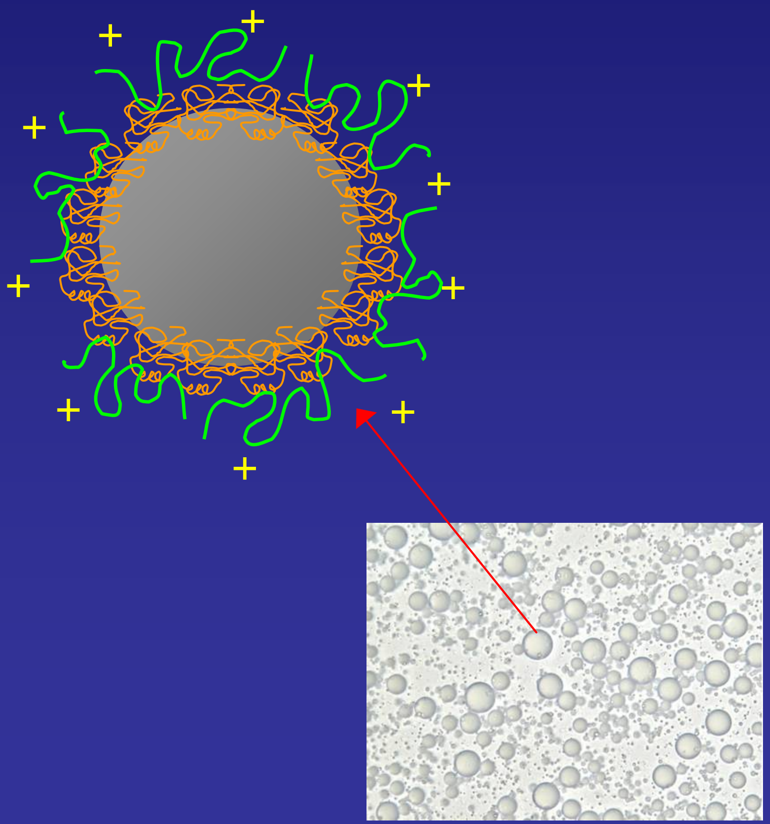
Utilization of Interfacial Engineering to Improve Food Emulsion Properties



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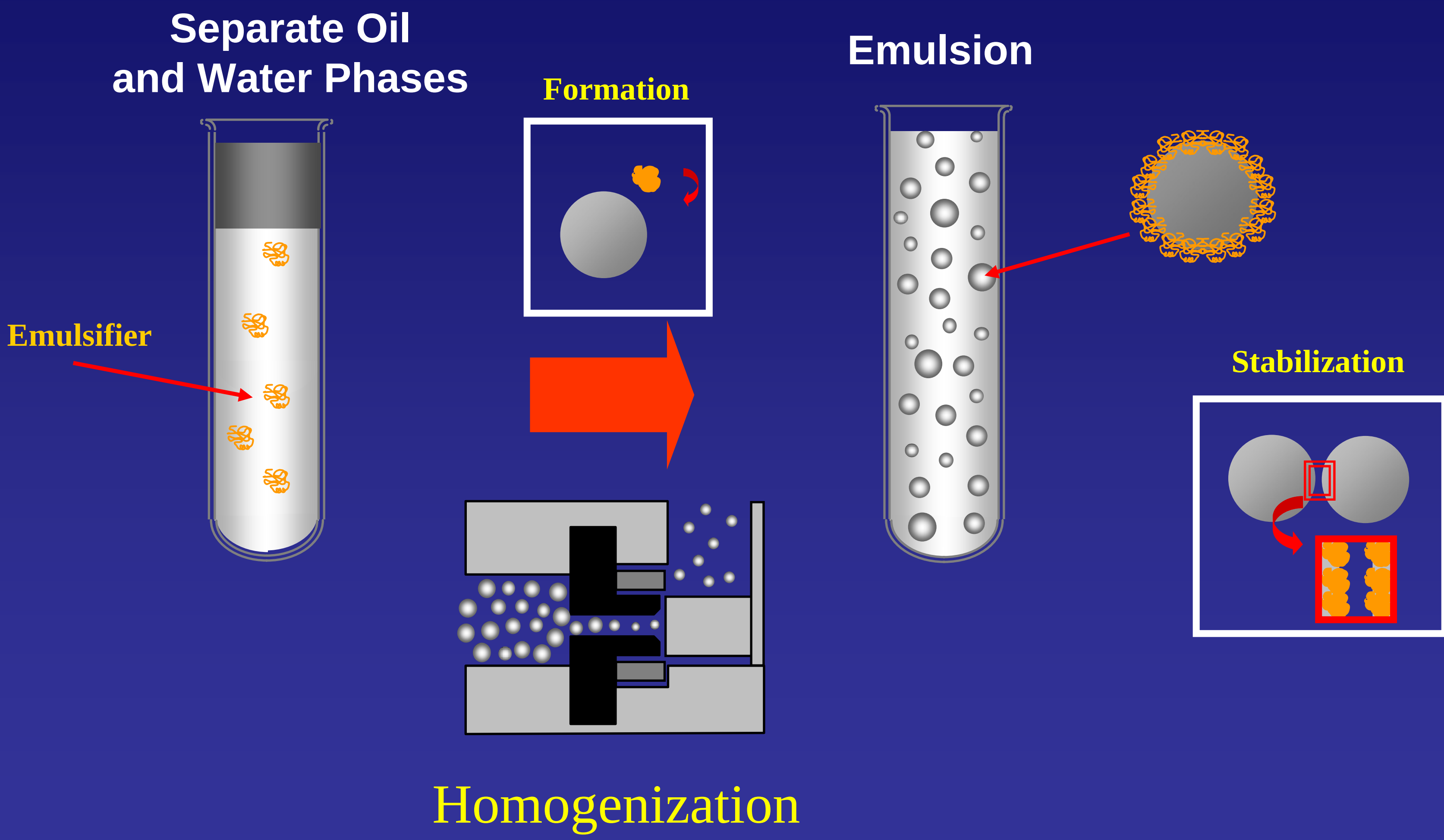
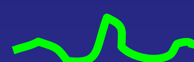
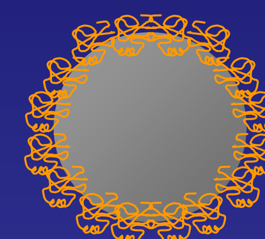
Traditional (Single-Step) Method of Emulsion Formation



Limitations of Single-Step Method

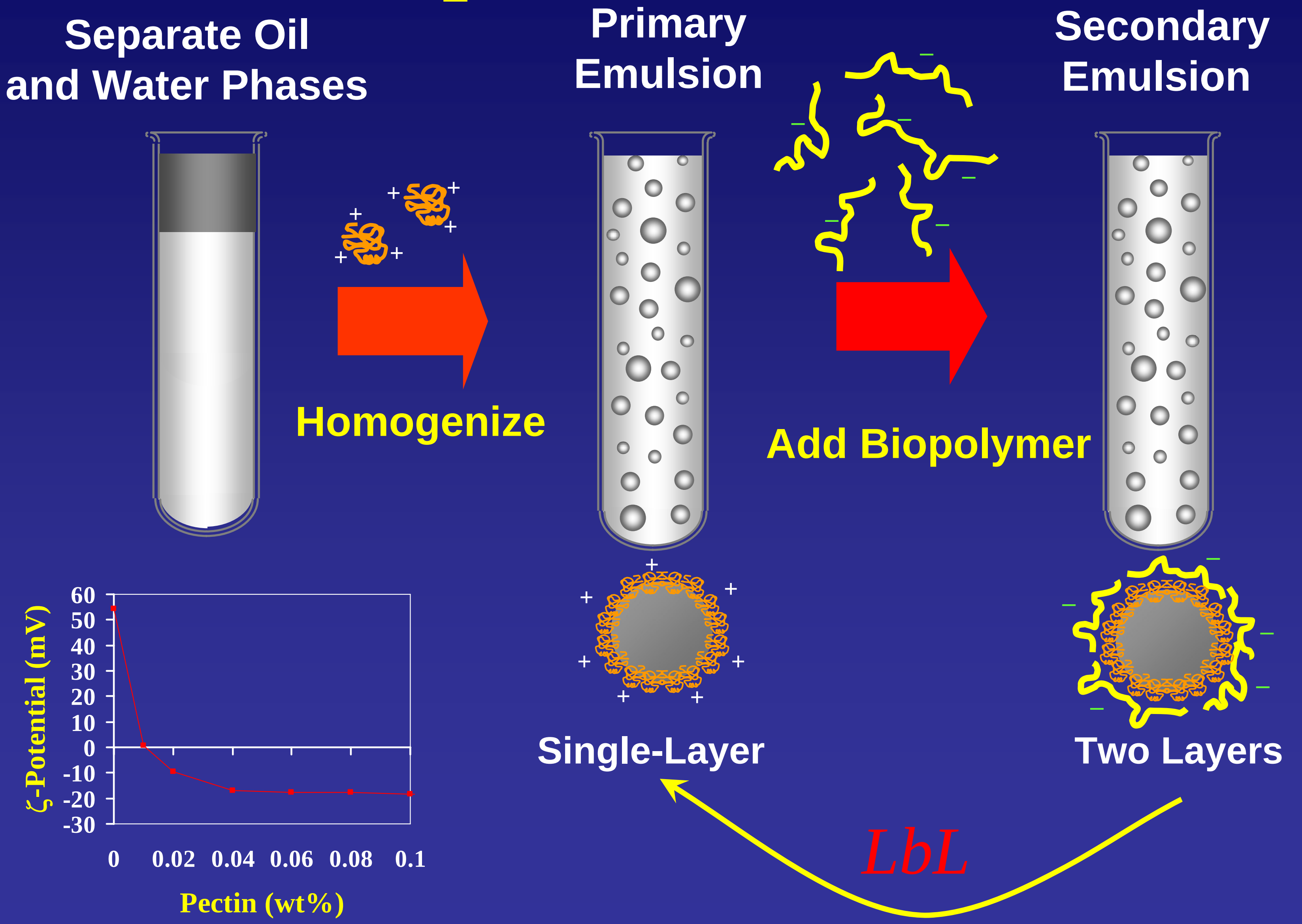
- Some emulsifiers are efficient at forming small droplets during homogenization, but not at providing good stability. 
- Some emulsifiers provide good stability, but are inefficient at forming small droplets during homogenization. 



- Existing emulsifiers provide limited scope for developing encapsulation & delivery systems.

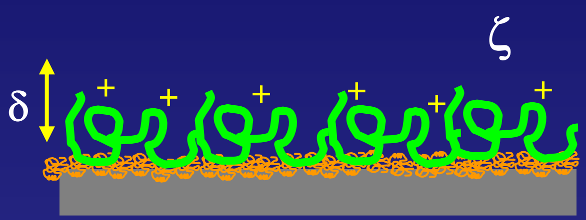
Hypothesis: Can we develop a new emulsifier strategy that combines the fast adsorption of small molecules and the good stability of large polymers to create emulsions with improved performance and functionality?

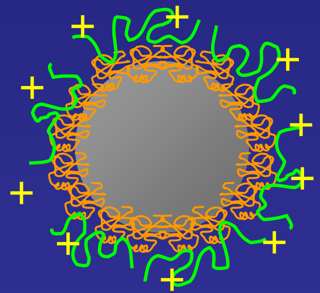
Multi-Step Emulsion Formation



Control of Interfacial Characteristics

- Control of Interfacial Properties
  - Charge Sign and Density
  - Thickness
  - Packing & Permeability
  - Rheology
  - Responsiveness



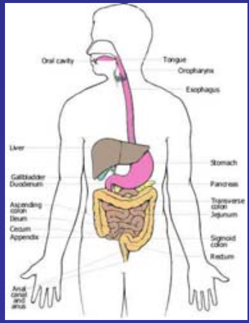


- Control of Emulsion Properties
  - Stability, Rheology, Release

Potential Advantages of Multilayer Emulsions

- **Improvement in Stability of Emulsions to Environmental Stresses**
  - – pH, Ionic Strength
  - – Heating, Chilling, Freezing
  - – Dehydration

- **Encapsulation and Delivery of Functional Components**
  - – Protection of Labile Ingredients
  - – Controlled or Triggered Release



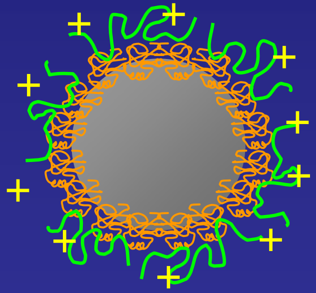
Potential Disadvantages of Multilayer Emulsions

- **More Difficult to Prepare**
  - Prone to flocculation

1º

- **More Expensive to Prepare**
  - Additional ingredients required
  - Additional processing required

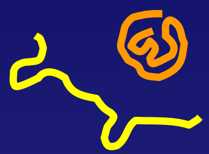
2º



Problem: Research is needed to establish optimum preparation conditions (ingredients and processes) for preparation of multilayer emulsions with specific performance and functionality.

Overall Project Objectives

Optimization & Application of Multilayer Technology



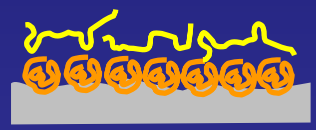
Food Ingredients
(Emulsifier, Biopolymers)

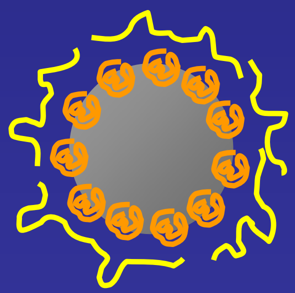
Preparation Conditions
(pH, I, T, Mixing)

Objective 1:
Prevent Flocculation

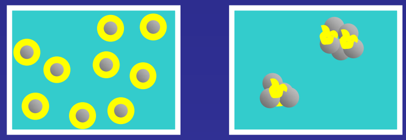
Objective 2:
Control Interface

Interfacial Properties
(Charge, Thickness, Response)





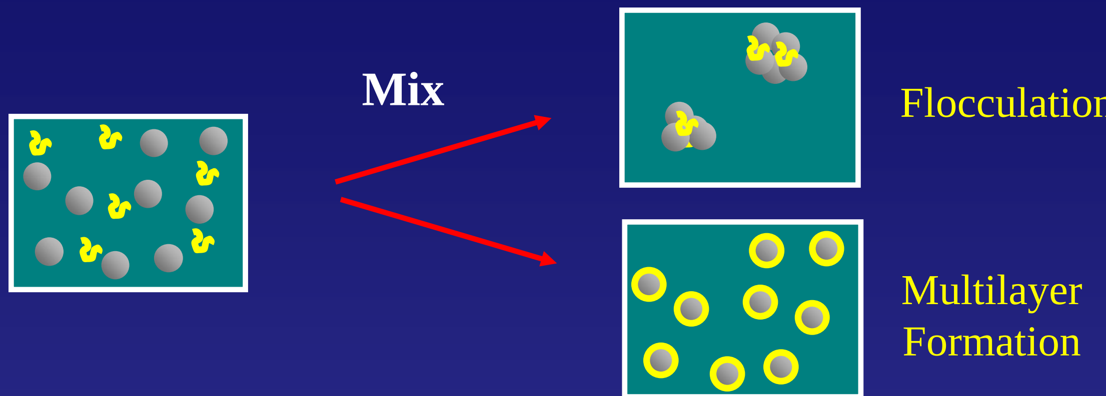
Emulsion Properties
(Stability, Rheology, Release)



Application
(New Food Products or Ingredients)

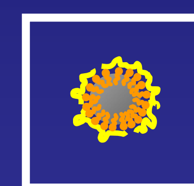
Objective 3:
Create New or Improved Functionalities

Understanding Formation of Multilayer Emulsions: Theoretical Model



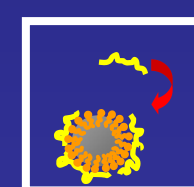
C_{SAT} = Characteristic Saturation Concentration

- The minimum amount of polymer required to completely cover all of the droplet surfaces.



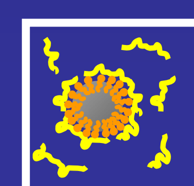
C_{ADS} = Characteristic Adsorption Concentration

- The minimum polymer concentration required to ensure adsorption occurs faster than collisions.



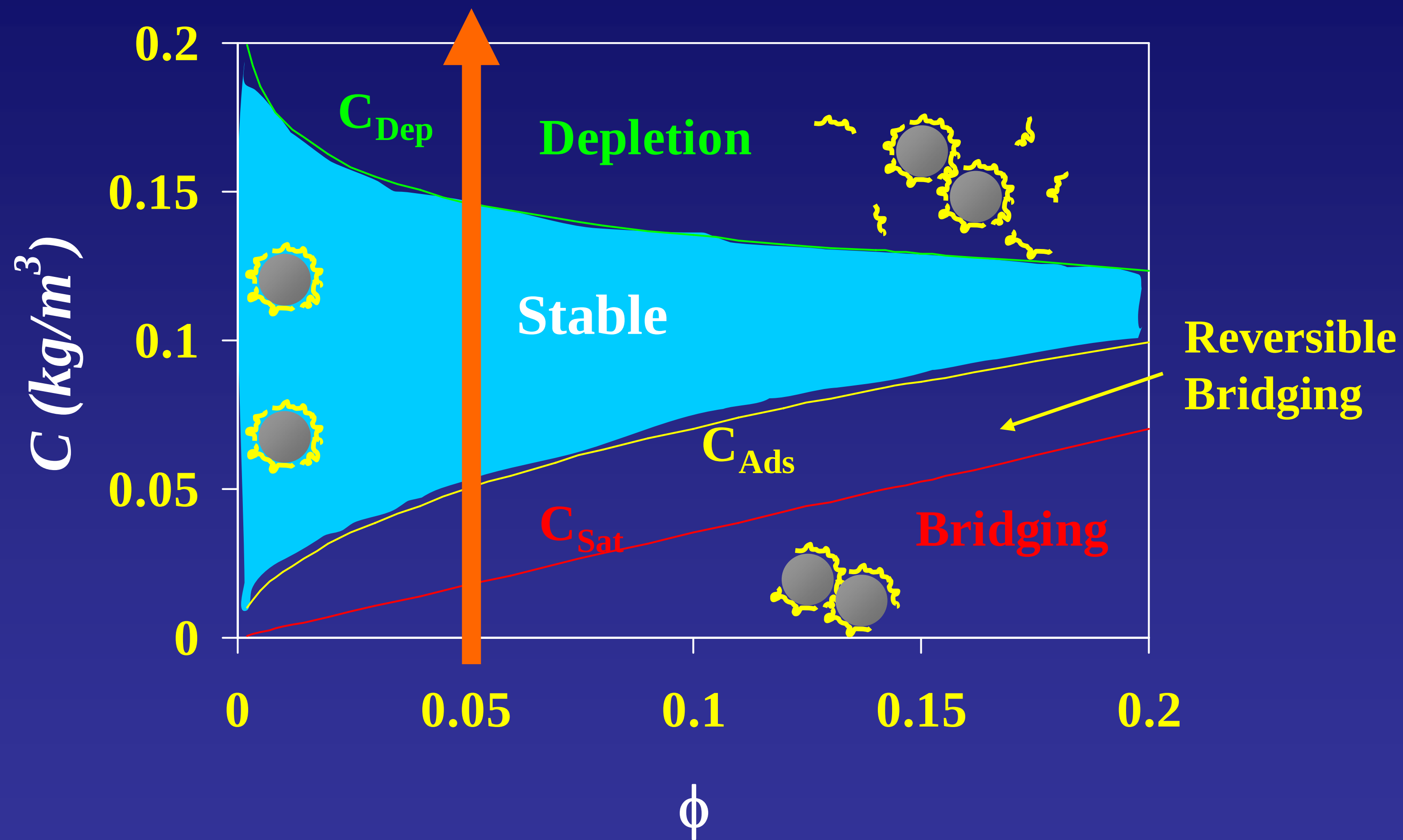
C_{DEP} = Characteristic Depletion Concentration

- The polymer concentration where depletion flocculation is first observed.



Theoretical Stability Map

Effect of Droplet & Polymer Concentration

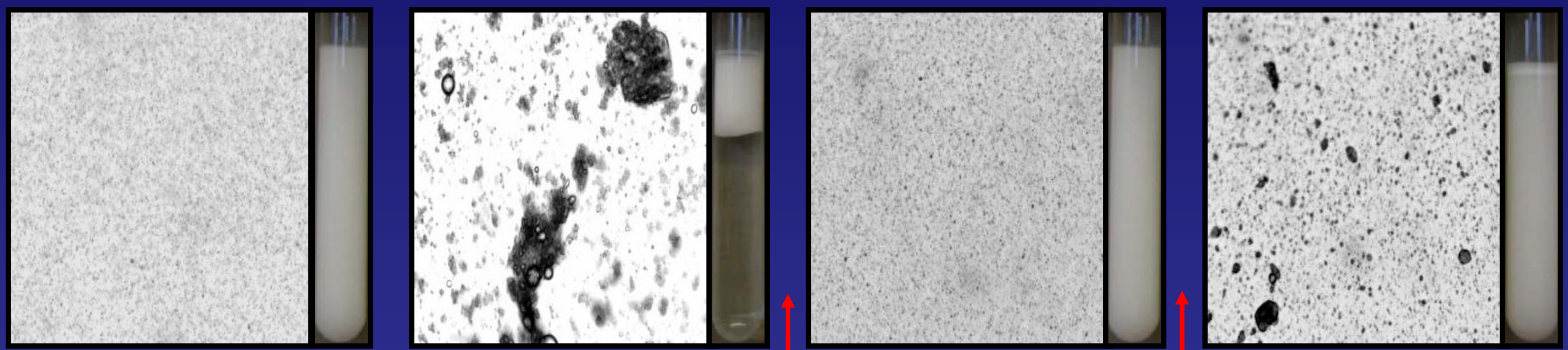


For stable system: $C_{Ads} < C < C_{Dep}$

Multilayer Emulsion Formation:

Bridging & Depletion (pH 3.5)

Pectin Concentration →

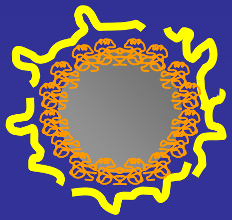


0% | 0.01 wt% | 0.04 wt% | 0.5 wt%

Bridging Flocculation | c_{Sat} | **Multilayer Droplets** | c_{Dep} | **Depletion Flocculation**

Coating Properties:

- Surface load (Γ)
- Thickness (δ)
- Permeability
- Responsiveness



Droplet Concentration: 1 wt%

Multilayer Emulsion Formation:

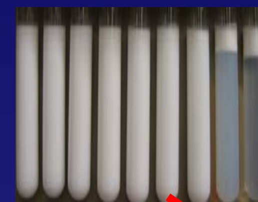
Establishment of "Creaming Stability" Map

pH 3.5

pH < pI		Droplet Concentration (wt %)					
		0.5	1	3	5	8	10
Pectin (wt %)	0	S	S	S	S	S	S
	0.01	S	C	C	C	S	S
	0.02	S	S	C	C	S	S
	0.04	S	S	C	C	C	S
	0.06	S	S	S	C	C	C
	0.08	S	S	S	C	C	C
	0.10	S	S	S	C	C	C
	0.30	S	S	S	S	S	S
	0.50	C	C	S	S	S	S

Bridging

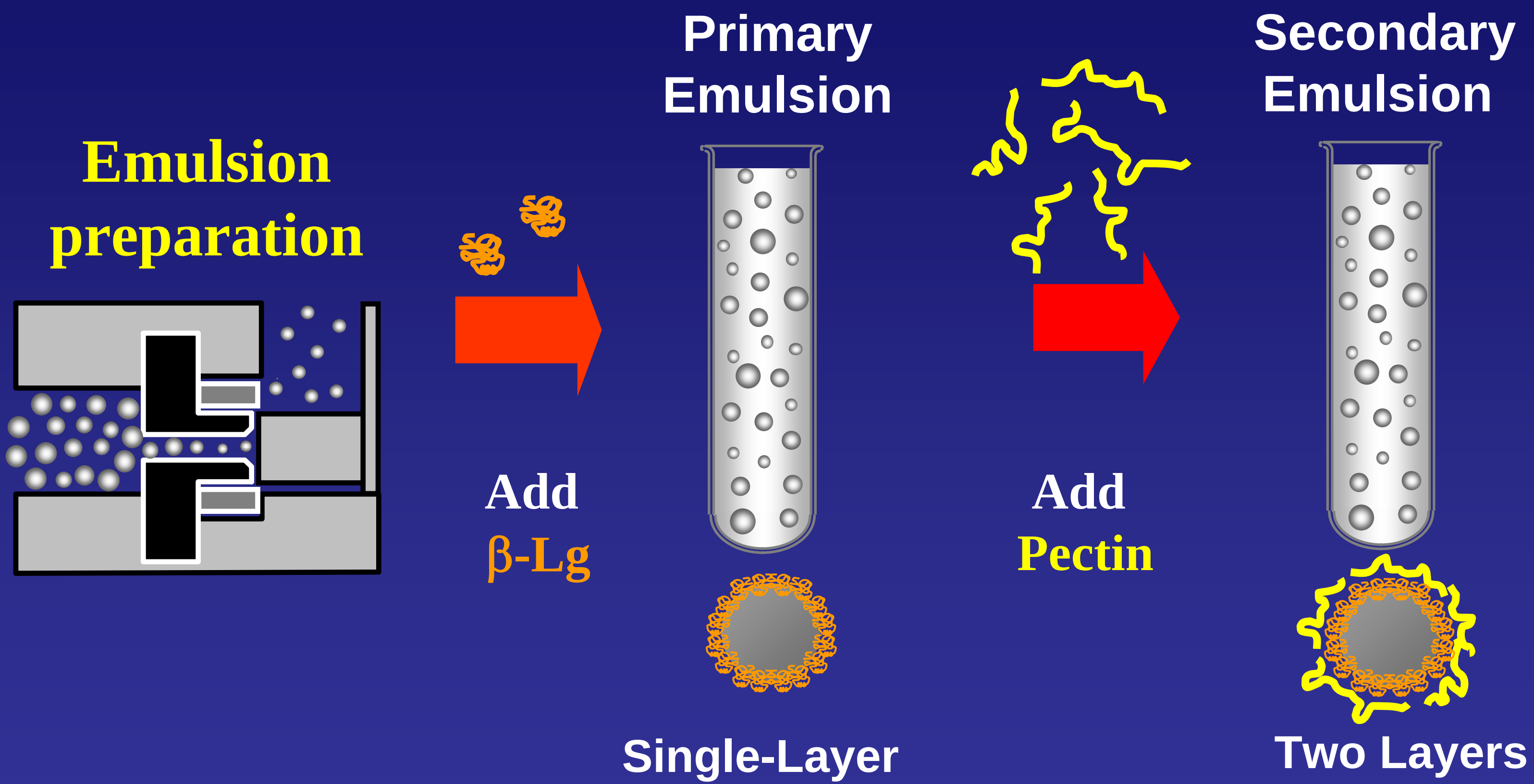
Depletion



pH 7.0

pH > pI		Droplet Concentration (wt %)					
		0.5	1	3	5	8	10
Pectin (wt %)	0	S	S	S	S	S	S
	0.01	S	S	S	S	S	S
	0.02	S	S	S	S	S	S
	0.04	S	S	S	S	S	S
	0.06	S	S	S	S	S	S
	0.08	S	S	S	S	S	S
	0.10	C	C	C	C	C	C
	0.30	C	C	C	C	C	C
	0.50	C	C	C	C	C	C

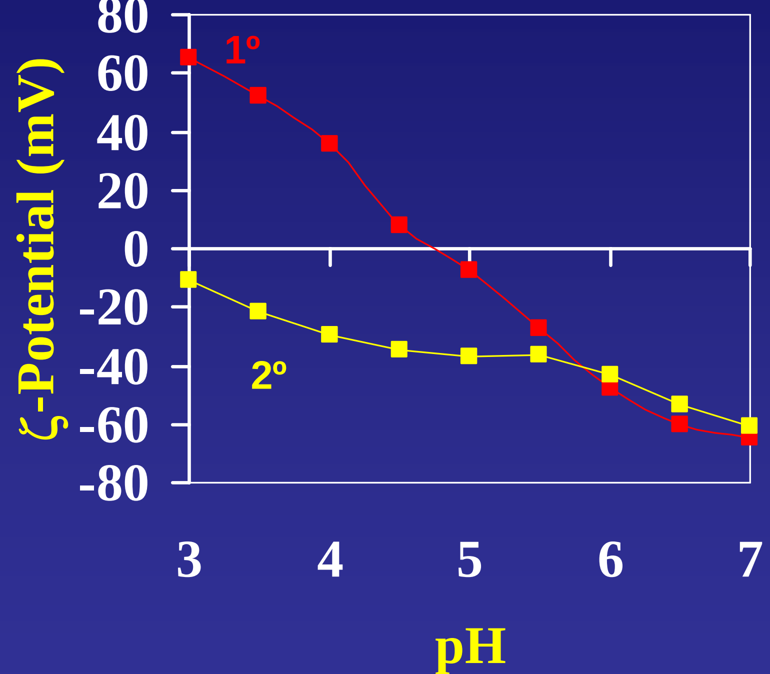
Understanding Formation of Multilayer Emulsions: Experiments

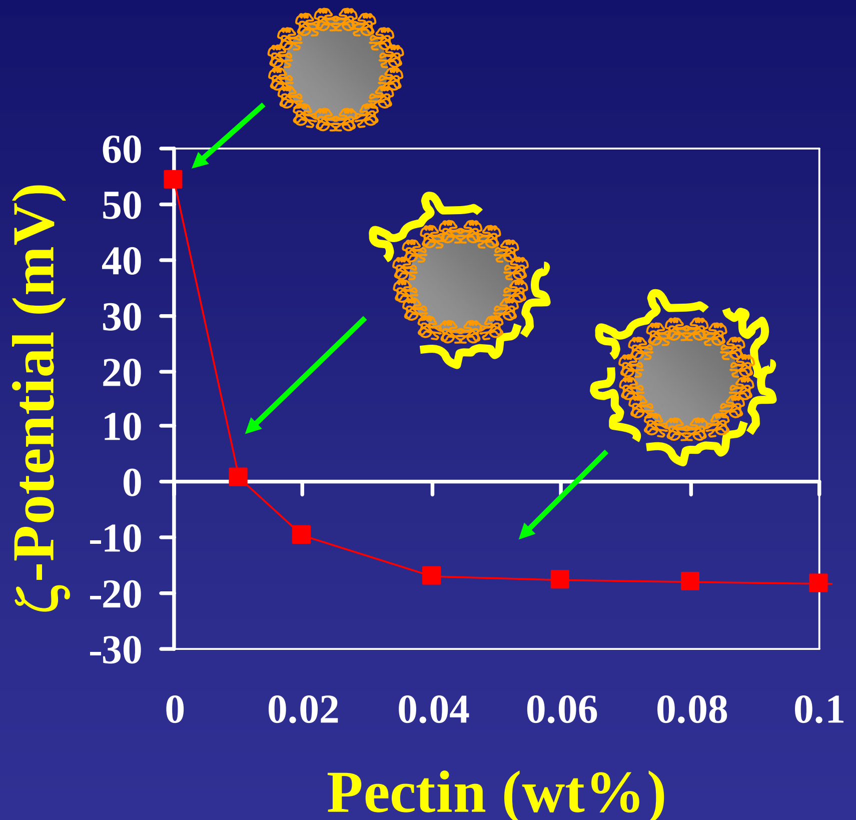


Measure:

- **Adsorption (ζ-potential); Microstructure (Microscopy); Stability (Laser Diffraction, Creaming); Rheology (Shear rheometry)**

Multilayer Emulsion Formation:
Establishment of Adsorption Range



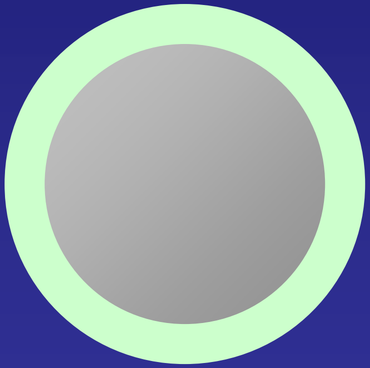


ζ-Potential Measurements Show Where Adsorption Occurs

Interfacial Characteristics:
Determination of Interfacial Properties

ζ-Potential
Dynamic Light Scattering

Interfacial Properties:
- Polymer Concentration
- Thickness
- Packing
- Charge



Protein-Pectin Multilayers: Γ_{Sat} = 1.6 mg m^{-2}; δ = 45 nm; ϕ = 2%

Application of Technology:
Improving Emulsion Stability

Motivation

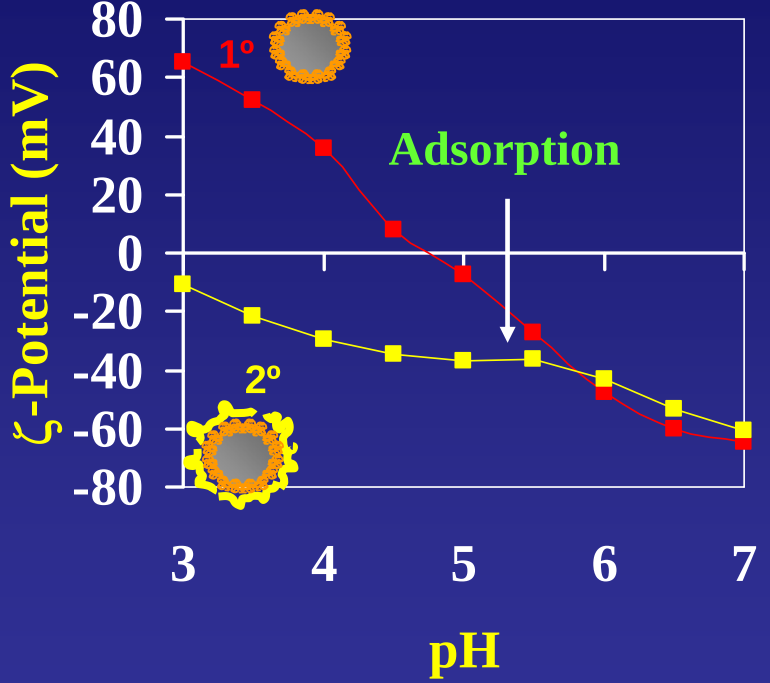
- Multilayer technology could be used to improve the stability of many food emulsions to environmental stresses

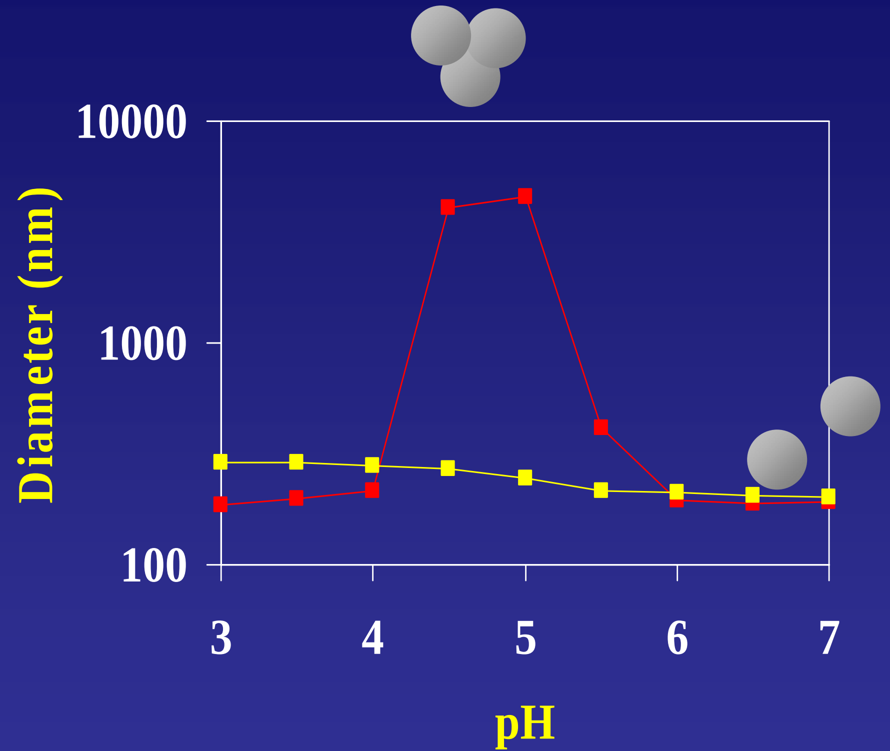
Environmental Stresses

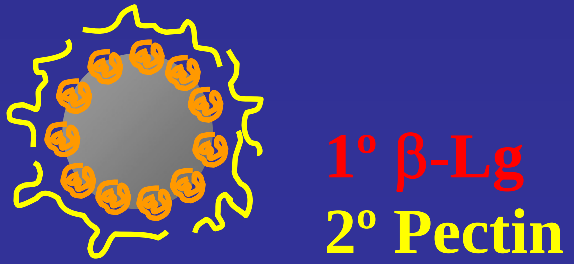
- pH, Ionic Strength
- Thermal processing, Chilling, Freezing
- Dehydration

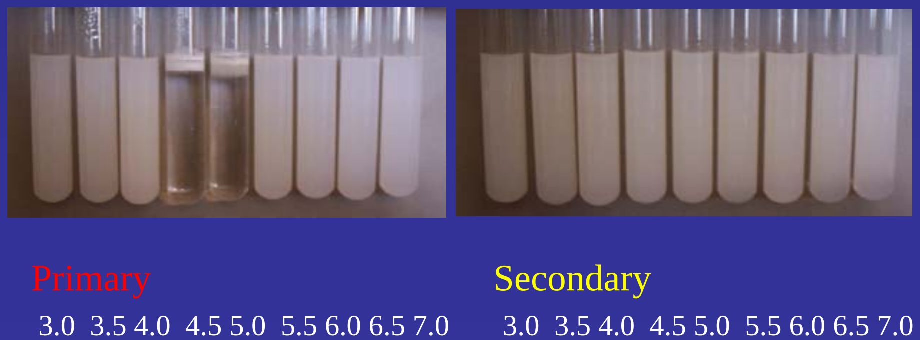
Multilayer Emulsion Properties:

Extension of pH Range

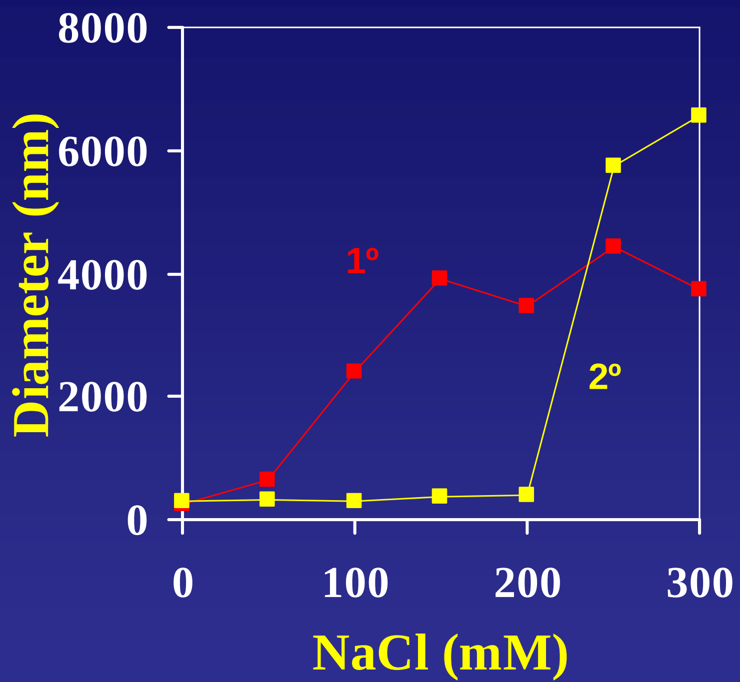


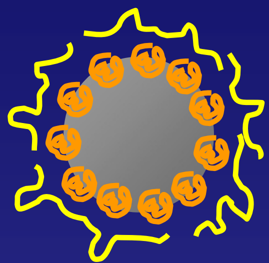






Multilayer Emulsion Properties:
Extension of NaCl Stability Range



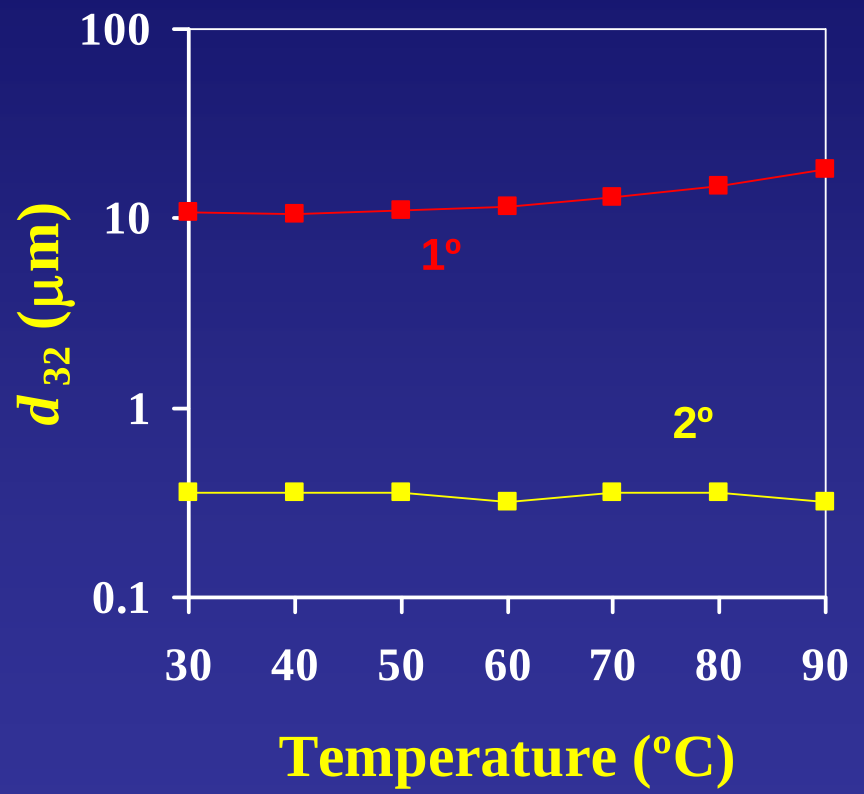


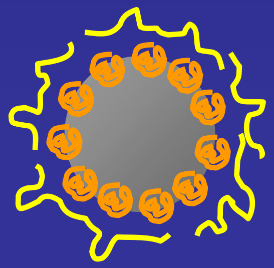
1º β-Lg
2º Pectin

Origin of Stability:
- Reduction in VDW
- Increase in ES
- Increase in Steric

pH 3.5

Multilayer Emulsion Properties:
Improvement of Thermal Stability



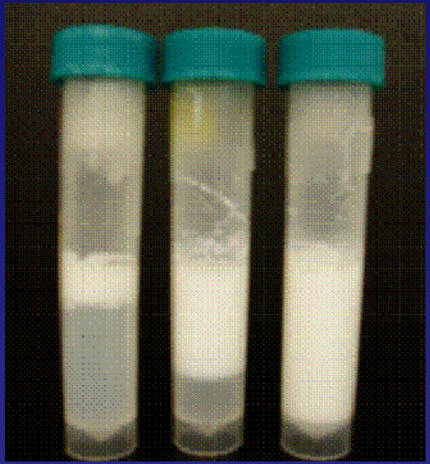


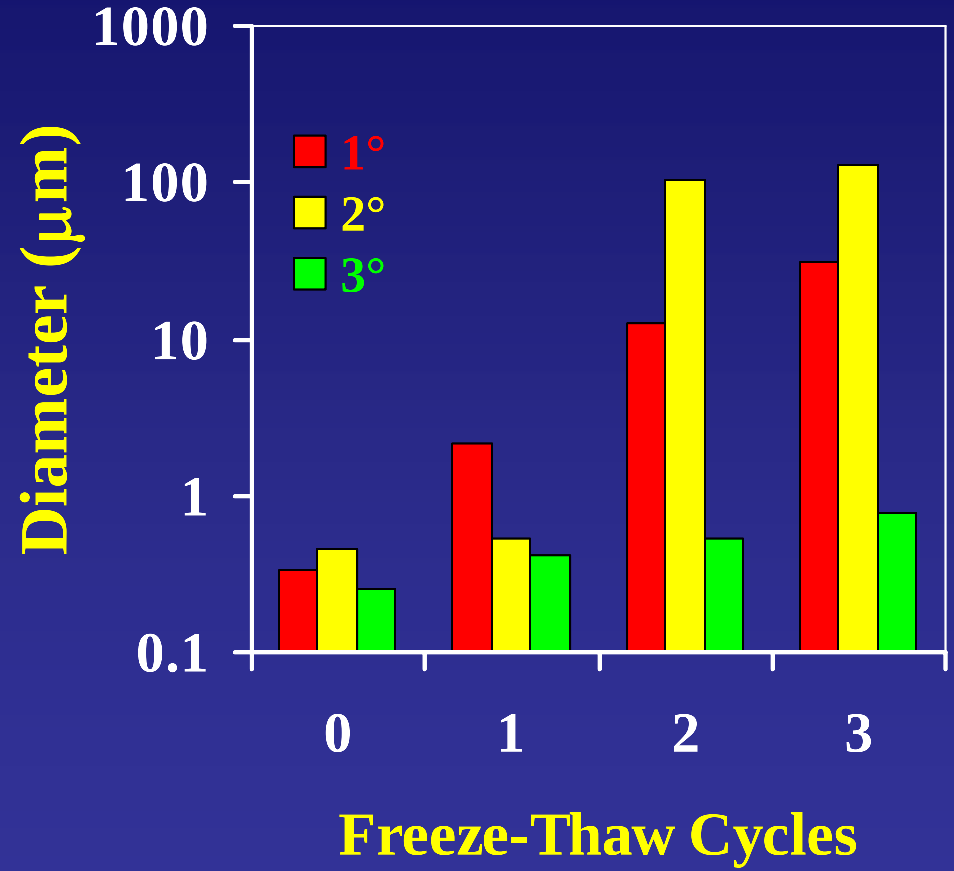
1º β-Lg
2º Pectin

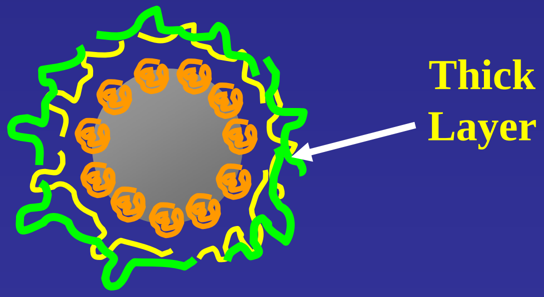
pH 4

Multilayer Emulsion Properties:

Improvement of Freeze-Thaw Stability







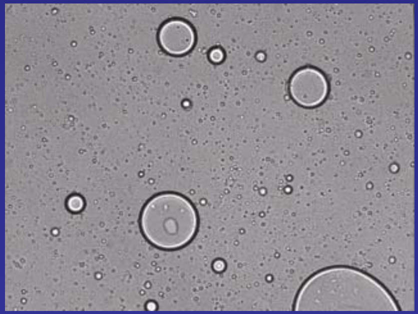
1º β-Lg
2º Carrageenan
3 º Gelatin

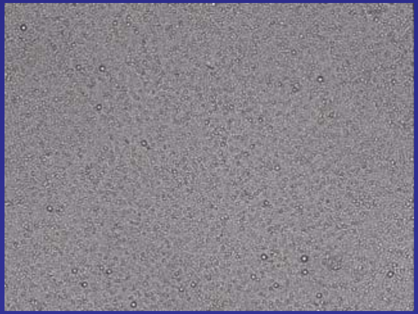
0% Sucrose

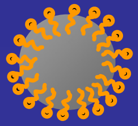
Multilayer Emulsion Properties:
Improvement of Dehydration Stability

Primary

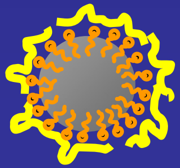
Secondary





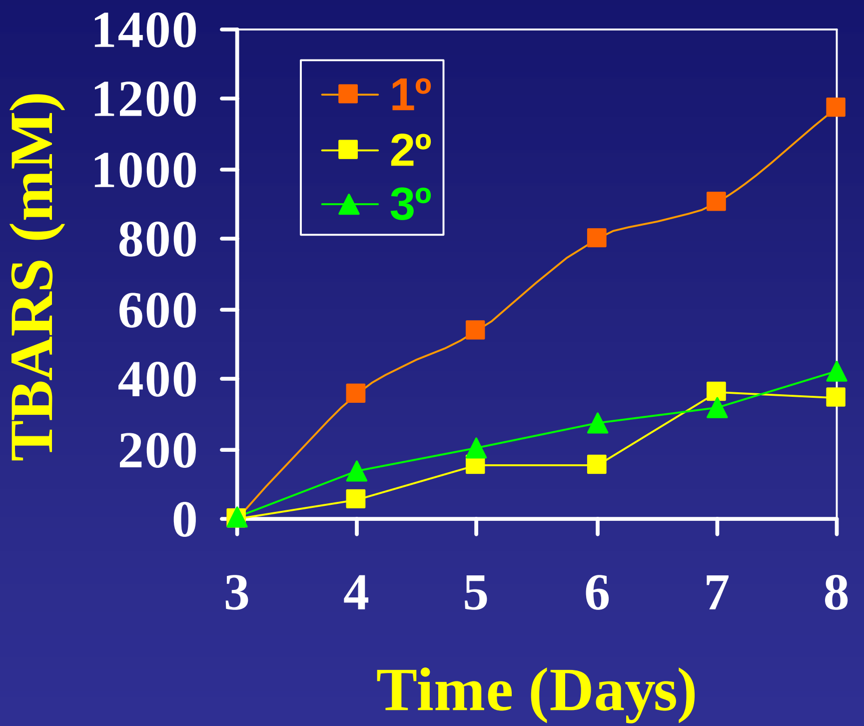


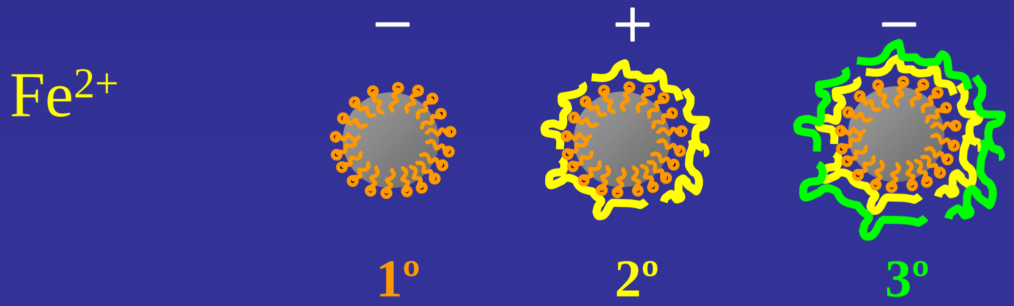
1º



2º

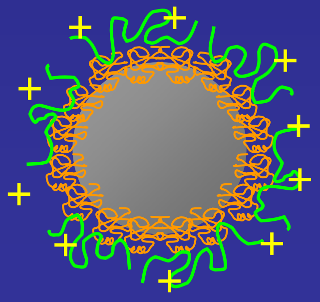
Multilayer Emulsion Properties:
Improvement of Oxidative Stability





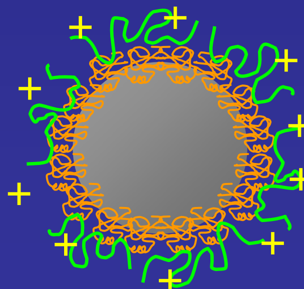
Current Status of Multilayer Emulsions

- Emulsions containing lipid droplets coated by nano-laminated layers can be prepared by a simple cost effective method using food ingredients
- These emulsions have improved stability to environmental stresses, such as heating, freezing, drying, pH extremes, and high mineral contents
- Future studies are needed to determine their suitability for use in real foods (encapsulation, controlled release, triggered release)



Future Work

- Investigate use of mixed biopolymers to form the outer interfacial layers (so can control charge and thickness).
- Investigate methods of cross-linking adsorbed layers so that they retain functionality over wider range of conditions.
- Investigate digestibility of multilayer emulsions.
- Investigate applications to real food systems, *e.g.*, beverage emulsions.



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