



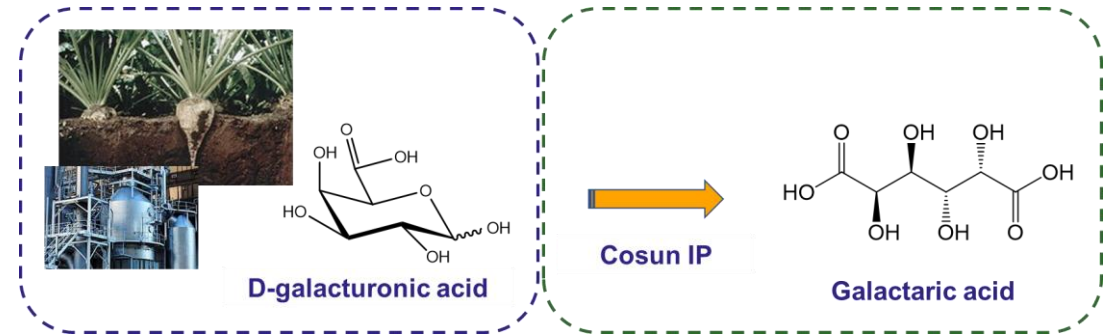
Biorefinery of Agri-Food Residues: Versatile Galactaric Acid from Sugar Beet Pulp

Webinar NPT biobased green chemistry: flagship projects and scale-ups

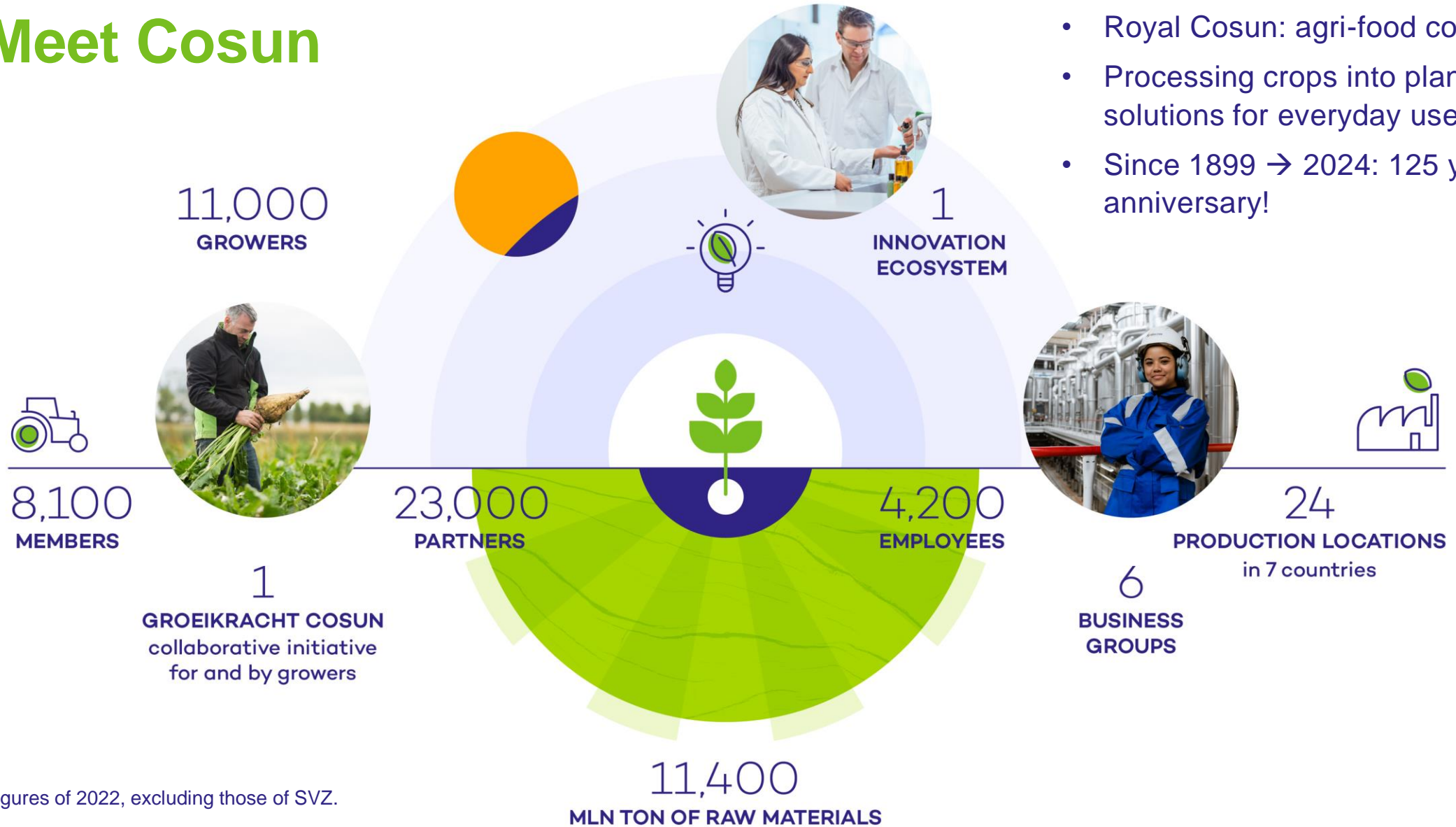
Wouter Huijgen
12-3-2024

Outline Presentation

- Meet Cosun
- Sugar Beet Pulp
- Galactaric Acid
- Discussion & Questions



Meet Cosun



- Royal Cosun: agri-food cooperative.
- Processing crops into plant-based solutions for everyday use.
- Since 1899 → 2024: 125 yrs anniversary!

Figures of 2022, excluding those of SVZ.

Production Sites

and research centers

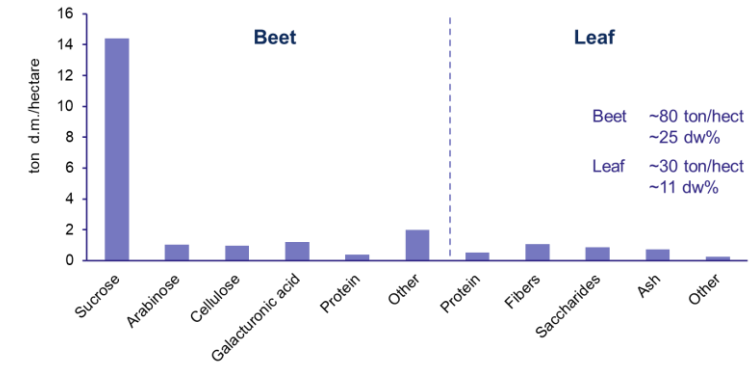
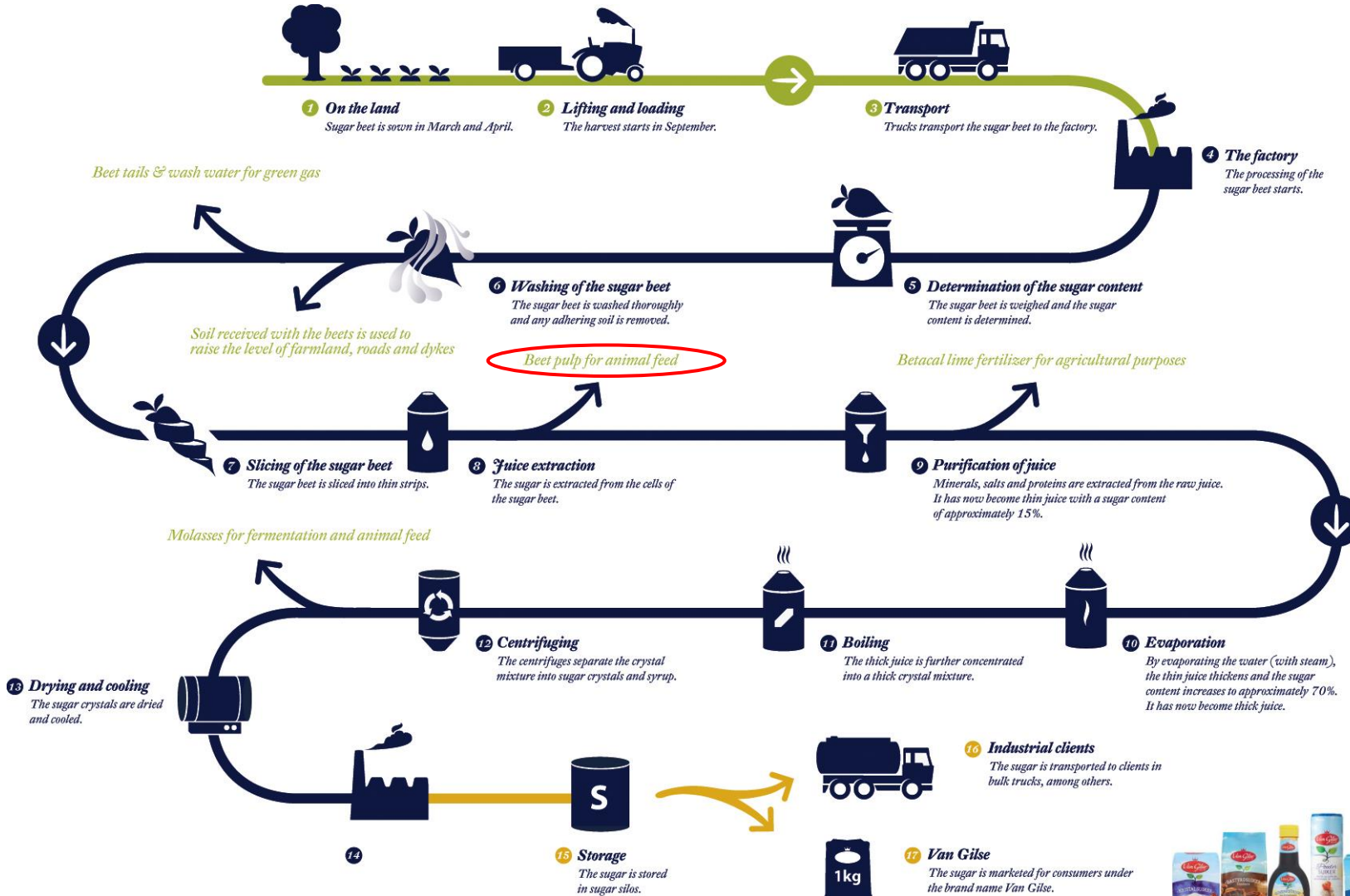


-  Cosun
-  Cosun Protein
-  Cosun Biobased
-  Sensus
-  Aviko
-  Cosun Beet Company
-  Duynie Group
-  Cosun Nutrition Center
-  Cosun innovation center



Sugar Beet Pulp

Sugar Process



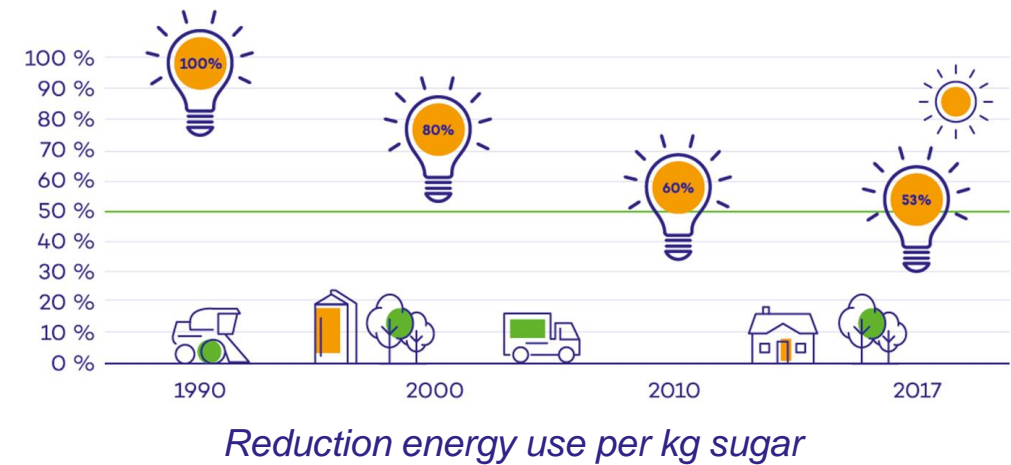
Van der Poel et al., Sugar Technology (excl water and soil tare).



Development Dutch Sugar Industry

- A story of scale-up and efficiency increase
- Production 2023: 1.2 Mton sugar from 7.4 Mton sugar beets

Production of ~1 Mta sugar	1985	2023
Companies	2	1
Plants	10	2
Average plant capacity (ton beet/day)	< 8.000	~30.000
Employees	2500	800
Area (ha)	125.000	75.000



Sugar Beet Pulp

Large residual biomass stream:

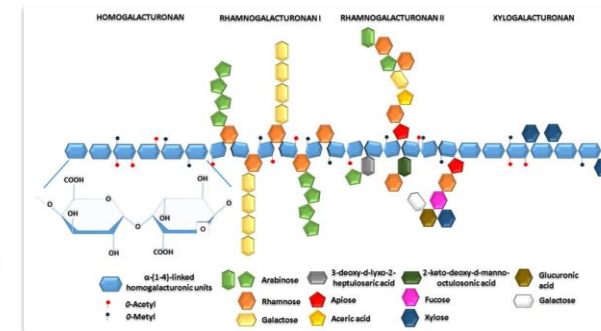
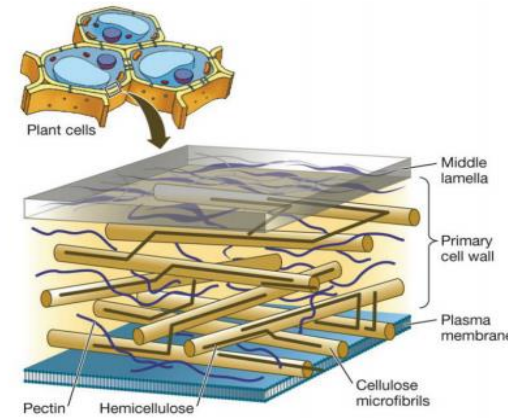
- Cosun: ~1 Mton/yr ton of pulp (Europe: ~13 Mton/yr).

Mainly residual primary cell walls:

- Cellulose (~25wt%)
- Hemicellulose (arabinans) (~20wt%)
- Pectin (polygalacturonic acid) (~20wt%)

Uses:

- Today: cattle feed & anaerobic digestion (green gas)
- Emerging: packaging & upcycling for food
- Next: multi-product biorefinery sugar beet pulp for biobased economy
 - Example today: galactaric acid



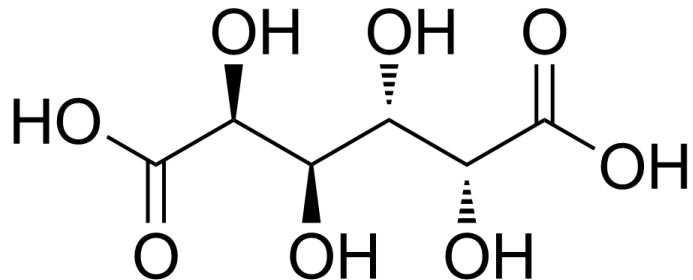
PhD thesis M Leijdekkers (WUR, 2015)



Galactaric Acid: Unique Molecule

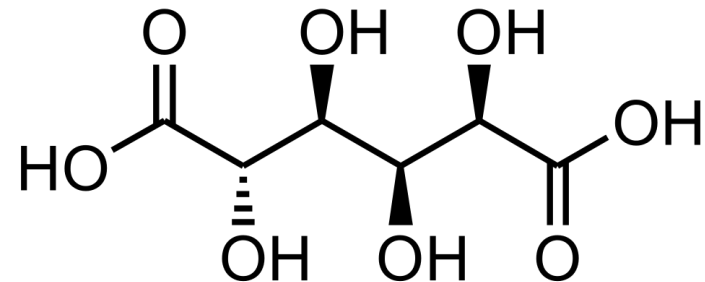
- Galactaric acid: an aldaric acid (common name: mucic acid)
- Readily biodegradable & non-toxic
- Galactaric acid structure similar to glucaric acid, but chiral difference
→ big difference in **physical chemical properties** by **hydrogen bonds**

Galactaric acid



- Symmetric, not optically active
- Insoluble in water at low pH
- Melting point 220°C

Glucaric acid



- 32% soluble in water
- Melting point 130°C

Galactaric Acid: Versatile Molecule



Metal treatment



Personal care
(drop in)



Pharma
(drop in)



Coatings

Examples Potential Markets



Food



Home care

Corrosion Inhibitor

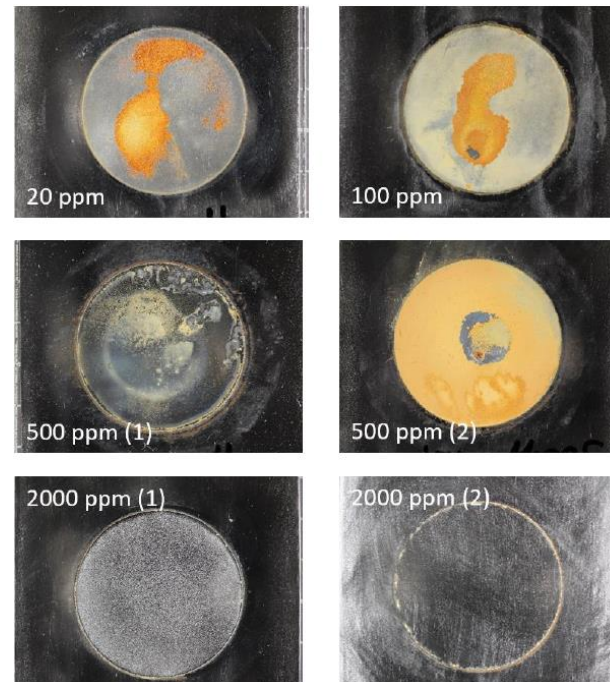
- Galactaric acid acts as corrosion inhibitor in various applications.
- Mode of action includes thin film former.
- Main market driver: future phasing out of conventional products → opportunity for biobased!

Aluminium staining at high pH



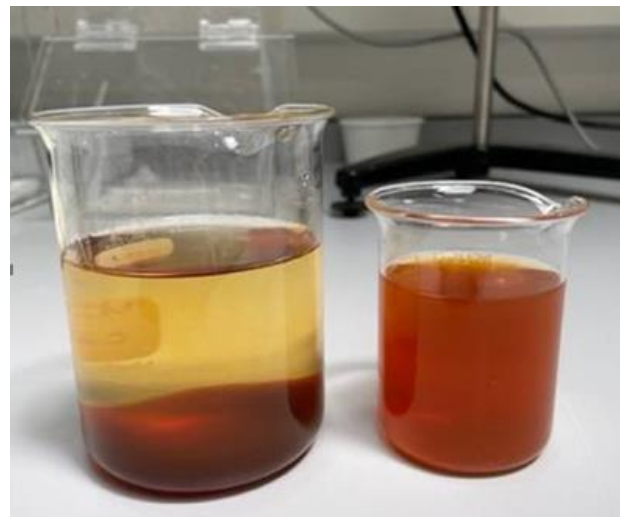
Reference

Galactaric acid



Chelating Agent

- Galactaric acid: excellent complexing agent for metal ions
- Complexing agents used in various markets, both food & non-food → focus: home and personal care applications
- Market drivers: demand for natural products & phasing out of conventional complexing agents (e.g., EDTA, phosphates)



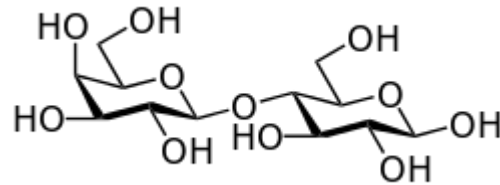
$\text{FeCl}_3 + \text{NaOH}$

+ sodium galactarate

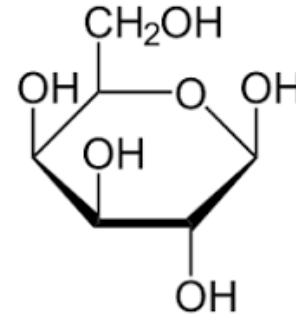
Processes to Galactaric Acid



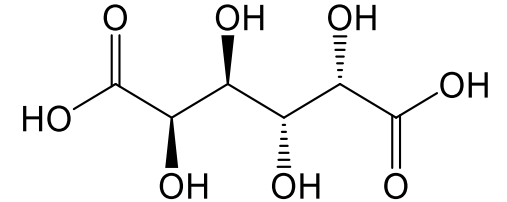
Milk



Lactose



Galactose

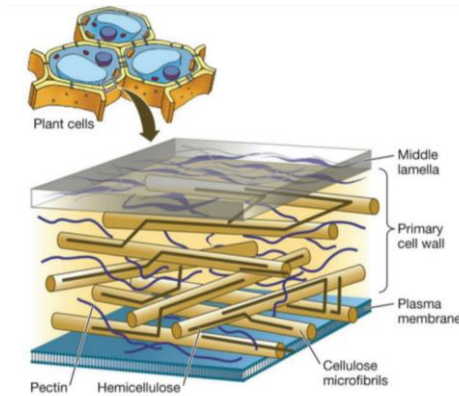


Commercial at small scale

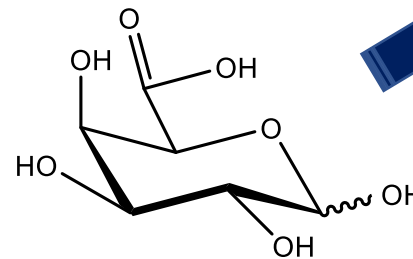
- Nitric acid oxidation
- Not sustainable



Sugar Beet Pulp



Pectin-rich cell wall



D-galacturonic acid



Galactaric acid

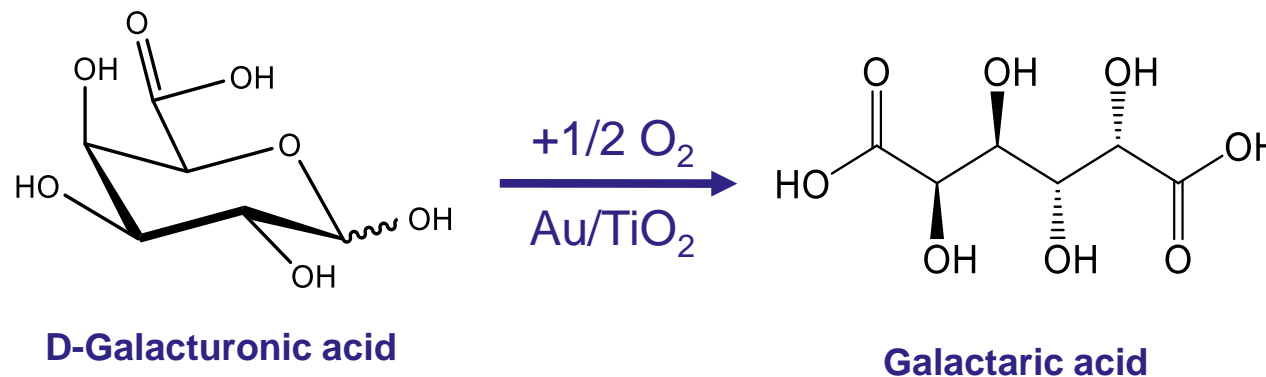
Our process:

- Competitive
- Sustainable
- Plant-based

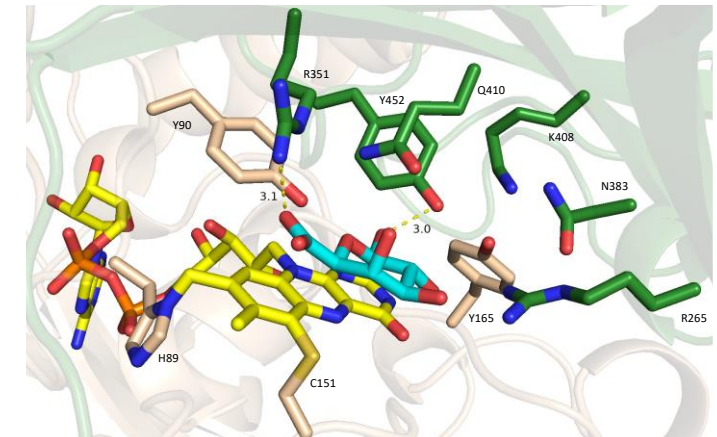
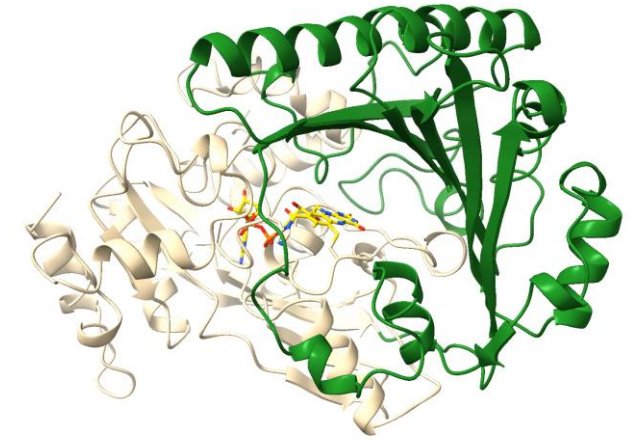
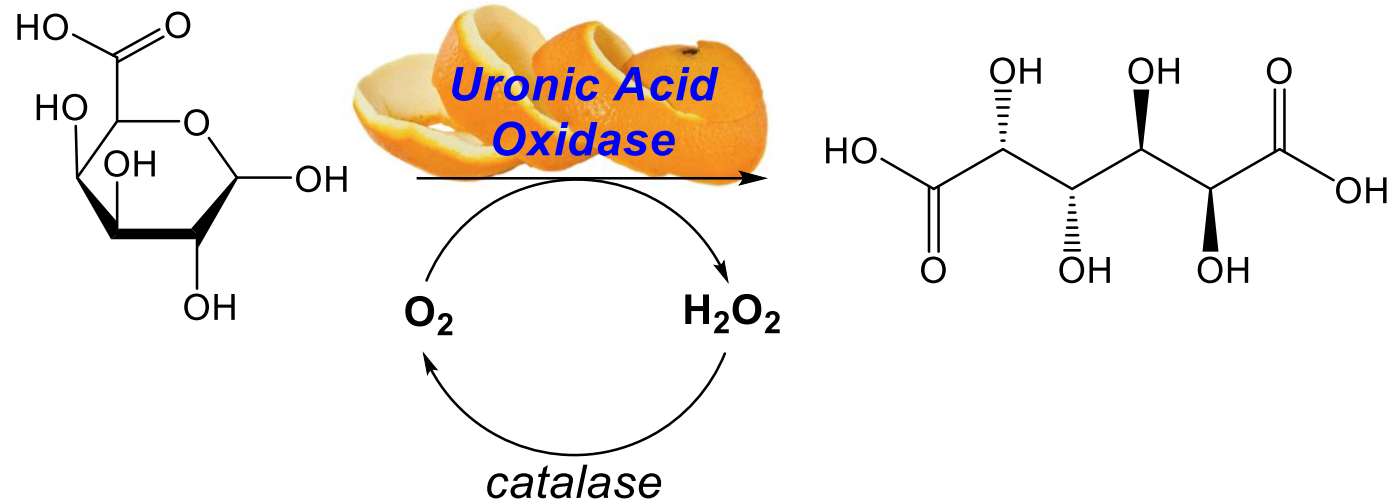


Chemocatalytic Oxidation to Galactaric Acid

- Oxidation galacturonic acid to galactaric acid key proprietary step.
- Route 1: Chemocatalytic oxidation
 - Mild conditions (water, pH 9, 50-60 °C, oxygen/enriched air)
 - High yield: ~90 %
 - Highly selectivity: up to 94%
 - Purification D-galacturonic acid required



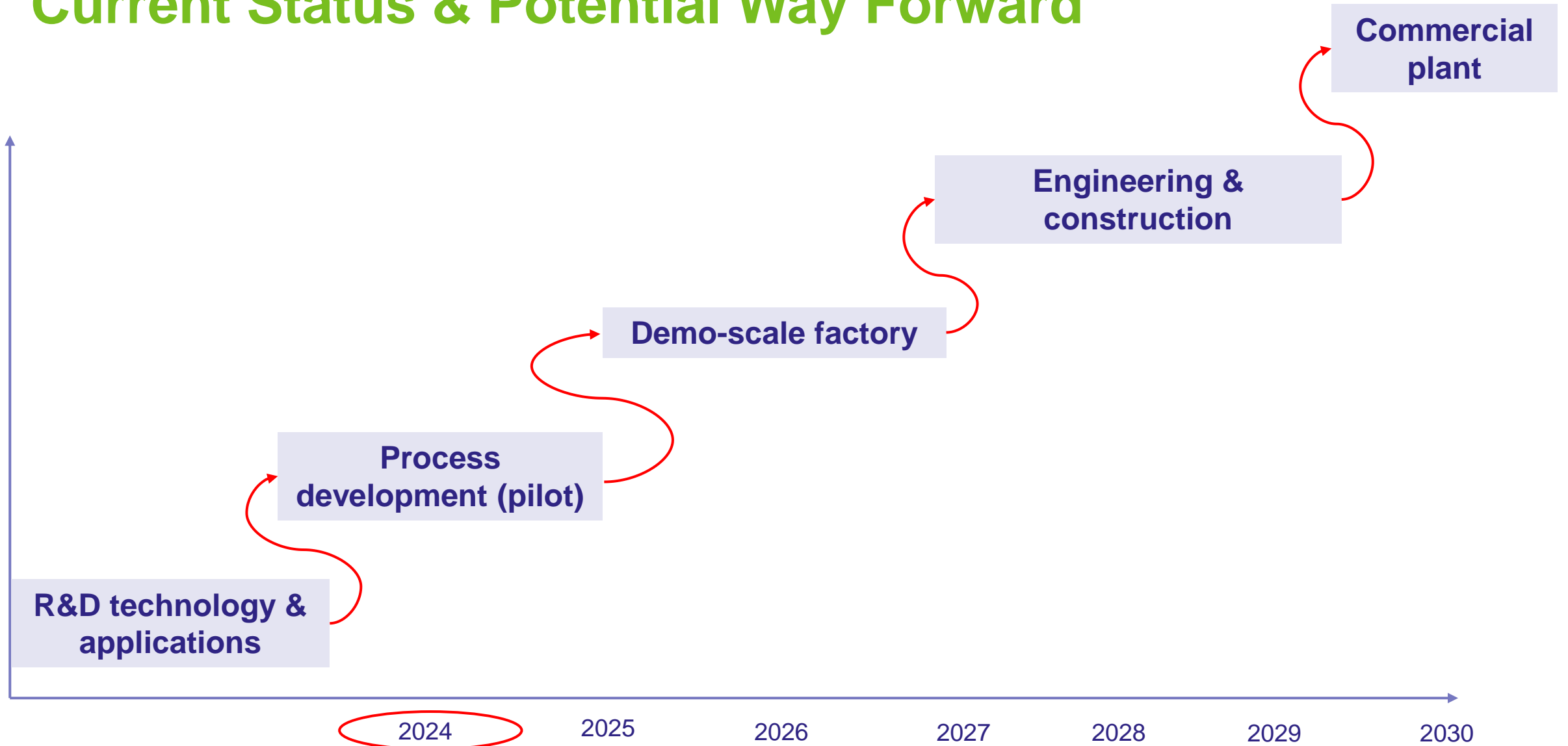
Enzymatic Oxidation: D-Galacturonic Acid Oxidase



Docked galacturonic acid active site of URAO3.

- Route 2: Enzymatic Oxidation
- $URAO_{Cs}$ isolated from citrus peels (*Citrus sinensis*) and characterized
- URAO successfully expressed in *P. pastoris*
- High selectivity for uronic acids in complex mixtures

Current Status & Potential Way Forward



Thank you for your attention!

