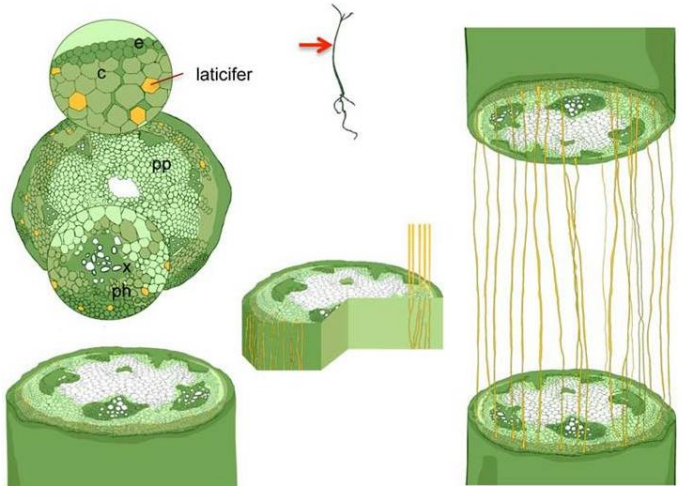
Plants have solved terpenoid toxicity



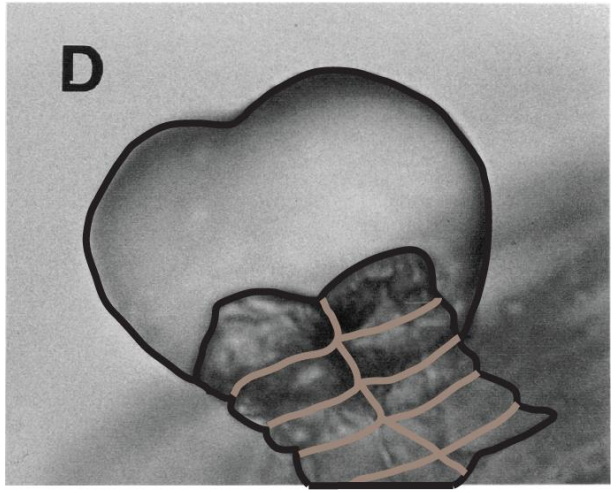
Liverwort oil bodies



Secretory ducts and cavities



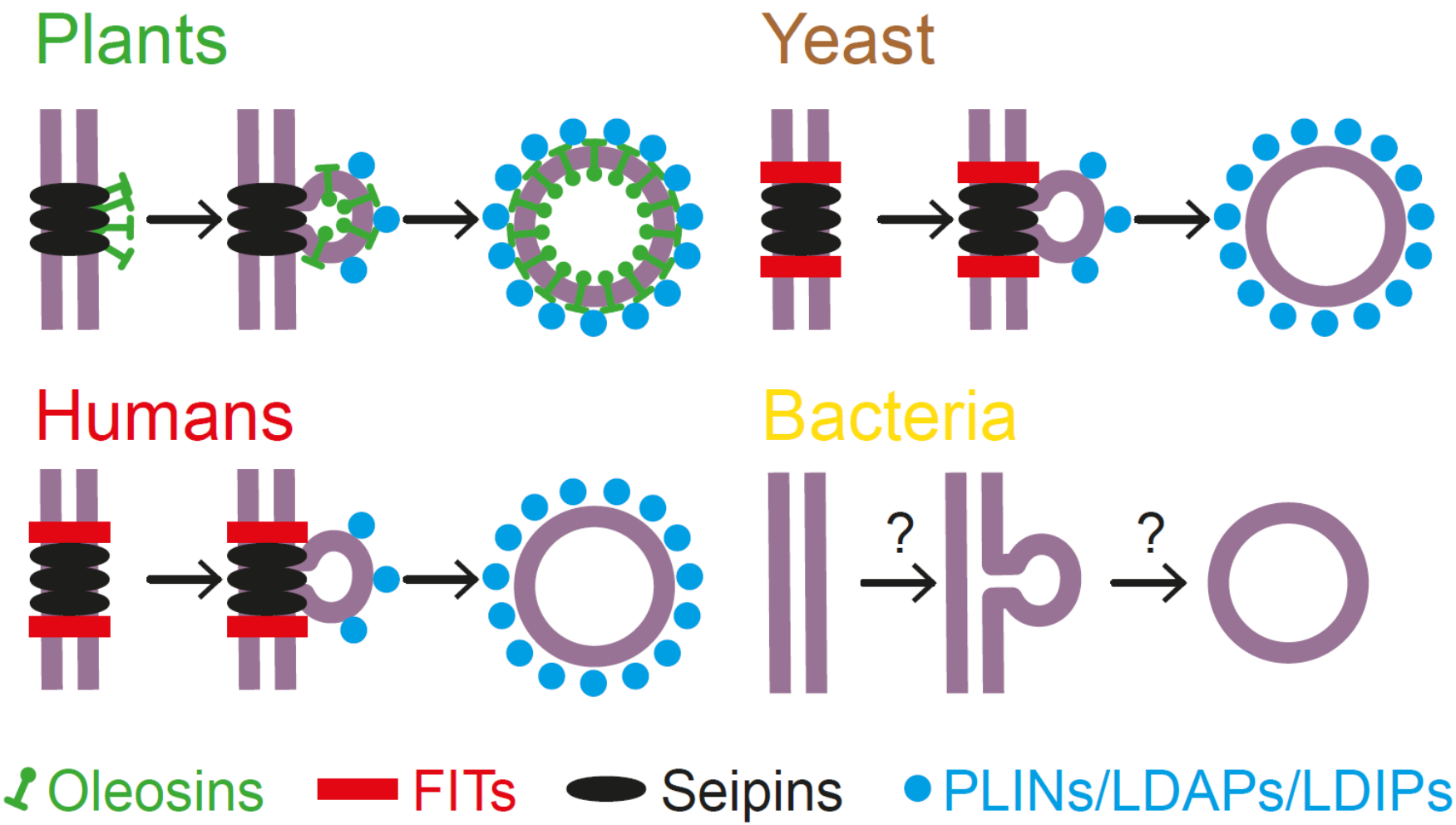
Laticifers

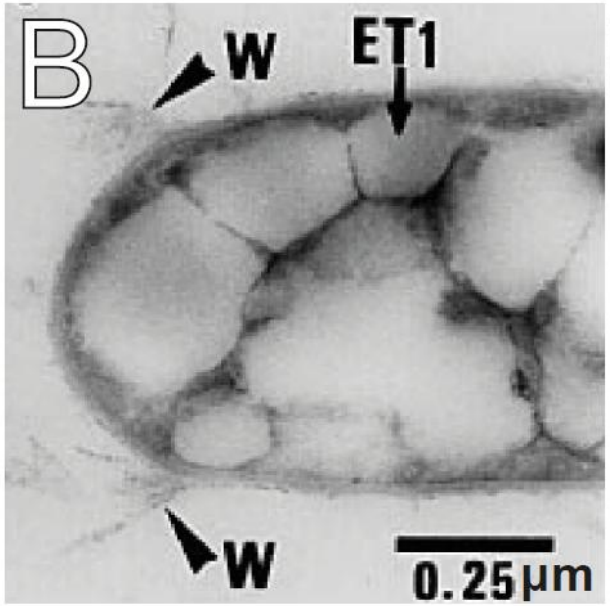


Glandular secretory trichomes

Lange 2015 Annu Rev Plant Biol, De Barros et al., 2017 Acta Bot Bras, Castelblanque *et al.*, 2016 Plant Phys, Ferreira and Janick 1995 Int J Plant Sci

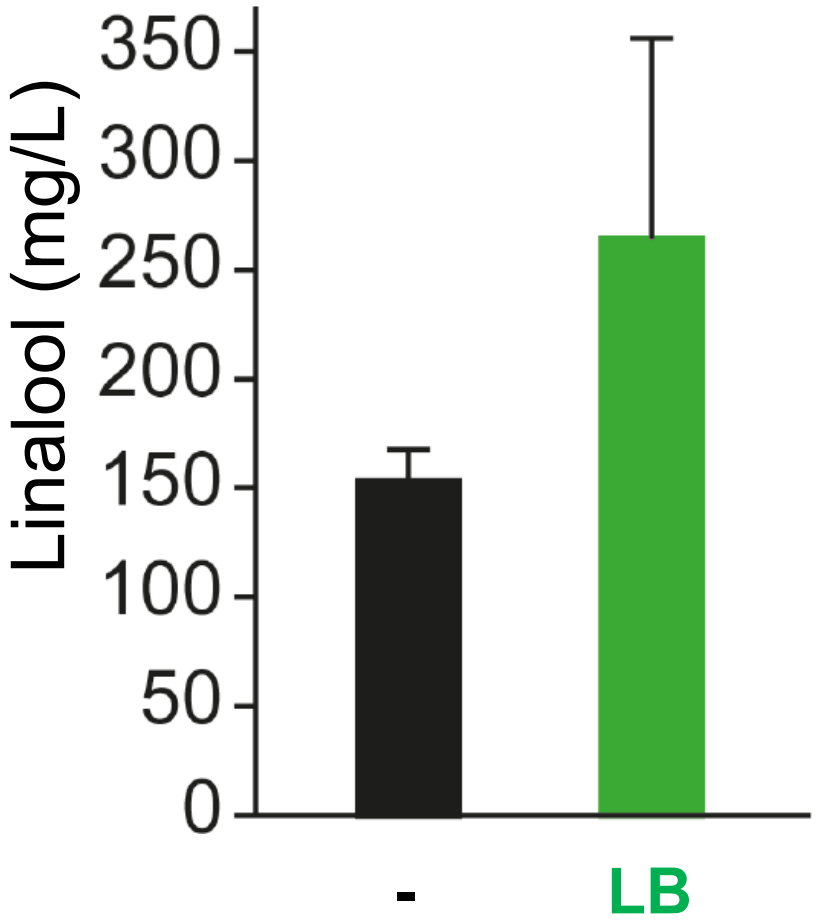
Lipid bodies across organisms

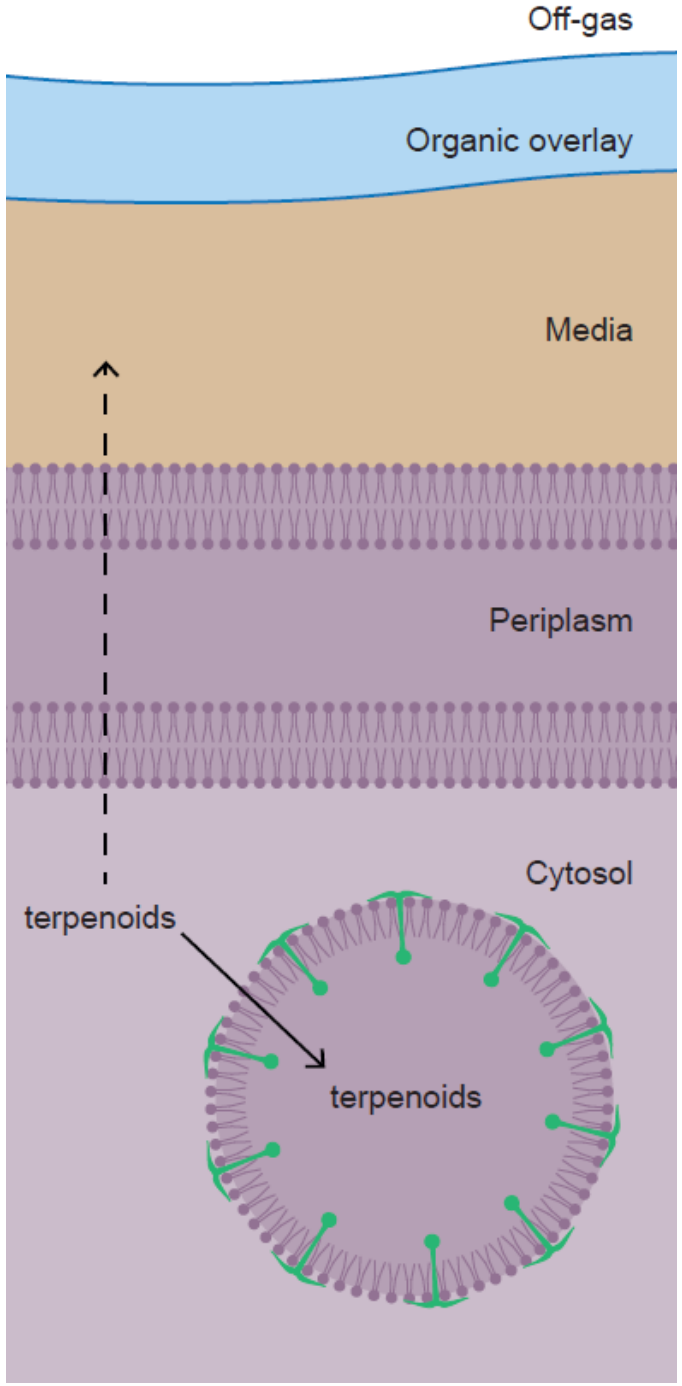




Alvarez HM *et al.*
1996 *Arch. Microbiol*

Lipid body genes increased terpenoid titres





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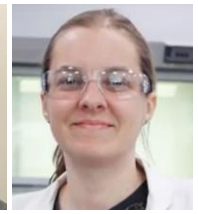

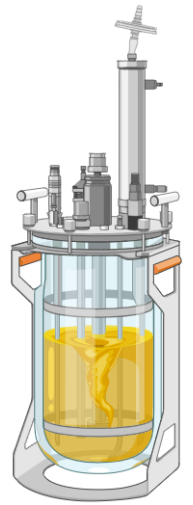

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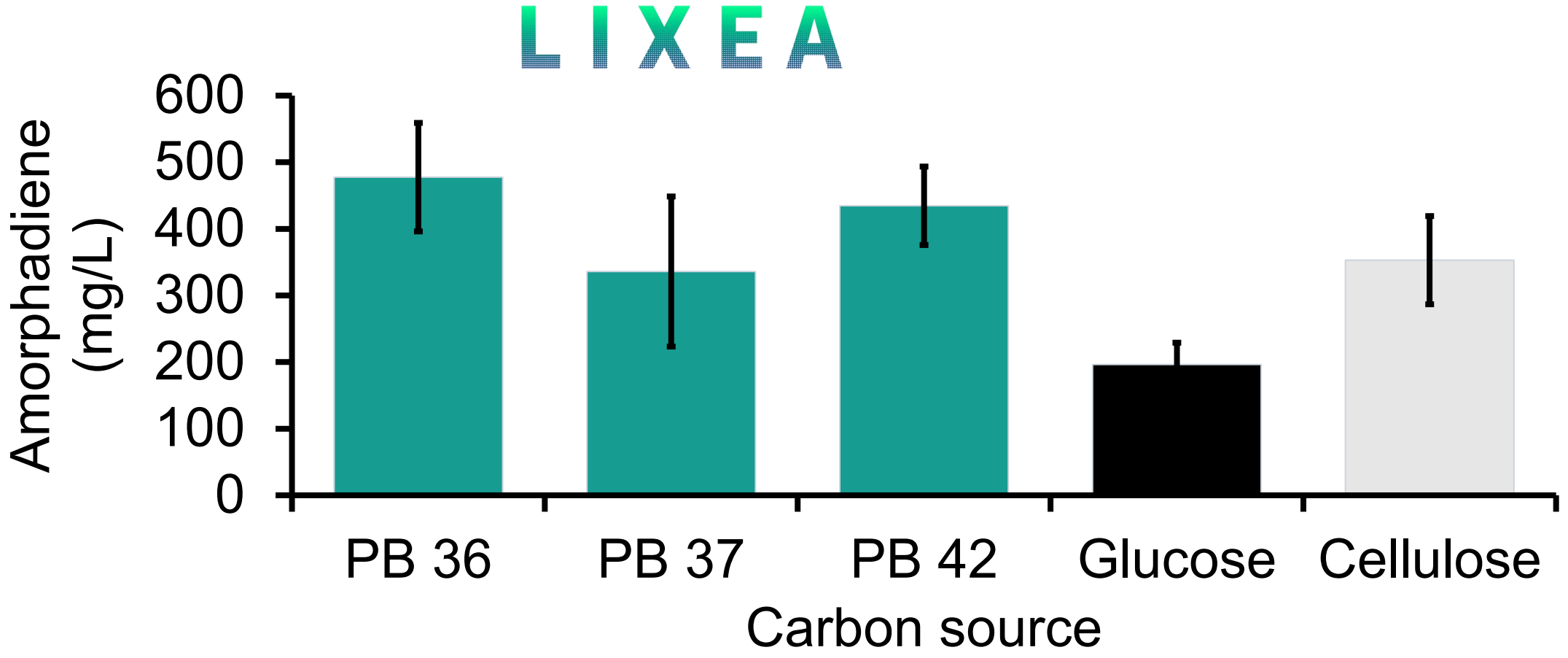
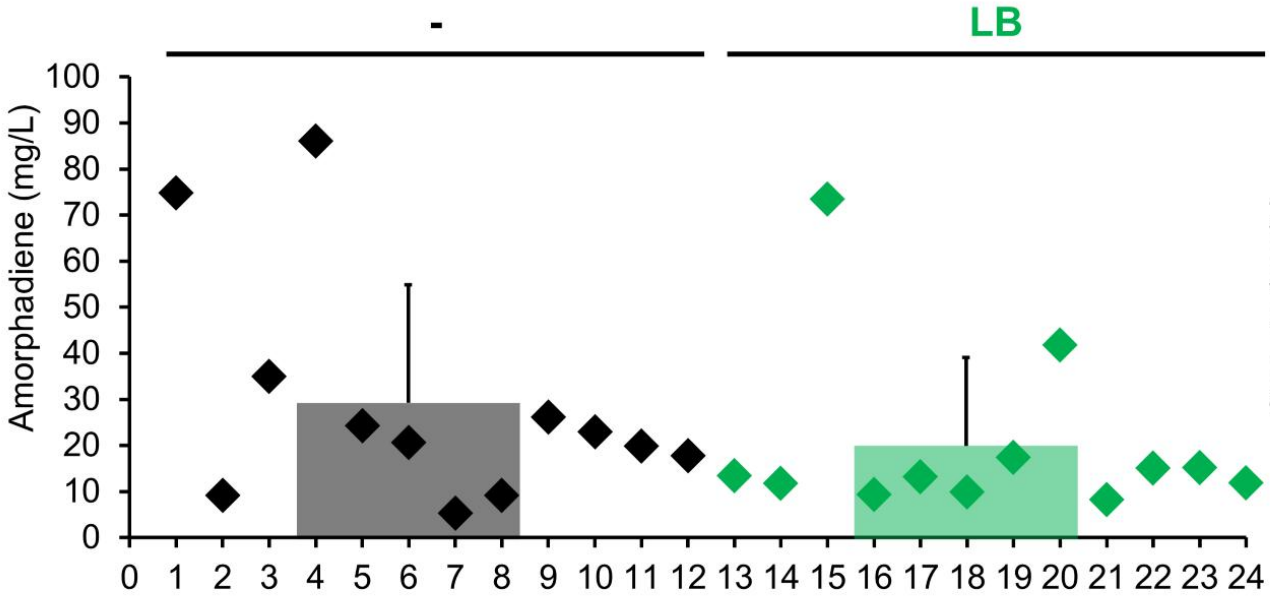
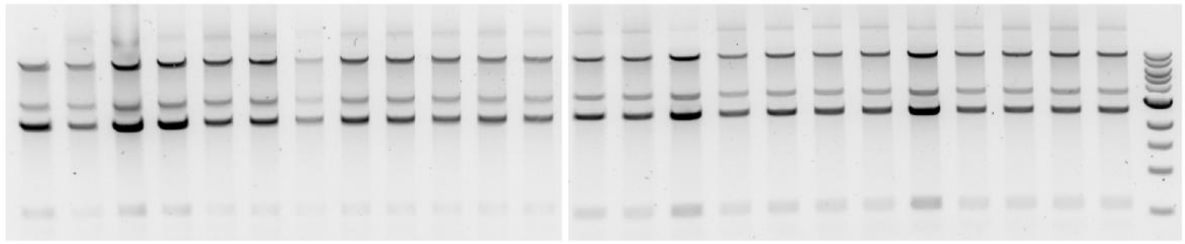
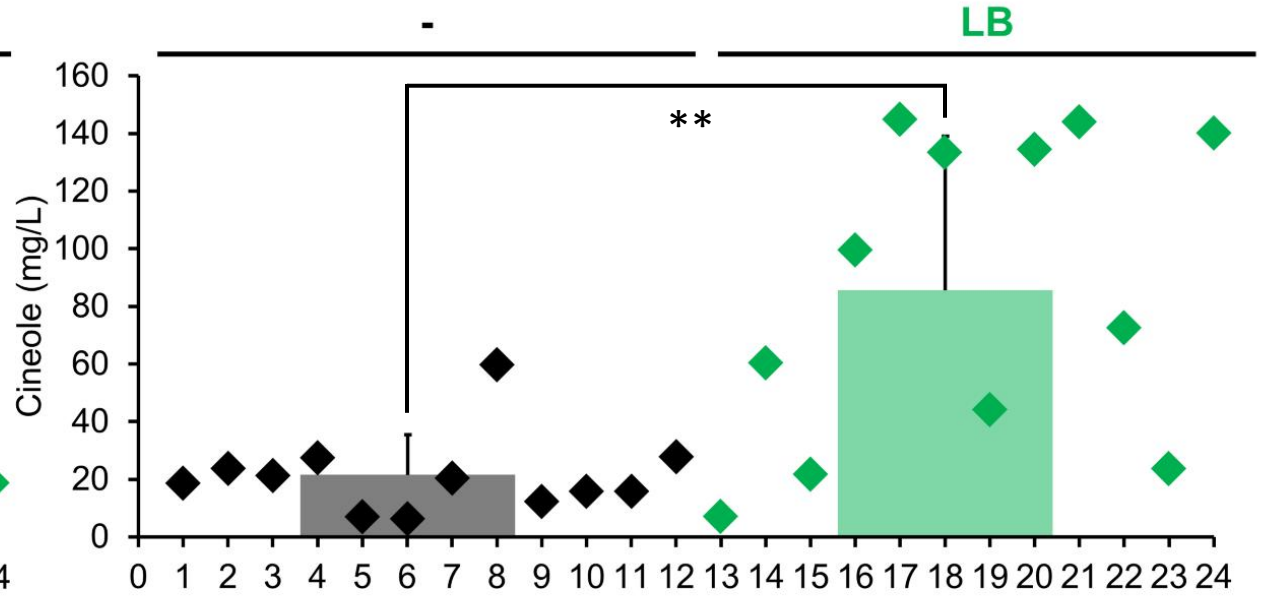
Lixea cellulose produced high terpenoid titres

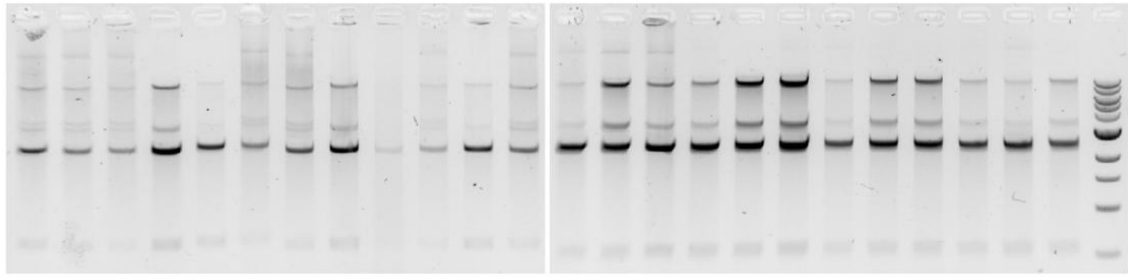


Lipid body genes increased terpenoid titres

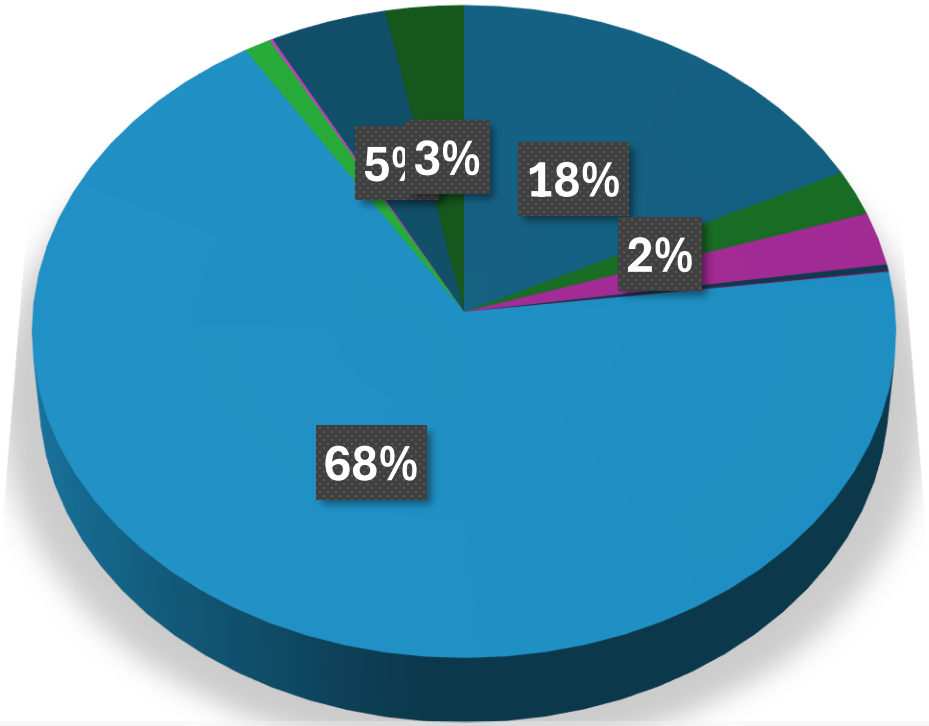




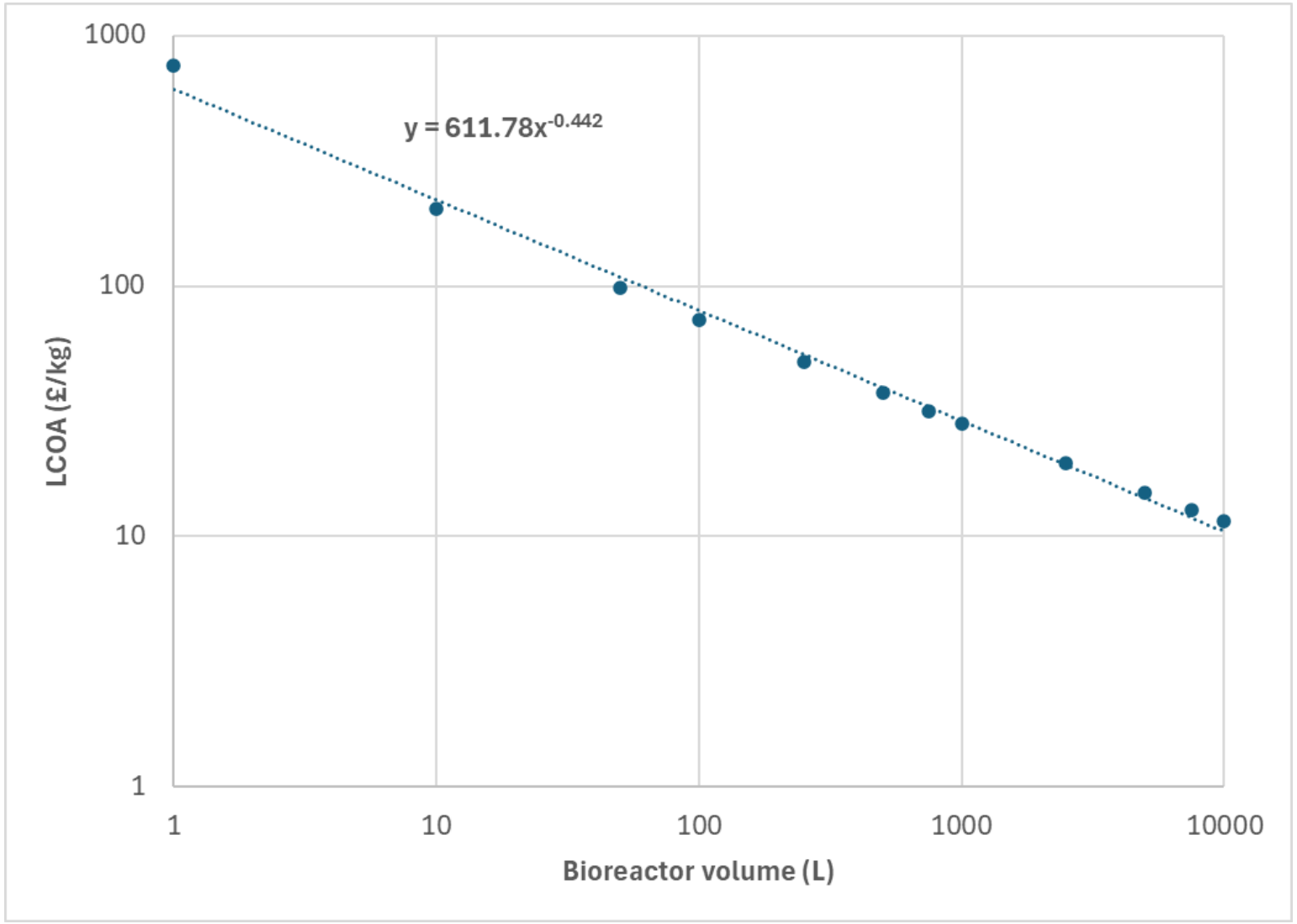




Preliminary LCA



Preliminary TEA



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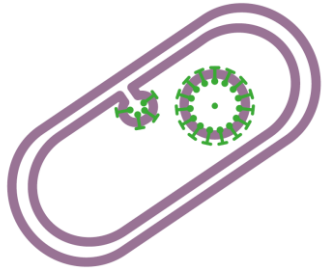
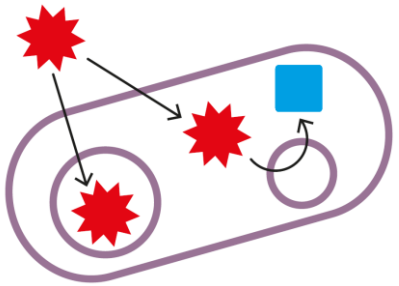
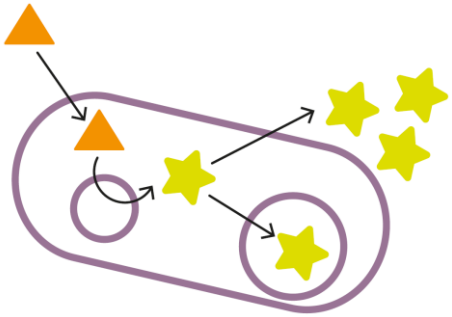


Biogenesis

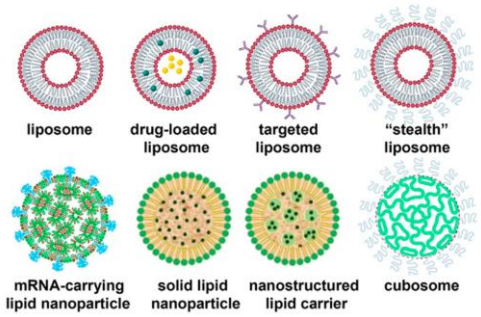


Bioremediation

Synthetic Organelles



Biomanufacturing

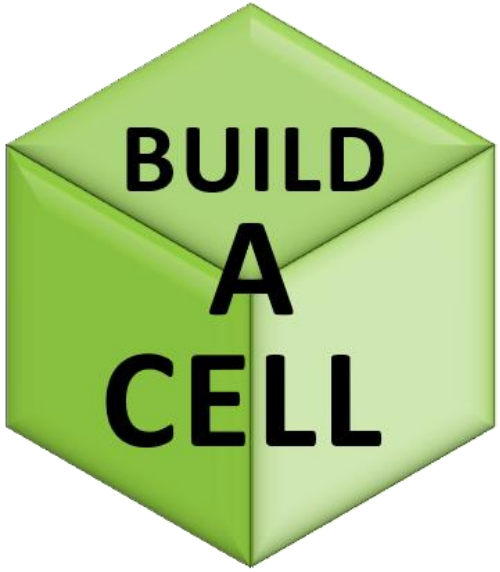


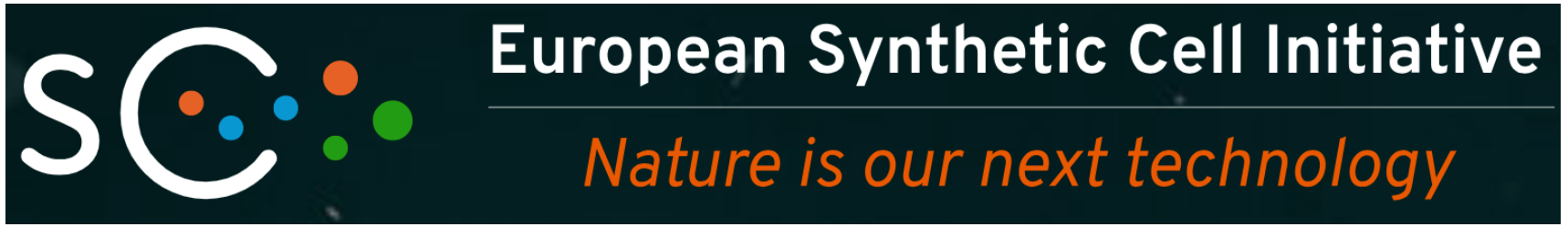
Tenchov *et al.* 2021 ACS Nano

Biomaterials

Graphics: BioRender

Synthetic cells





Acknowledgements

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- Alex Hartmann

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UKRI Biotechnology and Biological Sciences Research Council

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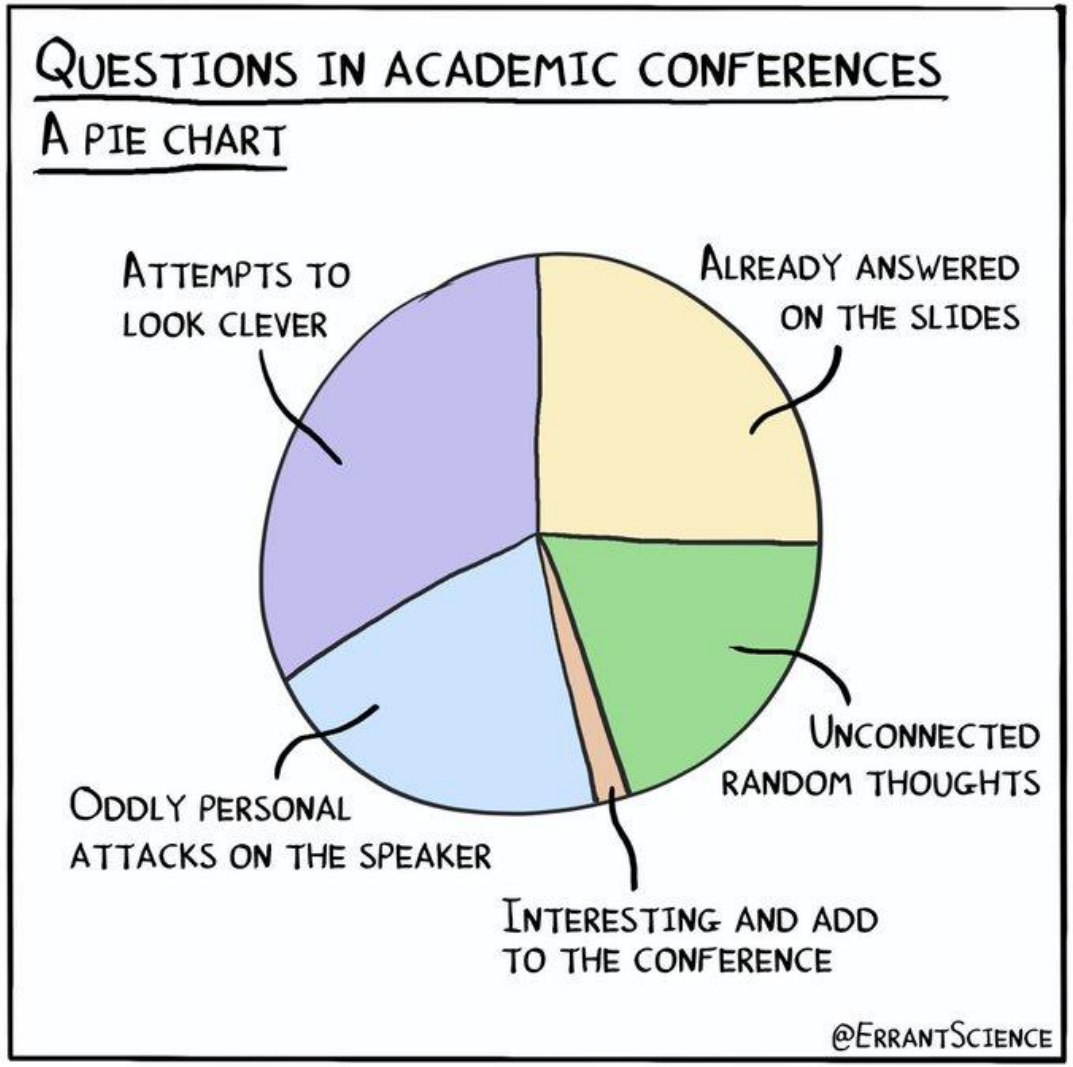
Microbiology Society

Biochemical Society

→ PhD studentship

Thank you!


QUESTIONS IN ACADEMIC CONFERENCES
A PIE CHART
ATTEMPTS TO LOOK CLEVER
ALREADY ANSWERED ON THE SLIDES
UNCONNECTED RANDOM THOUGHTS
INTERESTING AND ADD TO THE CONFERENCE
ODDLY PERSONAL ATTACKS ON THE SPEAKER
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4th BBNet Conference
Sheffield
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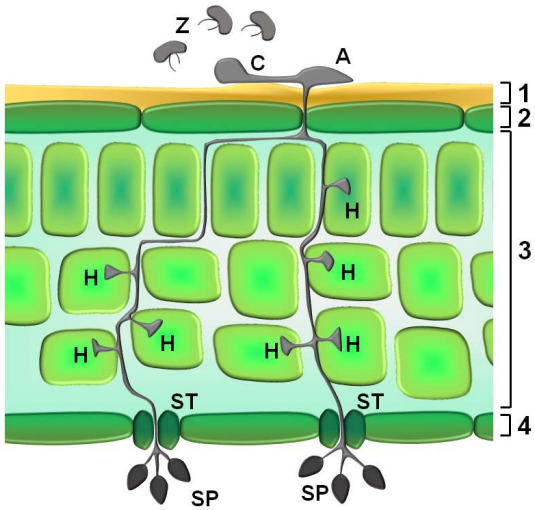
Enzyme discovery for agro-industrial applications

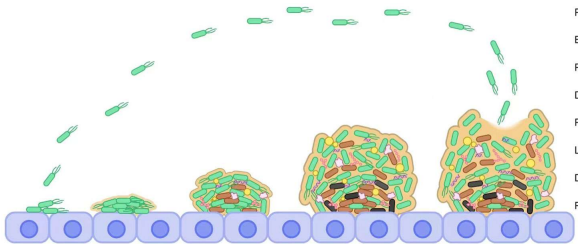
CWDEs in invertebrates

Virulence factors



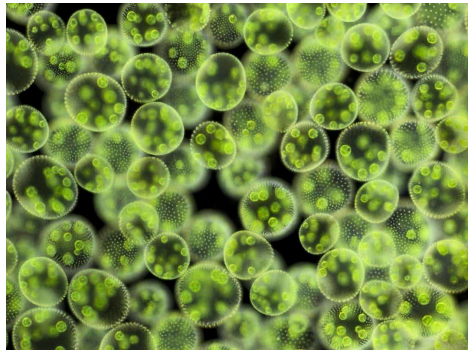
Keratin digestion in insects

Biofilm degrading enzymes



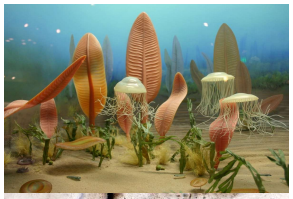
Insecticidal proteins

Micro and macroalgae



Rhodophyta: The Ocean`s Red Treasure

A 1.6-billion-year-old lineage



Bengtson S. et al. PLoS Biol. 2017 Mar 14;15(3):e2000735.

Among the oldest eukaryotic photosynthetic organisms

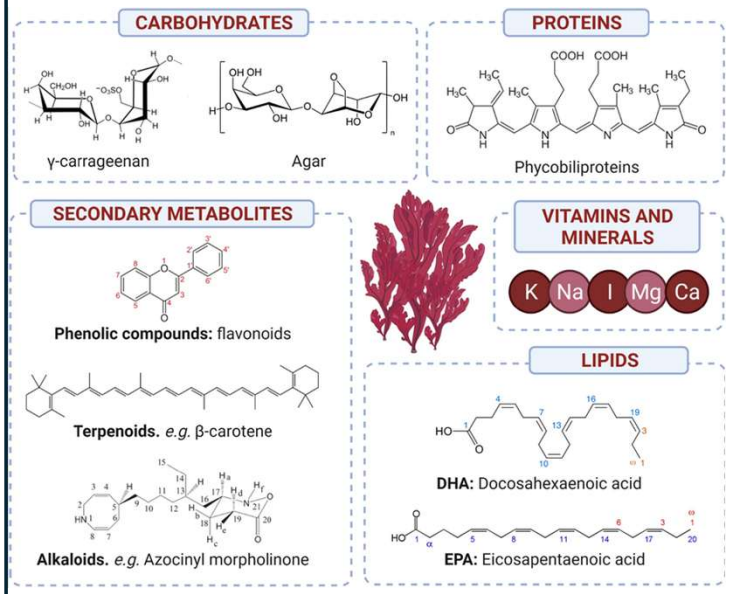
Proterozoic era, predating green algae and land plants

Key role in reef building and oxygenation of early oceans

Over 7,000 described species

https://metchosinmarine.ca/

Unique biology and chemistry



A wide range of applications

Food, drinks, supplements, feed, fertiliser

Hydrocolloids for food, pharma, cosmetics

Bioplastics, bioethanol, biogas

Objectives of the project

1. Compositional analysis of *Palmaria palmata* and *Porphyra* spp. (west coast of UK)

2. Physico-enzymatic extraction of oligosaccharides

3. Assessment of biological activities of oligosaccharides (antioxidant, anti-inflammatory, and prebiotic)

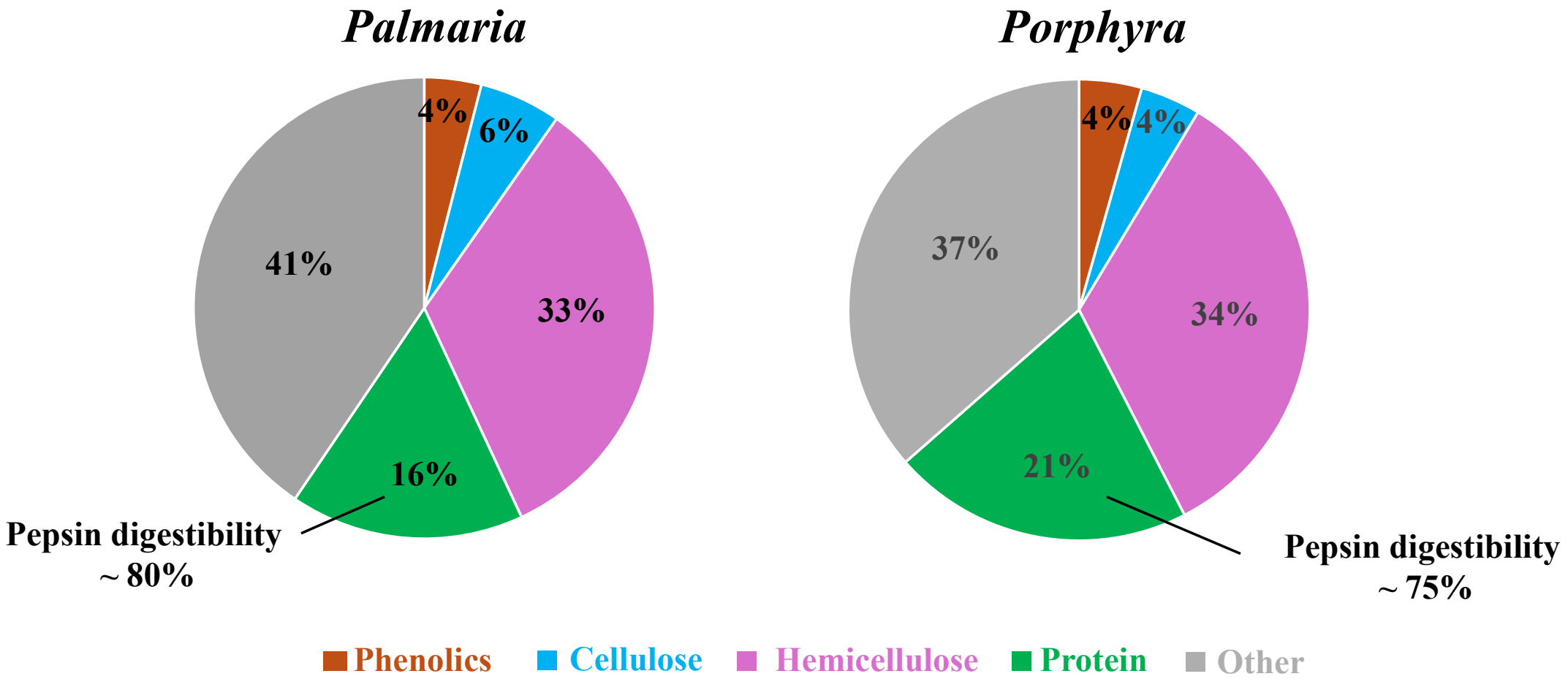
Dr Laura Faas
University of York

P. palmata

Porphyra spp.

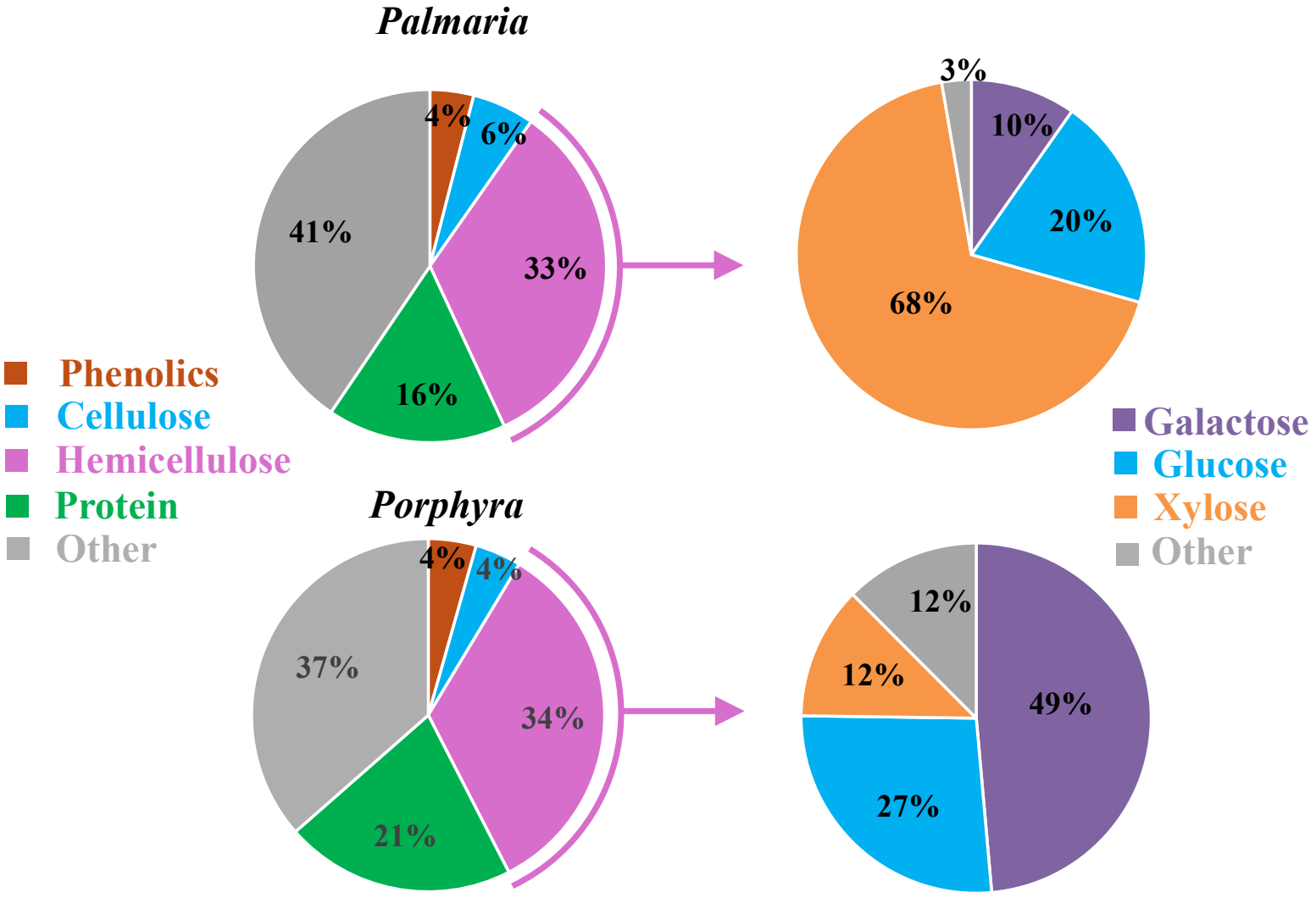
1. Compositional analysis

Phenolics, polysaccharides, protein



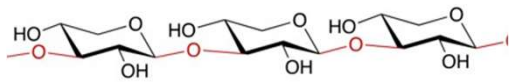
1. Compositional analysis

Monosaccharides

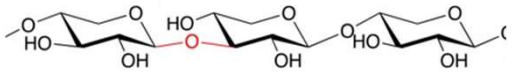


Xylans

***Porphyra*: 1,3-β-D-xylan**

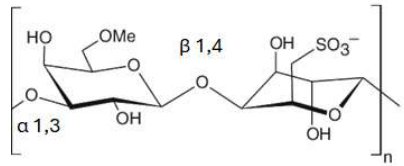


***Palmaria*: (1,3)(1,4)- β-D-xylan**

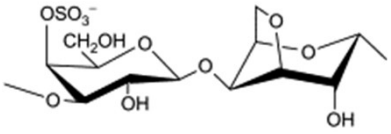


Sulfated galactans

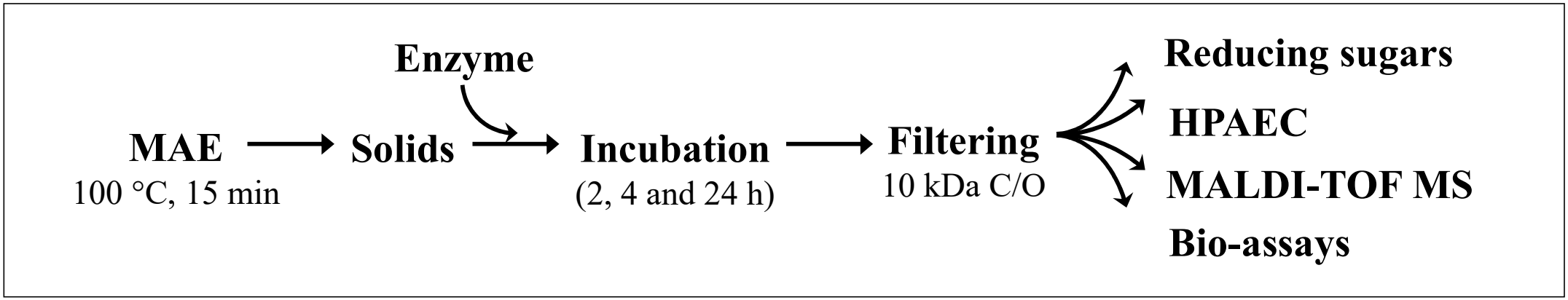
***Porphyra*: porphyran**



***Palmaria*: K-carrageenan**



2. Physico-enzymatic extraction of oligosaccharides

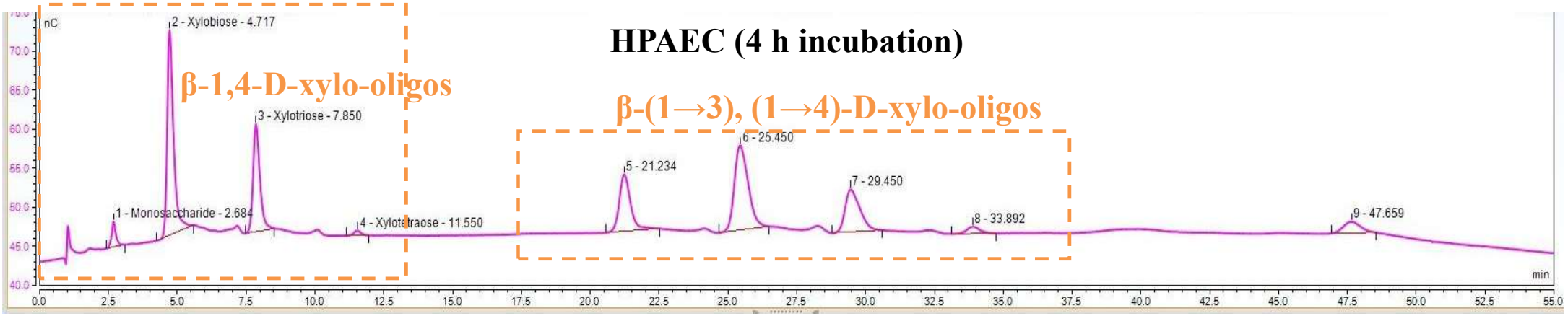


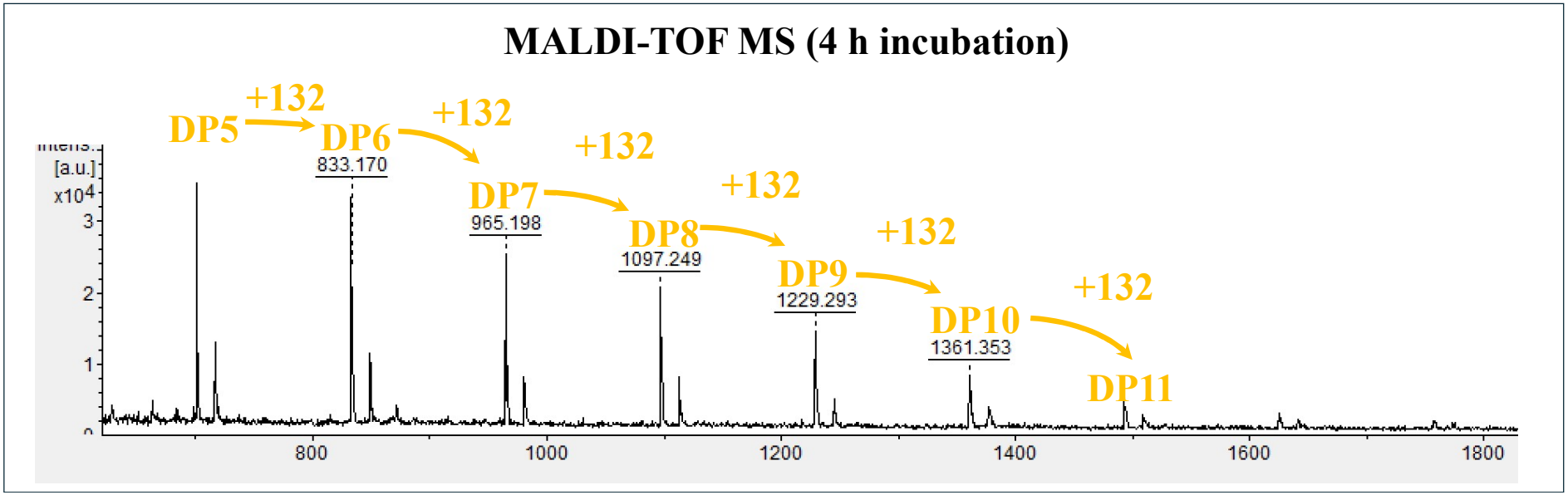
K-carrageenase (NZYtech) ⇨ *Palmaria* K-carrageenan

β-porphyranase (NZYtech) ⇨ *Porphyra* porphyran

Endo-1,4-β-xylanase (MegaZyme) ⇨ *Palmaria* xylan

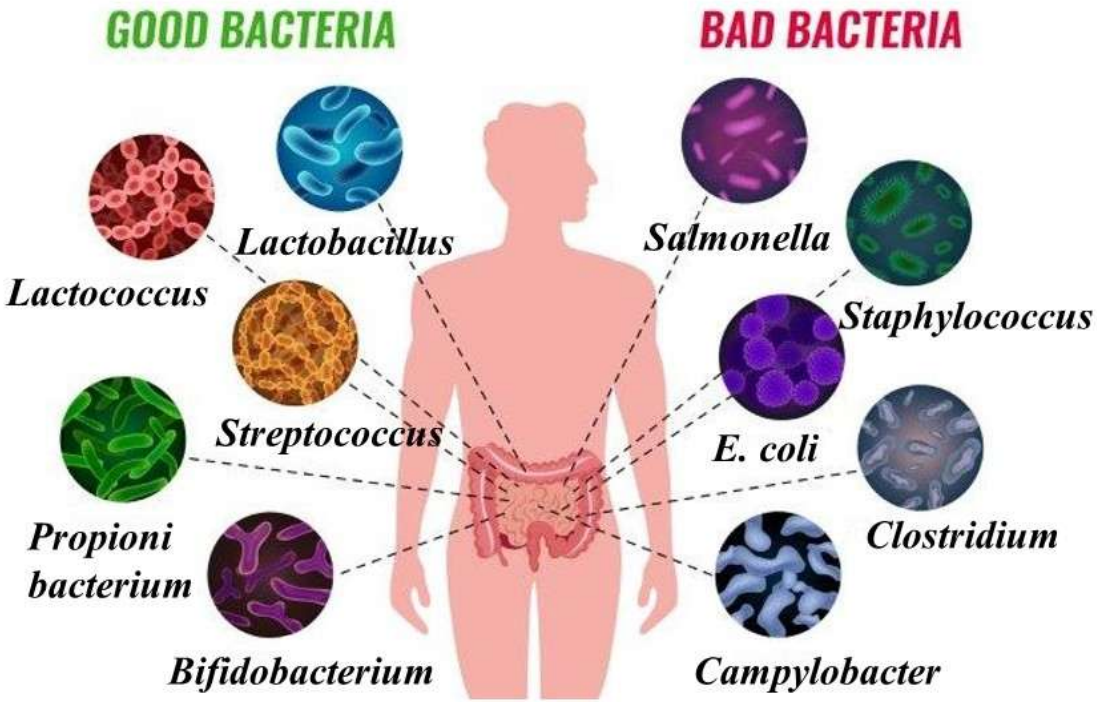
2. Physico-enzymatic extraction of oligosaccharides



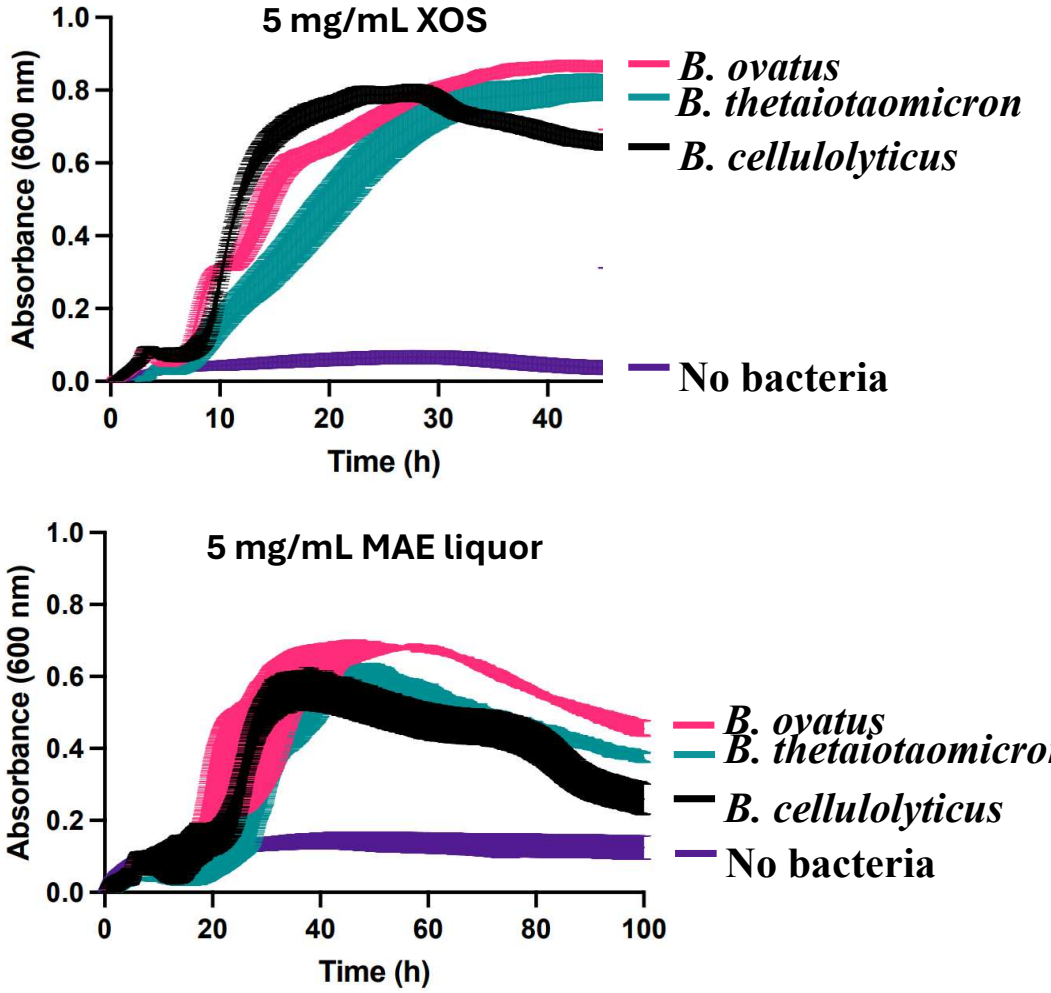


3. Bio-assays

Palmaria xylo-oligosaccharides (XOS) as prebiotics



https://www.nzoptics.co.nz/



UNIVERSITY of York

CNAP Centre for Novel Agricultural Products

Summary

Palmaria **and** ***Porphyra*** **are rich in digestible protein and polysaccharides**

Palmaria **70% xylan vs** ***Porphyra*** **50% sulphated galactans**

MAE plus enzymes releases high amounts of oligosaccharides (e.g. > 200 mg XOS per gram of ***Palmaria*** **biomass)**

Palmaria **XOS and MAE liquor are effective prebiotics**

Acknowledgements

Laura Faas

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Alan Cartmell

Debajit Dey

Duncan MacQuarrie

Suranjana Bose

Tim Van Berkel

Martin Sutcliffe

University of Nottingham
UK | CHINA | MALAYSIA

UKRI Engineering and Physical Sciences Research Council

Valorising UK's horticulture waste: bio-based ingredients for the consumer goods sector

BBNet ECR PoC Award (2024/25)

Dr Parimala Shivaprasad, FHEA, AffIChemE
Assistant Professor
Department of Chemical and Environmental Engineering
University of Nottingham

Co-I of the Supergen Bioenergy Hub

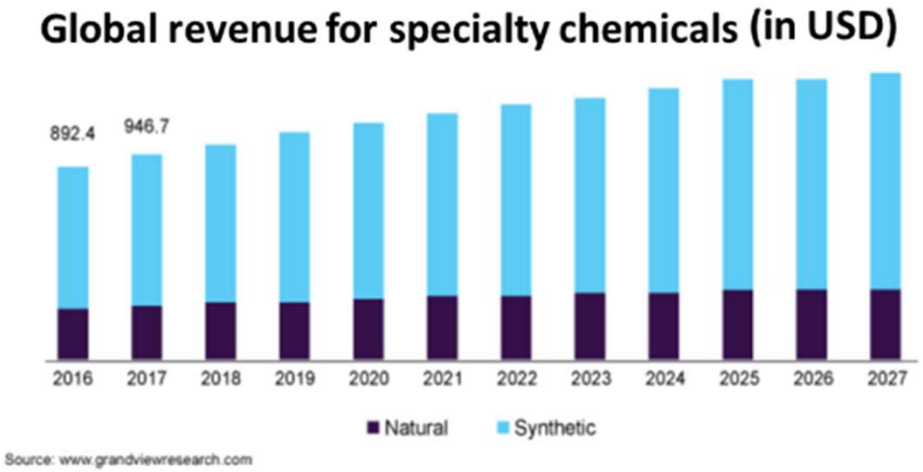
DSIT Fellow (Government Office for Science)

EPSRC Engineering ECR Forum member

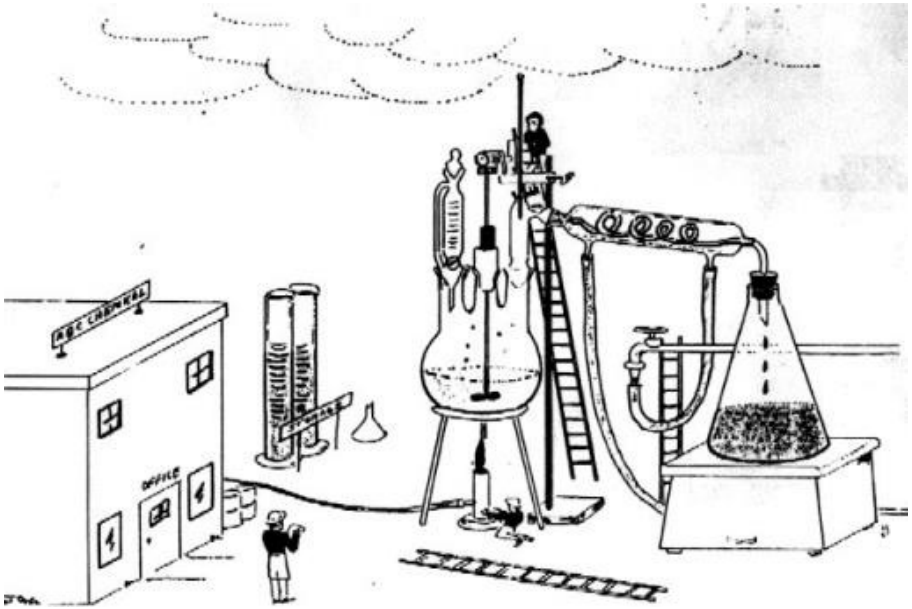
Parimala.Shivaprasad@nottingham.ac.uk

Current challenge

The chemical industry is the 3rd largest emitter of CO_2 and 87% of the processes are dependent on fossil fuels!



Lack of availability of raw materials and high cost of manufacturing for natural chemicals



Stitt, E. H. (2002) Chemical Engineering Journal

Opportunity

The UK imported £1.23bn of fragrance ingredients in 2020 from EU and non-EU countries (Statista)

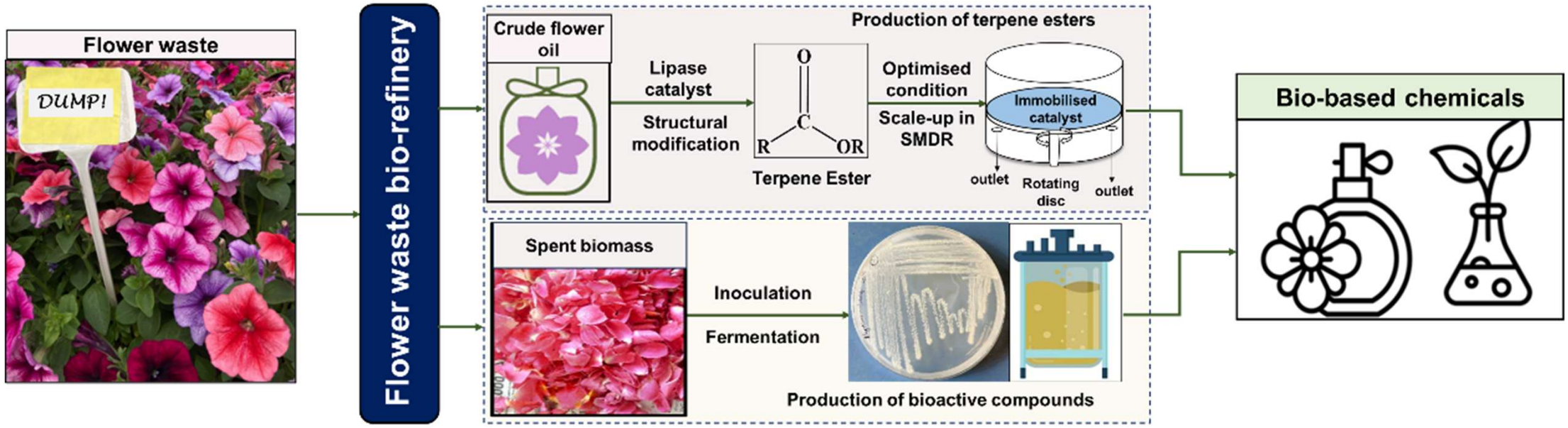
THE FUTURE OF MANUFACTURING:

A NEW ERA OF OPPORTUNITY AND CHALLENGE FOR THE UK

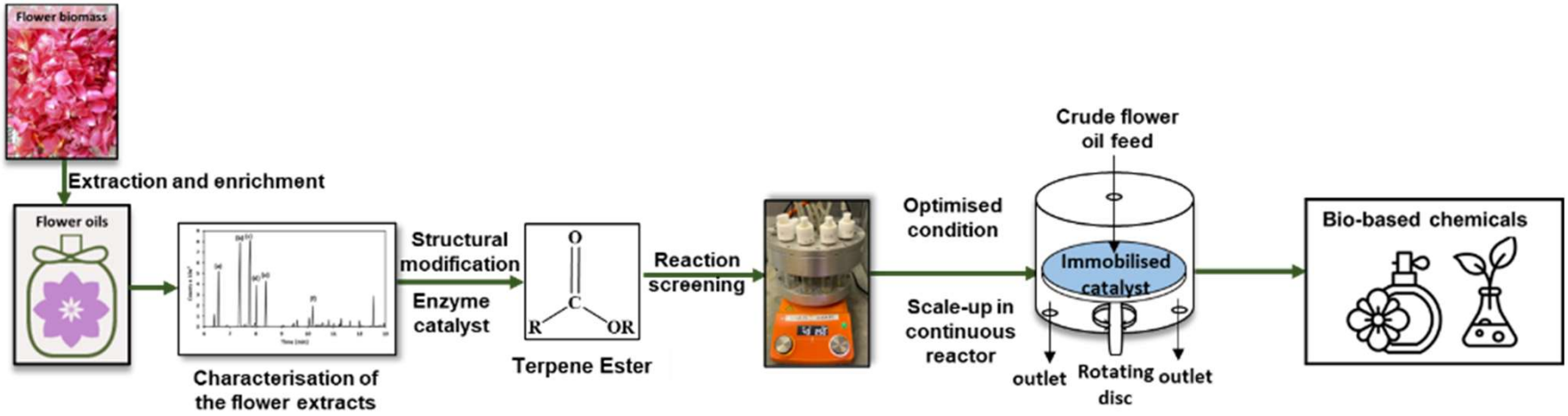
2013-2025: Efficiency & resilience	2025-2050: Experimentation with new systems	2050 & beyond: A resource constrained world
• Minimised material inputs	• New forms of value associated with products including sustainability	• Products use smaller amounts of materials and energy
• Waste management	• Products reused, remanufactured, recycled and redesigned with recovery in mind	• Material is not land-filled but kept in a 'productive loop'
• Increased energy efficiency	• More durable products designed for shared ownership	• Cleaner and quieter factories close to consumers, suppliers and academic institutions
• Reduced water usage	• Spare capacity built into supply chains to ensure resilience	• Supply chains with spare capacity at all stages
• Improved efficiency in land usage		
• UK leadership in areas including low-carbon technology		

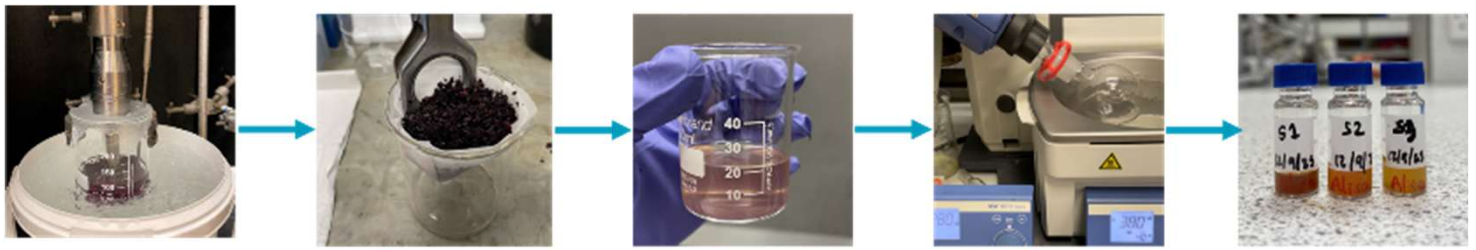
Bridge Farm (UK) produce 5m waste flowering plants and cut flowers annually

A circular approach to valorising flower waste

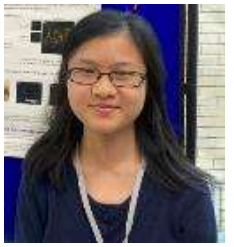


Enzyme catalysed structural modification of monoterpenoids





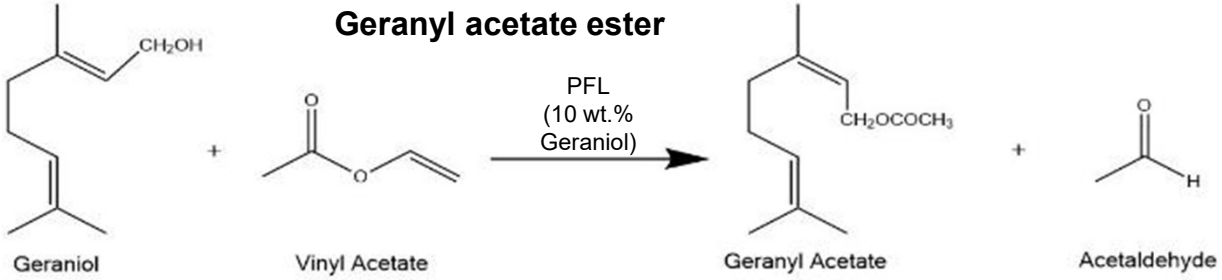
Alisa Wikaputri
PhD student



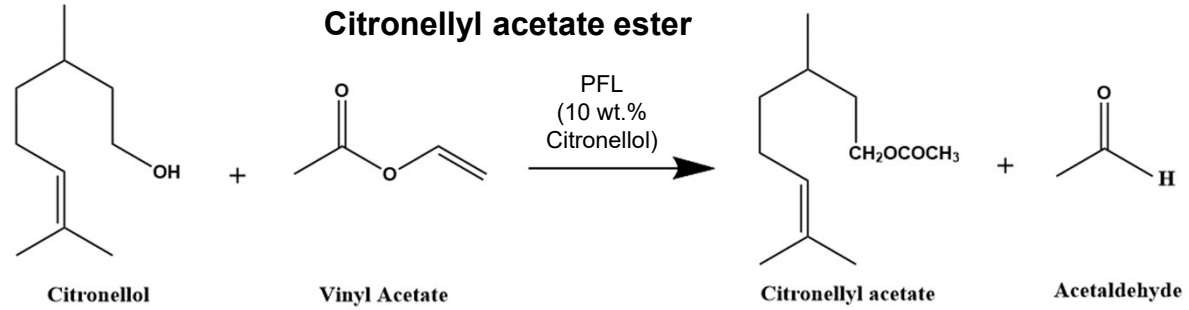
Xiao Wang
PDRA

Model reaction: Terpene esters

Geranyl acetate ester



Citronellyl acetate ester

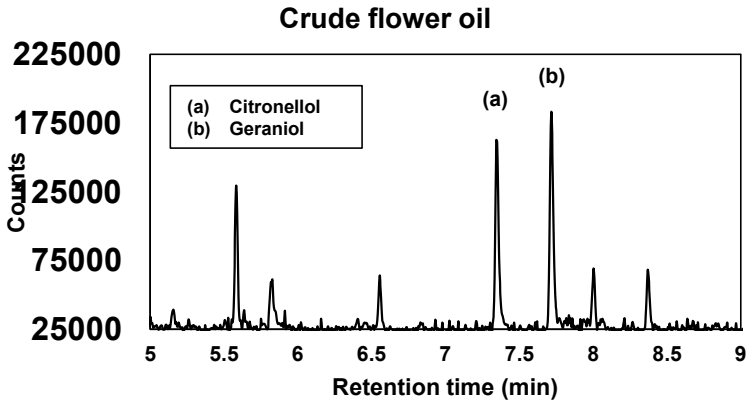


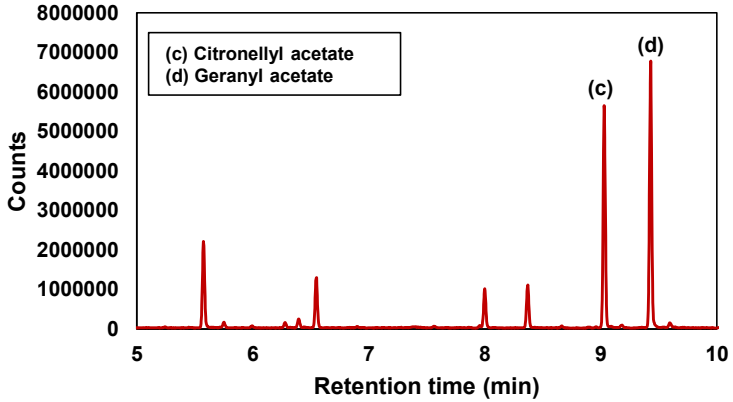
(Both no side/parallel reactions)

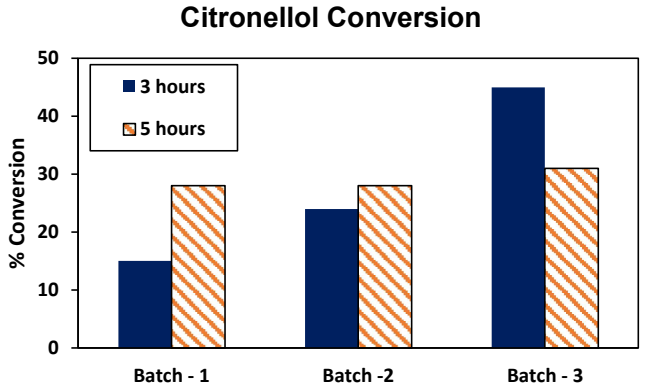
- Commonly used in **fragrance**, **cosmetic** formulations and **flavours**
- Typical synthesis via plant extraction or chemical synthesis

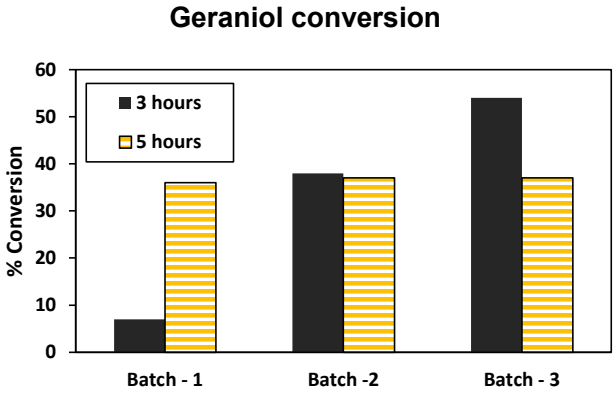
Case study - Crude flower oil transesterification

Solvent free transesterification with lipase catalyst



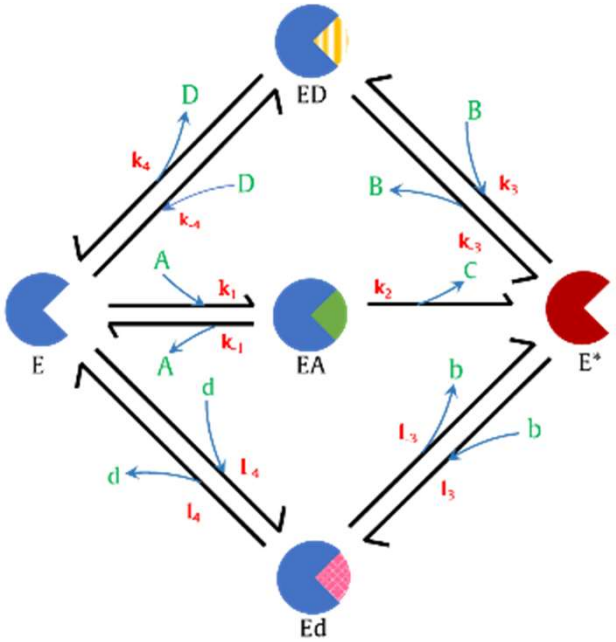






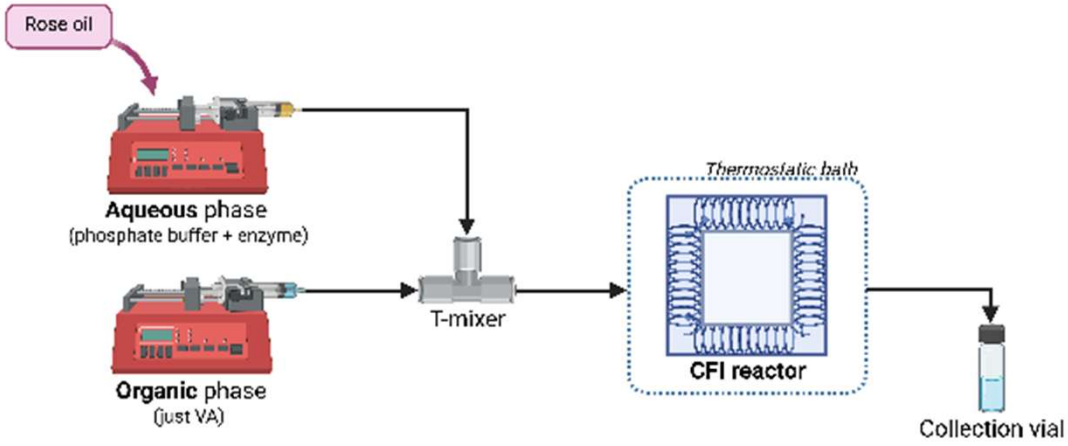
- Higher reactivity of geraniol observed
- Full conversion of citronellol and geraniol after 5 h
- Kinetic studies in progress

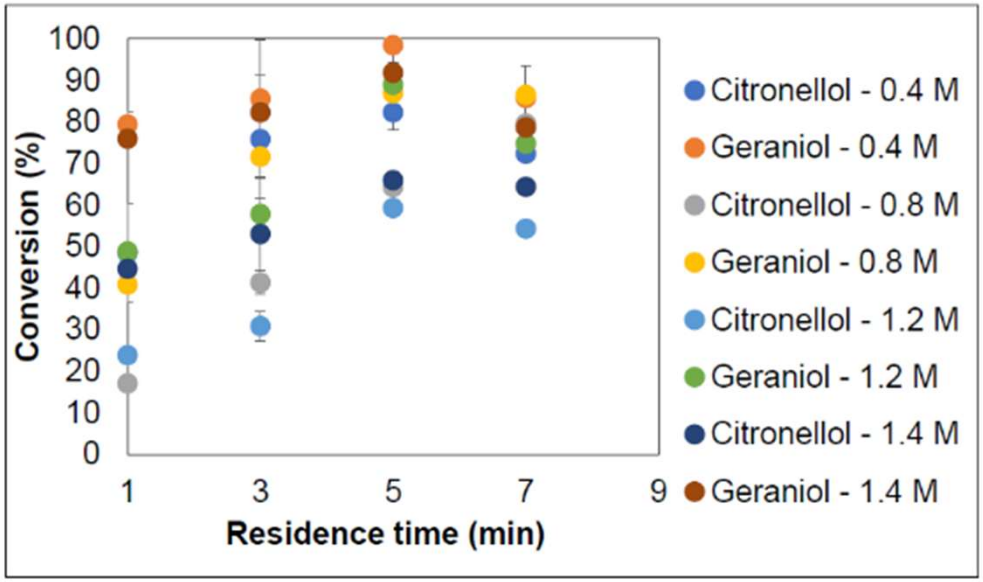
Batch to Continuous to produce terpene esters



Compound	Specificity constant (k_{cat}/K_M)	Turnover number (k_{cat})
Citronellol	14.45	0.3
Geraniol	6.86	5.0

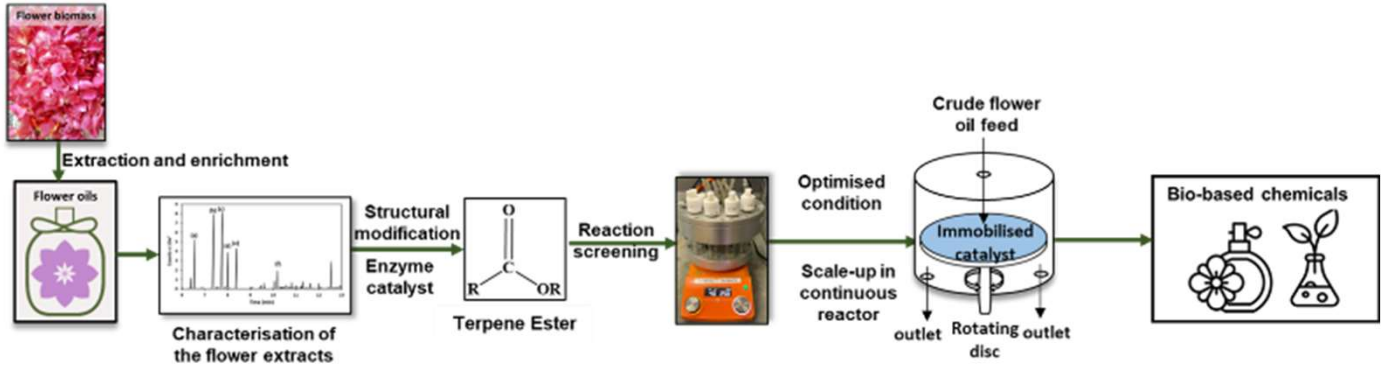
Higher enzyme affinity for geraniol, therefore higher yield of product





Alisa Wikaputri
PhD student

Modelling the Flower Waste Biorefinery

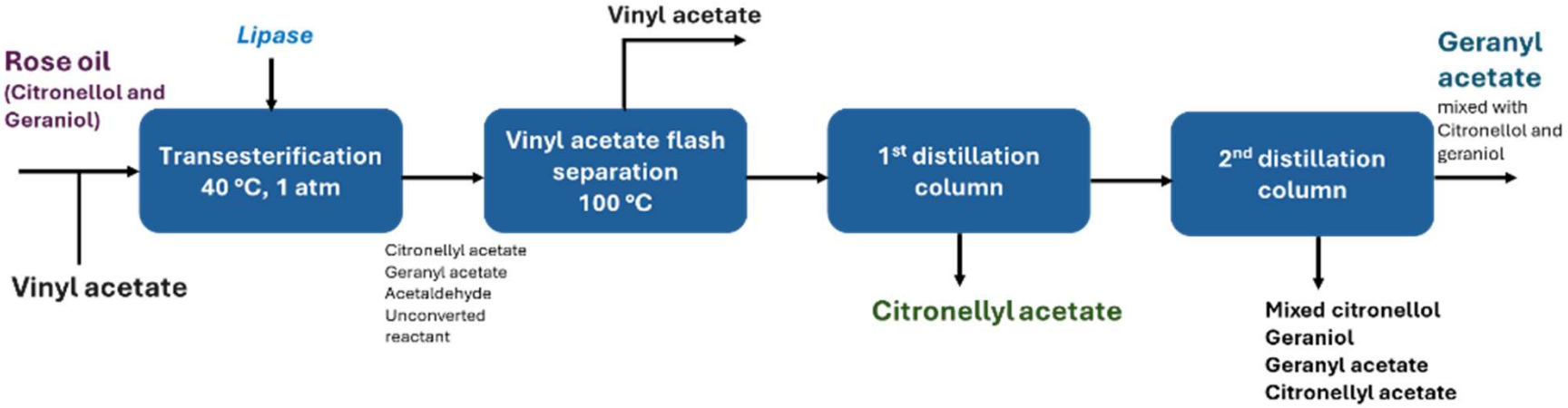


Dr Ioanna Dimitriou

Supported by:

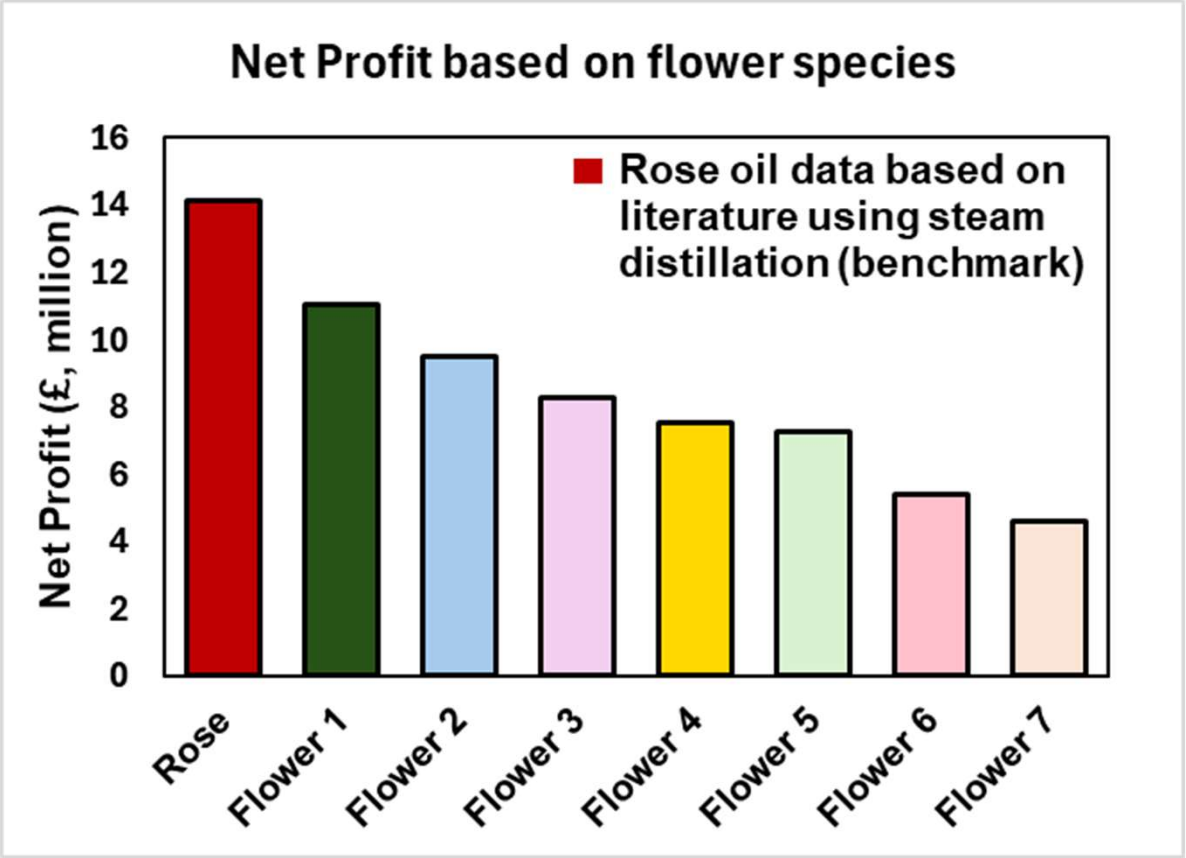
Vipada Sansen (PhD Student)

Dr Akos Cseke (Senior PDRA)



Net profitability of approximately £37 million using waste rose flowers (model feedstock)

Economic assessment based on flower oil quantity and quality



There is potential for horticulture waste originating in the UK, which is non-purpose grown, as an alternative feedstock for high value, fragrance ingredients

Impact assessment – oil refinery process using purpose grown rose flowers

Impact category	Unit	Flower production	Oil production	Oil refinery	Transport	Waste	Net emission
Global warming	kg CO_2 eq	1699.9	404.06	12.461	1.9822	4.1389	2122.6
		80.1%	19.04%	0.59%	0.09%	0.2%	100%

Key observations

- Over 99% of the global warming impact from flower production and subsequent oil production
- The high share of the impact from production is the result of the low yield (0.05%) of the oil distillation process which requires large quantities (1:2000 kg) of rose flowers
- Transesterification process contributes only to 0.59% of the total impact
- Transportation and waste treatment (vinyl acetate as waste solvent) is negligible

Next steps in the project

- Seasonal variation in composition of flower oils and effect on structural modification
- Reaction scale-up in flow reactor and the spinning mesh disc reactor
- Estimation of profitability for the biorefinery process
- LCA for the flower waste biorefinery using modular processes

BBNet impact on the Flower Power group

Collaboration with Bridge Farm and BDC through HVB BIV

Poster at the BBNet annual meeting in 2023

BBNet ECR PoC award in 2024

Feasibility data and further funding

Unilever trialling use of unwanted flowers to make fragrances for products

The consumer giant has launched the pilot as a way to make cost-effective ingredients by using plants that would otherwise go to waste.

Rebecca Speare-Cole • Thursday 29 August 2024 00:01 BST

Ray Marriott, chief scientific officer at Bridge Farm Group, and Parimala Shivaprasad, assistant professor at the University of Nottingham, selecting unwanted multi-coloured petunias in Bridge Farm Group's 60-acre greenhouse from which scientists will extract essential oils (Christopher Nunn/Unilever)

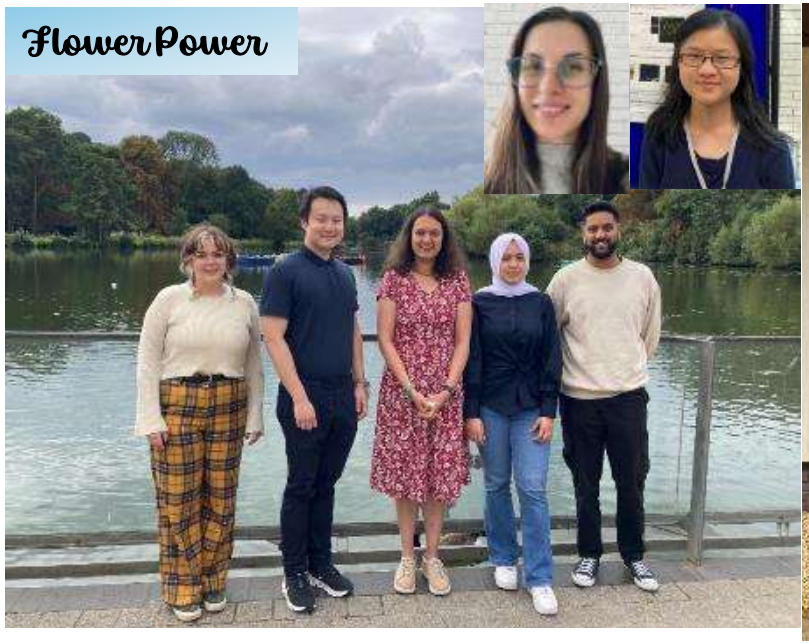
Supergen Bioenergy

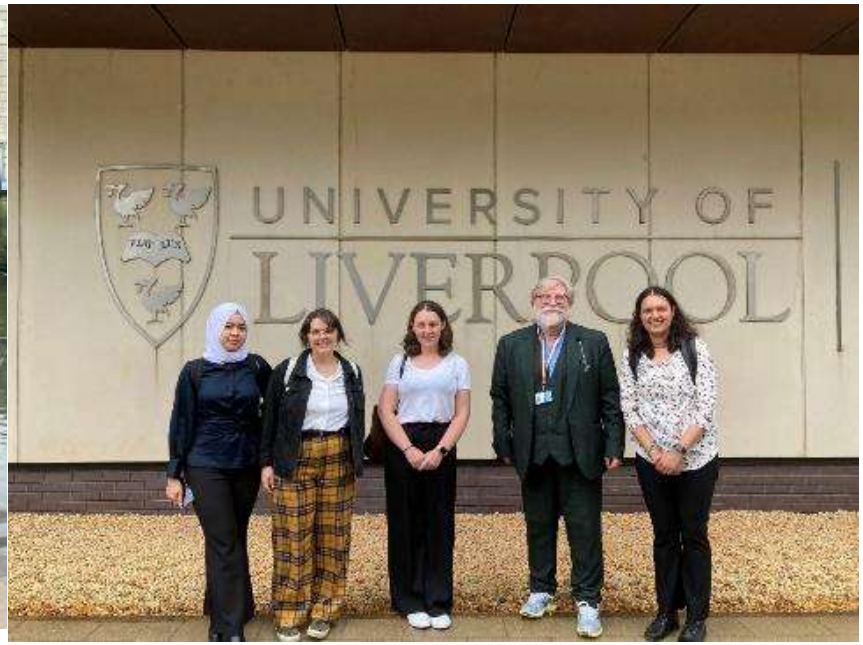
EXTRAORDINARY FLEXIBLE FUNDING AWARDED TO PARIMALA SHIVAPRASAD, UNIVERSITY OF NOTTINGHAM

The funding call was launched to provide a specific capability and activity within the Supergen Bioenergy Hub, focused on an identified gap around bio-based chemicals and materials.

Government Office for Science

Acknowledgement





Prof Derek Irvine

Prof Rob Stockman

Dr Samantha Bryan

James Richardson

Rhea Satpute

Bridge Farm: Dr Ray Marriott and PhD studentship for Rebecca Still

Dr Craig Jones and Dr Neil Parry at Unilever for the BBNet PoC funding support

Supergen Bioenergy

Supergen Bioenergy Hub Business Interaction Vouchers

Apply by 31 October 2025

- Up to £15,000 to fund short-term projects
- Build new partnerships, accelerate research impact and strengthen engagement between academia and industry
- Support energy and industrial priorities
- Cover costs of developing a collaboration with a university, eg consumable costs, researcher time, site visits

Pulcherrimin: a bio-based catalyst for base-free oxidation of 5-HMF

4th BBnet conference

17th October 2025

Jonathan Wagner

j.l.wagner@lboro.ac.uk

Loughborough University

#InspiringWinners since 1909

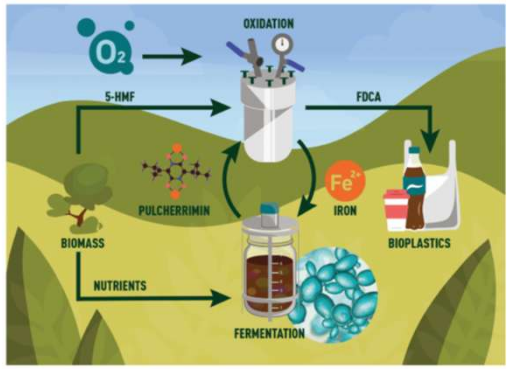
BB/S009779/: Bio-based catalysts for bioproduct oxidation

Dr Swathi Mukundan
Dr Fabio Santomauro

Dr Noelia Villarroel
Dr Daniel Miramontes Subillaga
Dr Adriano Randi
Prof Sandra Dann
Dr Jose Marco

BB Net Biomass Biorefinery Network

BIOME BIOPLASTICS



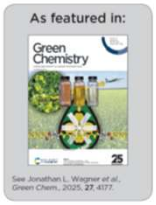
Showcasing research by Dr Jonathan Wagner, Dr Swathi Mukundan and Professor Sandra Dann *et al.* from Loughborough University, UK, and independent researcher Dr Fabio Santomauro, Spain.

Pulcherrimin: a bio-derived iron chelate catalyst for base-free oxidation of 5-hydroxymethylfurfural to furandicarboxylic acid

Pulcherrimin, a bio-mineral derived from yeast culture of Metchnikowia pulcherrima, was successfully applied to the selective base-free oxidation of 5-HMF into FDCA. The catalyst could be synthesised as part of a biorefinery approach and presents a commercially viable, environmentally friendly alternative to conventional noble metal catalysts.

Image reproduced by permission of Jonathan L. Wagner from *Green Chem.*, 2025, **27**, 4177.

As featured in:



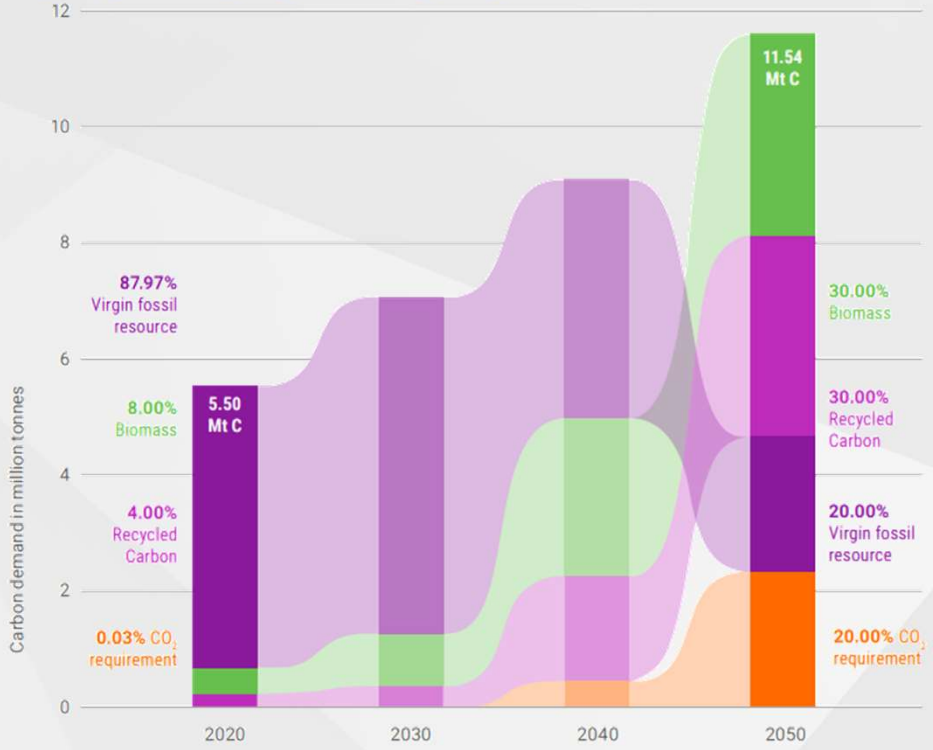
See Jonathan L. Wagner *et al.*, *Green Chem.*, 2025, **27**, 4177.

ROYAL SOCIETY OF CHEMISTRY

rsc.li/greenchem

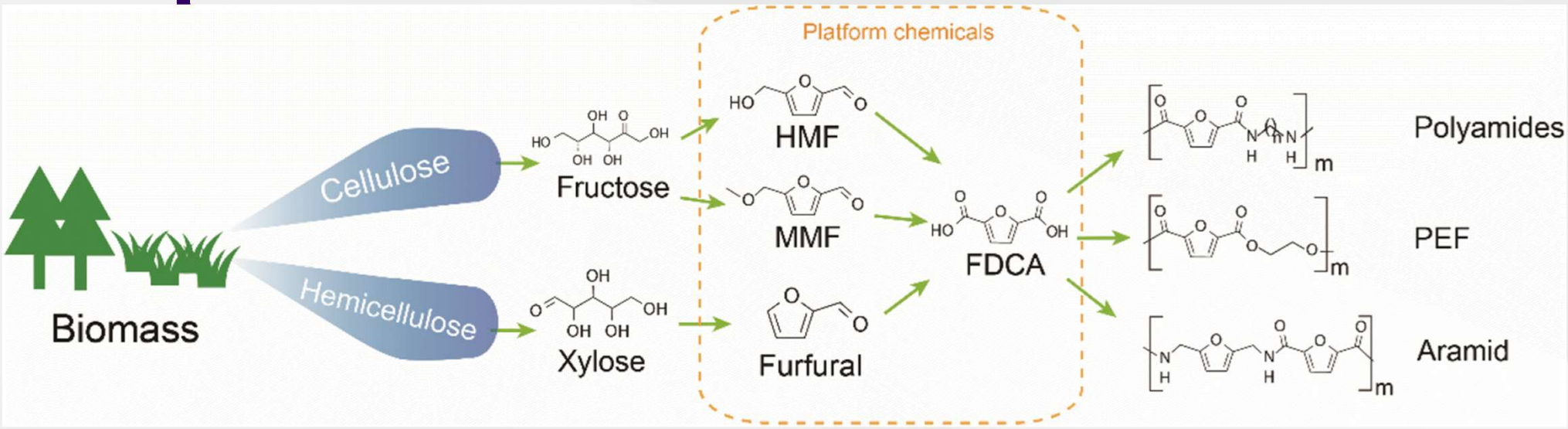
Need for bio-derived carbon

- 96% of all manufactured products contain chemicals
- Chemical industry cannot be ‘decarbonised’
- Require alternative source, including biomass
- Require new chemistries to exploit intrinsic functionality



Innovate UK, Sustainable carbon ambition for the UK chemicals industry, 2024

Bioplastics from cellulose

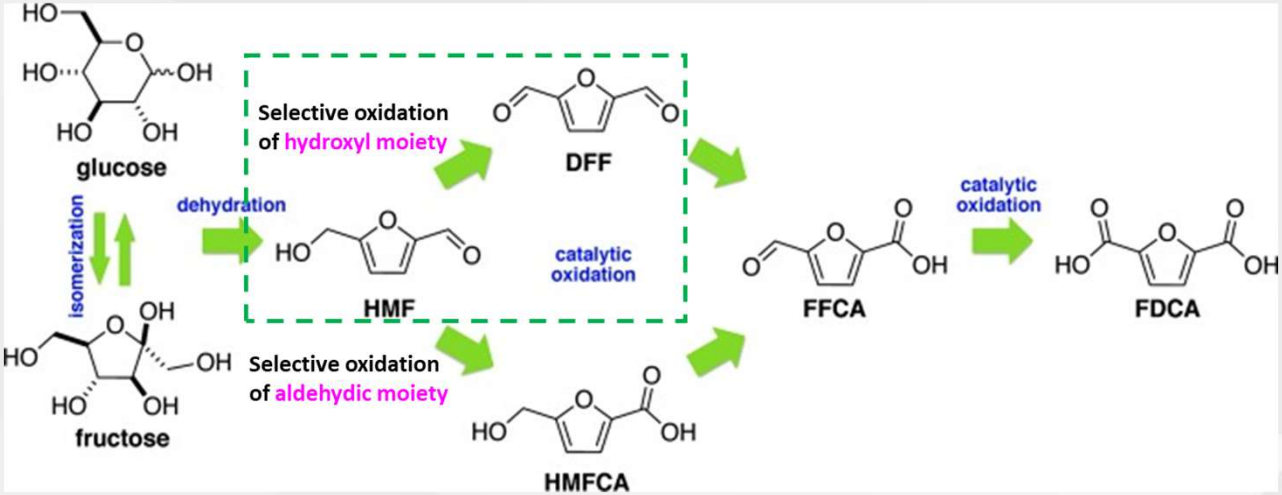


Applied Microbiology and Biotechnology volume 104, 527–543 (2020)

- Bioplastic market projected to increase from $9.2 billion (2023) to $20 billion (2026)
- FDCA can substitute terephthalic acid in the production of PET, reducing greenhouse gas emission by 45 – 55%

Oxidation of 5-HMF into FDCA

- 5-HMF is a key bio-based platform chemical which can be produced from dehydration of glucose
- Oxidation of 5-HMF yields 2,5-furandicarboxylic acid (FDCA), a potential substitute for terephthalic acid



- Reaction can follow two routes, via DFF, or HMFCA
- Range of existing catalysts, including homogenous bases, noble metals, transition metal oxides and biocatalysts, including both enzymes and whole cells

Pulcherrimin

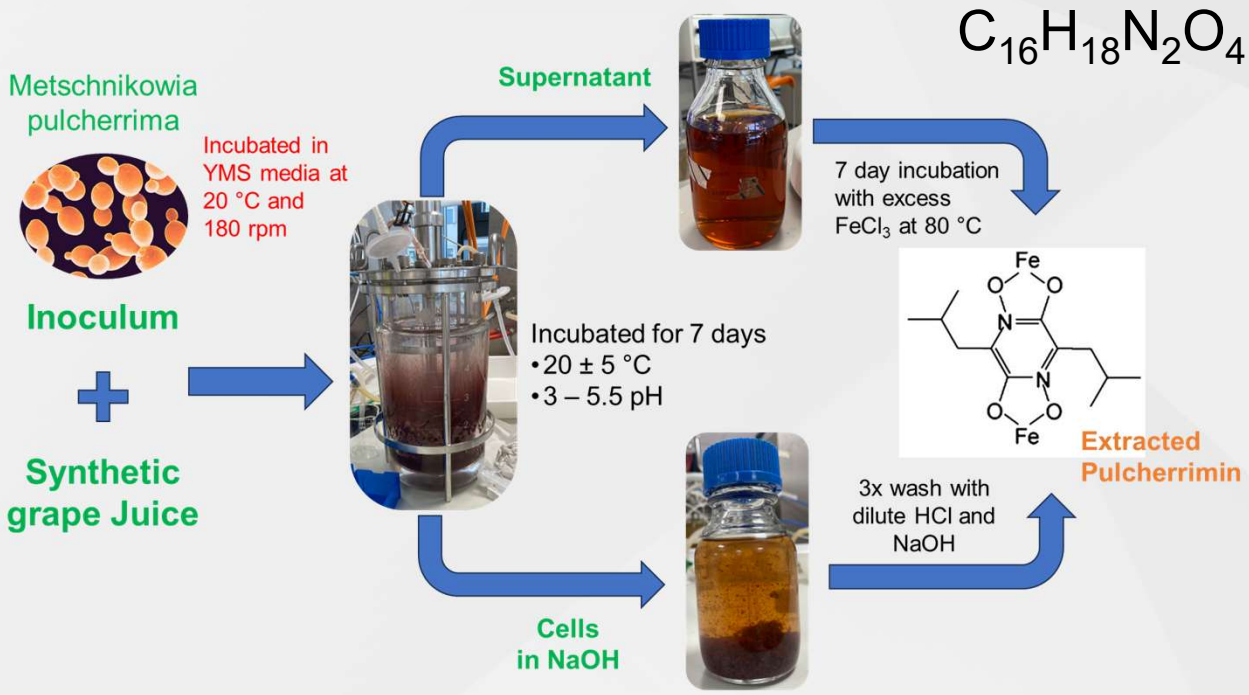
- Bio-based metal-organic framework produced by some bacteria and yeasts
- Insoluble in water and organic solvents (but highly soluble in strong base)
- Explored as antimicrobial agent, especially in biocontrol applications
- Potential oxidation activity

Sources:

- *M. pulcherrima* currently developed as source of palm oil replacement (>40% lipid yield) and 2-phenylethanol
- *Bacillus licheniformis* commercially used to produce subtilisin, probiotic animal feeds and 2,3-butanediol

CLEAN FOOD GROUP

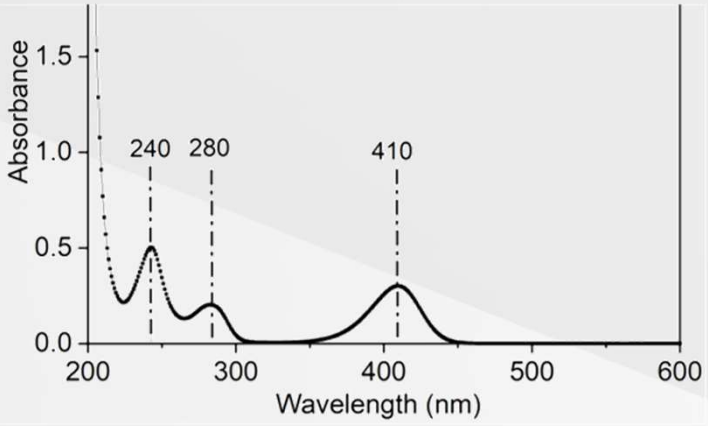
Pulcherrimin synthesis



$C_{16}H_{18}N_2O_4Fe$

Yield: ~ 26.4% (g/g) of the dried harvested biomass

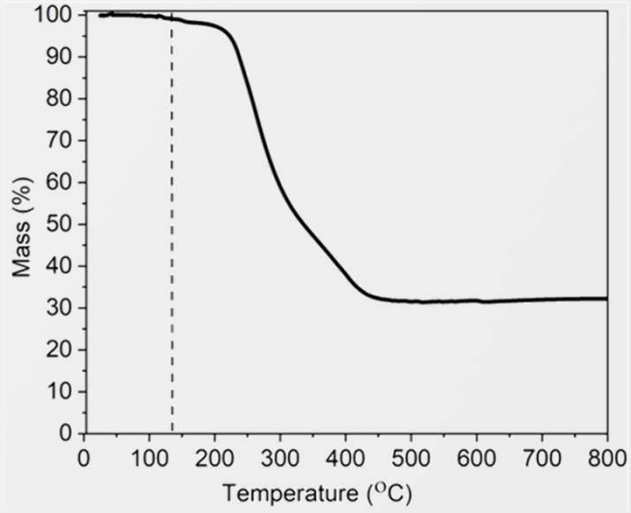
UV absorption spectrum



Elemental analysis

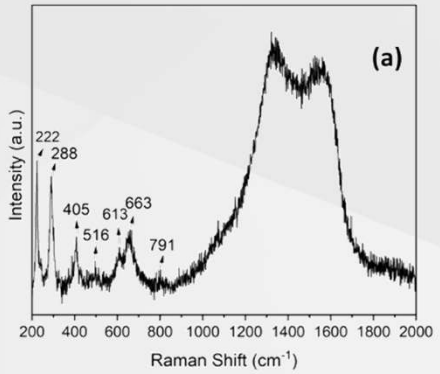
	C	H	N	Fe
Theoretical	53.6	5.0	7.8	15.6
Measured	47.8	6.7	8.9	11.2

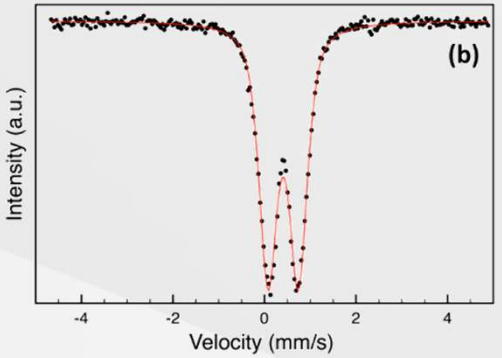
Pulcherrimin characterisation

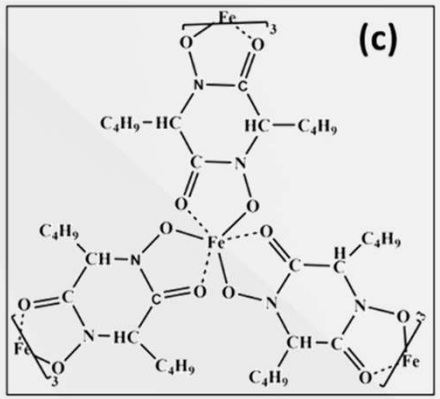


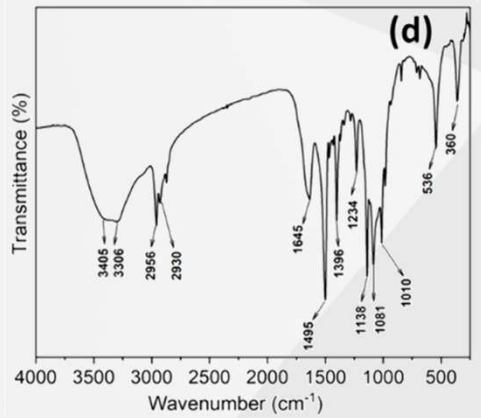
TGA in air:

Stable up to ~ 140°C





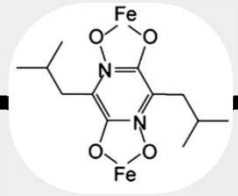




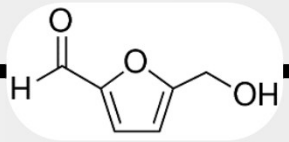
BET Surface area ($m^2 g^{-1}$)	29.05
Pore Volume ($cm^3 g^{-1}$)	0.153
Pore Size (nm)	15.2

5-HMF Oxidation experiments

50 mg Pulcherrimin



40 mL of 4.15mM 5-HMF in water

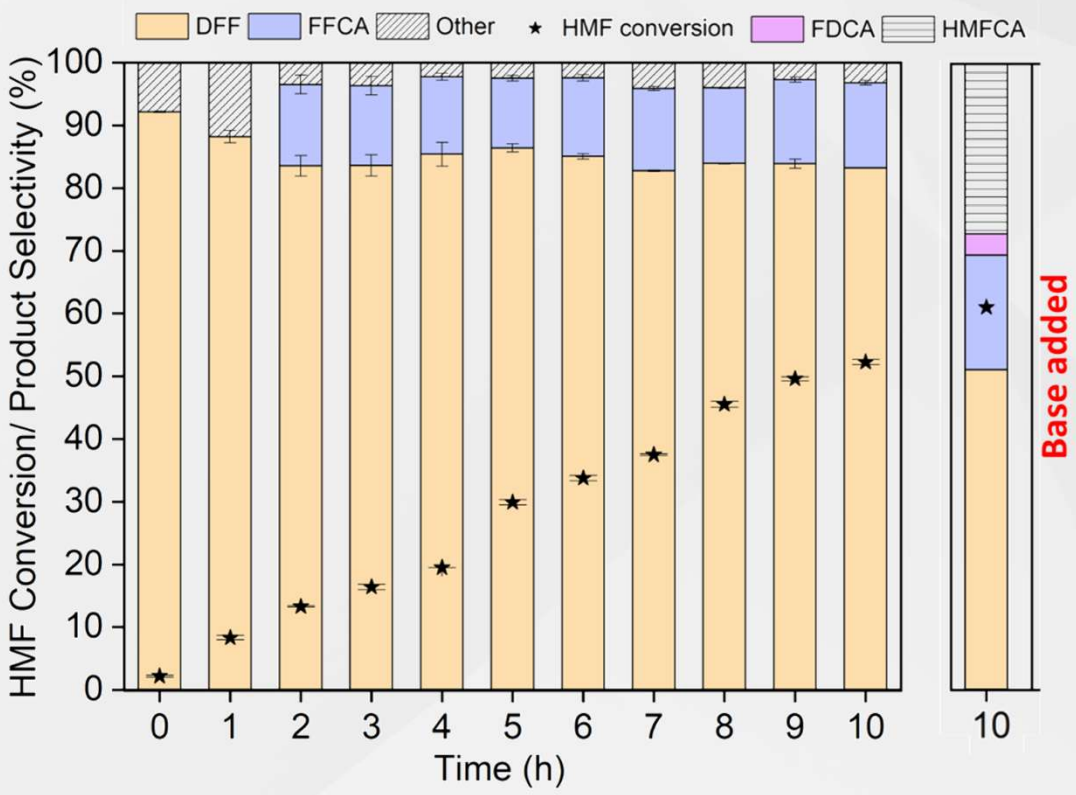


10 bar O_2

100 mL Parr reactor with online liquid sampling

- 10 h total reaction time with intermediate liquid sampling
- 100 °C, 120 °C, 140 °C
- Reactions done in absence of base
- Compared against Fe_3O_4/C baseline catalyst

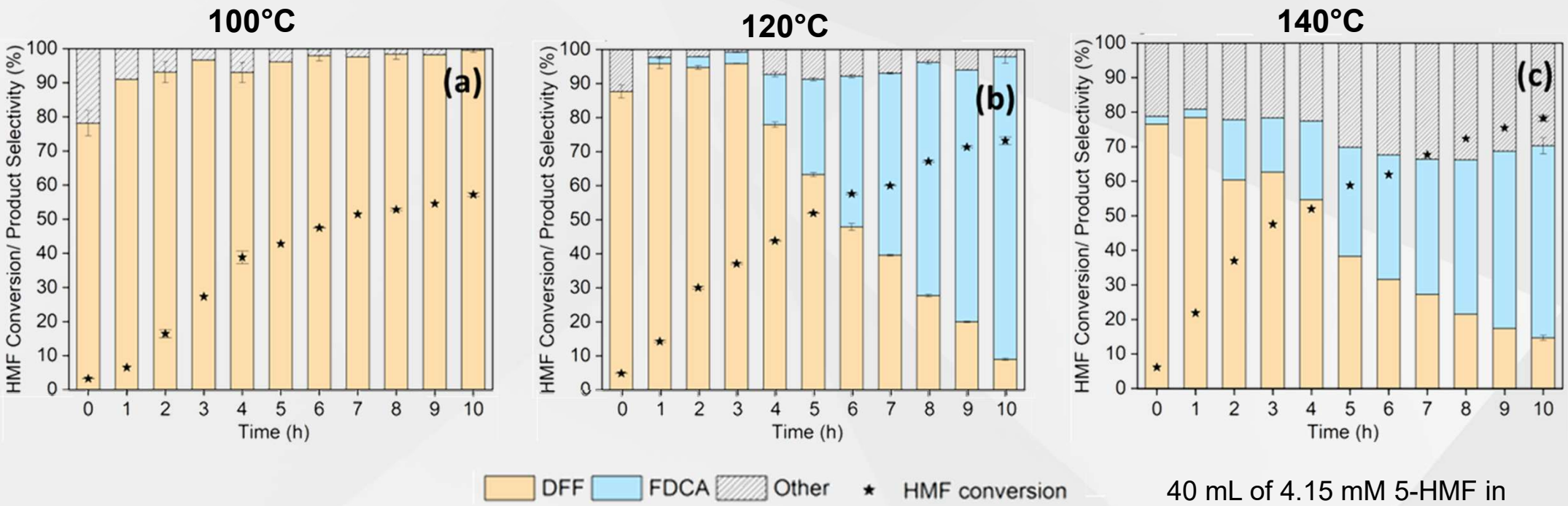
Baseline experiments with Fe_2O_3/C



- Partial oxidation to DFF and FFCA, but unable to oxidise second aldehyde group
- Base addition activates alternative pathway via HMFCA

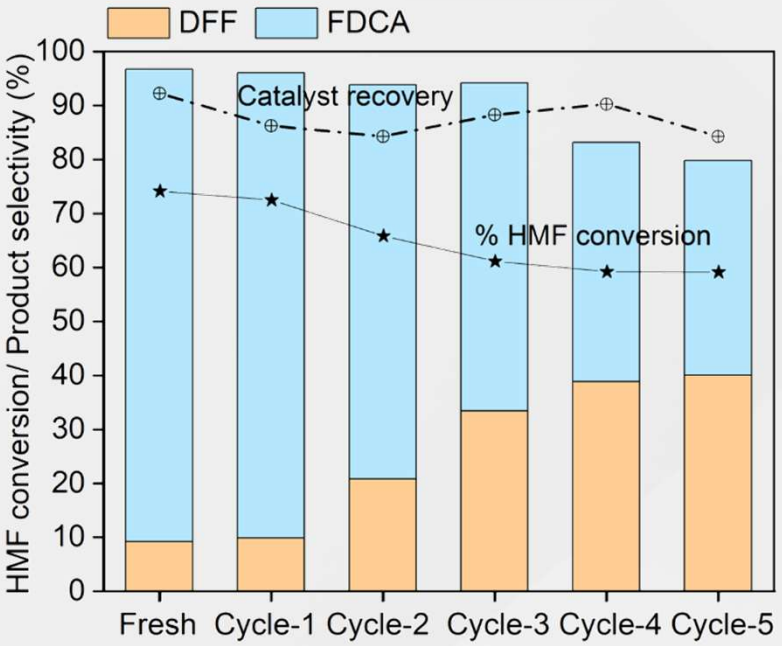
40 mL of 4.15 mM 5-HMF in water, 0.05g catalyst (0.008 M NaOH), 120°C, 10 bar O2,

Reaction with pulcherrimin



40 mL of 4.15 mM 5-HMF in water, 0.05g catalyst, 10 bar O2,

Catalyst stability



40 mL of 4.15 mM 5-HMF in water, 0.05g catalyst, 120°C, 10 bar O2,

- Selectivity shifts from FDCA to DFF, indicating deactivation of sites responsible for secondary oxidation steps
- Minor reduction in Fe content from 11.2%±0.2% to 10.4%±0.3% after five cycles

Economic perspective

Catalyst System	FDCA yield (%)	Catalyst Loading ($g\ g^{-1}_{HMF}$)	Catalyst cost per kg ($)	Catalyst regen. cost per kg FDCA ($)	Energy cost per kg FDCA ($)
5% Pt/C*	96.6	1.03 g	194	0.014	$0.087
Pulcherrimin	65.2	0.1 g	1.57	0.045	$0.153

*Based on Hussain Motagamwala *et al*. (2018) , *Sci. Adv.*, **4** , eaap9722.

- Costs dominated by increased catalyst replacement of 18.4%/run, vs 4%/year for reference study
- Energy costs higher due to increased separation, but do not account for use of milder conditions and use of water-only solvent

Environmental perspective

Catalyst system	Reactant (kg kg^{-1})		Solvent (kg kg^{-1})		Catalyst (g kg^{-1})		Total inputs (kg kg^{-1})	Mass raw waste (kg kg^{-1})	Mass recovered waste (kg kg^{-1})	E-factor
	5-HMF	Base	Total	Recovery	Total	Recovery				
Pt/C	1.27	0.817	68.2	61.3	0.438	0.438	70.7	69.7	61.8	7.90
Pd/C	1.41	0.910	75.8	68.3	0.509	0.504	78.7	77.7	68.8	8.91
Pulcherrimin (this work)	1.53	0.00	118	106	0.147	0.118	119	118	106	12.4

- Slightly higher E-factor for pulcherrimin, associated with slightly lower activity and selectivity
- Dominated by loss of solvent (water for pulcherrimin)
- Does not consider by-products from pulcherrimin synthesis

Conclusions

- Unlike Fe_3O_4/C, Pulcherrimin can selectively convert 5-HMF into FDCA
- Reaction proceeds in water, without base addition
- Activity is comparable to reported literature values for noble metal catalysts
- Material could be recovered and reused up to 5 times with, but DFF to FDCA conversion affected
- Although more expensive than Pt/C, significant potential for optimisation

Thank you

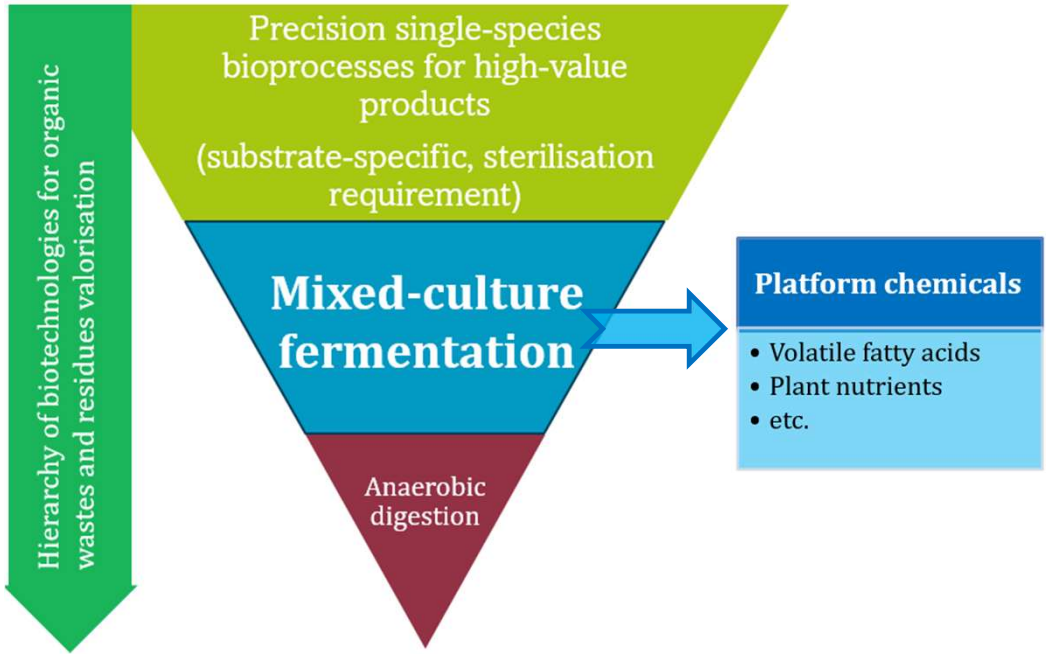
Anaerobic Fermentation Working Group

Yue Zhang, University of Southampton

Luca Alibadi, Cranfield University

Mixed-culture anaerobic fermentation

An enabling industrial biotechnology for a circular bioeconomy



- **Promote the valorisation of unavoidable organic wastes and residues, especially those that are putrescible and heterogeneous, while reducing its dependence on external chemical inputs**
  - ✓ **Anaerobic digestion sector** – transformation from an energy-driven into material-driven dirty biorefinery to enhance its profitability
  - ✓ **Chemical industries** – Valorisation of platform chemicals produced from the fermentation processes, e.g. aviation fuel production
  - ✓ **Water industries** – Integration with biological wastewater treatment processes and other opportunities

UKRI Biotechnology and Biological Sciences Research Council

BB Net Biomass Biorefinery Network

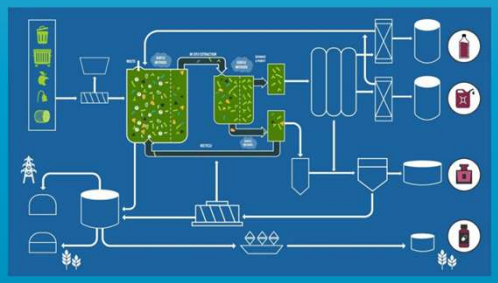
EBNet Environmental Biotechnology

UKRI Engineering and Physical Sciences Research Council

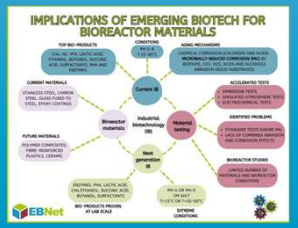
Anaerobic fermentation working group activities

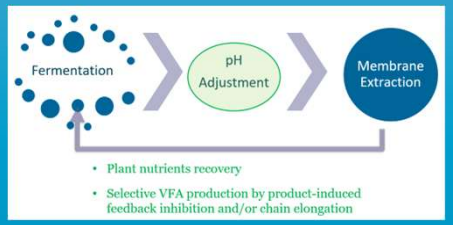
Workshop: The role of anaerobic fermentation in the circular bio-economy

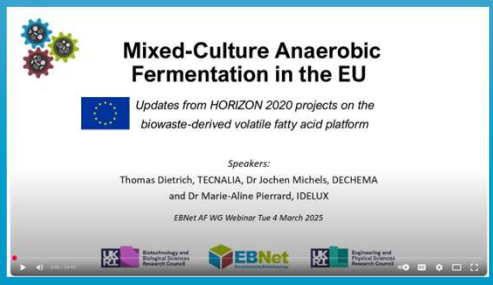
Animation: Anaerobic fermentations: a sustainable approach to everyday products by turning waste into value



Engaging interests & Enhancing collaborations







Desk-based and small-scale test-the-concept studies

Webinar: Mixed-culture anaerobic fermentation in the EU

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EBNet Environmental Biotechnology

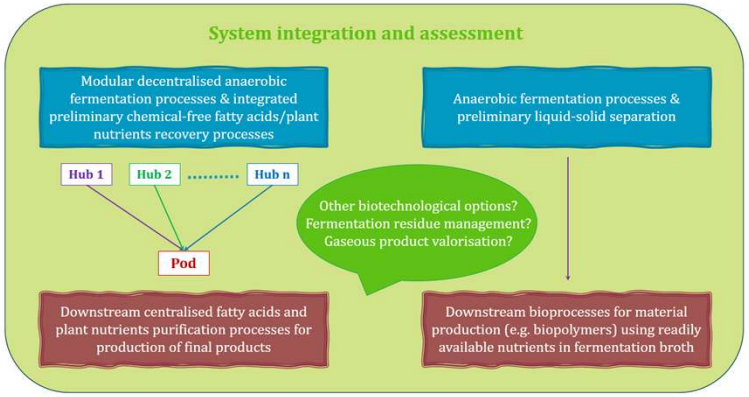
UKRI Engineering and Physical Sciences Research Council

Workshop: the role of anaerobic fermentation in the circular bio-economy

Aim: To assess the current development, potentials, challenges and opportunities of mixed-culture anaerobic fermentation, and put it in the context of national & international decarbonisation and circular bio-economy framework

Three case studies: wastewater biosolids; household FW/OFMSW; agro-industrial wastes/residues

- ✓ Fundamental research and innovation
- ✓ Development of integrated approach
- ✓ Detailed engineering appraisal, scaling and market considerations
- ✓ Stakeholder engagement, business support and policy development



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EBNet Environmental Biotechnology

UKRI Engineering and Physical Sciences Research Council

Look forward to further developing ideas and expanding them in the WG and beyond

Y.Zhang@soton.ac.uk

Biotechnology and Biological Sciences Research Council

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EBNet Environmental Biotechnology

Engineering and Physical Sciences Research Council

Biomass Biorefinery Network

4th BBNet Conference

The future prospects for biorefining: Feedstocks, technologies and products

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Perspective Economics

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Biochar Working Group

Recent Workshop and Future

Dr Meredith Barr, London South Bank University

4th BBNet Conference, October 2025

Biochar-Microorganism Interactions: How and Why?

- Adsorption
  - How?
    - Physical or chemisorption
  - Why?
    - High surface area (universal adsorbent)
    - Surface chemistry determines strength

- Growth substrate
  - How?
    - Biochar metabolism (stability?)
  - Why?
    - Co-location of C, N, and micronutrients

Biochar-Microorganism Interactions: Applications

- Soil microbiomes
  - Why?
    - Promote PGPMs
    - Outcompete plant pathogens
  - How?
    - Biochars with ***selective*** properties
    - Microbially-enhanced biochars

- Polluted environments
  - Why?
    - Oil spills, heavy metal contamination
  - How?
    - Promote microbial growth
    - MEBs

- Anaerobic digestion
  - Why?
    - Increase bio-gas yield & selectivity
  - How?
    - Promote methane-producing bacteria
    - Adsorb inhibitors

- Wastewater
  - Why?
    - Reduce pathogens & AMR
    - Reduce chemical pollutants
  - How?
    - Adsorb pathogens
    - Biofiltration

Workshop scope

Exploring how thermal, thermochemical, and biological conversion technologies may be integrated to ***improve environmental and economic outcomes*** of ***waste and biomass valorisation processes***.

Sessions

- Biological pretreatment of thermal/thermochemical feedstocks
- Biochar for microbiome engineering
- Thermal/thermochemical technologies in anaerobic digestion and fermentation
- Industry panel discussion

Consensus activities: “Café Delphi”

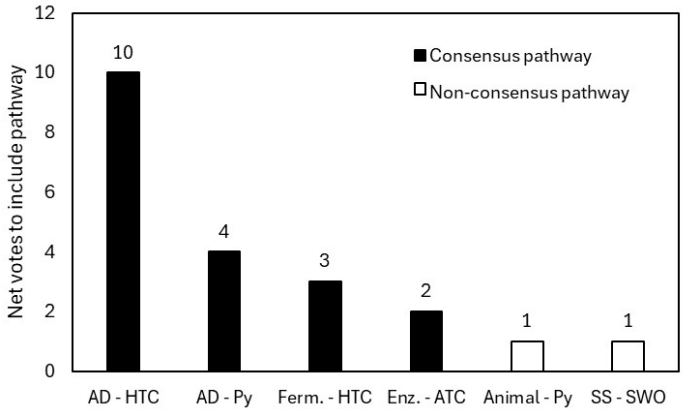
World Café: structured conversational process where participants discuss topics in small, rotating groups to encourage collaborative dialogue and idea-sharing.

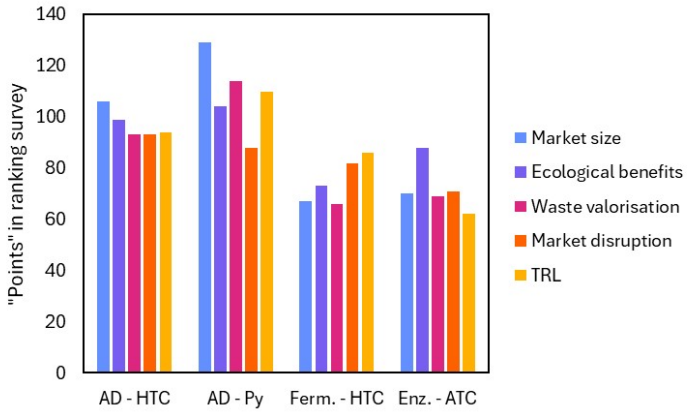
Delphi Technique: structured forecasting technique that gathers expert opinions through multiple rounds of anonymous surveys to reach a consensus.

Discussion and idea generation	Selecting consensus pathways	Ranking survey

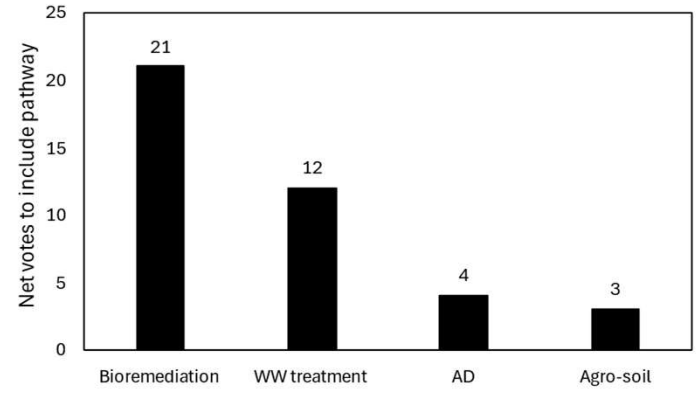
• ~15 min to:
  • discuss freely
  • propose pathways
  • vote on proposed pathways
	• Organisers determine vote cutoff for consensus pathways and prepare survey	• 5-10 min to complete survey ranking consensus pathways according to:
		  • Market size
		  • Ecological benefits
		  • Waste valorisation
		  • Market disruption
		  • TRL

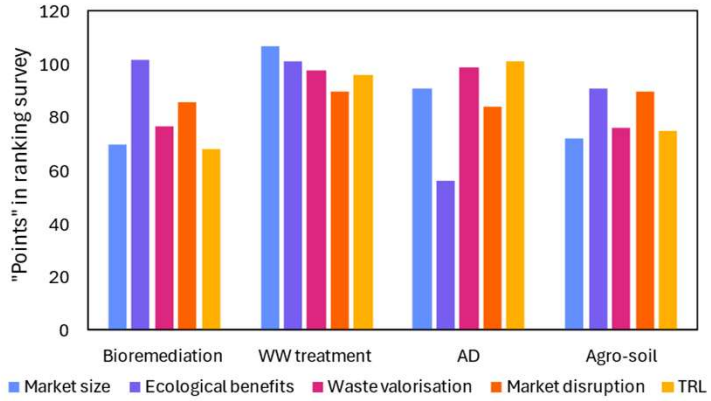
Biological pretreatment of thermal/thermochemical feedstocks



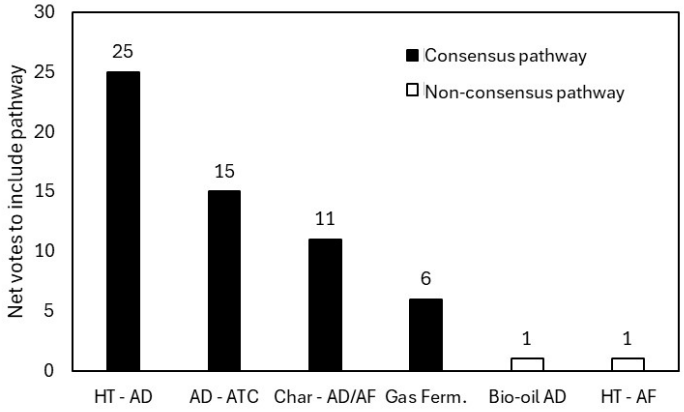


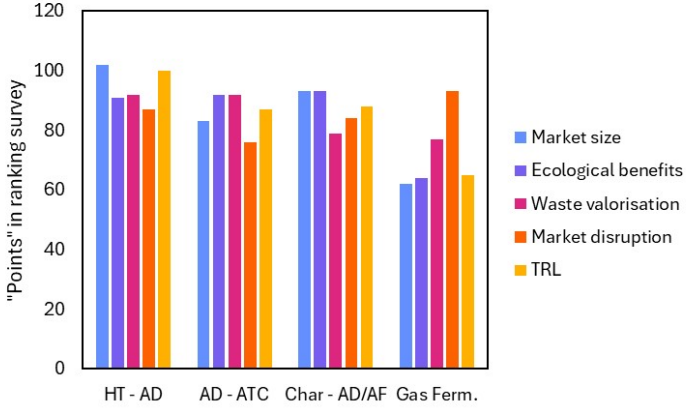
Biochar for microbiome engineering





Thermal/thermochemical technologies AD/AF





Industry Panel Discussion: Thematic Analysis

Opportunities:

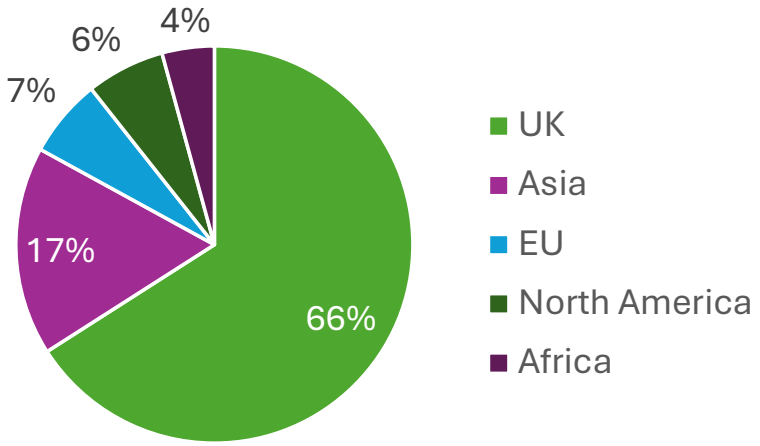
- Circularity and cross-industry synergies
- Multi-output value chains
- Decentralised local systems
- Complementary process matching

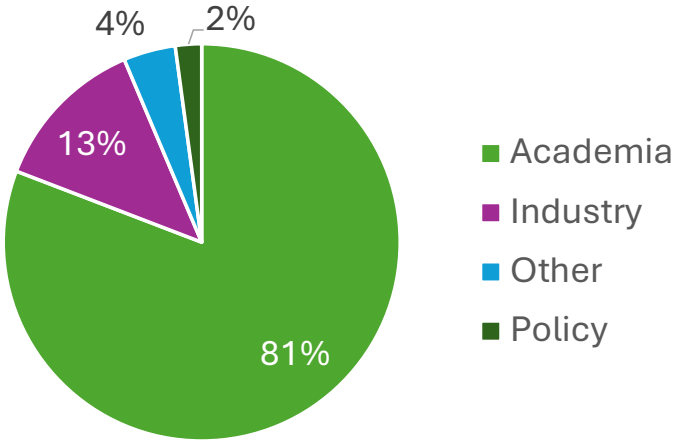
Challenges:

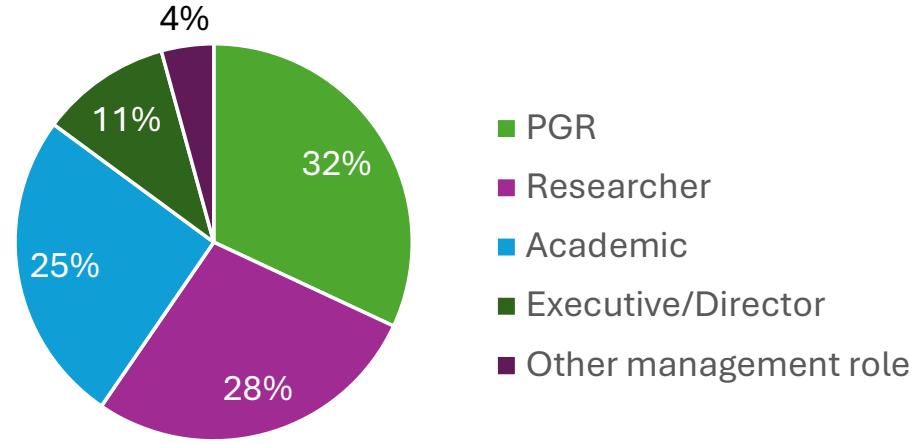
- Regulatory misalignment
- Policy lag
- Knowledge gaps
- Market volatility
- Scale-up complexity
- Limited industry–academic translation

Our future: who are we?

- 47 Members
- 12 Countries
- Mostly from academia
- Diverse career stages







Our future: ideas

Broader group:

- Policy event: “Aligning UK waste valorisation regulations with sustainability and innovation goals”
- Newsletter

“Core” group:

- Collaborative funding application (Horizon consortium?)
- Longer term: forming or joining a new network (integrated biorefinery?)

Please come talk to me if you have ideas!

Biomass Biorefinery Network

4th BBNet Conference

The future prospects for biorefining: Feedstocks, technologies and products

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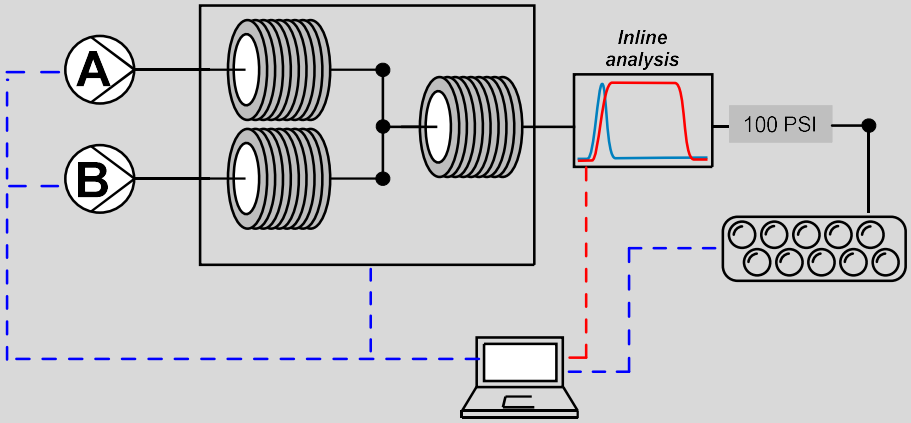
The Continuous BioFlow Network

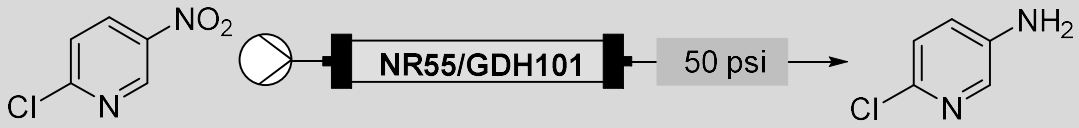
Dr Sebastian Cosgrove, Dr David Ellis, Dr Graeme Barker

4th BBNet Conference: Working group update

Continuous biocatalysis and biomanufacturing



- The running of processes in a continuous manner.
- Offers an alternative approach to typical batch processes.
- Yet to realise potential beyond small molecule synthesis and petrochemical production.



The Continuous BioFlow Network

- No network focussed specifically on continuous biomanufacturing in the UK.

- Arose from a rejected BBSRC grant application!
- Comments from review that team was strong and demonstrated good interdisciplinary skillset.

Seb Cosgrove: Keele
Flow, biocatalysis, biomanufacturing

Graeme Barker: Heriot-Watt
Flow, synthetic chemistry

David Ellis: Heriot-Watt
NMR, inline analysis, whisky research

Aims of the Network

- Promotion of the use of continuous approaches in biocatalysis, biomanufacturing and biomass utilisation, including increased use of inline analytics towards better data usage (i.e., self-optimisation).

- Increase cross-discipline collaboration centred around continuous biomanufacturing.

- Provide a focal point for disparate disciplines to work together in continuous biomanufacturing.

Launch event: 9th January 2025, Heriot-Watt

- Two keynote speakers, four research hub talks and a range industry and academia short talks.
- Attracted >100 registrations and ~80 attendees.
- ECR poster session with 12 posters on view.
- Stalls from six exhibitors.
- Great feedback (not about weather).

Further activities

- Follow up Summer Webinar with three academic speakers:
  - Dr Adam Clayton (University of Leeds): Self-optimising flow systems for flow biocatalysis
  - Prof Martina Contente (University of Milan): Continuous Biomanufacturing
  - Dr Rebecca Ruscoe (Keele University): Inline high NMR analysis of biocatalytic transformations

- LinkedIn group for member activities.

- Member database.

How did BBNet help?

- We applied for collaboration grant, but BBNet went beyond to help support:
- Arranging contact with relevant people from across the UK Bio sector.
- Advised and helped with logistics around the event.
- Gave us some money.

Future aims

- Second annual meeting scheduled for **Friday 23rd January 2026** at Keele University.
- Plans for networking grant application (UKRI…).
- Starting to track collaborations derived from the network, understand impact.

Acknowledgements

- Dr Graeme Barker
- Dr David Ellis

- BBNet
- Royal Society of Chemistry

- UK Catalysis Hub

Biomass Biorefinery Network

Be sure to visit our exhibition throughout the conference

AGRIFOODX

Anaero Technology

cpi

Supergen Bioenergy

BDC Biorenewables Development Centre

Plants • Processes • Products