Biosurfactants, their significance and novel candidates

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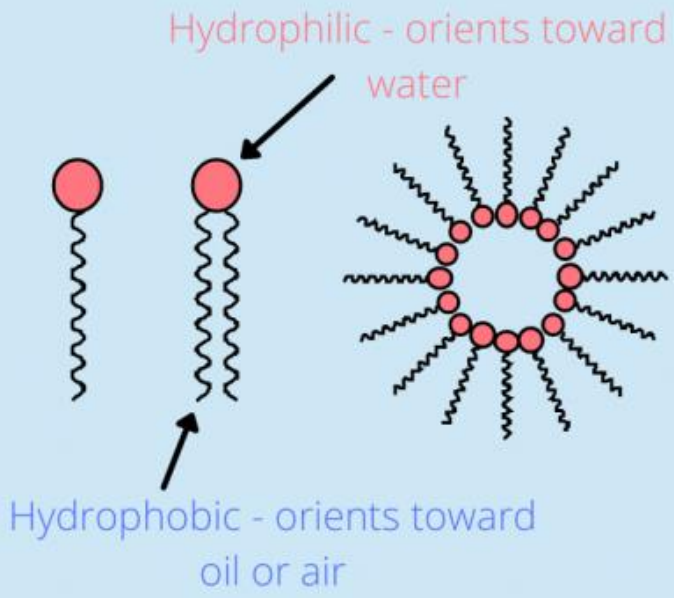
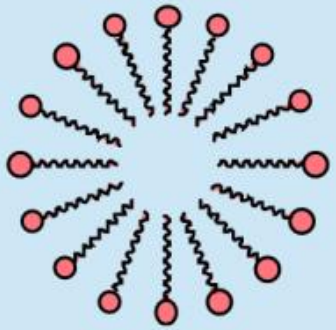
What Is a Surfactant?

A surfactant is a chemical that lowers surface tension.

Each surfactant molecule has a hydrophilic or water-loving component and a hydrophobic or water-fearing component.





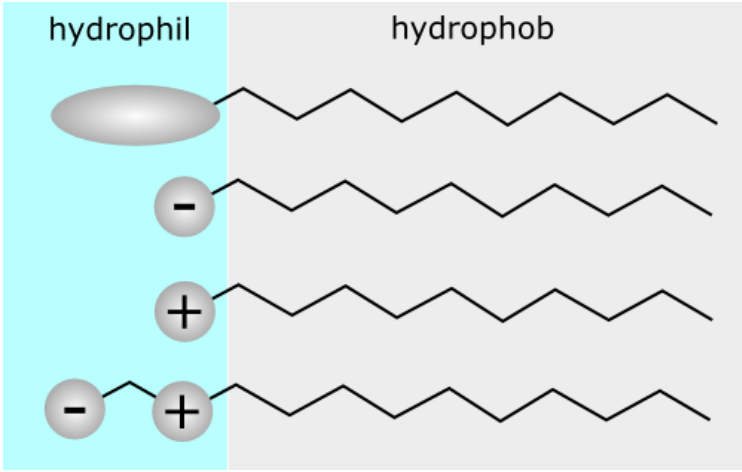
micelle

Examples

- detergent
- emulsifier
- wetting agent
- foaming agent

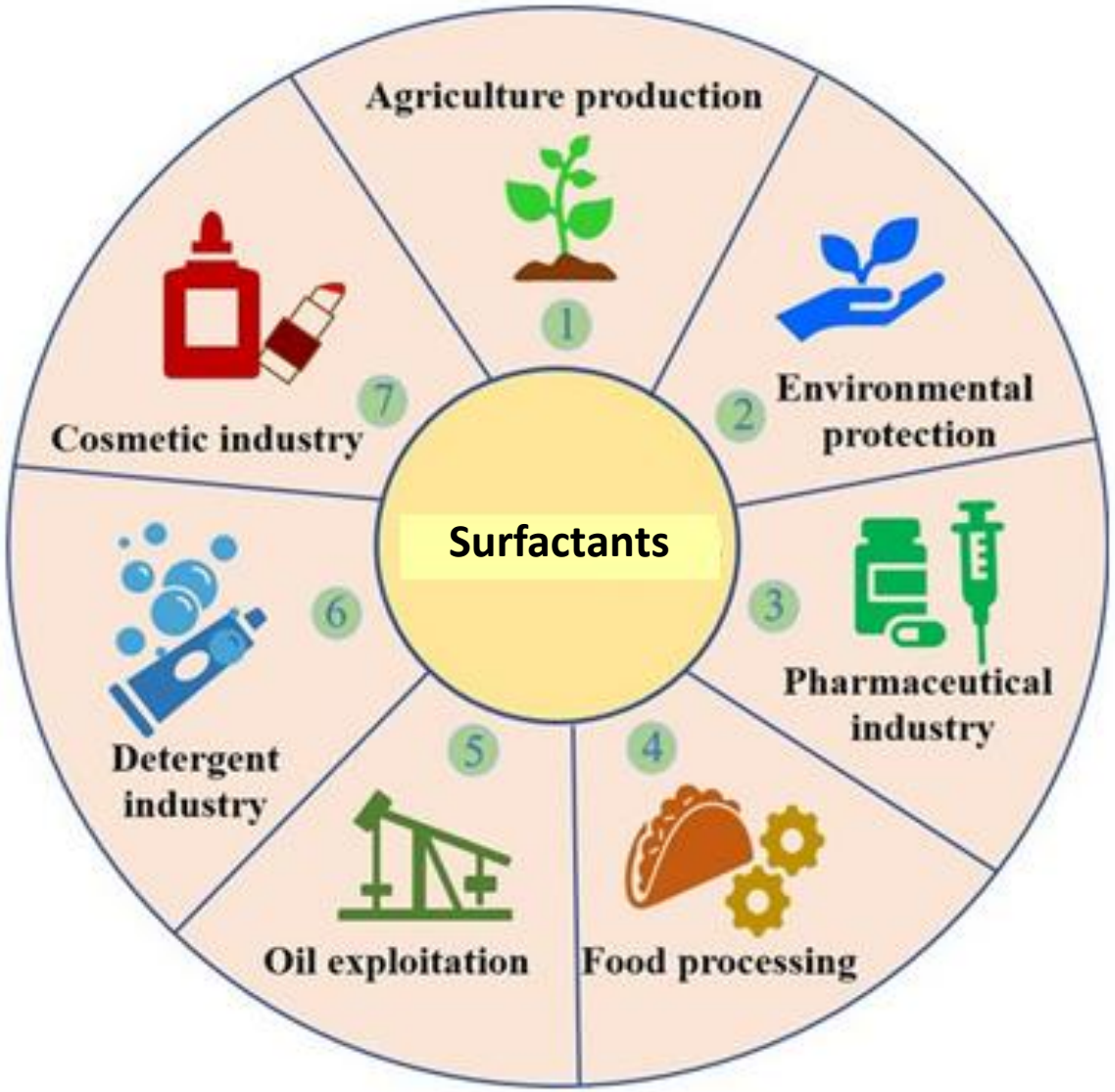
sciencenotes.org

amphiphilic compounds



- The largest categories:
  - non-ionic- and anonic surfactants which together represent around 90% of the total market value.
- Examples an-ionic:
  - alkylbenzenesulfonates and ligninsulfonates (2300 kton/y),
- Examples non-ionic:
  - ethoxylated surfactants (1200 ktons/y).

Applications



- World production of surfactants is estimated at 15 million ton/y.
- The world market is projected to reach $ 70 billion by 2032.
- Approx. 50% of products in Europe are now bio-based (approx. 10% globally)

https://www.fortunebusinessinsights.com/surfactants-market-102385

Bio-Based Surfactants

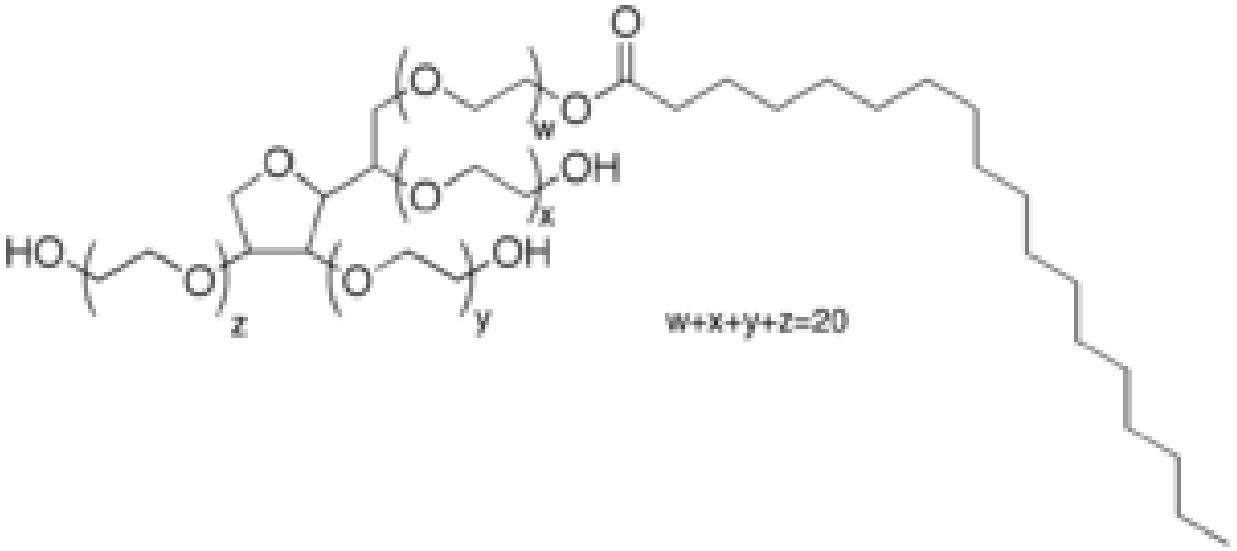
>95% renewable carbon

Biologically Produced (Biosurfactants)

from biological processes

Chemically Produced (Bio-Based Surfactants)

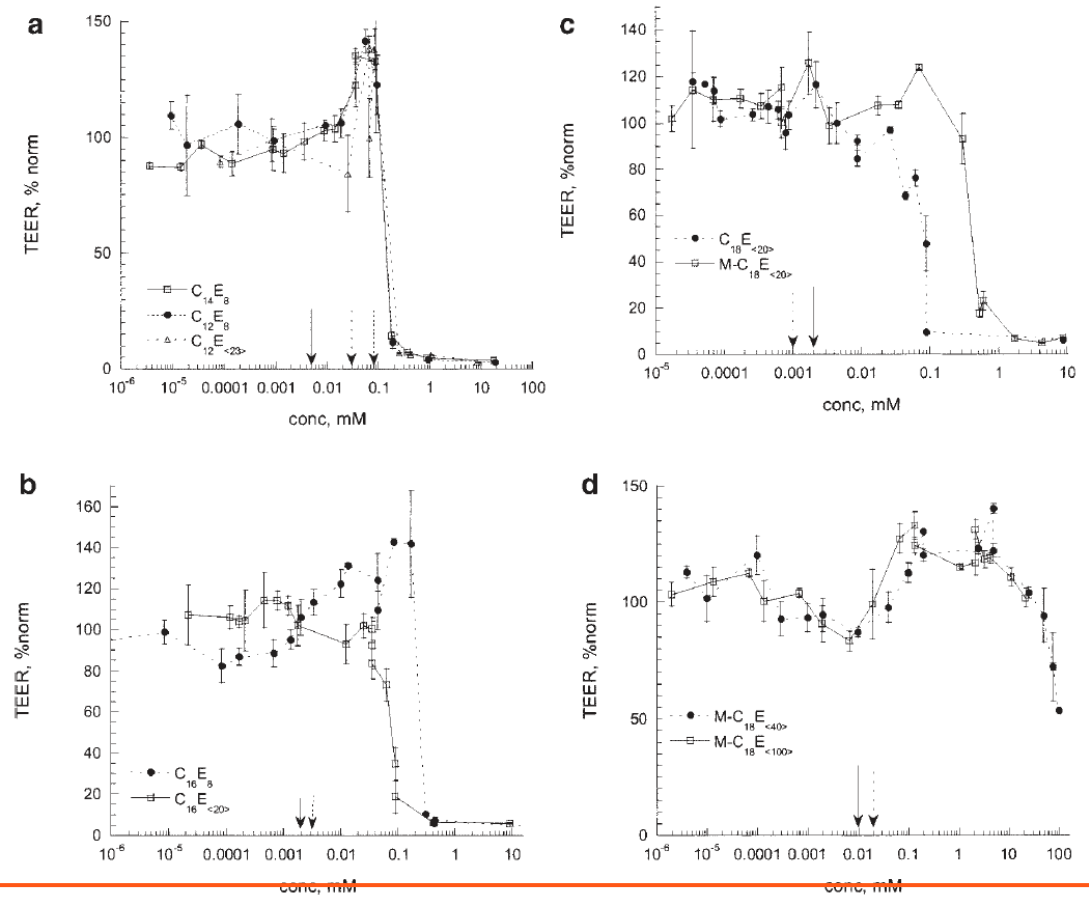
Bio-based surfactants (chemically produced)



- Often complex mixtures!
- Allergenicity? (suspected carcinogenic degradation products?)
- Ex. Polysorbate (3 rawmaterials: sorbitol, fatty acid (palmoil), and ethylene oxide).

Structure-function relationships

Structure vs cell toxicity for polysorbate surfactants



Extensive data from the Caco2 cell model shows that the combination of a long head group and a long fatty acid chain leads to beneficial cell toxicity properties

K. Ekelund, S. Ulvenlund et al, J. Pharm. Sci. 2005, 94, 730

Bio-Based Surfactants

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Biologically Produced (Biosurfactants)

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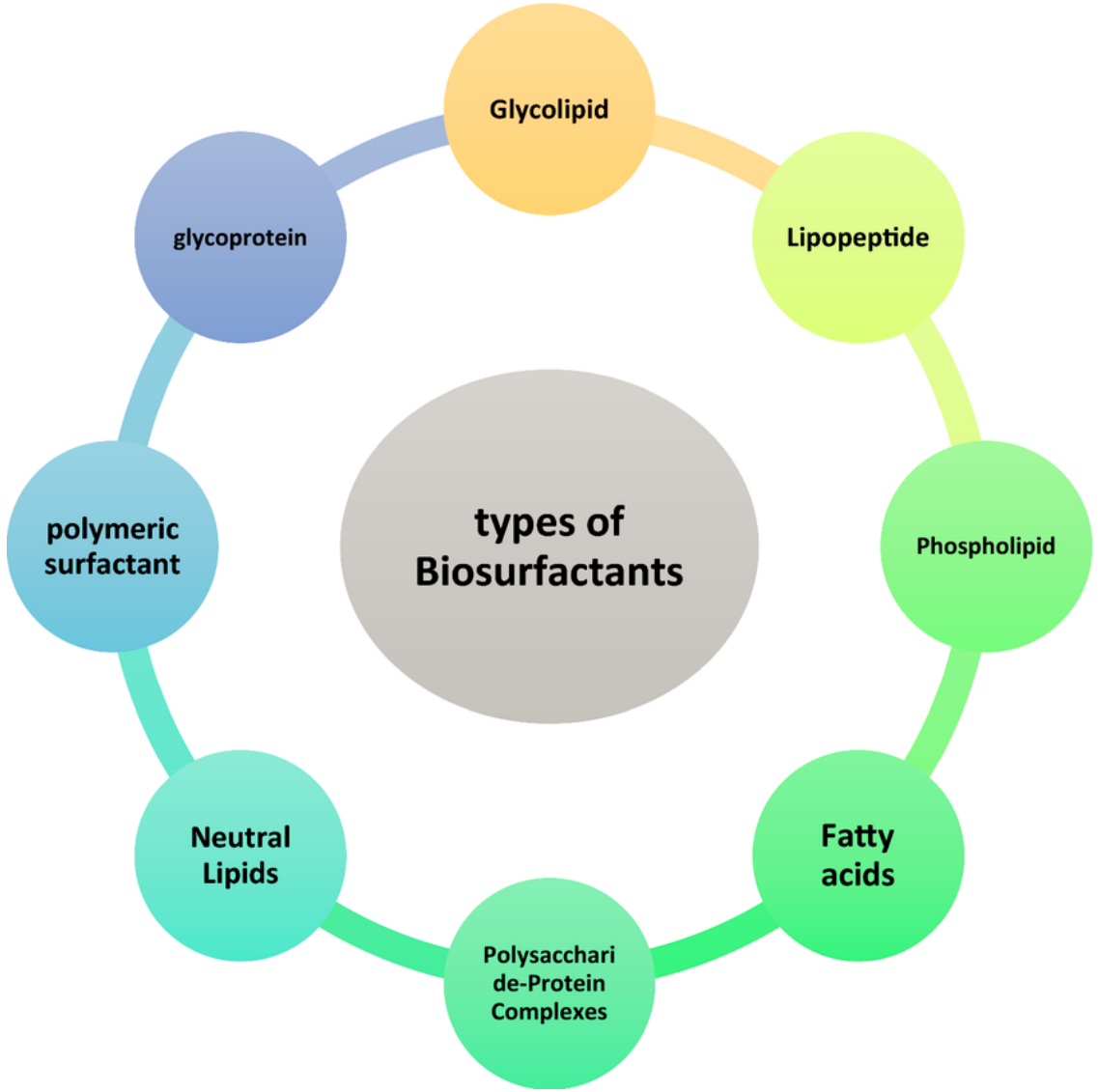
Chemically Produced (Bio-Based Surfactants)

Biosurfactants – microbially produced surfactants

- **Different compositions**
- Main groups:
  - phospholipids,
  - glycolipids,
  - lipopeptides,
  - polymeric and fatty acid biosurfactants
- Hydrophilic part: (poly)saccharides, protein or phosphorous compounds
- Hydrophobic part: lipid, glycerin or fatty acid



BENEFITS of BioSurfactants

- environmentally friendly
- readily biodegradable
- 100% biobased
- biologically produced

Do not require rating through the Renewable Carbon Index.
(RCI: measure of sustainability dividing number of Carbon from renewable source/total carbon in the ingredient).

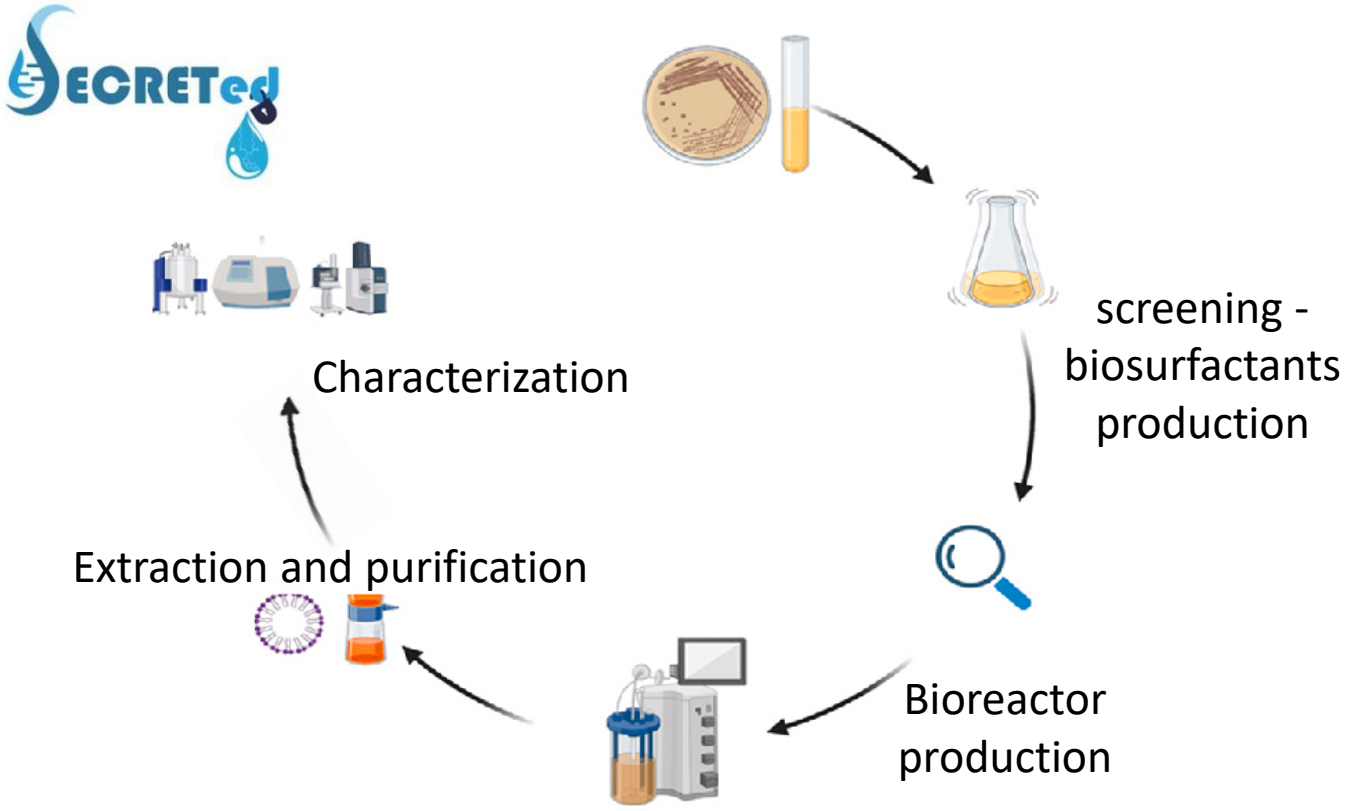
Do not contain any trace chemicals (no 1,4-Dioxane or other *Proposition 65* chemicals

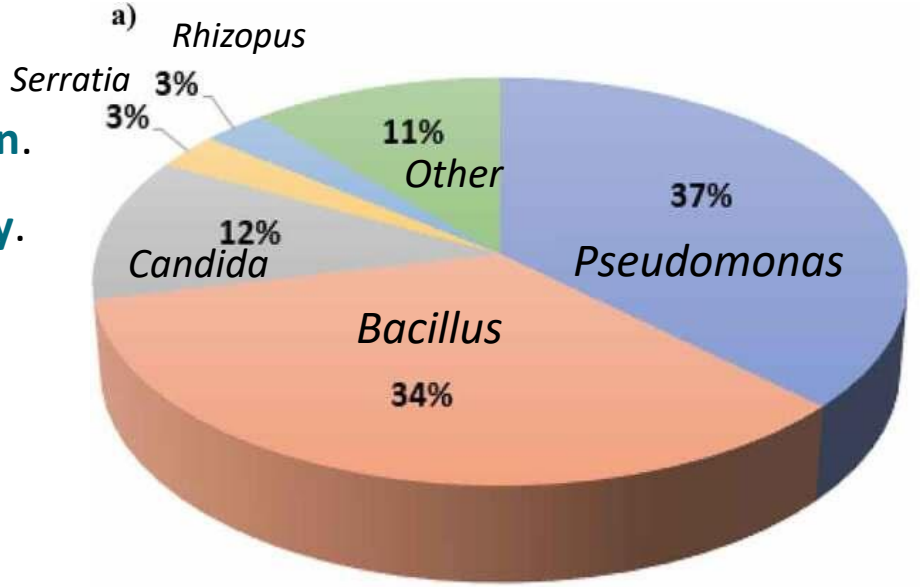
(minimized toxicity concerns)

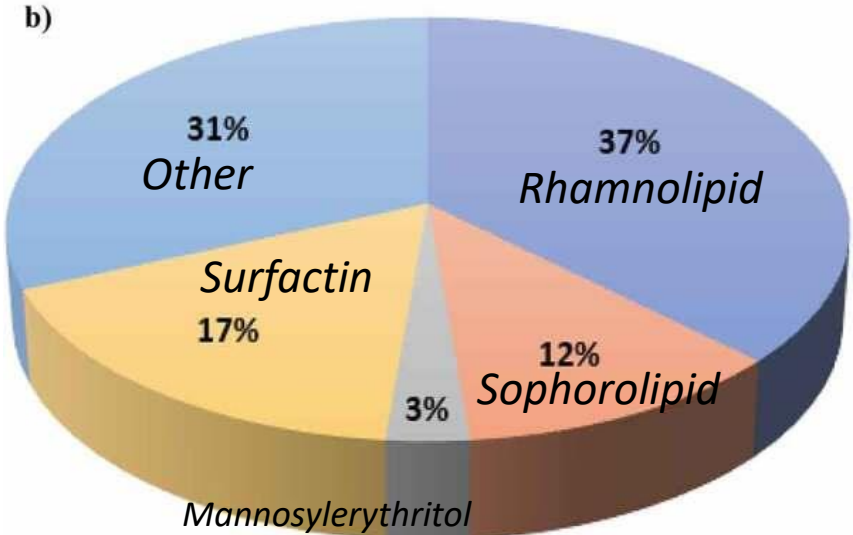
Microbial production of biosurfactants

Why microorganisms produce biosurfactants:

- **Enhance mobility,** to access nutrients **by reducing surface tension** of surrounding liquid.
- **Communicate** with other cells by **quorum sensing signals**.
- **Compete** with other microorganisms by **inhibiting growth** or **biofilm formation**.
- **Increase virulence** and infectivity by **altering host cell membrane permeability**.







Microrganisms from extreme environments

Hyperthermophilic
(80-113°C)

Thermophilic
(55-80°C)

Psychrophilic
(-2-20°C)

Halophilic
(2-5M NaCl)

Acidophilic
(pH<4)

Alkaliphilic
(pH>9)

Screening of thermophilic candidates

130 strains (from partner Matis, Iceland) screened for emulsification at identified growth conditions

22 pos strain (emulsification index >0)

Strain no	6708	7353	6691	7349	4752	493	7237	7409	1546	4723	4675	4708	4704	4730	4787	6891	4727	4627	4718	4600	1462	623
Emulsification index (%)	100	100	100	93	74	74	56	37	37	37	37	26	26	19	19	11	11	7	7	4	4	4

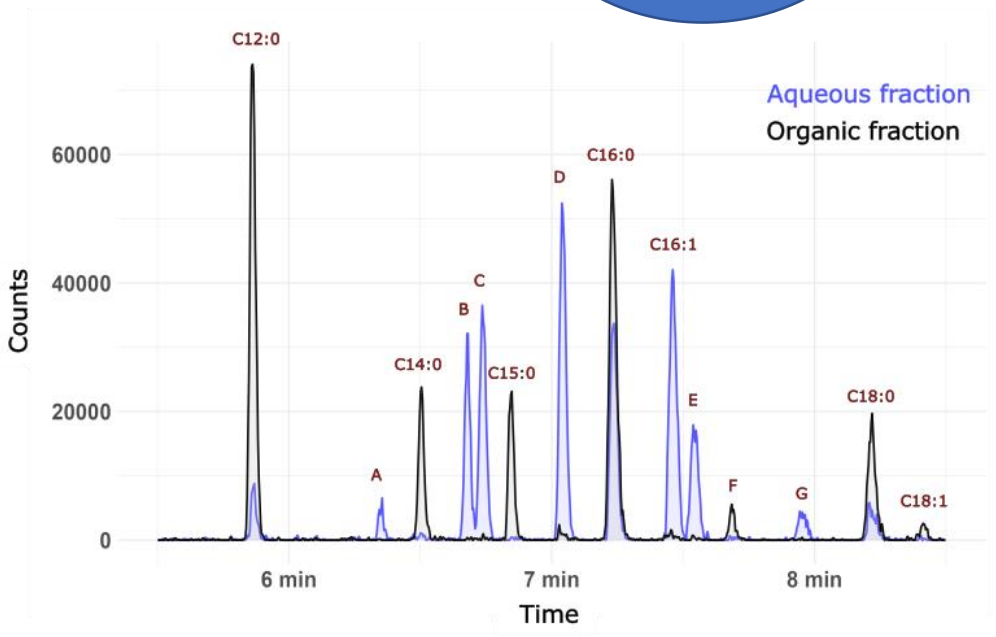
Production and characterization of an *R. marinus* emulsifying polymer

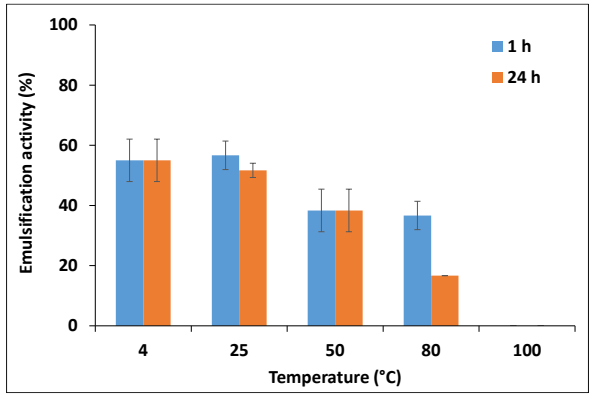
Microorganism (strain)	Growth temp. (℃)
Rhodothermus marinus (493)	65

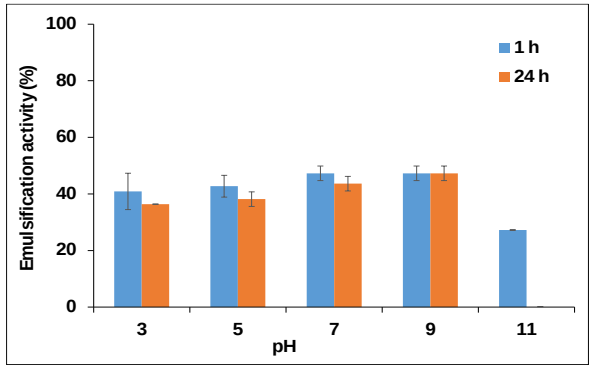
The molar ratio of the monosaccharides in the purified polymer				
Glucose	Galactose	Mannose	Arabinose	Rhamnose
1	1.52	8.44	21.34	26.93

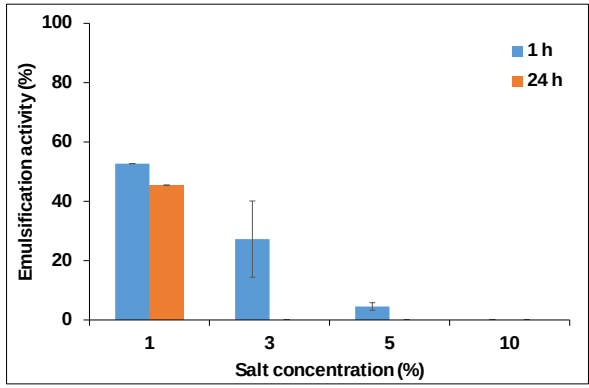
Amino acid (AA)	24 h hydrolysis (g AA/ 100 g polymer)
L-alanine	1.41 ± 0.01
L-arginine	1.94 ± 0.14
L-aspartic acid & L-asparagine	1.47 ± 0.55
L-cysteine	0.07 ± 0.03
L-glutamic acid & L-glutamine	0.91 ± 0.56
Glycine	2.13 ± 0.15
L-histidine	0.33 ± 0.03
L-isoleucine	0.74 ± 0.06
L-leucine	1.59 ± 0.20
L-lysine	1.71 ± 0.49
L-methionine	0.51 ± 0.10
L-phenylalanine	0.77 ± 0.02
L-proline	0.88 ± 0.05
L-serine	2.02 ± 0.24
L-threonine	0.99 ± 0.31
L-tyrosine	0.62 ± 0.01
L-valine	1.07 ± 0.01
Total	19.22 ± 0.29

Glycolipo-peptide



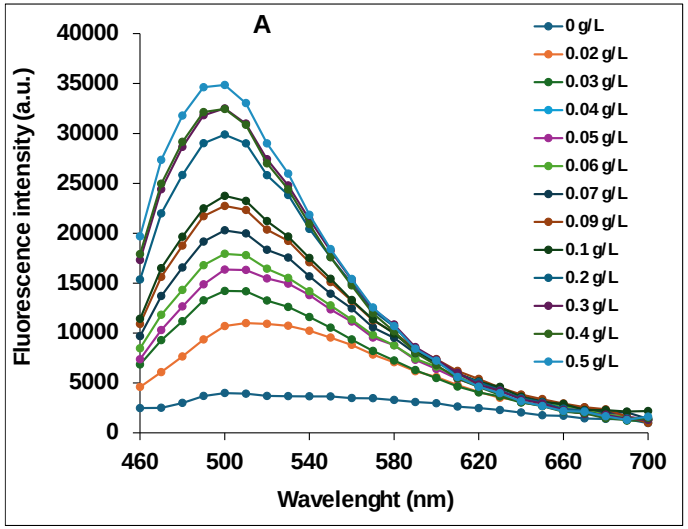


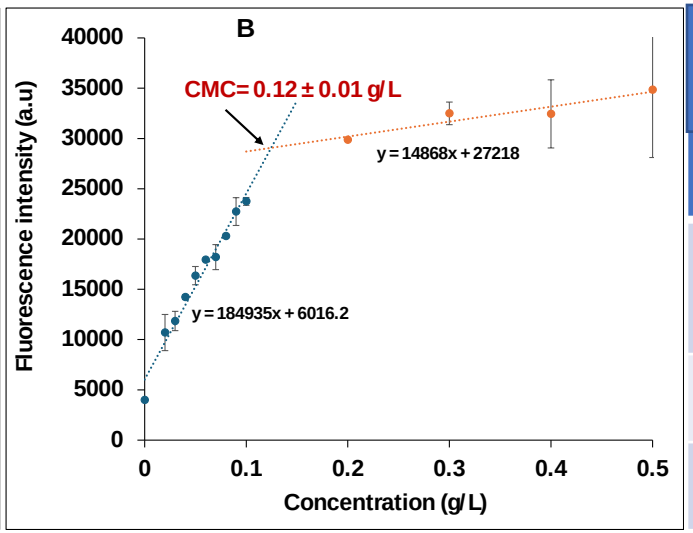




Critical micelle concentration (CMC) of emulsifying polymer from *R. marinus*

Microorganism (strain)	Growth temp. (℃)
Rhodothermus marinus (493)	65

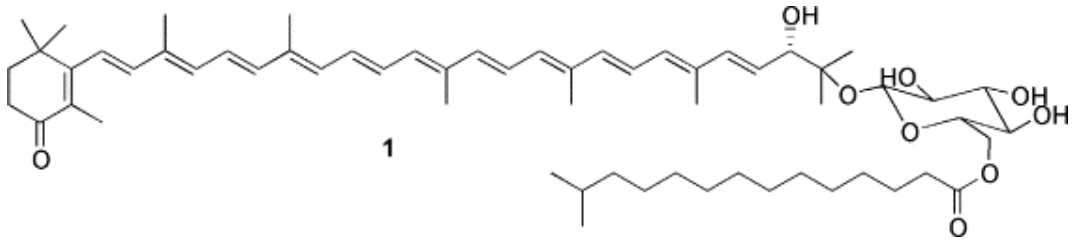


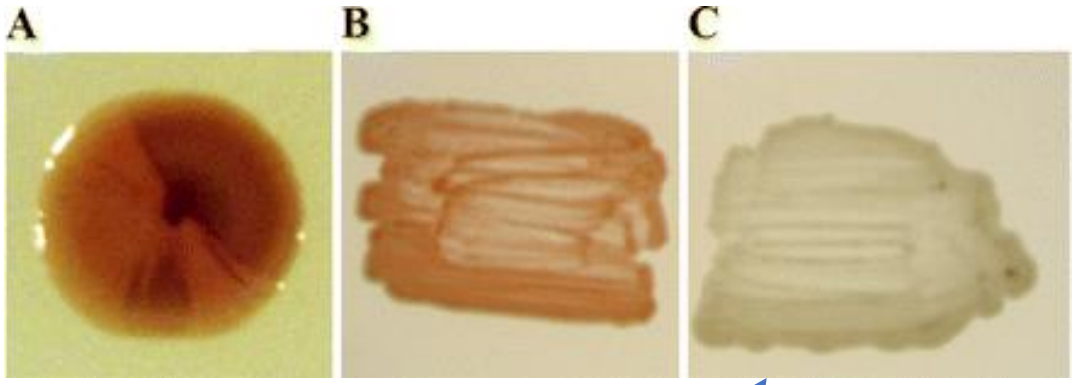


Examples of CMC for various compounds used in applications		
Application	**Compounds**	**CMC**
Food hydrocolloids	Xanthan gum, pectin	3 - 10 g/L
Detergent	SDS	7 - 9 g/L
Biomedical	Inuling-ceramide	0.06 g/L

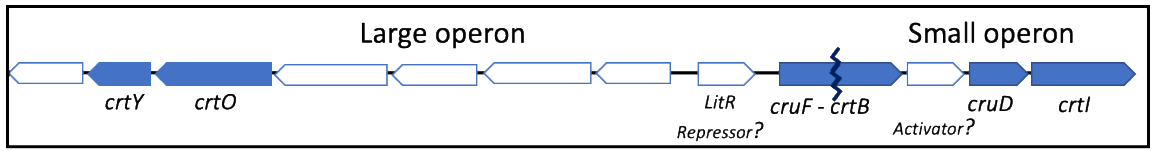
Carotenoids as surfactants?

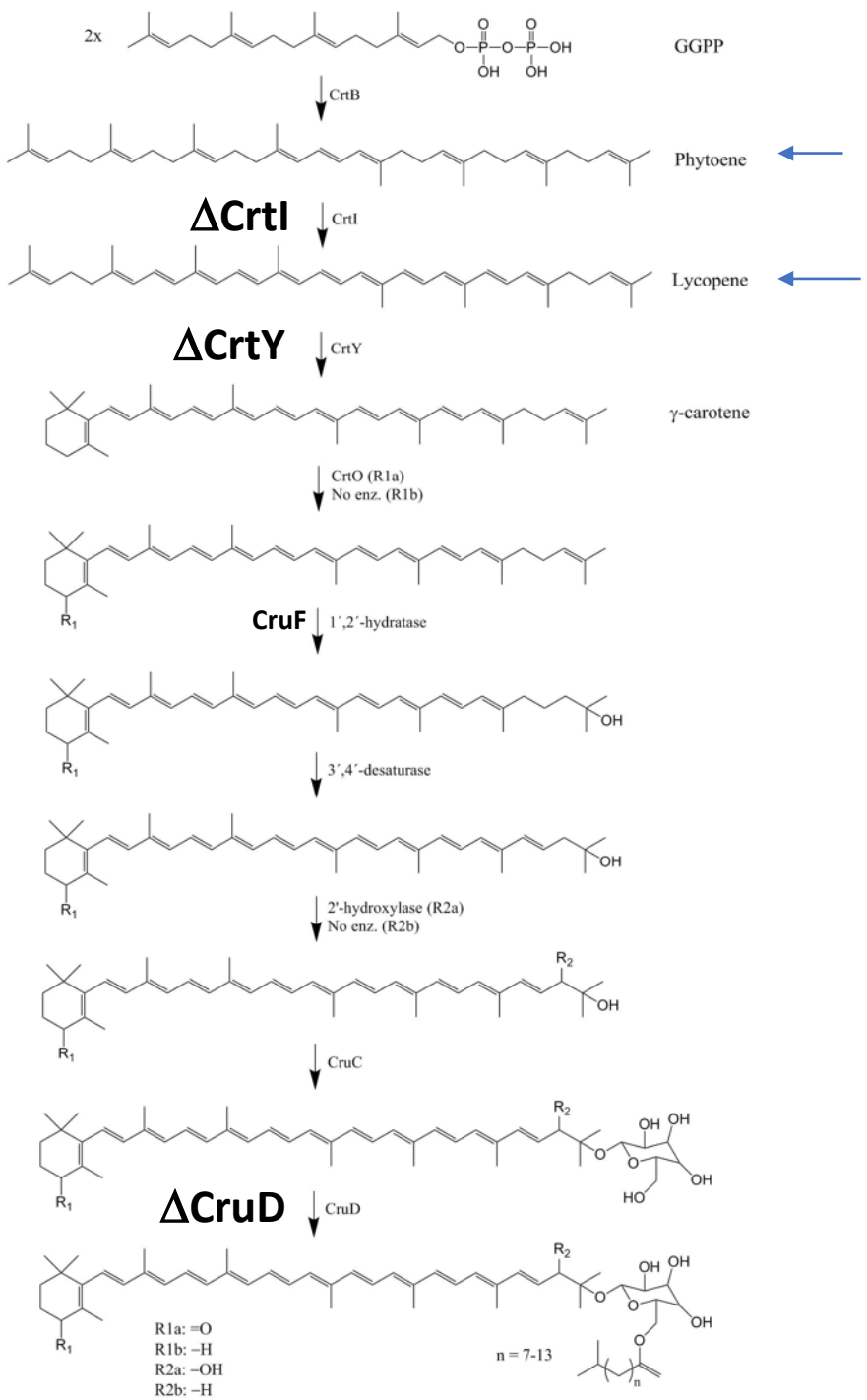
- *Rhodothermus marinus wt* forms deep red glycosylated γ-carotenoid

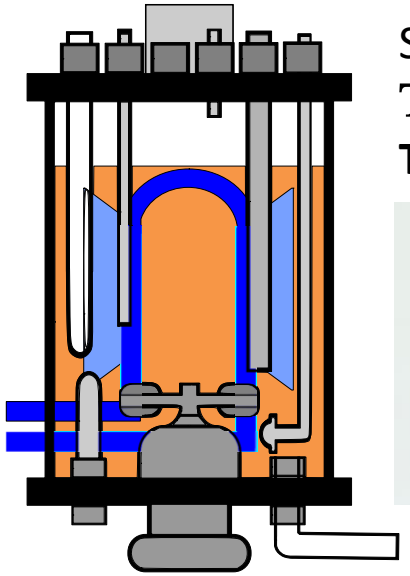




crtB & ctrI knock out







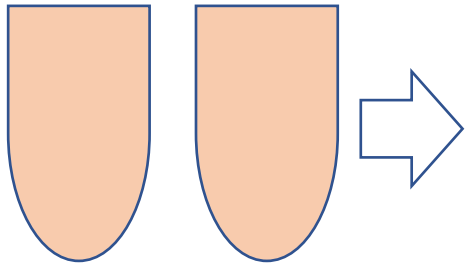
Batch cultivation

Strains:

TK21: ΔCrtY, ΔCruD (glycosylated lycopene)

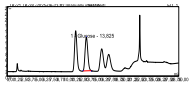
TK28: ΔCrtY, ΔCruD, ΔCrtI (glycosylated phytoene)

Cell separation

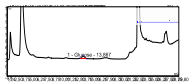


2X solvent extraction

Drying

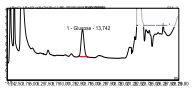


Glucose standard (5 mg/L)



TK-21

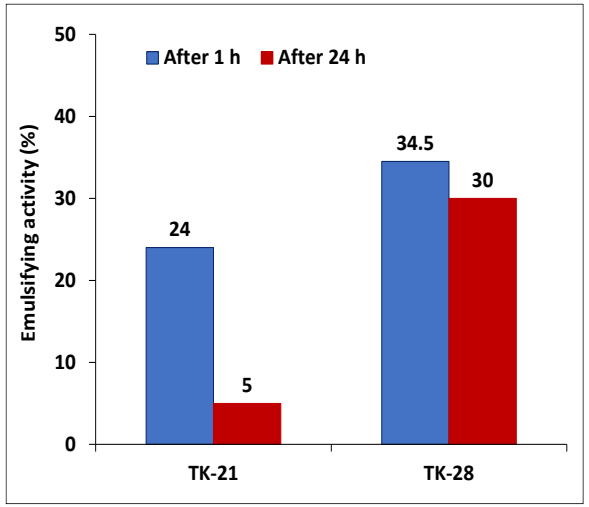
Glucose

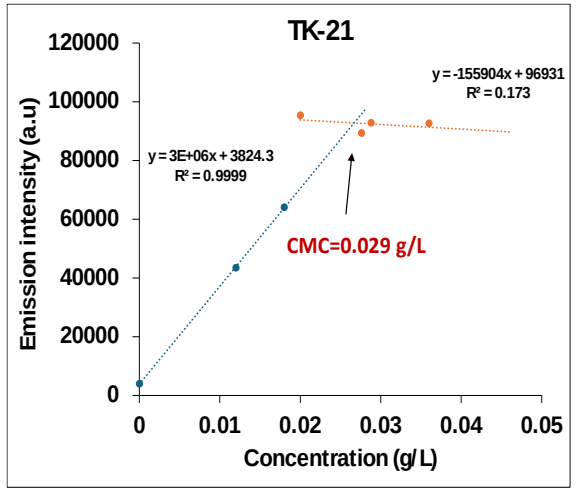


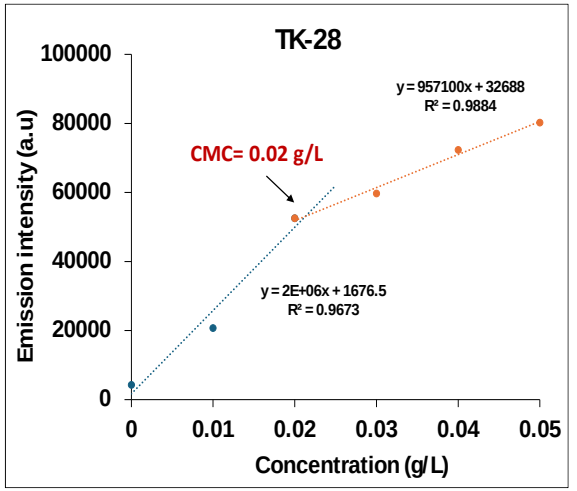
TK-28

Glucose

Surfactant properties







Glycosylated phytoene – show promising surfactant properties

Examples of CMC for various compounds used in applications		
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Detergent	SDS	7 - 9 g/L
Biomedical	Inuling-ceramide	0.06 g/L

Conclusion

BENEFITS of Biosurfactants

- 100% biobased
- Readily biodegradable
- Biologically produced and often efficient compared to synthetic surfactants

- **Applications**
  - Many sectors – including high end e.g. food , personal care, cosmetics and pharma – large potential to implement new types of biosurfactants

- **Novel biosurfactants (natural and engineered)**
  - Natural polymeric emulsifier identified in a thermophile
  - Novel type of carotenoid-based surfactant developed

Acknowledgement

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  - Dr Roya Sardari
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