From Flower Waste to High-Value Chemicals: Continuous Manufacturing in Coiled Flow Inverter (CFI) Microreactors

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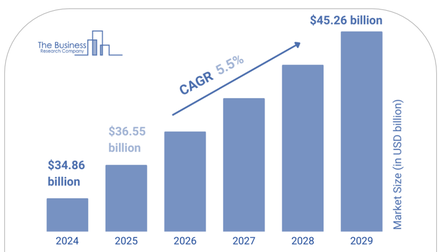
Driving UK economic growth through decentralised chemical manufacturing by utilising UK horticultural waste

The context: flower waste

Context: rising demand for **bio-based** flavours & fragrances



Global flavours & fragrances market

$45 billion by 2029[1] (5.5% CAGR)

Problems with… Current technology

- **Toxic** solvent, **slow** production, and **high-cost**
- Cheap and **sustainable catalysts** are **scarce**
- **Poor** sustainability metrics

Fact: UK still **imports £1.23 Billion of** fragrance ingredients in 2020[2]

Our solution: flower waste

Untapped **material** for **bio-fragrance** chemicals **rich in terpenoids***

34,000 tonnes/year of flower waste generated in the **UK alone**[3] (Landfilled)

Impact

Taking **10% of UK** flower waste could already generate **£100M in value** and **reduce CO_2** by **30%!**

***What are terpenoids?**

Valuable **scent & flavour** molecules **already present** inside flowers/plants

The opportunity

1 Decentralised manufacturing technology

- **Opportunity:** our technology aligns with the UK's shift toward **small, modular manufacturing** for sustainable fragrance **production**

2 A new market for wool!

- UK wool waste is at a loss (**low** demand): (**15–30p fleece vs > £1 shearing**[4])
- **Opportunity:** to use wool as a **low-cost catalyst** support to replace **expensive commercial catalysts**
- Enables a new **farm-to-chemicals supply chain**

Our approach: continuous processing on-site

Engineering a modular and continuous manufacturing platform

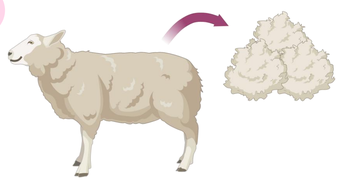
Our approach aligns with UN **Sustainable Development Goal 12**

Raw materials

1

Flower waste mix from the farm

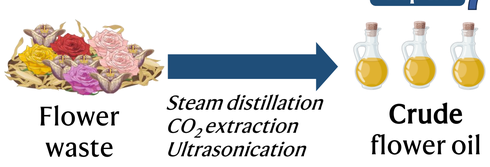
2



Wool waste (as an economical and sustainable support for our **catalyst**)

Process flow: developing the coiled flow inverter (CFI) microreactor technology

1 Flower oil **extraction**

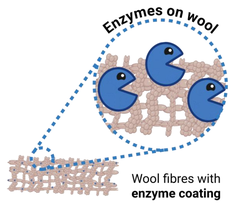


2 **Feasibility** tests and **enzyme modelling**

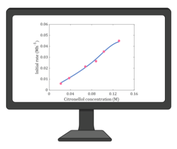
Preliminary batch test using commercial flower oil to produce high-value chemicals

Lab-scale **transesterification** system

We use a **water-based, non-toxic,** and **safe** solvent



Coating enzyme on wool



Enzyme **modelling** for **process optimisation**

3 **Continuous** production in **CFI microreactors**

Apply the best process conditions from **(2)**

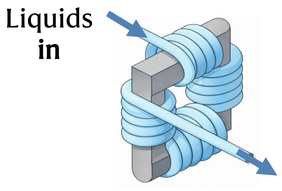


Illustration of a CFI microreactor

Advantages

1. **Faster,** intensified **production**
2. **Controlled,** consistent quality
3. **Scalable** manufacturing → **higher value** per **footprint**

4 **Quality control & product verification**

GC-MS ✓

Confirms **composition** and product **purity**

SEM ✓

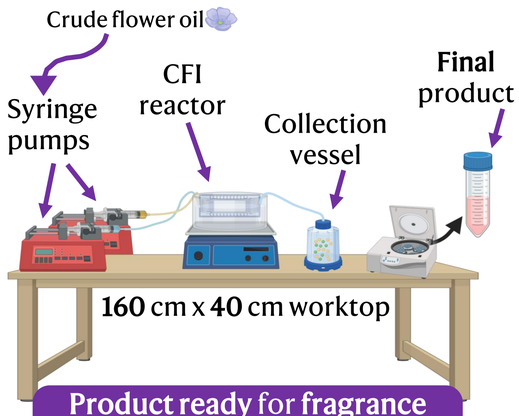
Verifies catalyst **structure** and **stability**

Output

Fragrance molecules

How does the setup look like?

A plug-and-play platform:



Product ready for fragrance manufacturing (e.g. perfume formulations)

The **whole** equipment can fit inside a **22" cabin suitcase!**

Scan here for our recent papers!

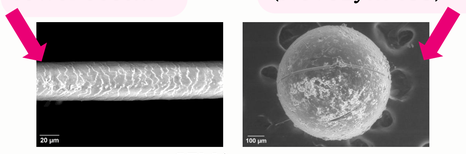
Key achievements

Sustainable and low-cost enzyme-based platform

Economic analysis for catalyst:

Wool-enzyme catalyst **46 % lower cost…**

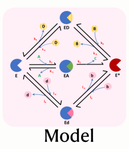
…Than **commercial ones** (Novozym 435)[5]



SEM images

Enzyme modelling & optimisation

Parallel Ping-pong bi-bi mechanism



Model

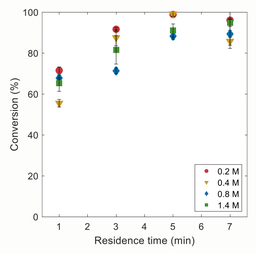
- **2x higher productivity** vs **fossil**-based routes
- Model can **predict scent outcome**

Outcome

Lower-cost, sustainable production with **predictable fragrance** profiles

Continuous scale-up via CFI microreactors

CFI microreactor performance:



- Fragrant terpenoids produced in **5 min**
- **7x higher** productivity than **batch**
- **Robust** to **impurities** in crude feedstocks

Economic productivity (normalised per L)

Based on measured productivity and bulk fragrance ingredient pricing

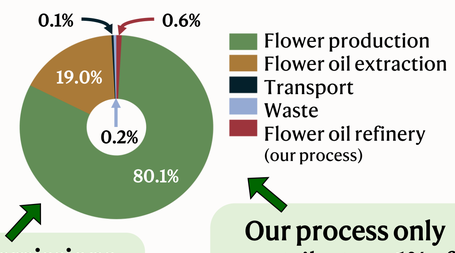
Batch	**Continuous (CFI)**
Start-stop production	*Steady flow production*
≈£2,500/day per **litre** of reactor	**≈£9,000/day per litre** of reactor

Outcome

High-throughput, modular **24/7** production **suitable** for **decentralised** manufacturing

Techno-economic and environmental performance

Global warming impact (kg CO_2 eq) via life cycle assessment

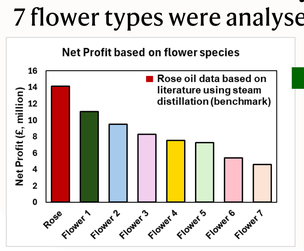


99% emissions arise from **flower cultivation**

Our process only contributes **<1%** of **total environmental** impact

Techno-economic analysis:

7 flower types were analysed



Outcome

Profit from **UK Horticulture waste** up to **£10M**

Impact

Utilising wool & flower waste enables **"farm-to-chemicals"** manufacturing

New revenue from **UK biomass** (strengthens the **£41 Billion** fine chemical sector)

30% lower CO_2 than conventional production

Applicable to other **terpenoid-rich UK biomass** (e.g. forestry residues)

Conclusion

Our technology supports **UK biomass** as a **scalable** material for next-generation, **decentralised production** of **sustainable** high-value chemicals.

Acknowledgements

The University of Adelaide: Adelaide-Nottingham Alliance

BBNet Proof of Concept Funds

References

1) MarketsandMarkets, Flavors & Fragrances Market Report (2025)
2) Statista, Value of UK imports of fragrance ingredients in 2020 (2021)
3) Bridge Farm UK (2026)
4) Gosling & Tully, Wool Innovation Action Plan, Innovate UK KTN (2023)
5) Wikaputri et al., Biochemical Engineering Journal 226, 110002 (2026)