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Bioprocesses for a sustainable world

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Photo by Stefan Els

Ethanol from waste

Technology potential

Waste/Product stream*	South Africa	Internationally
Paper sludge	500 thousand tons	62.5 million tons
Food waste	10 million tons	1.3 billion tons
Potential ethanol	940 million litres	1 154 billion litres

*Values on annual basis

- Massive potential for global roll-out of SA technology
- Access to different local & international markets
- First mover advantage

Global paper sludge production

Boshoff et al. (2016), DBG Bio Energy, WWF, WFP

Industrial demonstration scale fermentation of paper sludge waste to ethanol

- Track record
  - 10 years' research, EtOH concentrations > 40 g/L at >90% yield
  - Different paper sludges, fed-batch process, 100 L scale
- Demonstration under industrial conditions
  - Mobile, containerised demonstration plant
  - 1 000 L reactor and bespoke steriliser
  - Replicable, scalable, technical barriers
- Business case
  - Tech & financial feasibility
  - Technology package

Team & Stakeholders

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Stakeholders

science & innovation
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REPUBLIC OF SOUTH AFRICA

PAPER
MANUFACTURERS ASSOCIATION
OF SOUTH AFRICA (PAMSA)

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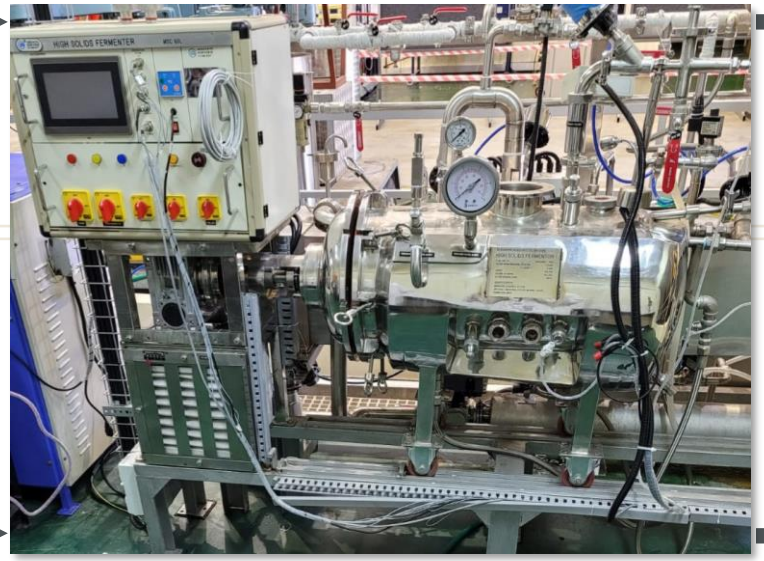
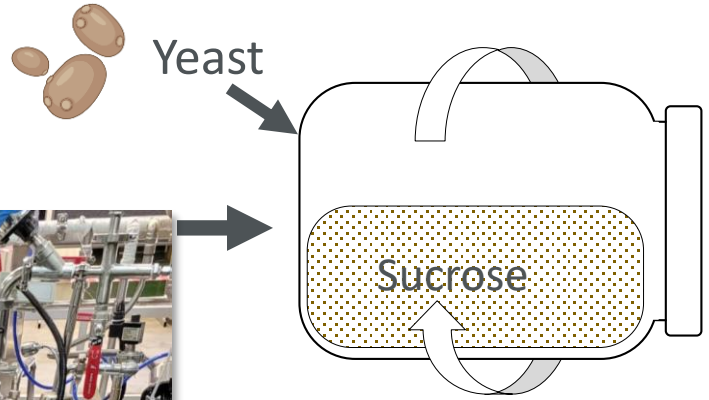
Ethanol production via Solid State Fermentation

SUGARCANE

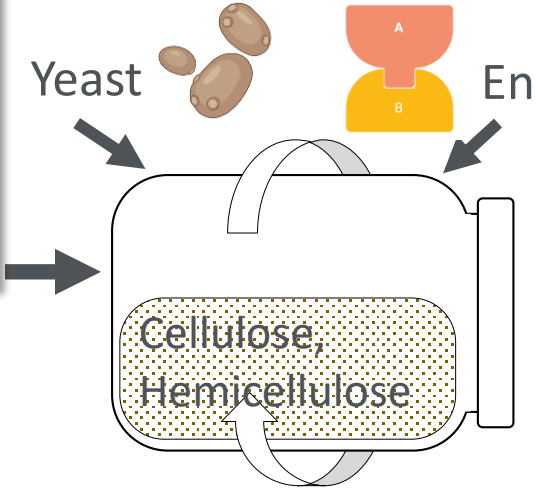


50 L solid-state reactor

PAPER SLUDGE

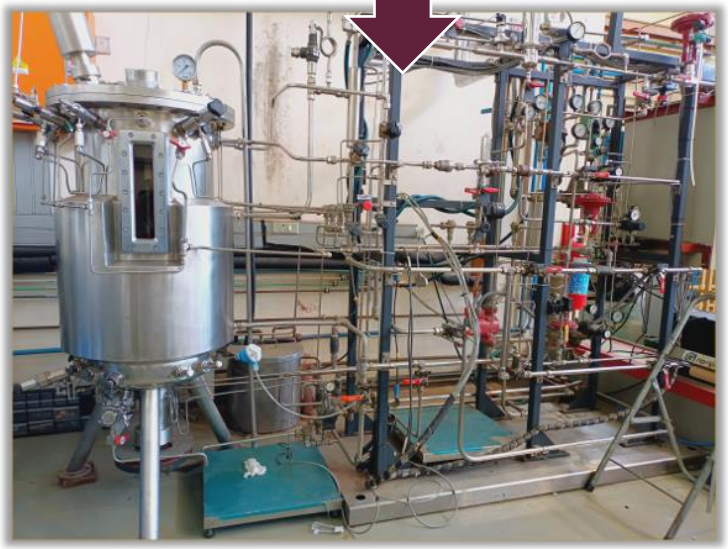


1G Ethanol



2G Ethanol

Fermentation of furfural residues to ethanol



Furfural residues
Sugarcane bagasse after steam explosion to produce furfural

Objectives
Compare various enzymes
Compare various yeast strains
Optimise the enzyme dosage & solid loading
Lower the enzyme cost/L ethanol
Scale-up

Bioethanol Production from Food Waste




- 931 million tonnes of Food Waste generated globally
- Rich in starch and sugars
- South African legislation
  - Wastes with moisture content ≥40% prohibited from landfill
  - Western Cape to ban 100% of organic wastes (like food wastes) from disposal at landfills by 2027
- Objectives
  - Assess the feedstock potential of food waste
  - Develop a bioconversion process to bioethanol

Fermentation & Anaerobic digestion of waste-paper streams

Waste paper

Milled waste

20 L Bioreactor

Value to industry

Bio-ethanol
- Fuel additive
- Sustainable aviation fuel
- Platform chemical

Biogas
- Automotive fuel
- Domestic
- Tri-generation

Anaerobic digestion

Improvements to Anaerobic Digestion of Organic and Biowastes

Biomethane potential assessment

Scale-up to 50 L pilot scale digesters

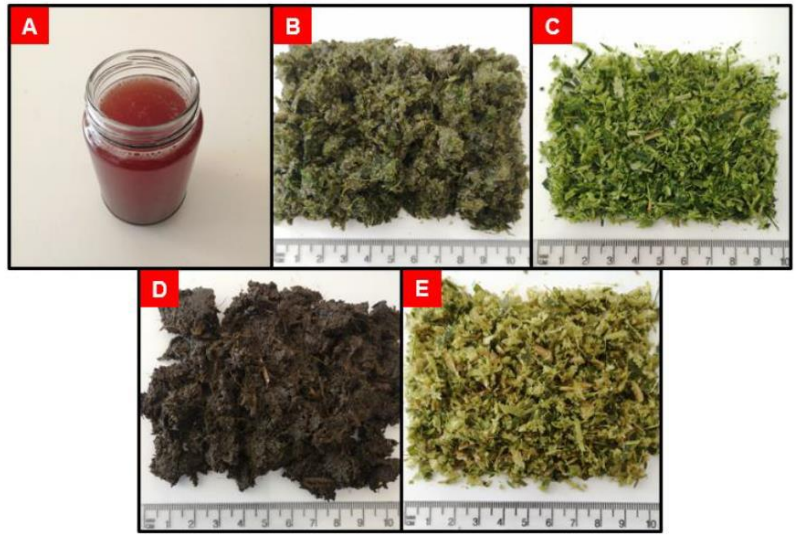
Biogas-> Biomethane

Digestate -> fertiliser

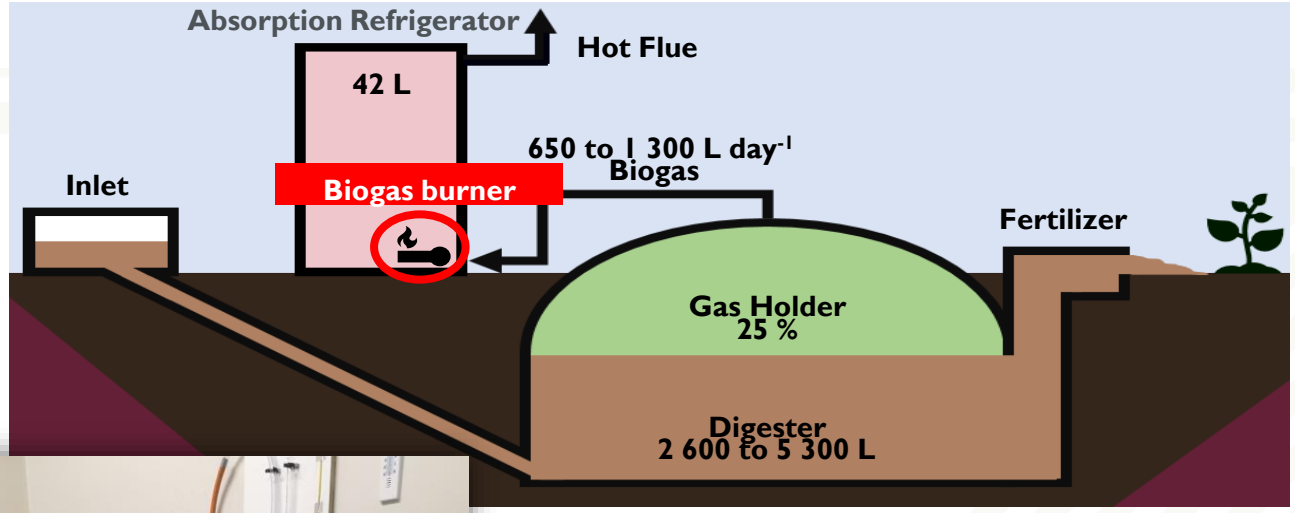
Biogas-fuelled absorption refrigeration to curb post-harvest losses

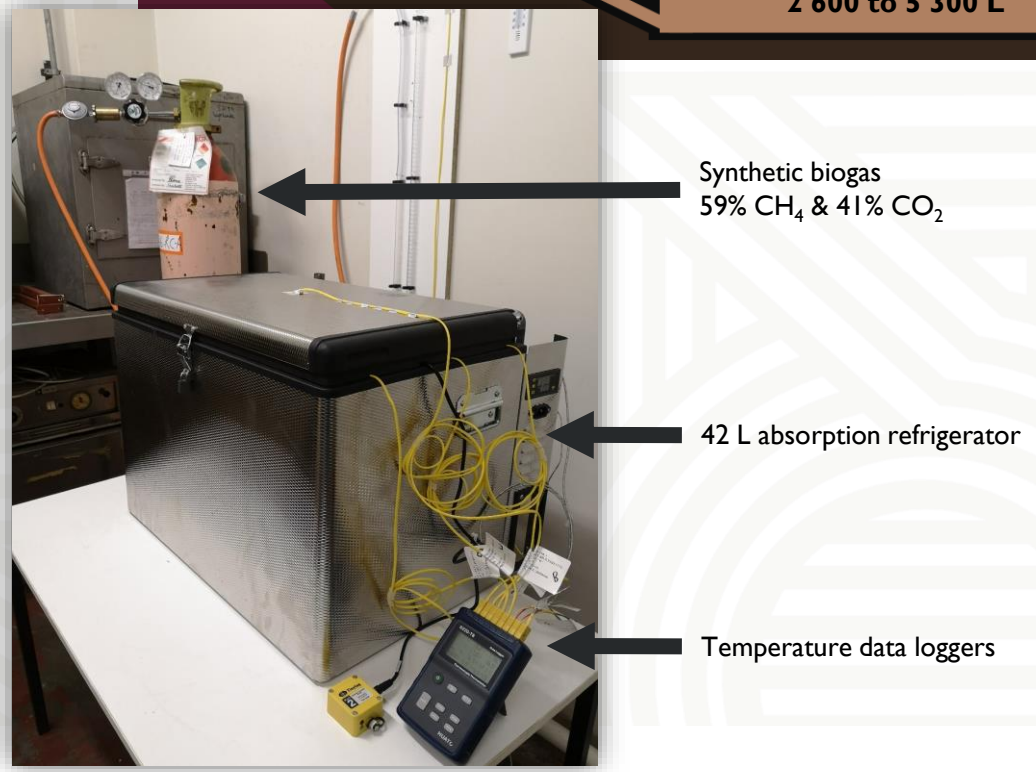
Completed Objectives

- Modified refrigerator running on biogas
- BMP selected feedstocks
- Fridge performance
- Thermodynamic modelling



Fresh shredded substrates for BMP analysis before ensilage and anaerobic digestion. A: Fish effluent; B: Water hyacinth; C: Common reed; D: Cow manure and E: Maize stover



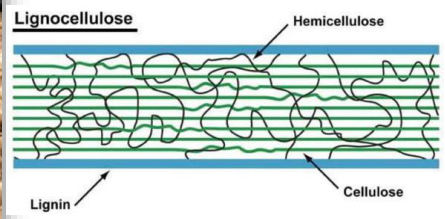


Synthetic biogas
59% CH_4 & 41% CO_2

42 L absorption refrigerator

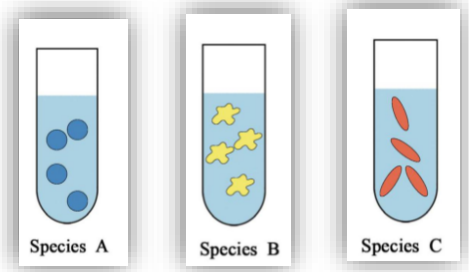
Temperature data loggers

Bioaugmentation of anaerobic digestion



Lignocellulosic wastes → Rigid chemical structure

- Incomplete hydrolysis
- Slow degradation rates
- Low gas yields



Different bioaugmentation organisms with cellulase activity

Biomethane Potential Tests (400 mL)

- Different microbial loadings
- Different solids loadings & blend ratios
- Pure microbial strains and consortium

Pilot-scale (21 L)

- Scale-up of preferred lab-scale conditions
- Assess scale-up effects

Improving the anaerobic digestion of organic wastes through micro-aeration

Complex organic matter
(Carbohydrates, protein, fats)

Hydrolysis

Soluble organic molecules
(sugars, amino acids, fatty acids)

Acidogenesis

Volatile fatty acids

Acetogenesis

Acetic acid, CO_2, H_2

Methanogenesis

Methane, CO_2

Target facultative anaerobic bacteria

Increase hydrolytic enzymes

Improve process:

- Hydrolysis rate
- Process stability
- H_2S Scavenging

DECAY FACTORS OF PAPER MATERIALS

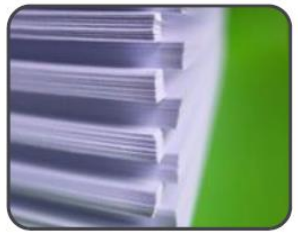
BACKGROUND

- ❑ Decay factors required for landfilled waste
- ❑ SA lacks waste-specific data
- ❑ Impacts pulp and paper industry

AIM & OBJECTIVES

- ❖ Estimate decay factors for key paper materials
- ❑ Upper limit of gas production
- ❑ Prediction factors
- ❑ Realistic estimate

Packaging papers



Office paper

Newsprint and coated papers

Label backing paper

Paper sacks

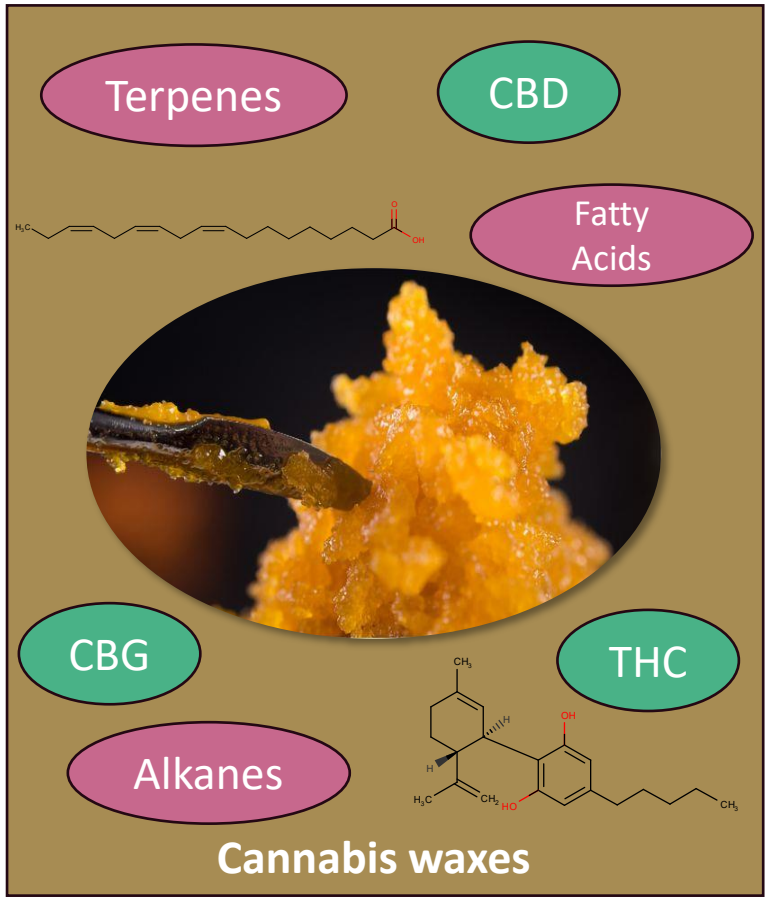
Liquid board packaging

Multilayer paper-based packaging

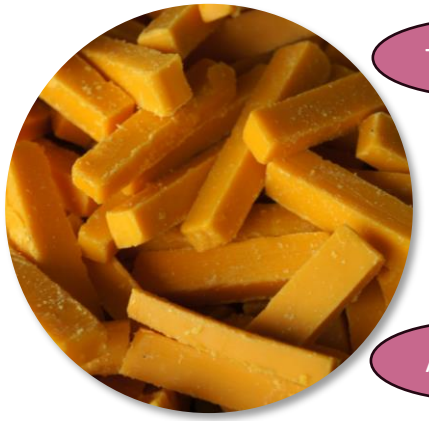
High value commodities

Valorisation of *Cannabis* extraction wastes

Integration with growing industries – winterisation wax separation



Solvent extraction



currently..

- Loss of product
- Cost of disposal
- Loss of revenue

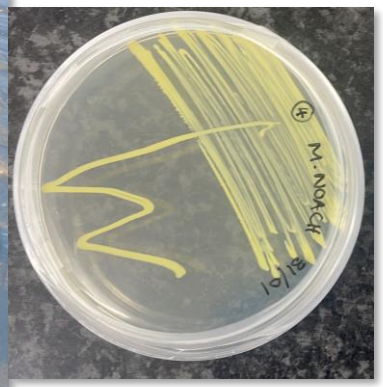
Enzymatic production of alginate oligosaccharides

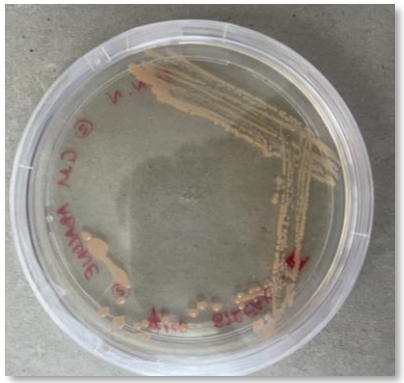
Background

- Hydrocolloid in brown seaweeds
- Alginate lyase catalyse the degradation of alginate
  - Create unsaturated alginate oligosaccharides with functional bioactivities
  - Potential tool for alginate processing and seaweed biorefinery practices
  - Plant stimulants/crop growth promotors/enhancers
  - Feed additives for animal feed

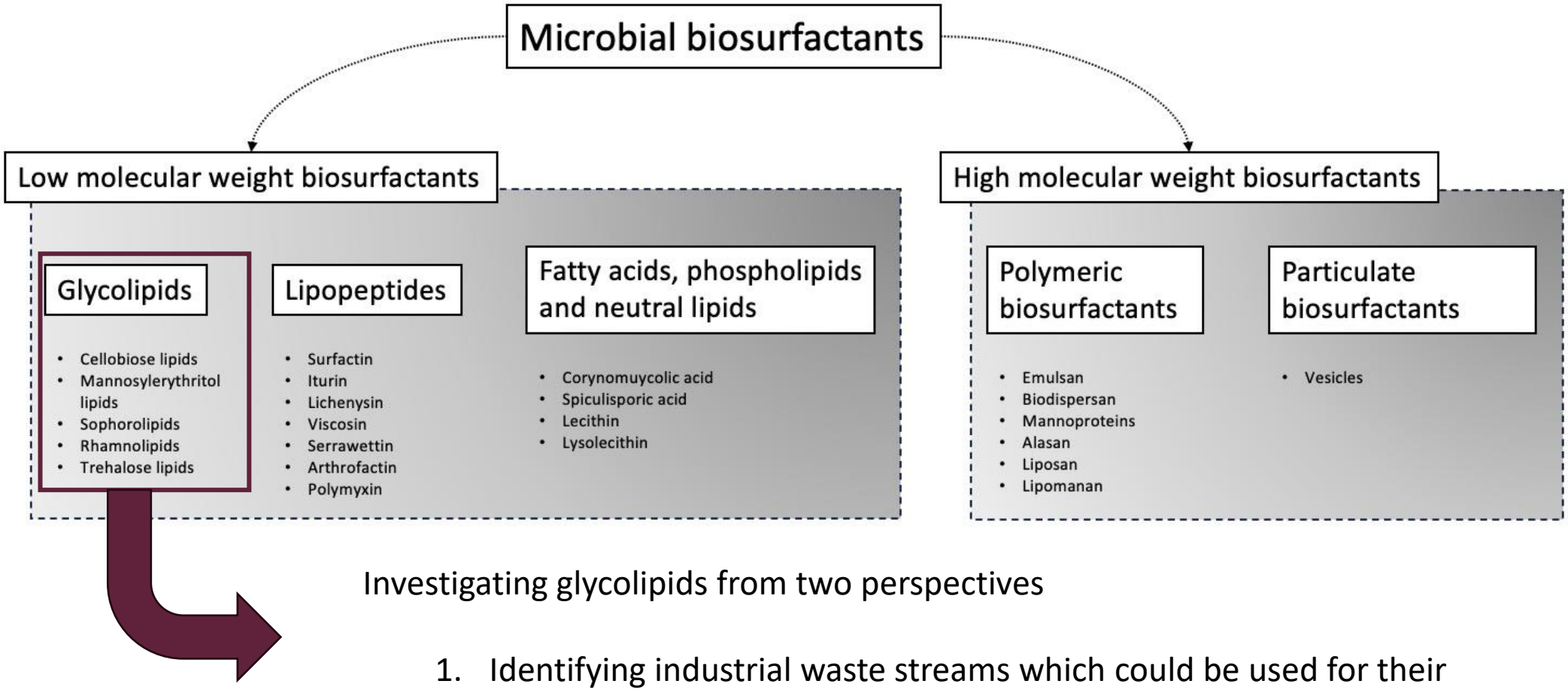
Aim

- Develop a fermentation strategy for alginate oligosaccharides production from endemic *Ecklonia maxima*
  - Facilitated by isolated wild type native alginate lyase producing microorganisms





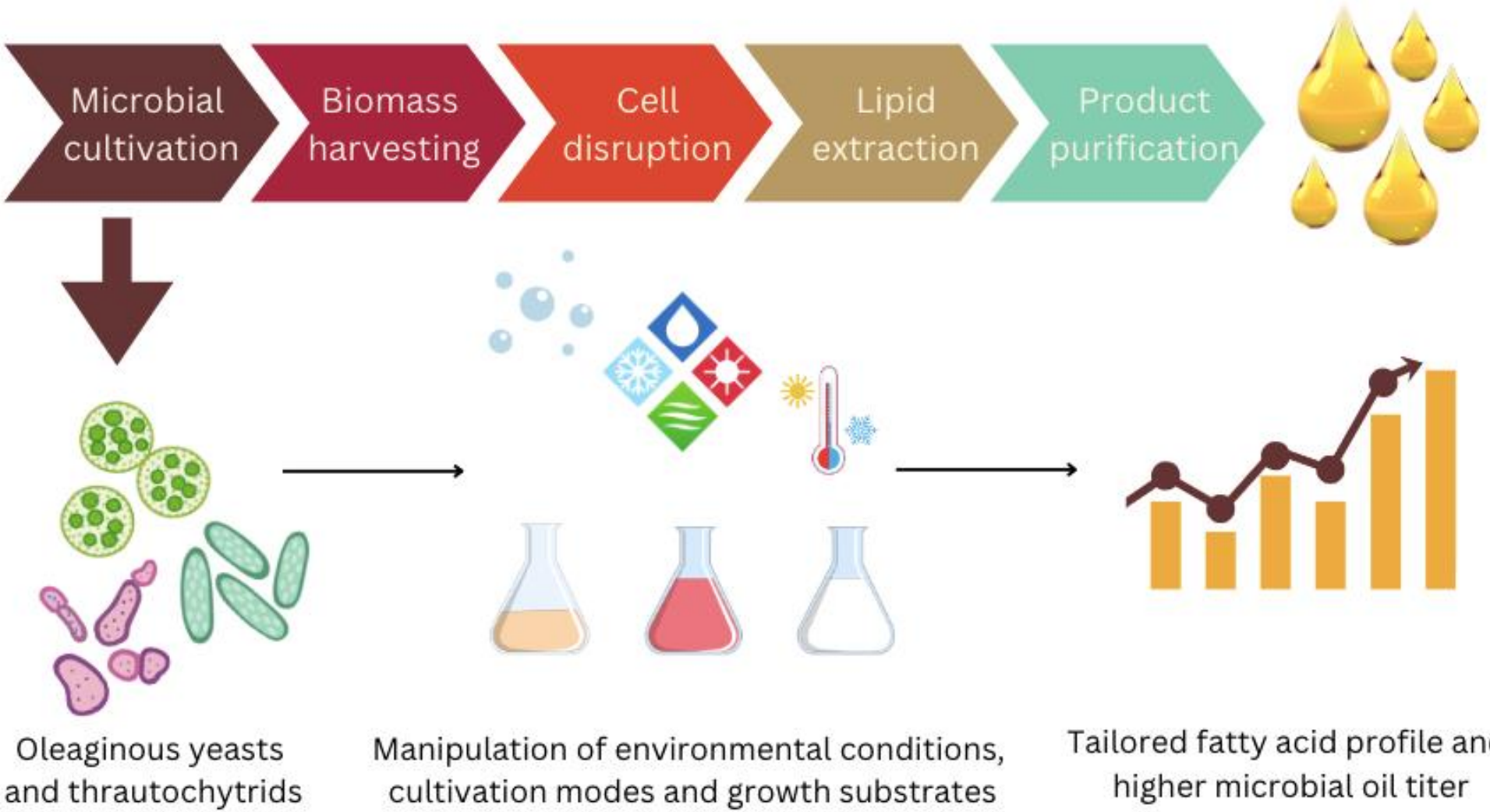
Developing novel processes to produce glycolipid biosurfactants

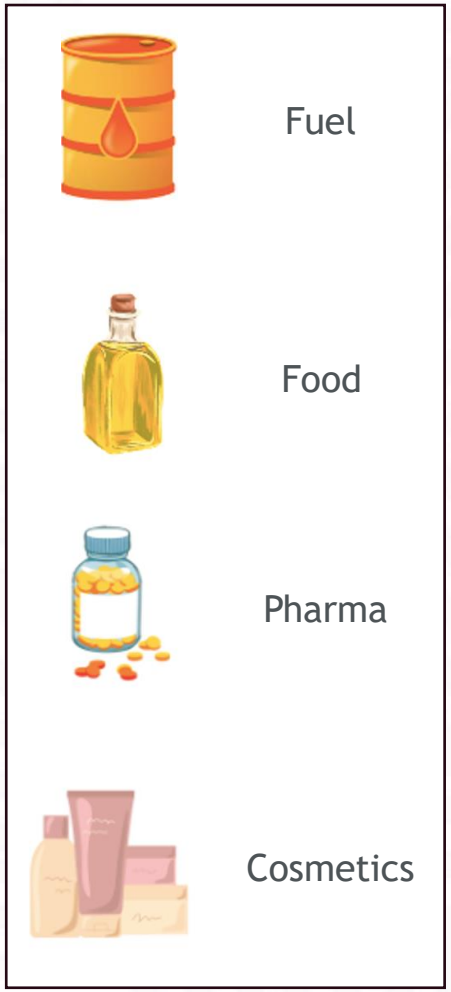


Investigating glycolipids from two perspectives

1. Identifying industrial waste streams which could be used for their production, including waste cooking oils and refining wastes.
2. Developing novel bioprocesses to achieve enhanced glycolipid production.

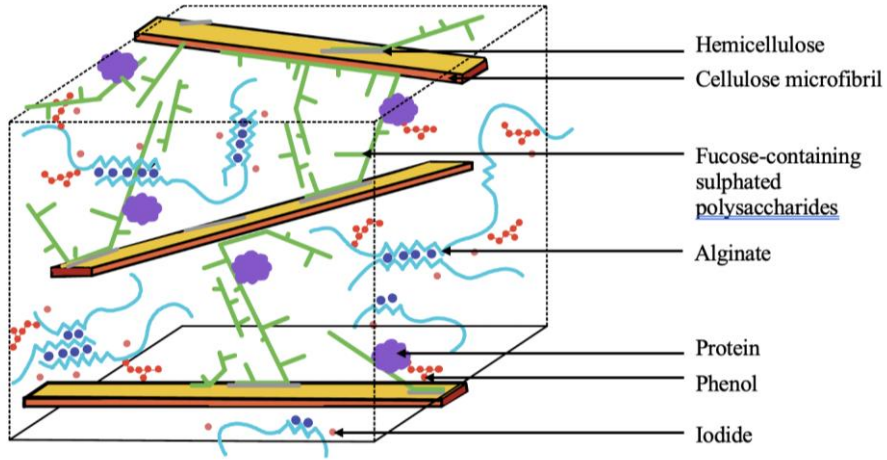
Microbial oil production



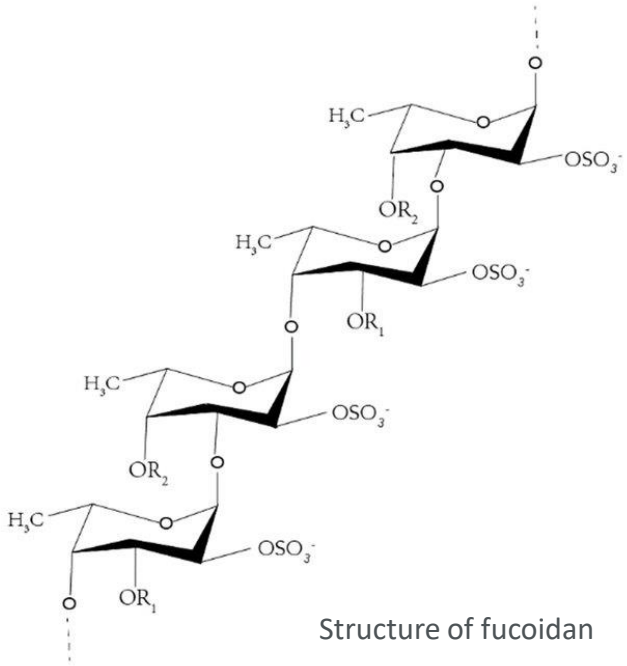


The Purification & Characterisation of Fucoidan from the South African Seaweed *Ecklonia maxima*

- **FUCOIDAN** → A family of **structurally diverse**, **water soluble**, **fucose-rich sulphated** polysaccharides (FSPs)
- Fucoidan is found in the cell wall of brown macroalgae
- Exhibits many biological properties
  - Anti-coagulant
  - Anti-inflammatory
  - Anti-tumour
  - Anti-cancer
  - Anti-viral
  - Anti-oxidant



Simplified model of the cell wall structure of brown algae



Structure of fucoidan

Questions and discussion

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Photo by Stefan Els