



**INTERNATIONAL  
CONGRESS ON  
NATURAL  
PRODUCTS  
RESEARCH**

Kraków

2024, July 13-17



# Natural Cosmetics: How to Harness the Potential of Eutectic Solvents for the Formulation and Enhancement of Natural Ingredients

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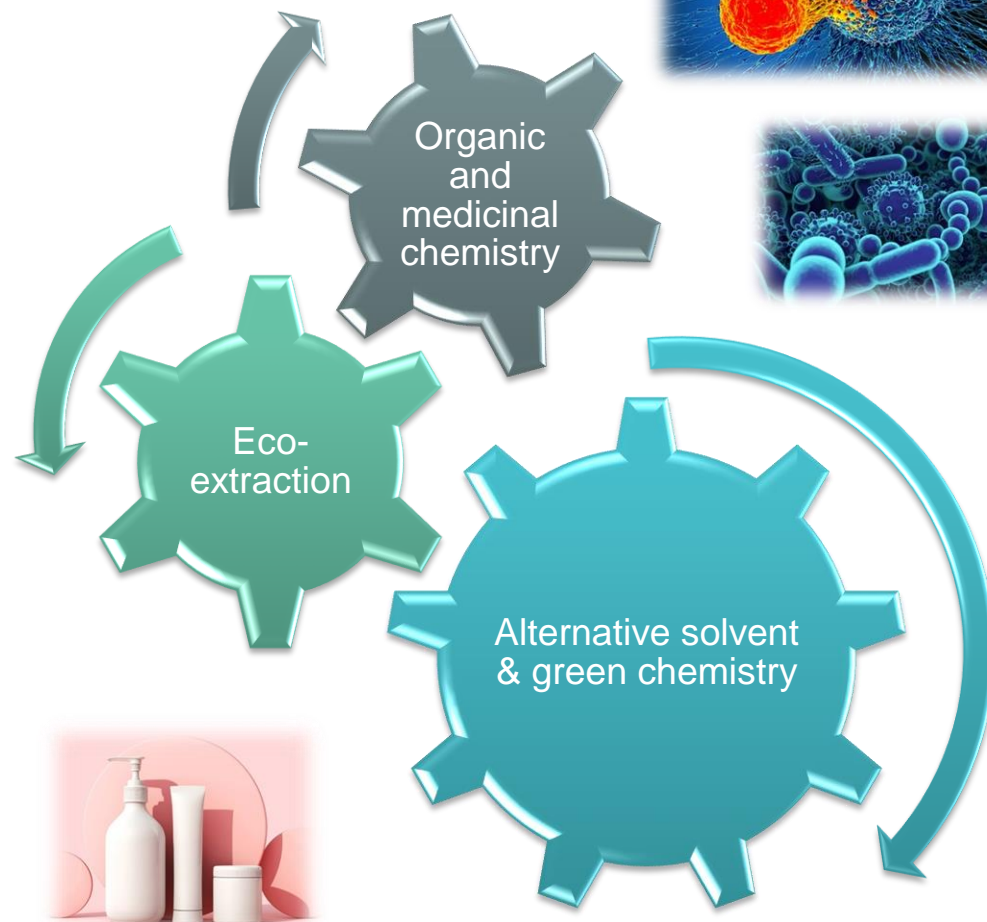
13 novembre 2024



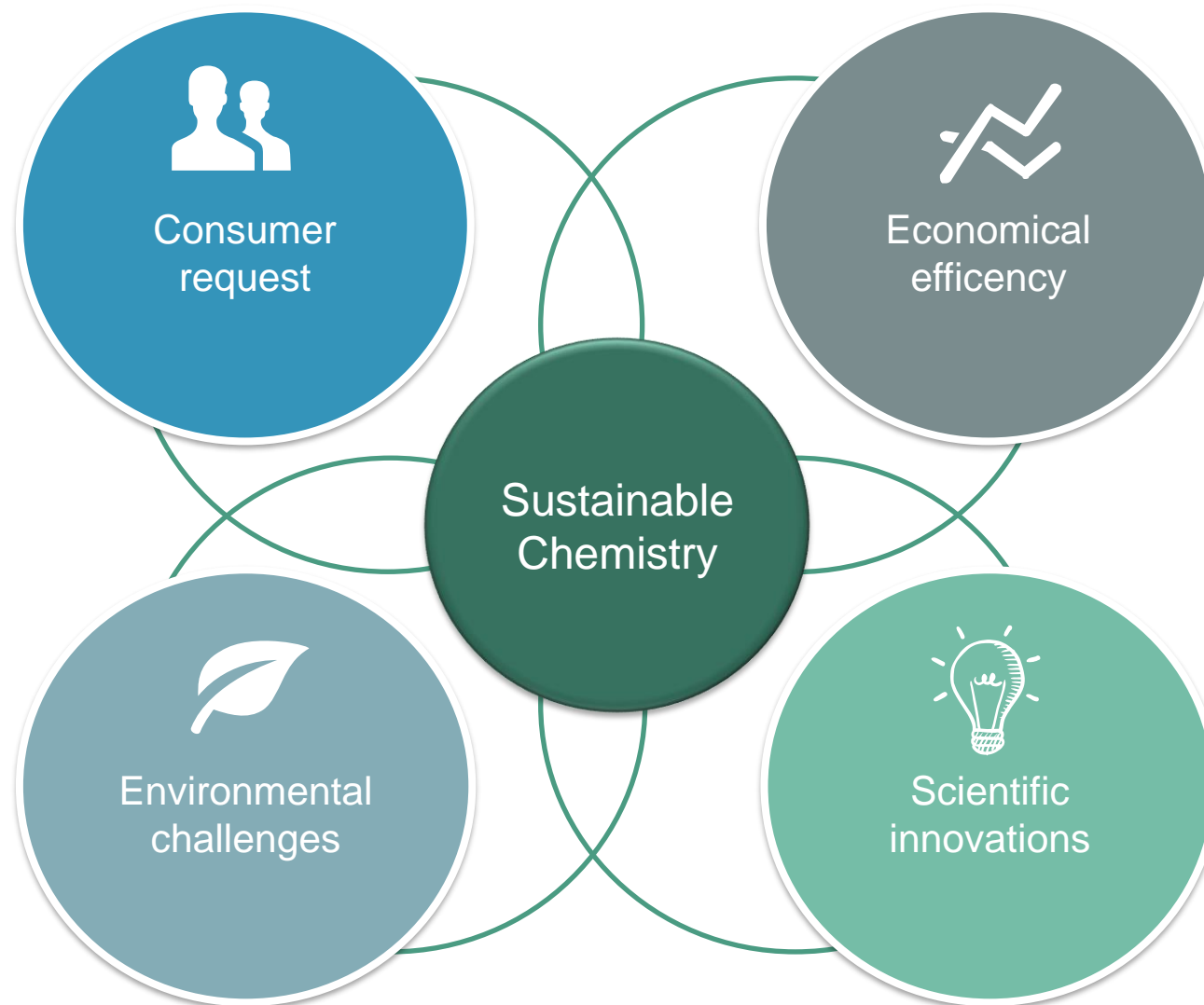
22 researchers

4 Professors, 6 Associate professors  
5 Technical assistants

6 PhD students  
1 post doctoral fellow

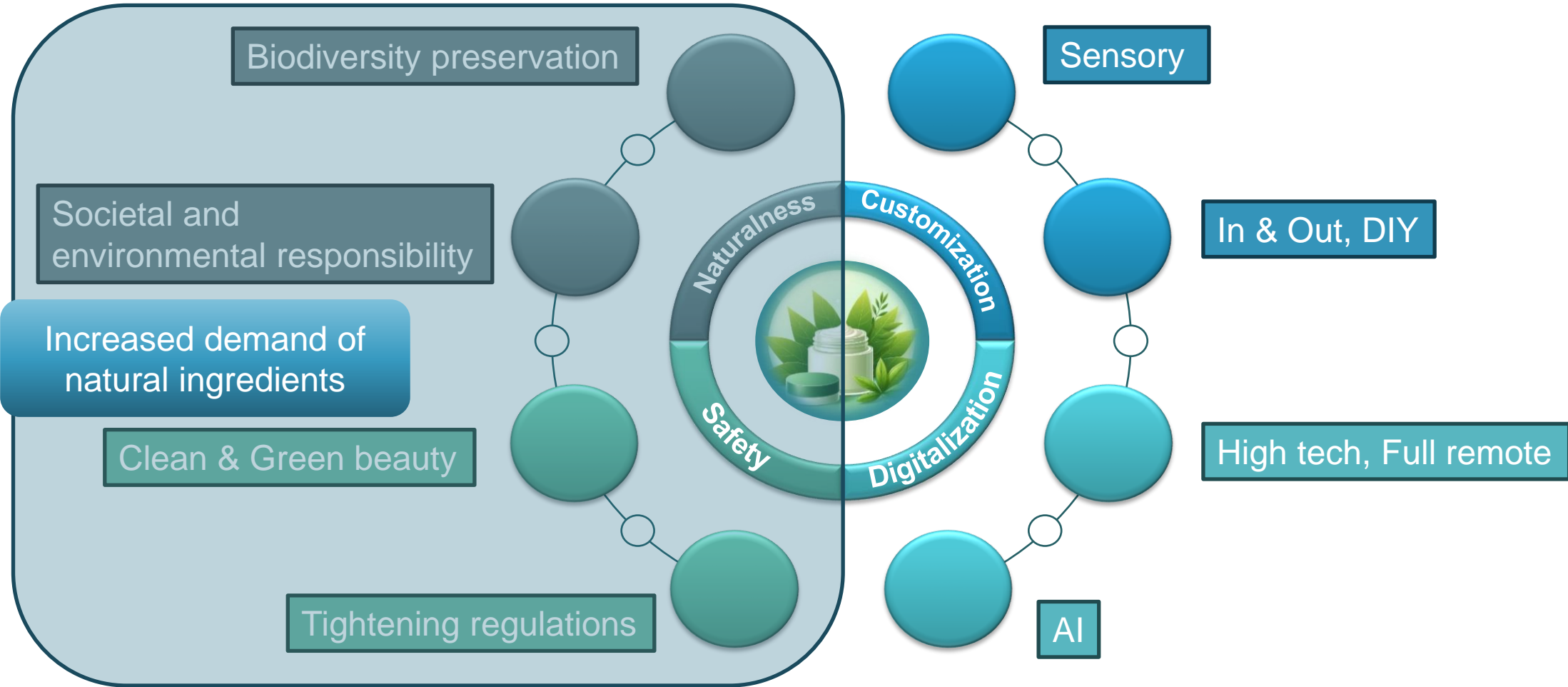


# A global trend towards green innovations



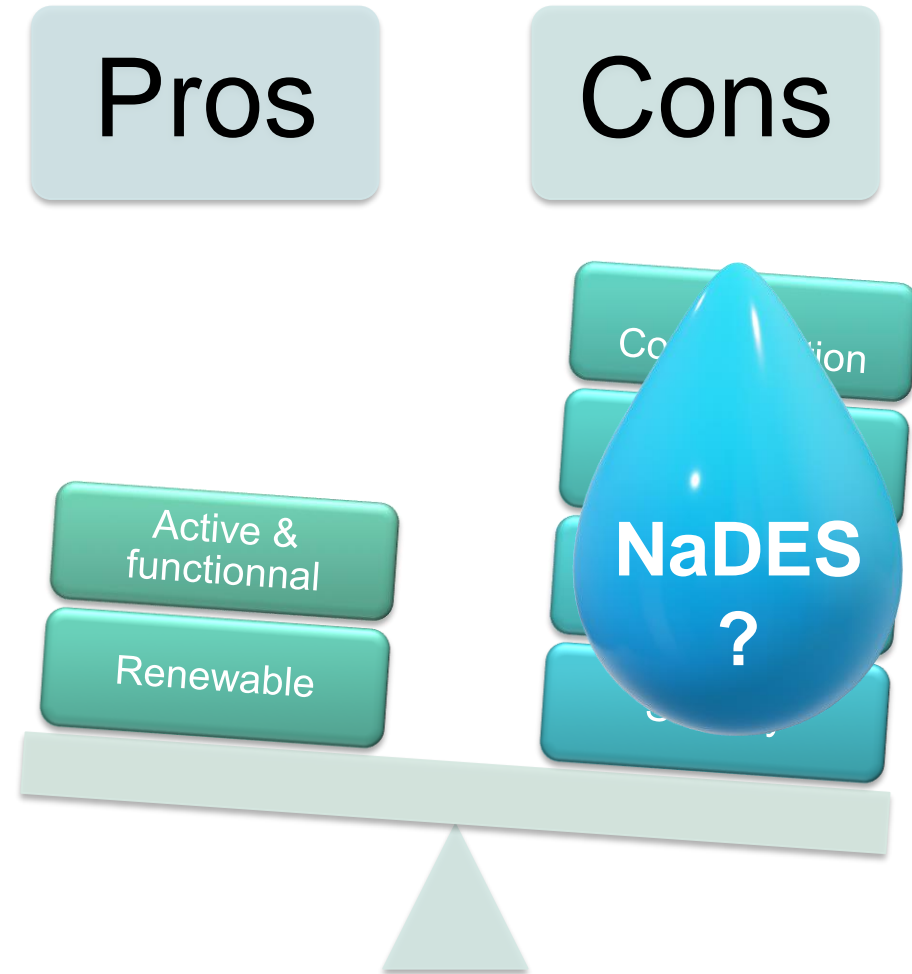
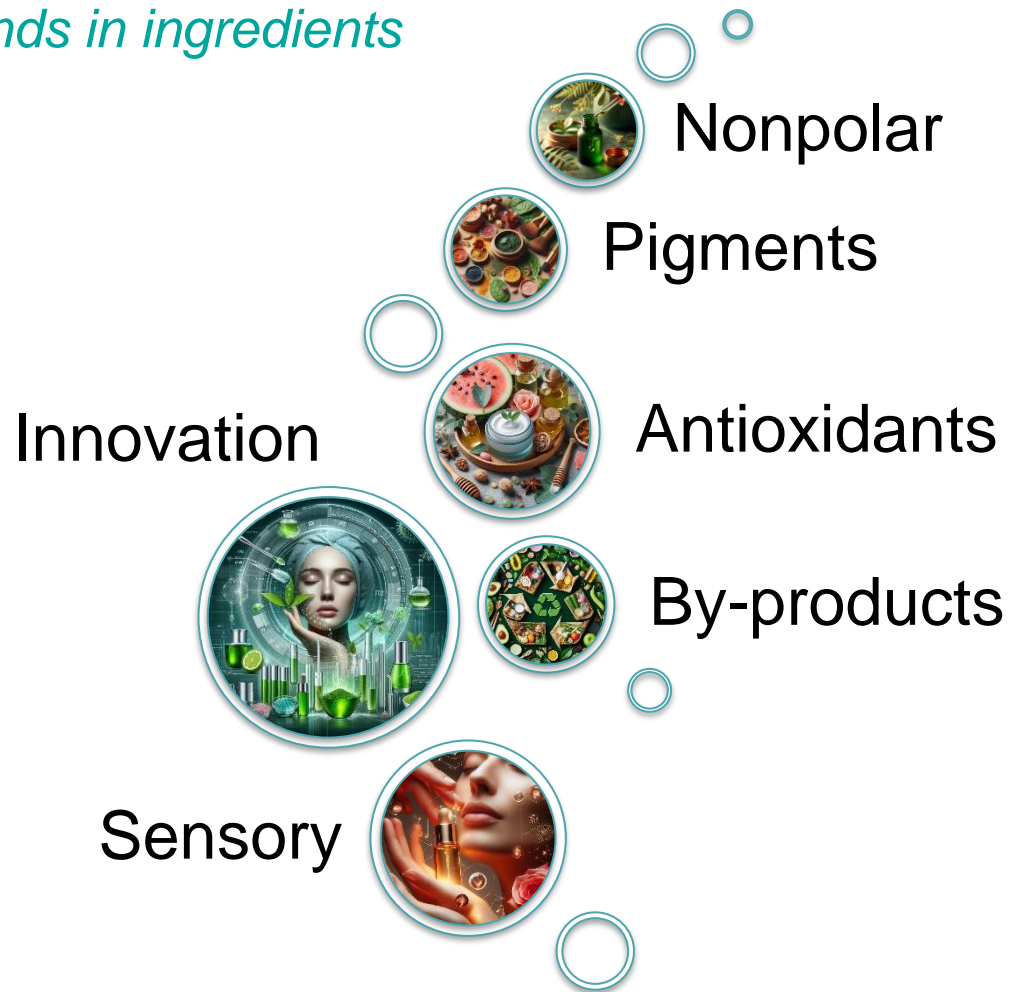
What about cosmetics?

# Major trends in cosmetic innovation



# Natural ingredients & Cosmetics

*Trends in ingredients*

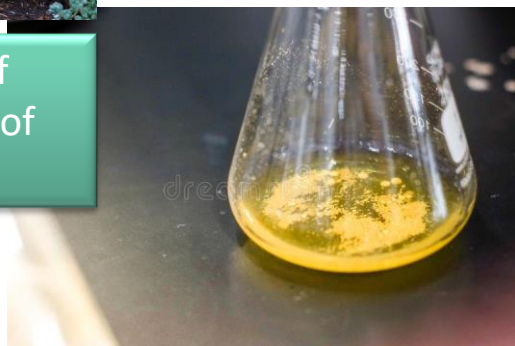




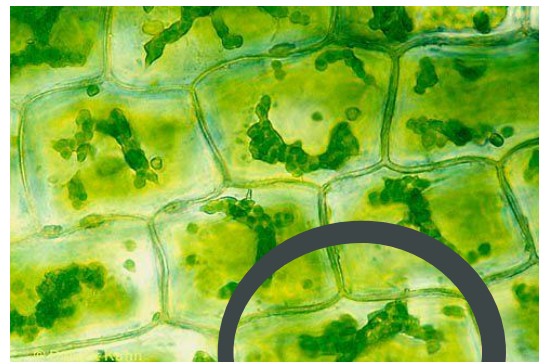
# Natural Deep Eutectic Solvents (NaDES) bioinspired solvents



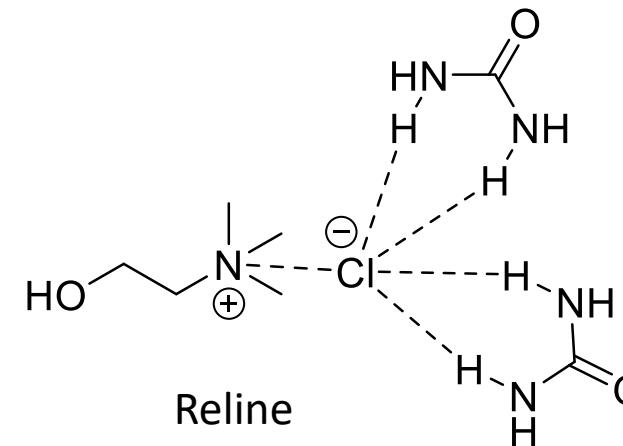
Metabolic activity of succulents in periods of extreme drought



Natural products insoluble in water or oil



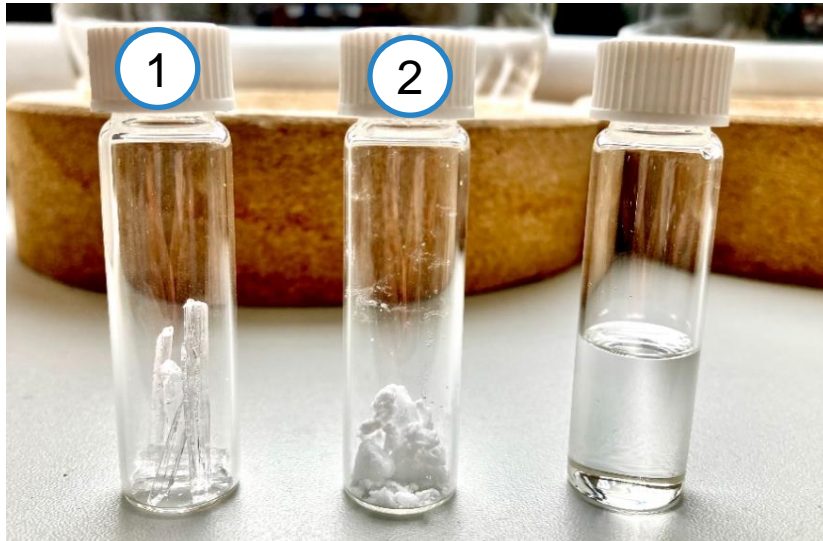
3<sup>rd</sup> plant physiological liquid  
=  
Natural Deep Eutectic Solvent



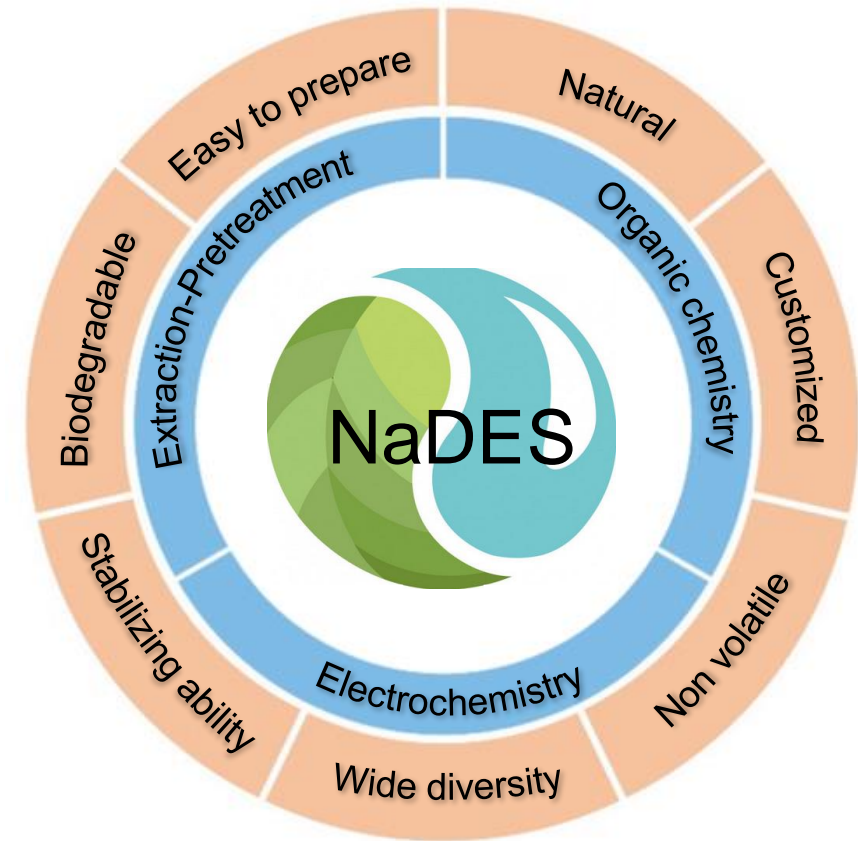
# NaDES : original properties

## ➔ NaDES :

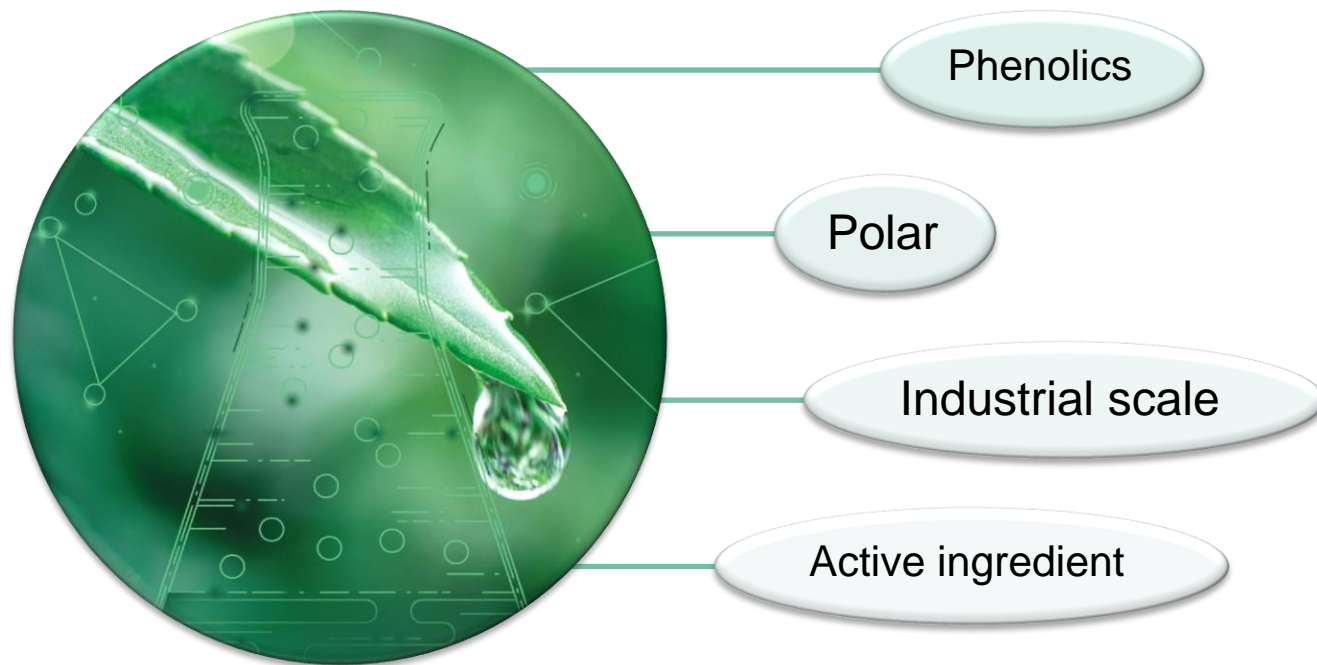
- Natural compounds mixture
- In a specific ratio
- Ideality deviation of fusion temperature
  - Liquid at room temperature



## ➔ Properties



# NaDES & Cosmetics



- Original selectivity
- High concentrated ingredients
- Stabilized ingredients
- Biocompatible

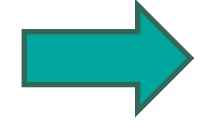


- IP/regulations
- Complex selection
- Lack of prediction
- Recycling
- NaDES removal



# NaDES selection: a crucial step in cosmetics development

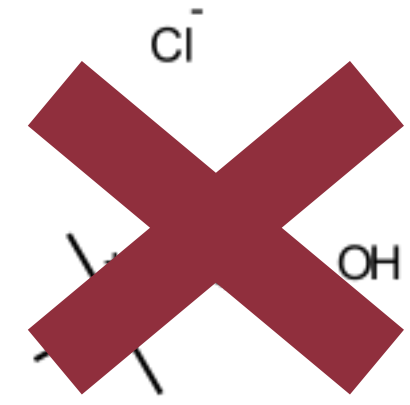
 No NaDES/metabolites separation step



- ✓ in compliance with industry regulation
- ✓ part of the final product
- ✓ can bring new properties



CosIng - Cosmetics Ingredients



Smart NaDES selection strategy

Rente, D., et al. (2022). Journal of Cleaner Production, 380, 135147. <https://doi.org/10.1016/j.jclepro.2022.135147>

# Smart NaDES selection strategy

## Raw material selection

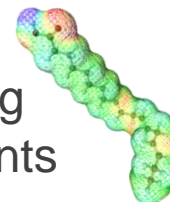


CosIng - Cosmetics Ingredients

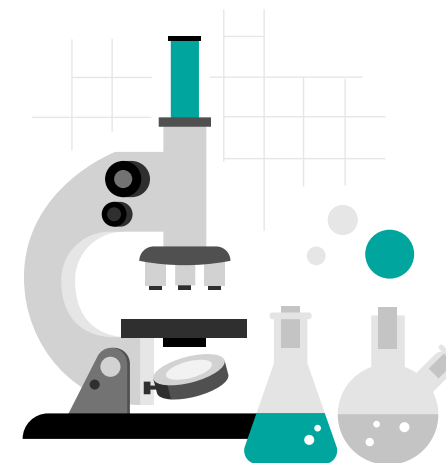


## *In silico* conception & properties prediction

COSMO-RS  
COnductor-like Screening  
MOdel for Realistic Solvents



## Experimental validation

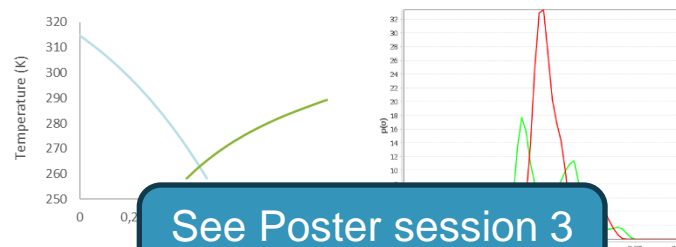


- ✓ Density
- ✓ Viscosity
- ✓ pH
- ✓ Extraction ability

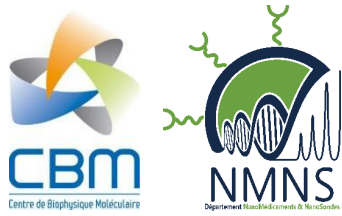


Accepted raw material  
Biosourced  
Good life cycle assessment

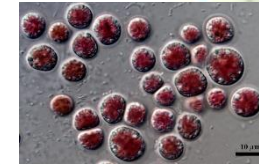
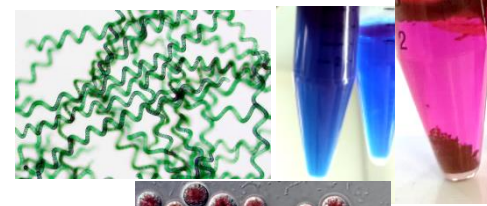
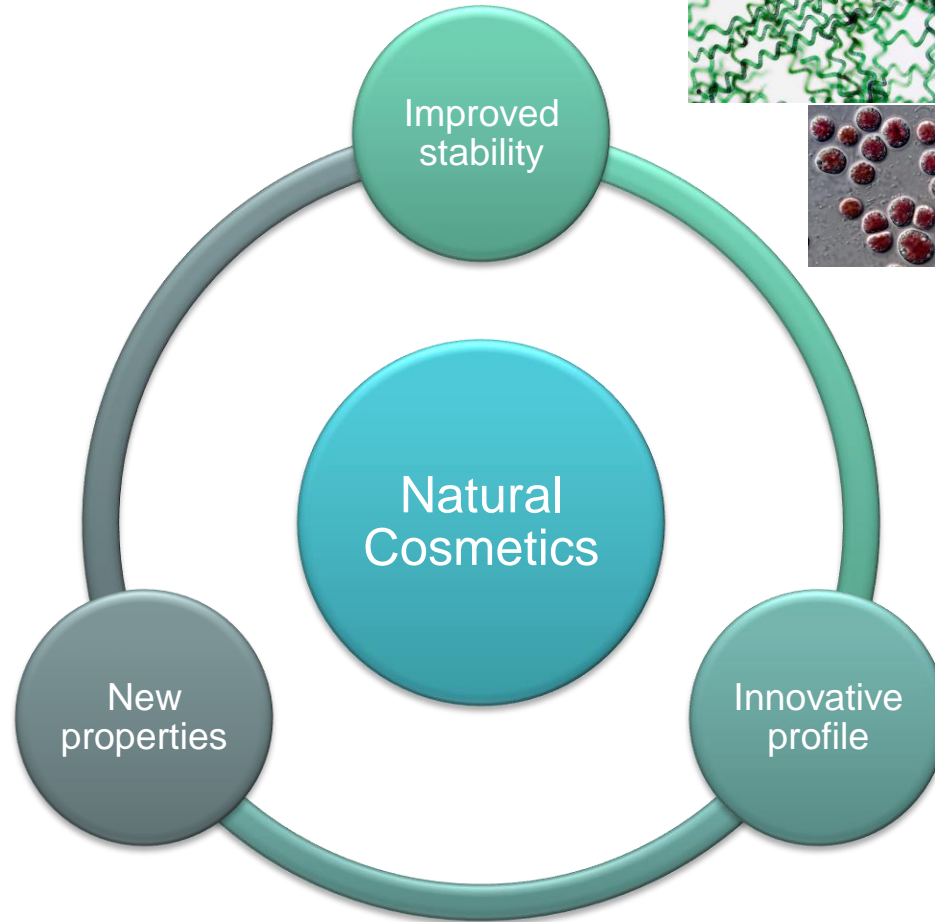
Eutectic window  
Short list of suitable systems



# How to harness natural cosmetics using NaDES?



Introduced in Gels



**Microalgae**  
(*Spirulina* & *Porphyridium cruentum*)

- ✓ *Phycocyanin*
- ✓ *B-Phycoerythrin*

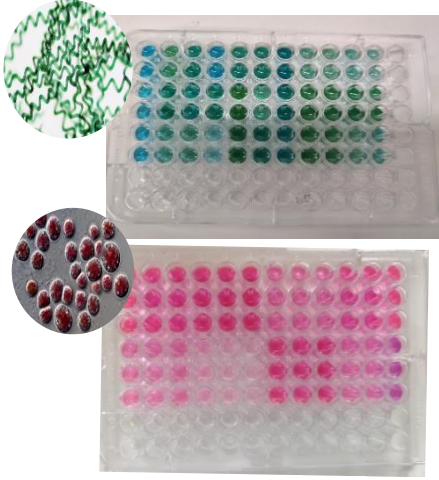


**Marigold (*C. officinalis*)**

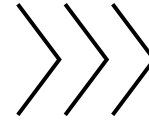
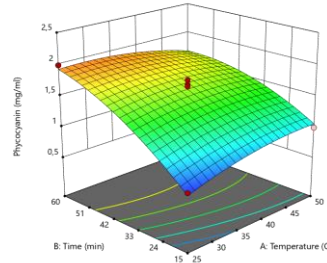
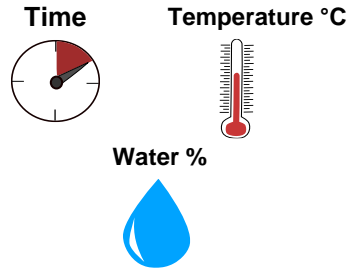
- ✓ *Flavonoids*
- ✓ *Carotenoids*

# Phycobiliproteins stabilization using NaDES

60 screened NaDES



Ultrasonic Assisted Extraction UAE



Optimum conditions

- 30-40 °C maximum
- 20-30 % water
- 60 min UAE

Glycerol/Gucose (GG)  
Glycerol/Betaine (GB)

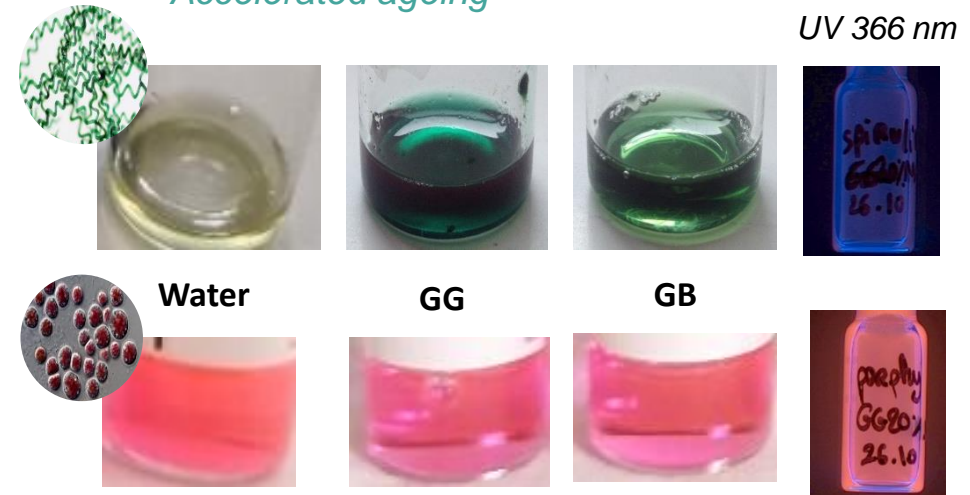
→ Glycerol-based NaDES

Spirulina  
Green instead of blue  
Nonpolar Pigments  
Purification?

100% loss in water  
10% loss in NaDES

30% loss in water  
10% loss in NaDES

Accelerated ageing

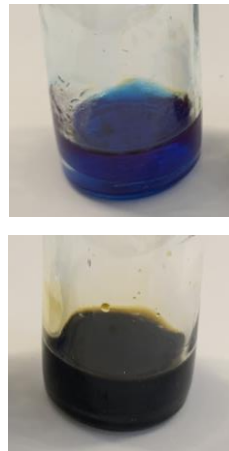
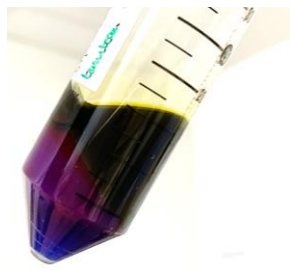
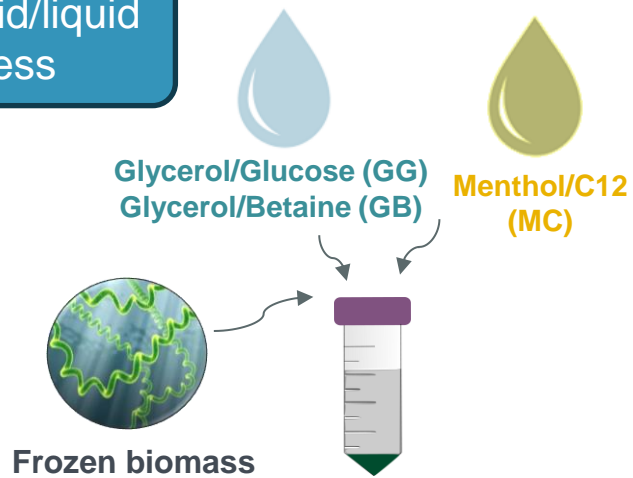


van Gheluwe, L., et al. (2024). Sustainable Chemistry and Pharmacy, 40, 101654. <https://doi.org/10.1016/J.SCP.2024.101654>  
Hilali, S., et al. (2022). Biomass Conversion and Biorefinery, 12(S1), 157–170. <https://doi.org/10.1007/s13399-021-02263-6>



# Phycobiliproteins purification/stabilization using NaDES

Solid/liquid/liquid process



SL  
extraction

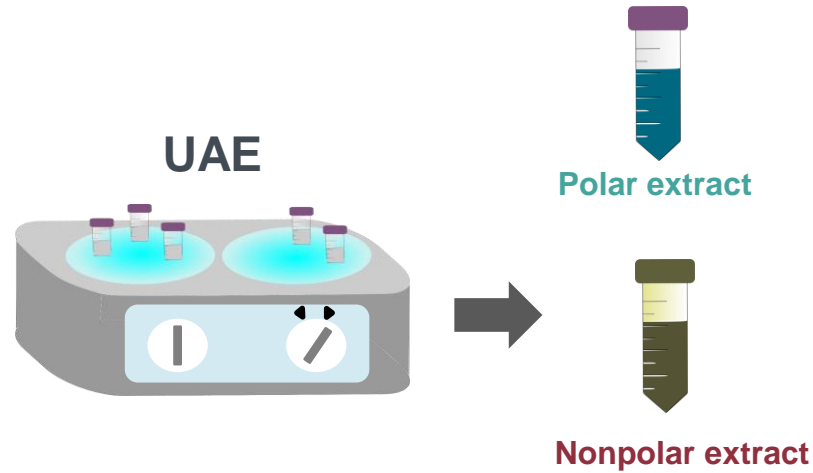
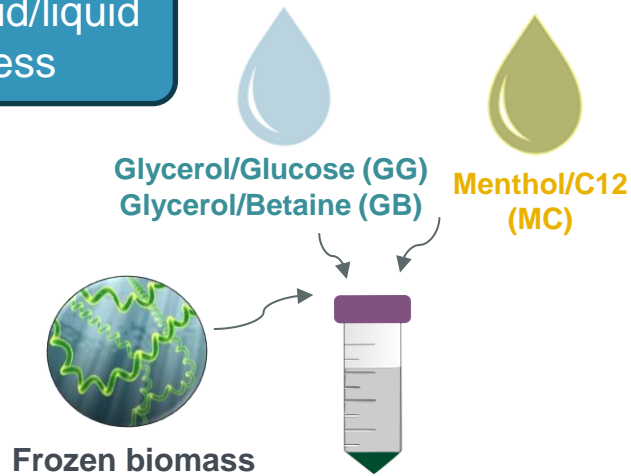
SLL  
extraction

- ✓ Similar phycocyanin content
- ✓ Bright blue color
- ✓ Extraction/Purification
- ✓ Stabilization ok

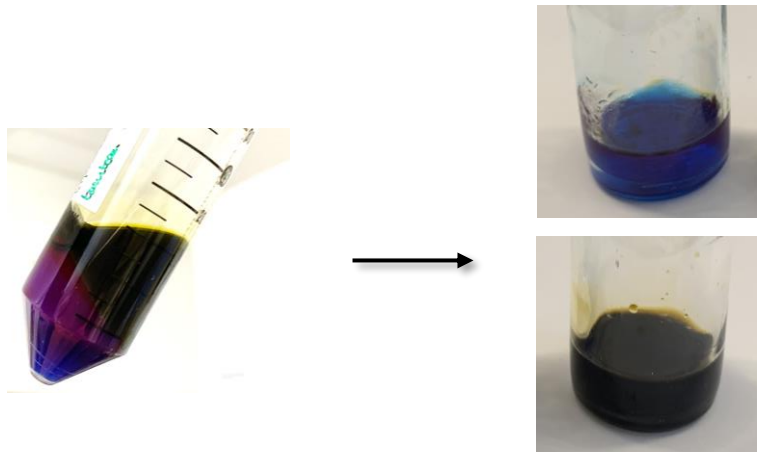
→ Introduction in gels  
→ GG and GB phycobiliproteins extracts

# Phycobiliproteins purification/stabilization using NaDES

Solid/liquid/liquid process



90 min extraction  
20 min centrifugation



- ✓ Similar phycocyanin content
- ✓ Bright blue color
- ✓ Extraction/Purification
- ✓ Stabilization ok

→ Introduction in gels  
→ GG and GB phycobiliproteins extracts

Hilali, S. et al, (2024) Separation and Purification Technology, 329, 125123. <https://doi.org/10.1016/J.SEPPUR.2023.125123>



# NaDES extract in gels: what impact?

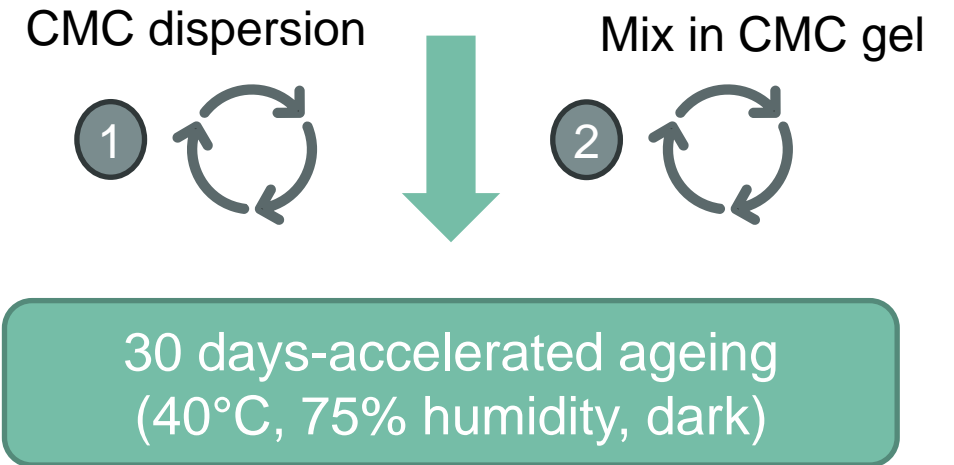


Green gel formula  
COSMOS ok

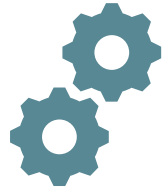
		%wt in the samples	
Ingredients	function	Control	NaDES gels
NaDES (%wt.)	Solvent	0	1 or 10
CMC (%wt.)	Gelling agent	3	3
Dehydroacetic acid/benzyl alcohol mix (%wt.)	Antimicrobial agents	0.3	0.3
Water (%wt.)	Solvent	q.s 100	

✓ Process

**1% or 10%wt NaDES or NaDES extract  
in the aqueous phase  
Before or After gellation**



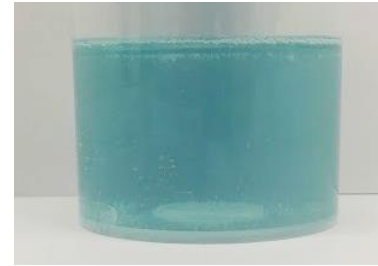
# NaDES extract in gels: what impact?



Process

No process impact  
Same properties of gels

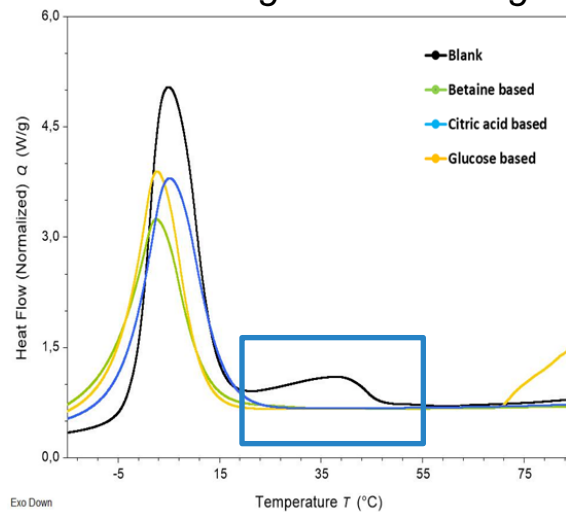
Introduction after gellation  
→ Preservation of phycobiliproteins



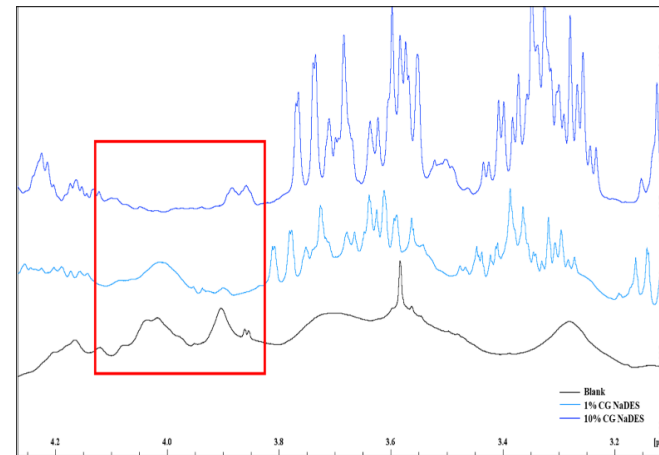
Gel structure

Better solubilization  
of CMC

DSC thermograms of CMC gels



$^1\text{H}$  NMR spectra of CMC gels in  $\text{D}_2\text{O}$



Signal loss:  
implication of  
protons in new  
bonds



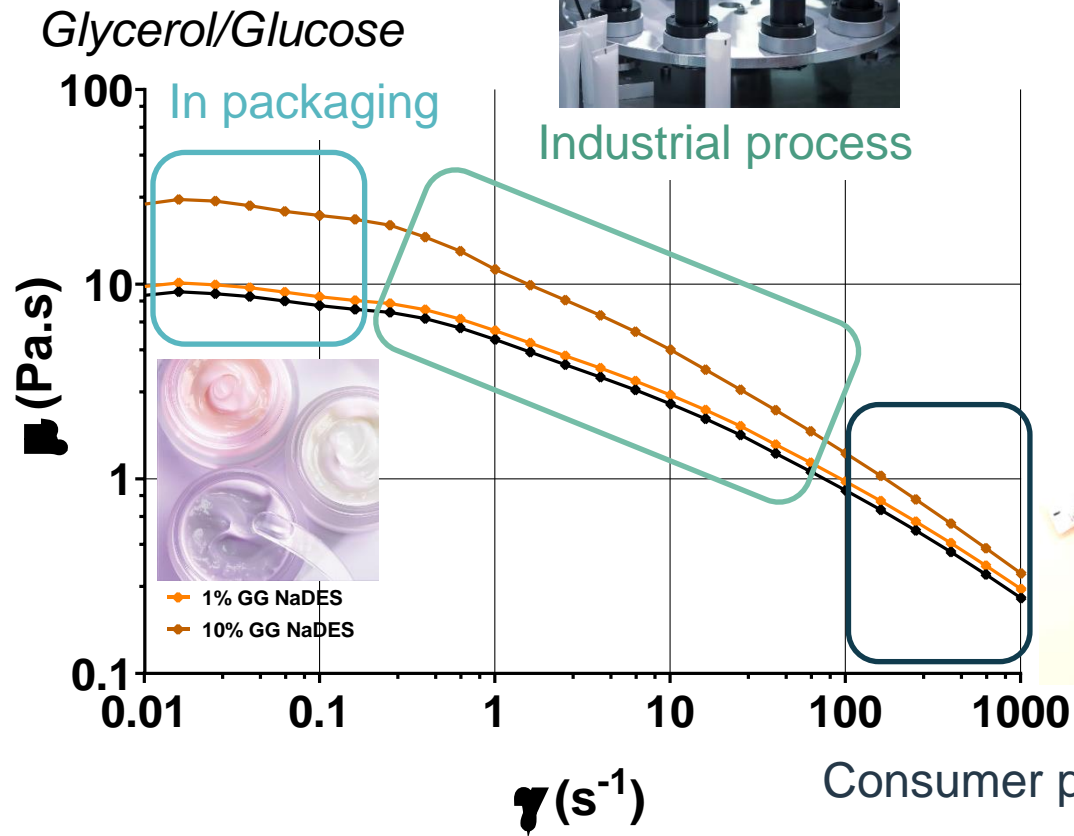
# NaDES extract in gels: what impact?



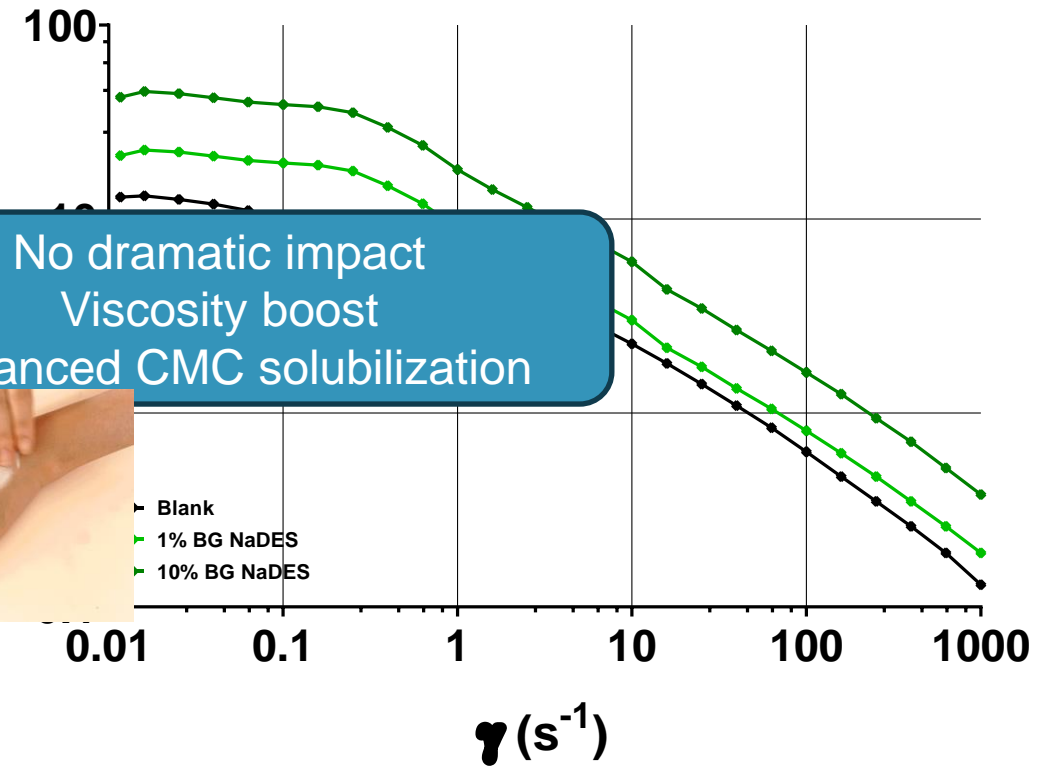
Viscosity



Industrial process



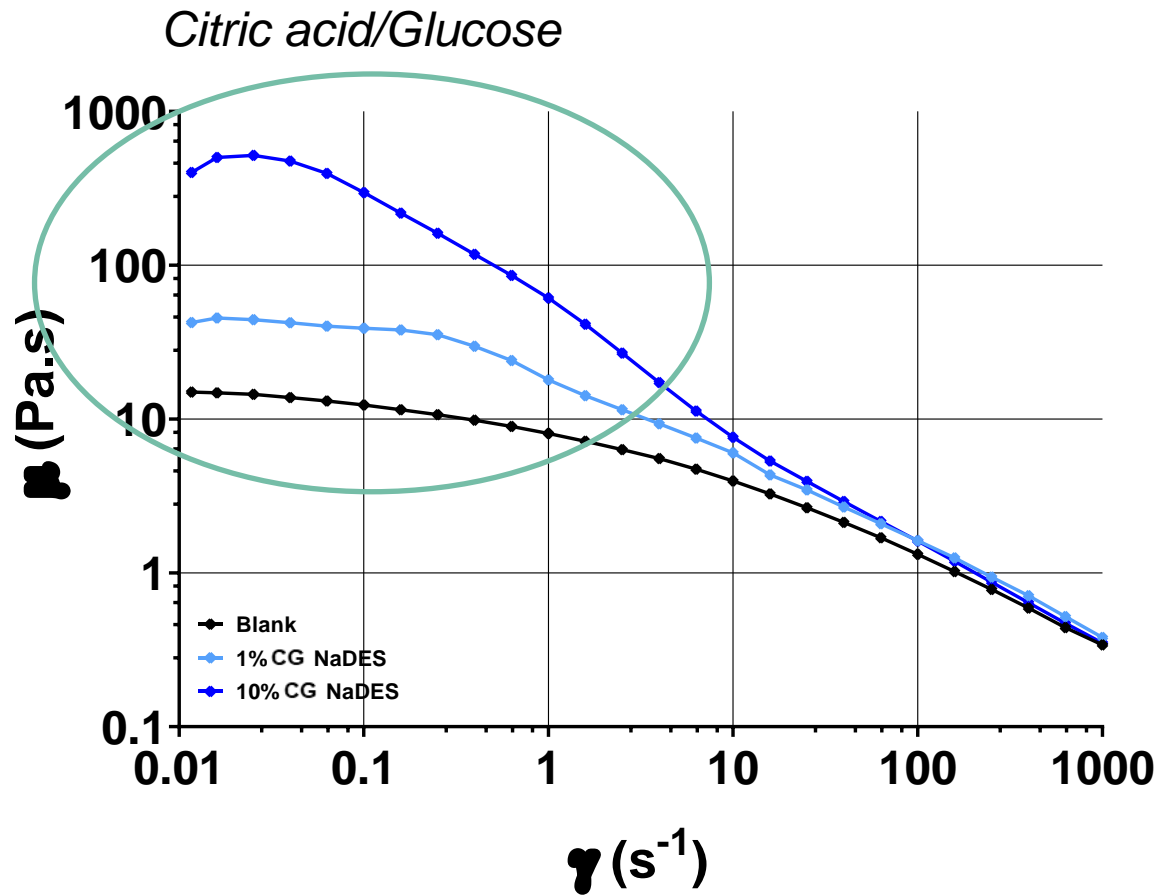
Glycerol/Betaine



# NaDES extract in gels: what impact?



Viscosity



High increase of viscosity  
Industrial process impact  
Consumer impact = pick up

No generalization  
→ Case-by-case development  
→ NaDESs dependent  
→ Gelling agent dependent



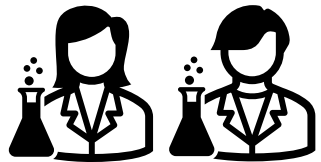
# NaDES extract in gels: what impact?



Sensory



GG 10% gel



Expert panel  
10 descriptors

Improved consumer perception



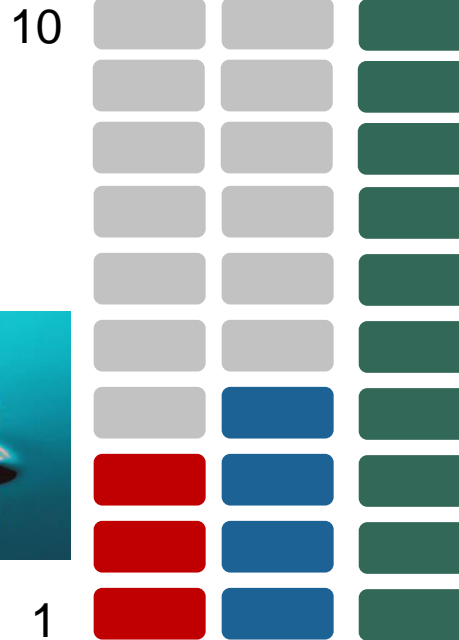
Control  
Gel without NaDES



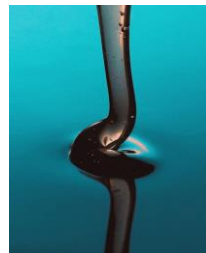
Sample  
10% GG gel



Benchmark  
Styling gel



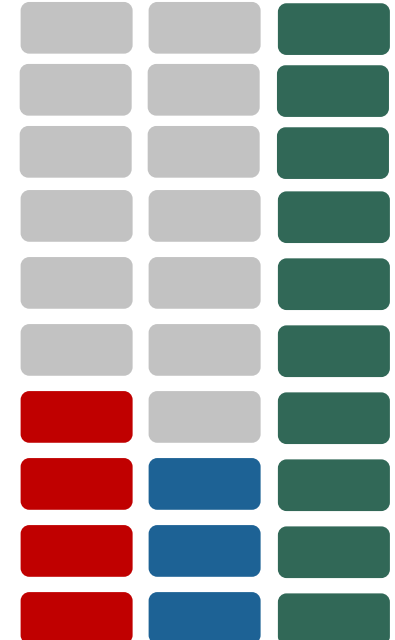
Perceived viscosity



Stringiness



Stickiness





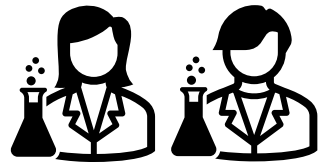
# NaDES extract in gels: what impact?



Sensory



GG 10% gel



Expert panel  
10 descriptors

Improved consumer perception



Control  
Gel without NaDES



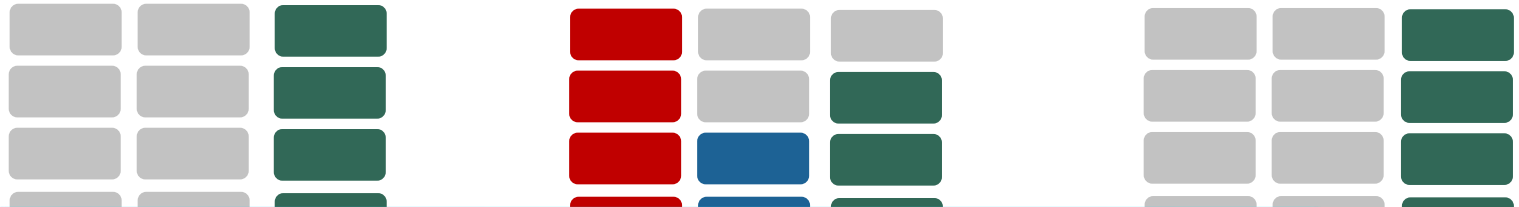
Sample  
10% GG gel



Benchmark  
Styling gel



10



- ✓ Stabilized phycobiliproteins
- ✓ Preservation of color and antioxidant ability
- ✓ Ready to use ingredient for gels
- ✓ NaDES = viscosity booster in this case
- ✓ Improved consumer experience

1

Perceived viscosity



Stringiness



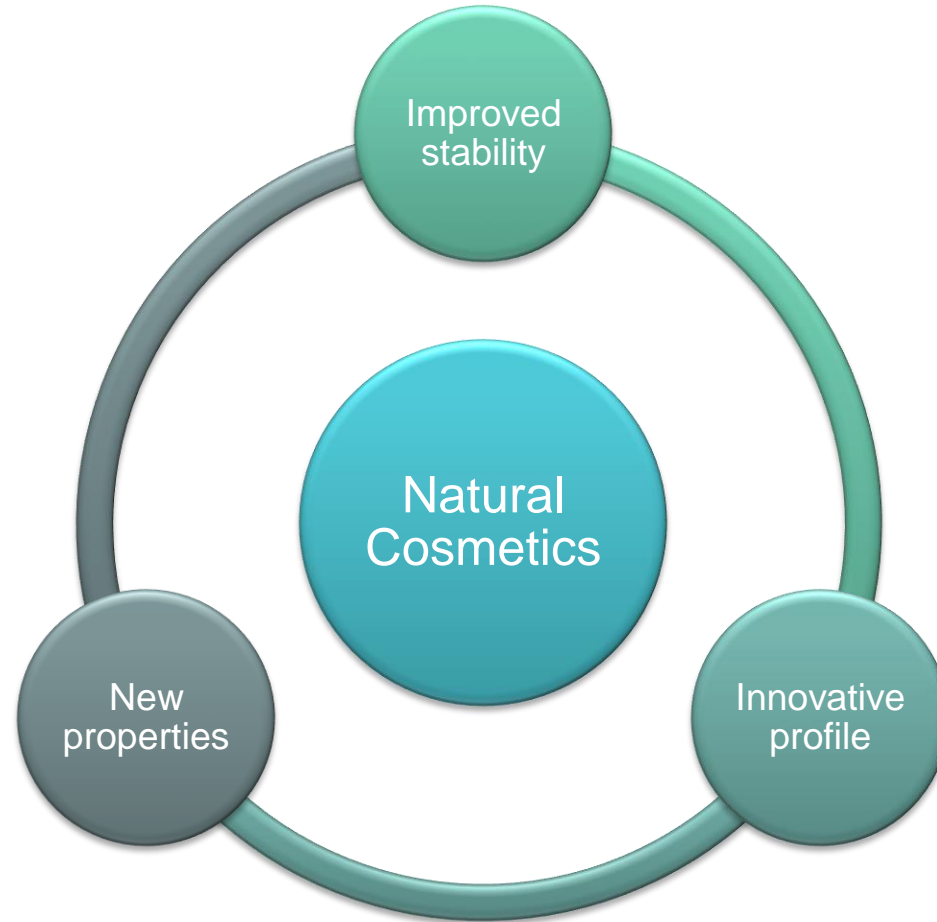
Stickiness



# How to harness natural cosmetics using NaDES?



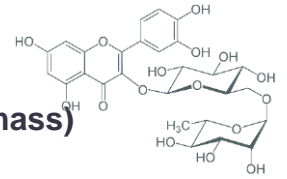
In emulsion system



**Marigold (*C. officinalis*)**

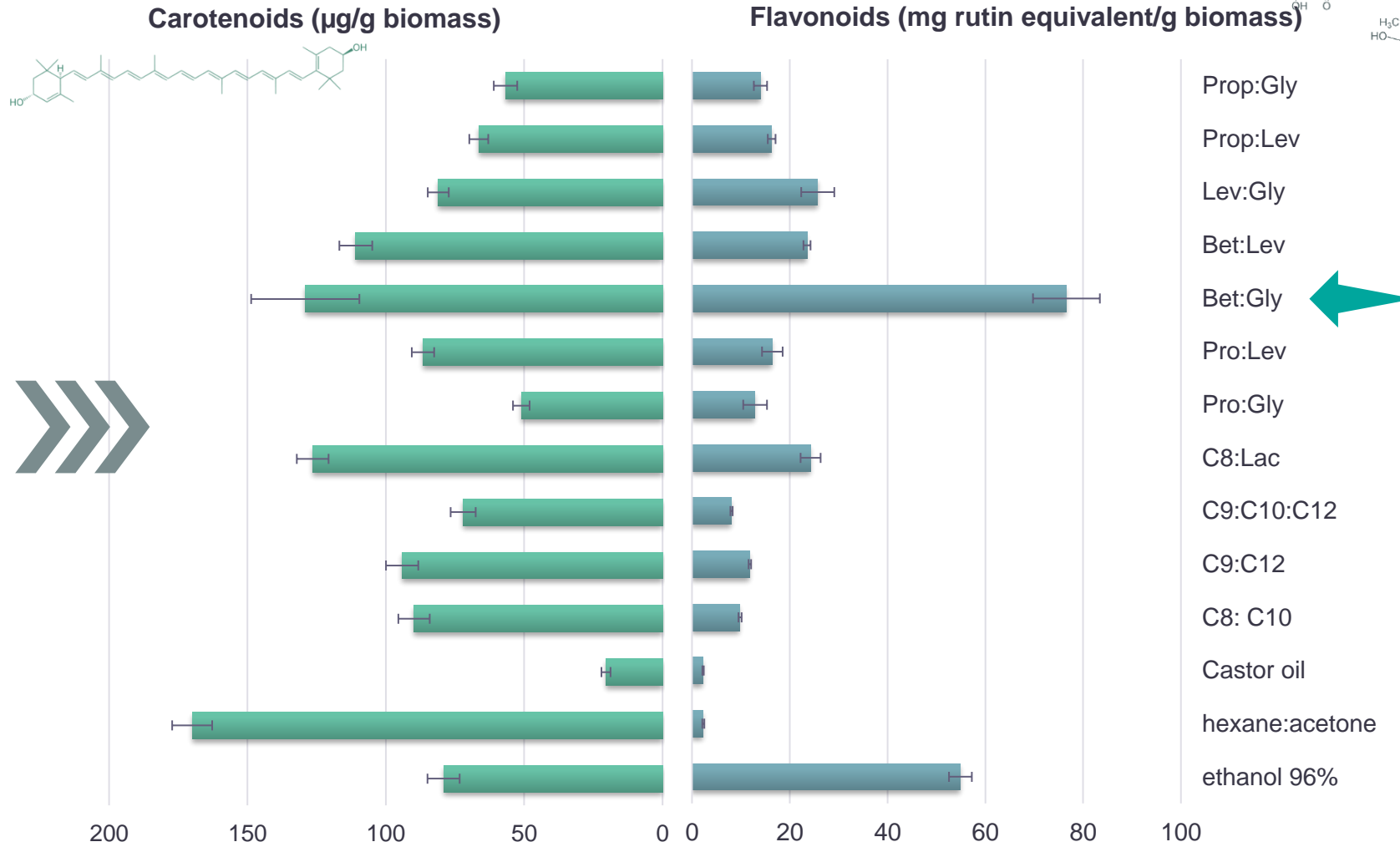
- ✓ Flavonoids
- ✓ Carotenoids

# NaDES for original phytochemical profile



NaDES library  
OK cosmetics

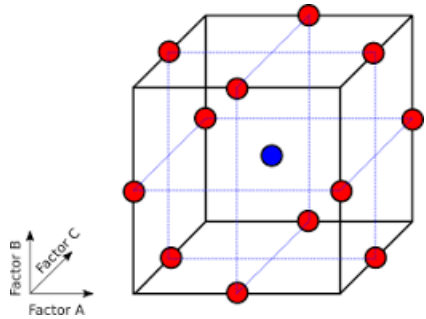
- Set of
- ✓ 46 nonpolar NaDES
  - ✓ 73 polar NaDES
  - ✓ 30 min UAE



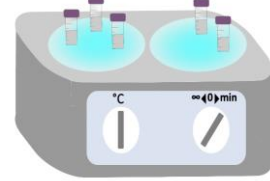
Boudesocque-Delaye, et al, *Cosmetics* 2024, 11, 17. <https://doi.org/10.3390/cosmetics11010017>

# Process screening and optimization

## Design of Experiment (DoE)

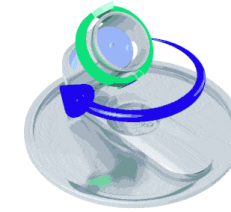


## UAE



- 👍 Mass transfer
- 👍 Easily scalable
- 👎 Rising t°C
- 👎 Attenuation

## Dual Asymmetric Centrifugation

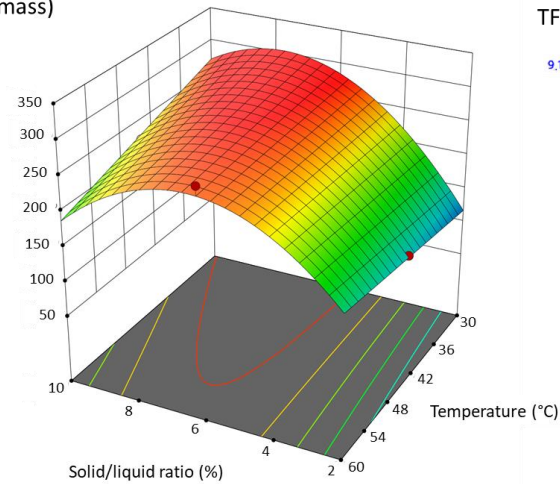


- 👍 Room t°C
- 👍 Intense mixing
- 👍 Viscous solvent
- 👎 Development

- ✓ Temperature = 30°C
- ✓ S/L ratio = 6%
- ✓ Extraction time = 15 min
- ✓ 250 µg/g carotenoids
- ✓ 26 mg/g flavonoids

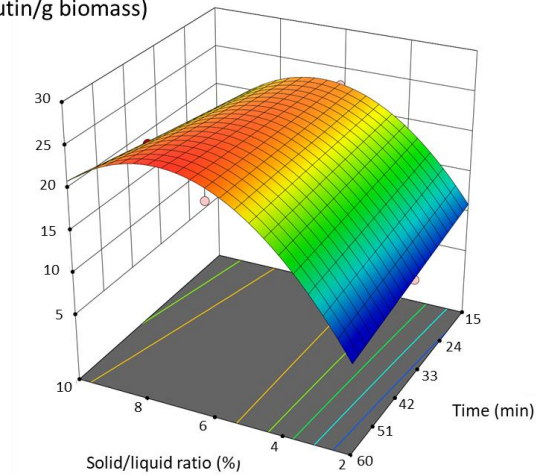
TCC (µg/g biomass)

89.9 282.5



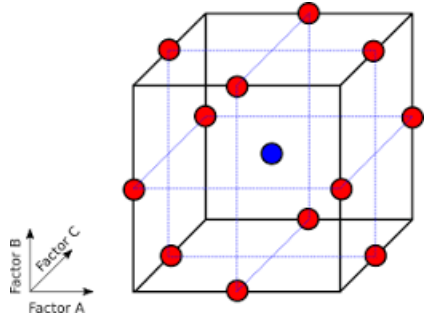
TFC (mg equiv. rutin/g biomass)

9.18474 25.1506



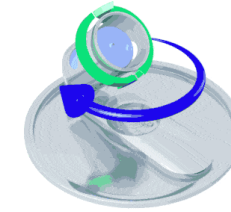
# Process screening and optimization

## Design of Experiment (DoE)



Impact of the introduction in a cream

## Dual Asymmetric Centrifugation

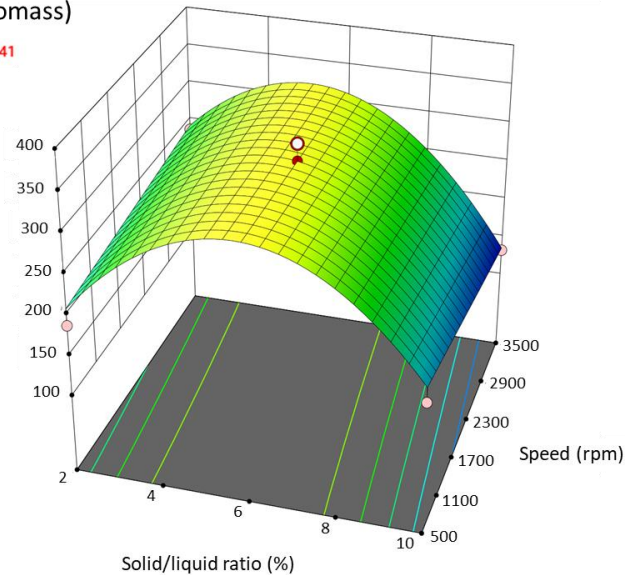


- 👍 Room t°C
- 👍 Intense mixing
- 👍 Viscous solvent
- 👎 Development

- ✓ Speed = 1500 rpm
- ✓ S/L ratio = 6%
- ✓ Extraction time = 30 min
- ✓ 385 µg/g carotenoids
- ✓ 45 mg/g flavonoids

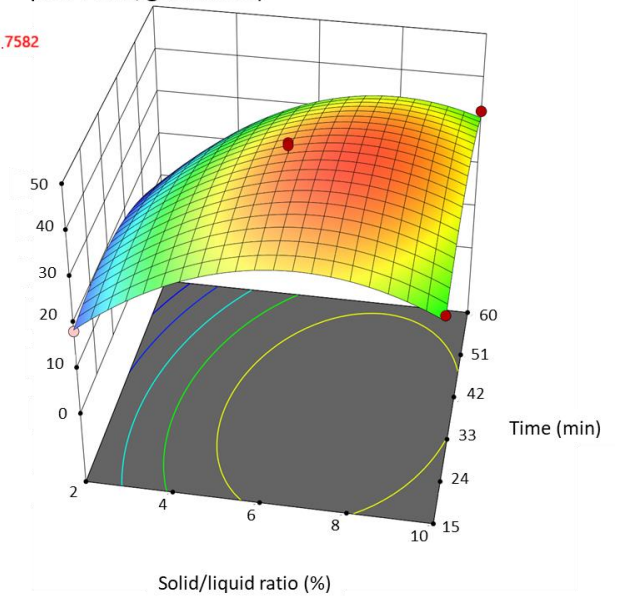
TCC (µg/g biomass)

132.142 384.741

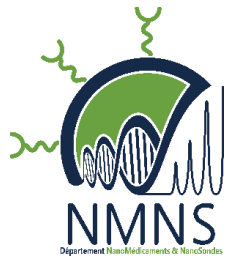


TFC (mg equiv. rutin/g biomass)

18.5775 41.7582







# Introduction of Betaine:Glycerol extract in a cream



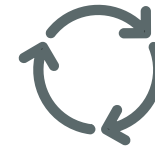
Green cream formula  
COSMOS ok

		%wt in the Analyzed Samples	
Ingredients	Function	Control	Calendula Creams
Bet:Gly extract (%wt)	Active	0	1 or 10
Xanthan gum (%wt)	Thickener	0.25	0.25
Sclerotium gum (%wt)	Thickener	0.75	0.75
Glycerol (%wt)	Humectant	10	9 or 0
Hydrogenated lecithin (%wt)	Emulsifier	3	3
Caprylic/capric triglycerides (%wt)	Emollient	25	25
Dehydroacetic acid/benzyl alcohol mix (%wt)	Antimicrobial agent	1	1
Water (%wt)	Solvent	q.s 100	

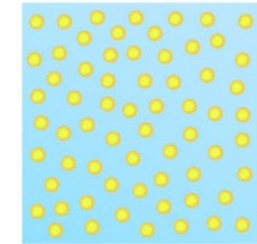
## ✓ Process

**1% or 10%wt NaDES extract  
in the aqueous phase**

Emulsification



W/O emulsion

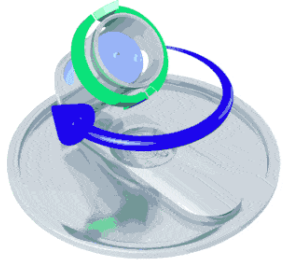


90 days-accelerated ageing  
(40°C, 75% humidity, dark)

Boudesocque-Delaye, et al, *Cosmetics* 2024, 11, 17. <https://doi.org/10.3390/cosmetics11010017>

# Impact of Betaine:Glycerol extract in our COSMOS cream

Process adaptation



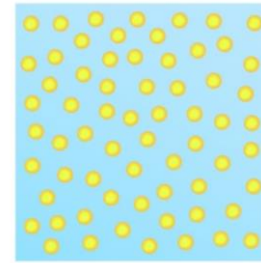
Process modified to include 10% of extract in the emulsion

More shear force required



Stability at 90 days

Droplets size



Stable  
7.3-9.2  $\mu\text{m}$



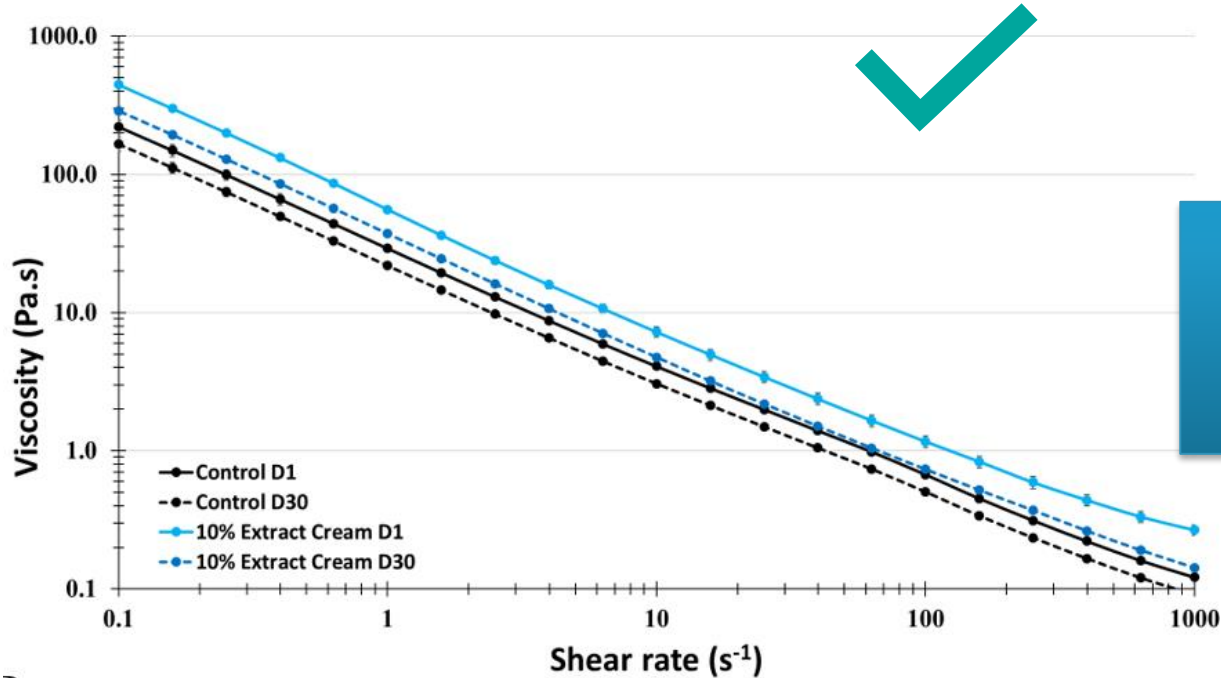
Stable  
5.0-5.8



# Impact of Betaine:Glycerol extract in our COSMOS cream



 Viscosity



Low impact on the rheological properties  
Viscosity booster ?

# Impact of Betaine:Glycerol extract in our COSMOS cream



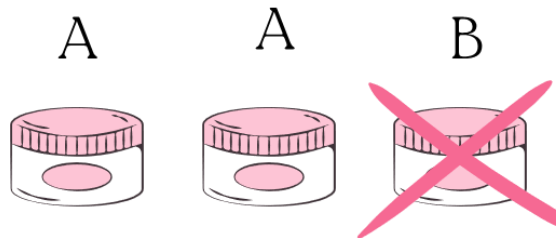
Sensory



No significant impact  
on cream texture



Naive panel



Triangle test

Could replace conventional extract  
up to 10% without perceived effect

# Impact of Betaine:Glycerol extract in our COSMOS cream



Sensory



A

A

B



No significant impact  
on cream texture



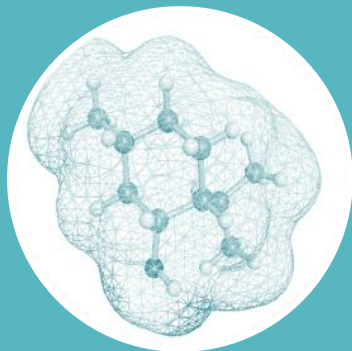
Naive panel

- ✓ Original full antioxidant spectra ingredient
- ✓ Innovative extraction process designed
- ✓ Ready to use ingredient for creams
  - ✓ NaDES = viscosity booster
  - ✓ Improved consumer experience

Original extract  
up to 10% without perceived effect



# NaDES driving innovation in cosmetic ingredients



## Smart strategy

- A priori selection
- Custom made
- Prediction tools
  
- Go/No go



## Innovative profile

- Tunable selectivity
- Wide range of polarity
  
- Stabilizing ability



## Process innovation

- Mandatory
- User-friendly
- Guidelines
  
- New technologies



## Product innovation

- Sensory +
- Ready-to-use
- Active ingredients
- Functional ?



# NaDES: more than just solvents?



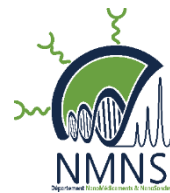
1) Strategies of formulation/process

3) Sensoriality

2) Safety, efficacy

4) Predictive tool

**NaDES and emulsion-based products**

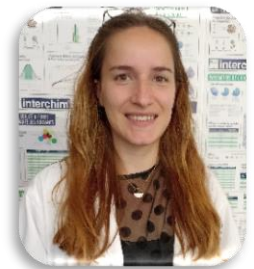




Dr L Wils



Dr S Hilali



Dr L van Gheluwe



Dr B Clément Larosière



A Chevalley



Dr E Thiery



I Thery



M Yagmur



S Odou



A Desprès



L Divoux



IM Ardeza

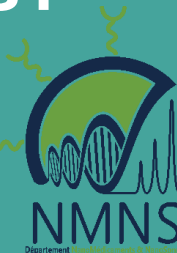
Any questions?



Dr J Jacquemin



Dr B Montigny



Pr E Munnier



Dr A Verger



Dr H Kichou