

The problem



Biopolymers

- The development of new bio-based plastics is of growing priority mainly due to health and environmental concerns derived by the petroleum-based plastics
- Among several types of natural polymers, protein-based films have emerged as potential bio-based plastics for producing biodegradable films and coatings.
- Edible films applied onto the surface of food in order to extend their self-life.



Milk proteins

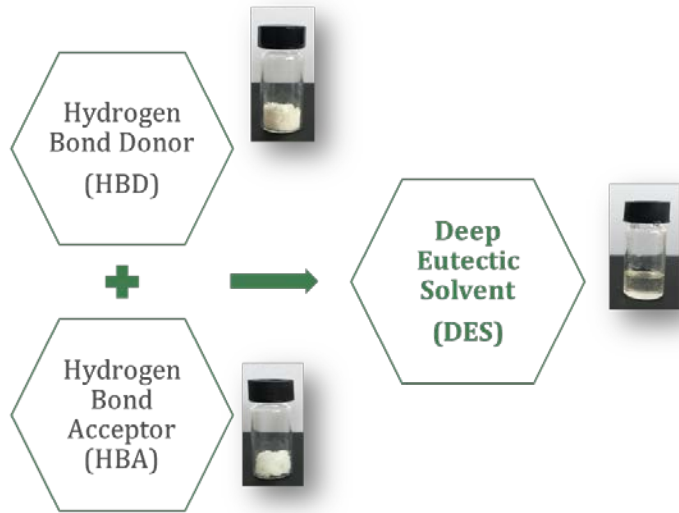
- Several protein types can be obtained from milk: casein (80%) and whey proteins (20%) such as whey protein concentrate (WPC), isolate (WPI).
- Whey is a by-product from the cheese industry and is mainly considered to be a waste product.
- Whey proteins have been used as valuable food ingredients with high nutritional content and also as gelling, emulsifier and foam agents



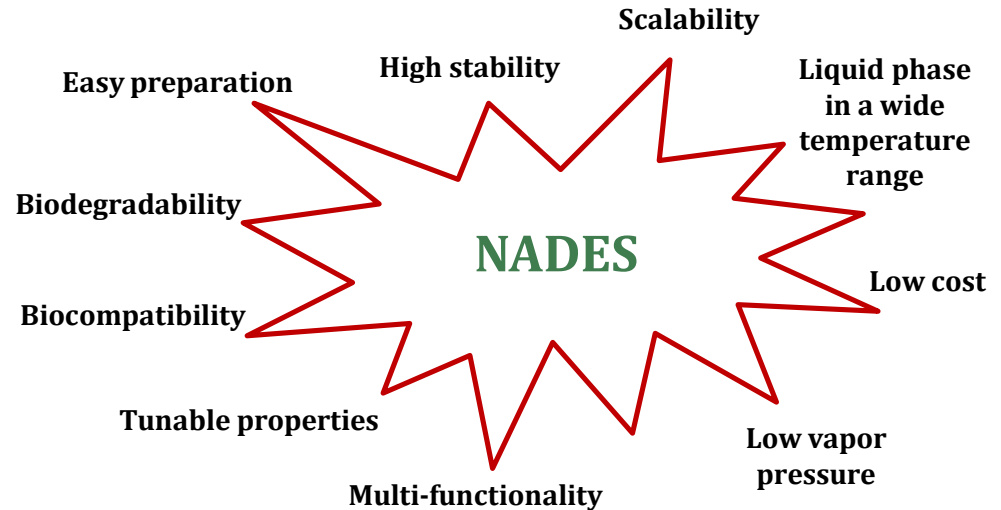
Novelty

- Use of industrial by-products, as starting material for film production considering them as valuable resources for the development on novel materials rather than wastes
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- Design of novel protein biopolymers using green solvents as well as their extracts in order to improve their properties

Natural Deep Eutectic Solvents (NADES)



Green Solvents of 21st century

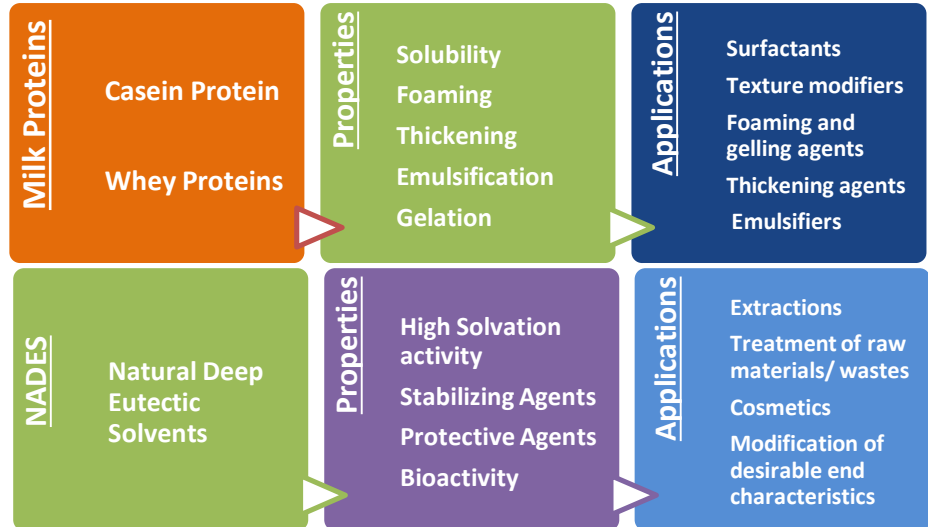


Aim

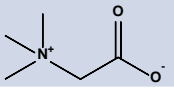
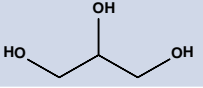
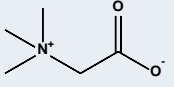
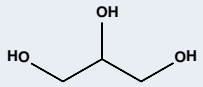

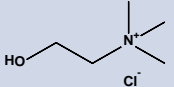
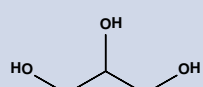
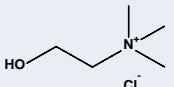
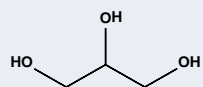

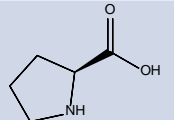
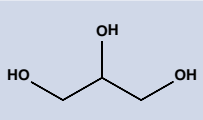
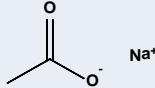
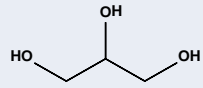
3. Development of edible films for coating applications

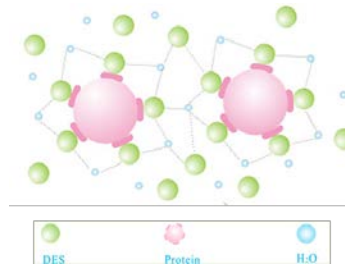
2. NADES in the protein films formation process

1. Targeted design and synthesis of Natural Deep Eutectic Solvents (NADES)



1. Targeted design and synthesis of Natural NADES

NADES	Compound 1	Compound 2	Compound 3	Molar ratio
Bet-Gly			-	1:2
Bet-Gly-W				1:2:1
ChCl-Gly			-	1:2
ChCl-Gly-W				1:2:1
Pro-Gly			-	1:2
NaOAc-Gly			-	1:9



Wang *et al.*

<https://doi.org/10.1016/j.talanta.2016.01.042>

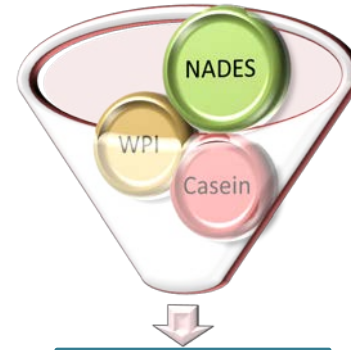
- ✓ Plasticizing effect (replacement of conventionally used additives)
- ✓ Alteration of properties (e.g. elasticity, water vapor permeability)
- ✓ Zero waste process
- ✓ Added-value protein films

2i. NADES in the protein films formation process

3. Development of edible films for coating applications

2. NADES in the protein films formation process

1. Targeted design and synthesis of Natural Deep Eutectic Solvents (NADES)



Novel products

- Edible films
- Bioplastics for packaging and coatings



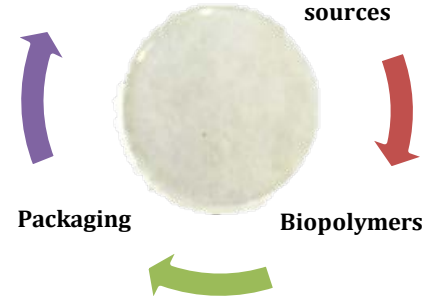
Whey Protein Isolate

Biodegradation

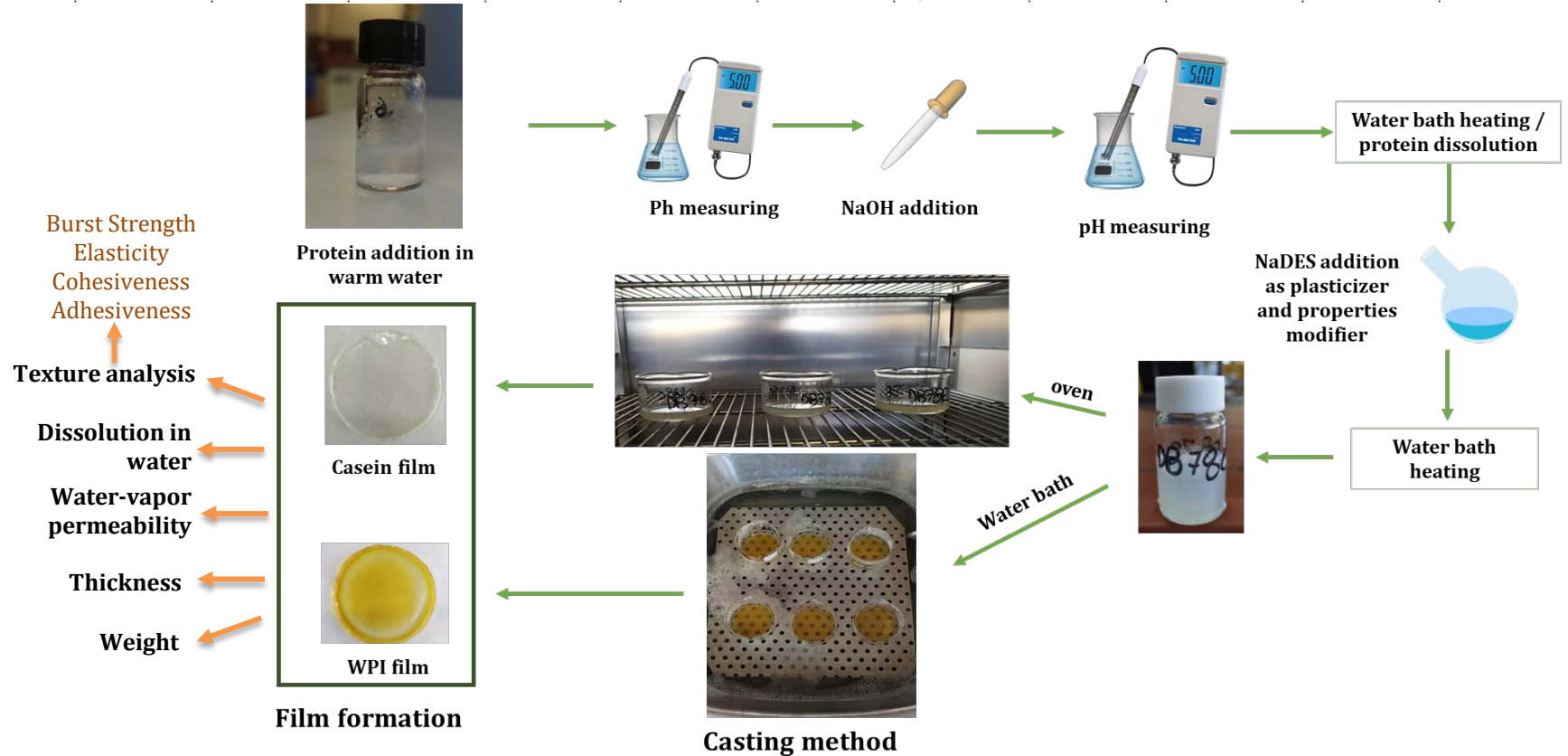
Proteins from various sources

Packaging

Biopolymers



2ii. NADES in the protein films formation process



Casein-based films using NADES as plasticizers

Various Casein/ plasticizer ratio (w/w) were tested in all cases: 3:1, 2:1, 1:1, 1:2.

Bet/Gly 1:2

Casein / plasticizer ratio (w/w)	Result
2:1	✓ 
1:1	✓ 
2:1	✓ 
1:1	✓ 






Bet/Gly/W 1:2:1

ChCl/Gly 1:2

ChCl/Gly /W 1:2:1

L-Pro/Gly 1:2

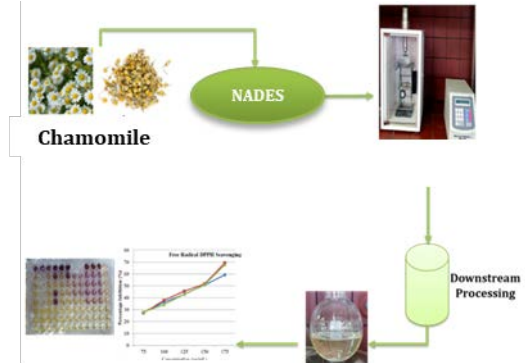
S.A/Gly 1:9

Casein / plasticizer ratio (w/w)	Result
2:1 ✓ 	
2:1 ✓ 	
1:1 ✓ 	
1:2 ✓ 	
1:1 ✓ 	

Casein/ plasticizer ratio (w/w) Result



Chamomile Extract
Bet/Gly/W (1:2:1)



1:1






Casein-based films using physical mixtures as plasticizers

Various Casein/ plasticizer ratio (w/w) were tested in all cases: 3:1, 2:1, 1:1, 1:2.

Casein / physical mixtures ratio (w/w)	Result
Physical mixture Betaine - Glycerol (1:2)	
1:1	✓ 
Physical mixture Betaine - Glycerol - Water (1:2:1)	
1:1	✓ 

Casein / physical mixtures ratio (w/w)	Result
Physical mixture L-Proline - Glycerol (1:2)	
1:1	✓ 
Physical mixture Betaine - Glycerol - Water (1:2:1)	
1:1	✓ 


Casein/ Glycerol ratio (w/w)	Result
2:1	✗ 
1:1	✗ 
1:2	✗ 

Glycerol (Reference)

WPI-based films

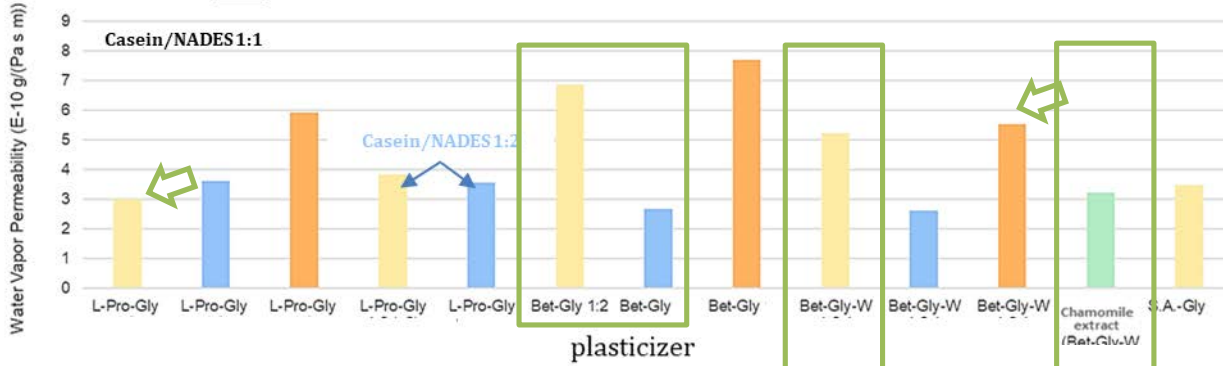
Various WPI/ plasticizer ratio (w/w) were tested in all cases: **1.4:1, 1.3:1, 1:1, 1:1.5, 1:2.**

WPI / plasticizer ratio (w/w)		Result
Bet/Gly (1:2)		
1:1	✓	
Bet/Gly/W (1:2:1)		
1:1	✓	
Pro/Gly (1:1)		
1:1	✓	

WPI / Glycerol ratio (w/w)		Result
<u>Glycerol (Reference)</u>		
1:1	✗	

Films Characterization (i)

Films: Casein - DES | Casein-natural mixture | Casein - extract | WPI - DES



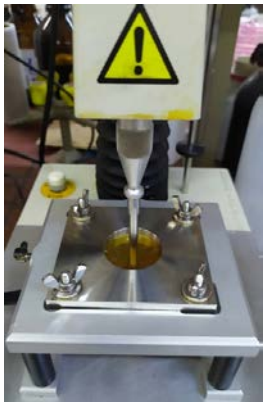
Water Vapor Permeability ↓

Casein:

L-Pro-Gly (1:2) in casein/NADES ratio=1:1
Extract -> lower WPI than only NADES as plasticizer

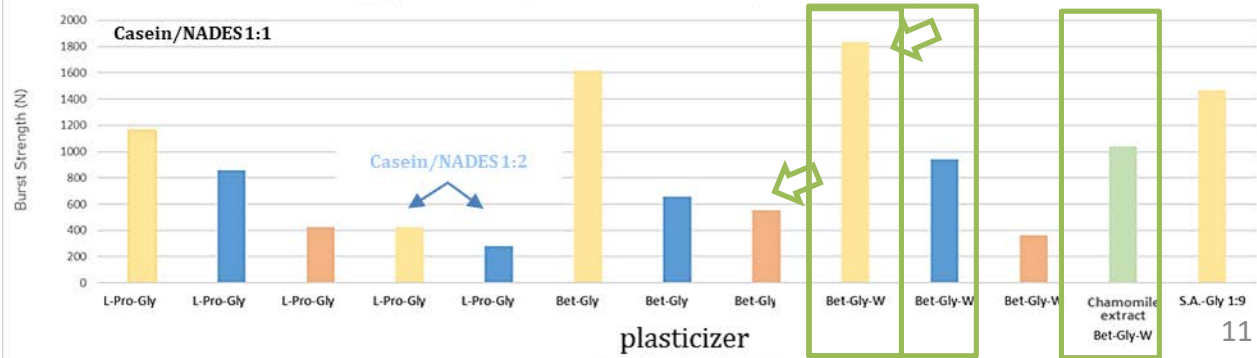
WPI:

Bet-Gly-W (1:2:1) in casein/NADES ratio=1:1



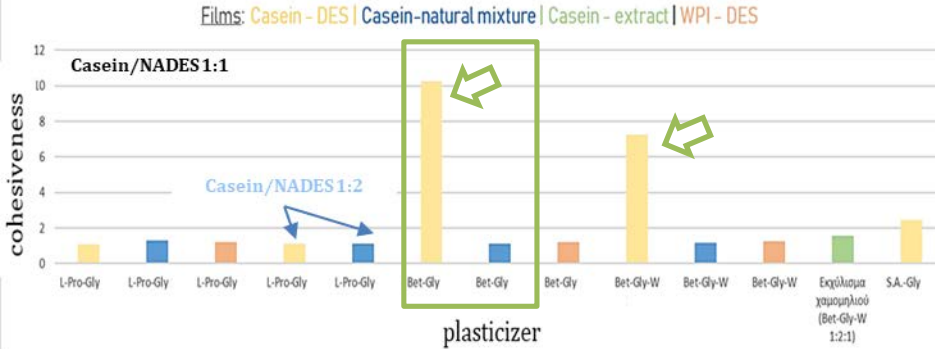
Burst Strength

Films: Casein - DES | Casein-natural mixture | Casein - extract | WPI - DES

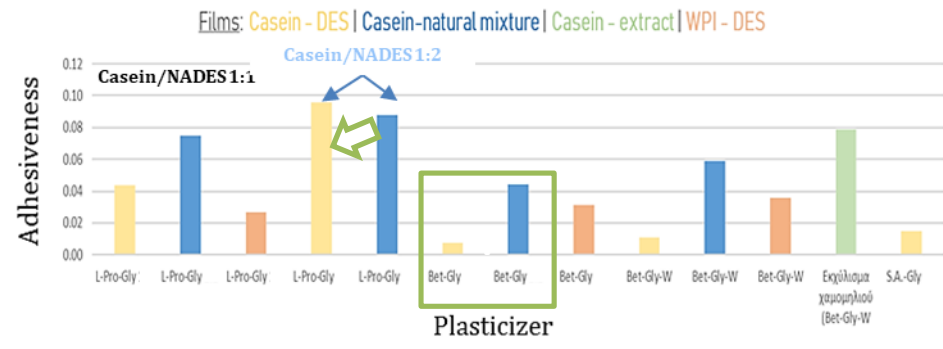


Films Characterization (ii)

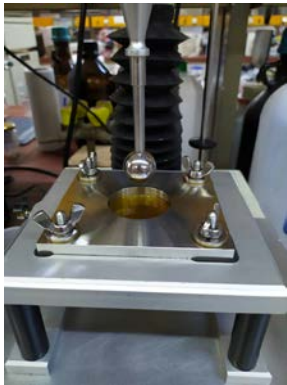
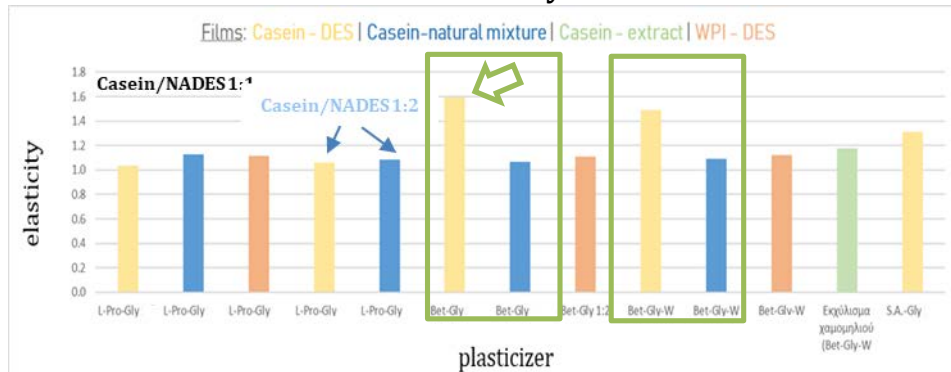
Cohesiveness



Adhesiveness



Elasticity



Films Characterization (ii)

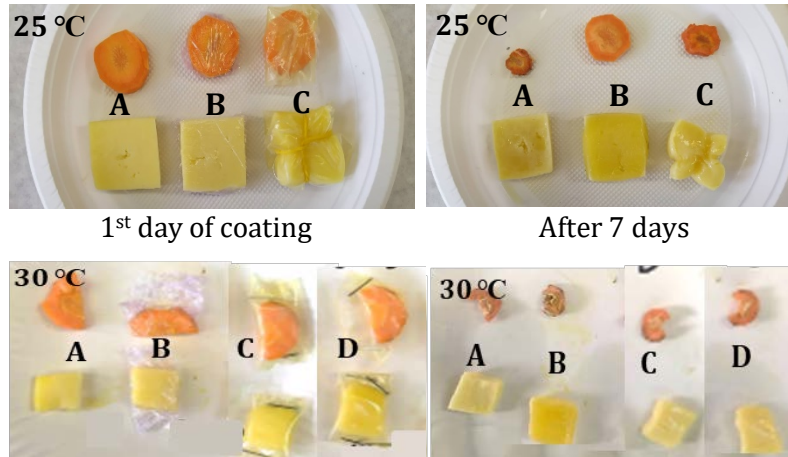
Preliminary Results

Coating	Carrot				Cheese			
	Without (A)	Commercial Membrane (B)	Casein/NADES film (C)	Casein/NADES-chamomile extract film (D)	Without (A)	Commercial Membrane (B)	Casein/NADES film (C)	Casein/NADES-chamomile extract film (D)
Weight Loss (%) at 25 °C	88.264	48.694	54.827	-	30.258	14.021	32.919	-
Weight Loss (%) at 30 °C	81.3891	83.5337	80.5424	78.4315	37.1602	27.4148	40.3214	38.6400

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Ongoing study...

- ✓ WPI-based films as coatings
- ✓ Alteration on the coating procedure
- ✓ Bioactivity measurements on the protein films



Development of added-value products from the dairy industry wastes: Utilization of whey cheese using biocompatible green solvents



Consulting support from the company
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Thank you for your attention

? Questions ?