



HAL
open science

Whey protein emulsions: how to control texture in a large range of protein concentration.

Thomas Croguennec, Marie Chevallier, Thibault Loiseleux, Catherine Garnier, Alain Riaublanc, Christelle Lopez

► To cite this version:

Thomas Croguennec, Marie Chevallier, Thibault Loiseleux, Catherine Garnier, Alain Riaublanc, et al.. Whey protein emulsions: how to control texture in a large range of protein concentration.. 1st symposium in food Science and technology of Tocantins “Quality control in food processing, Advanced research applied to food industry and Entrepreneurship”., Nov 2018, Palmas, Brazil. hal-02790199

HAL Id: hal-02790199

<https://hal.inrae.fr/hal-02790199>

Submitted on 5 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Joint Research Unit



AGROCAMPUS Ouest–INRA
Science and Technology of
Milk and Eggs (STLO)

**Whey protein emulsions: how to control texture
in a large range of protein concentration ?**

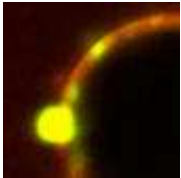
CHEVALLIER M, LOISELEUX T, LOPEZ C, GARNIER C,
ANTON M, RIAUBLANC A, CROGUENNEC Thomas



www6.rennes.inra.fr/stlo_eng
www.agrocampus-ouest.fr

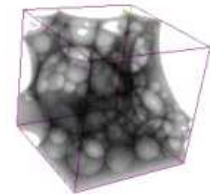


STLO: main research areas



Increase the knowledge on **molecular and supramolecular structures** of milk and egg components

Understand protein-protein, protein-lipid, protein-mineral **interactions** leading to expected technological and bioactivity **functionalities** and understand their **digestion**



Analyze **transfers** during **technological processes**

Characterize **interactions between bacteria/environment** in relationship with product quality, food safety and probiotic activity



Whey protein emulsions: how to control texture in a large range of protein concentrations ?

Introduction

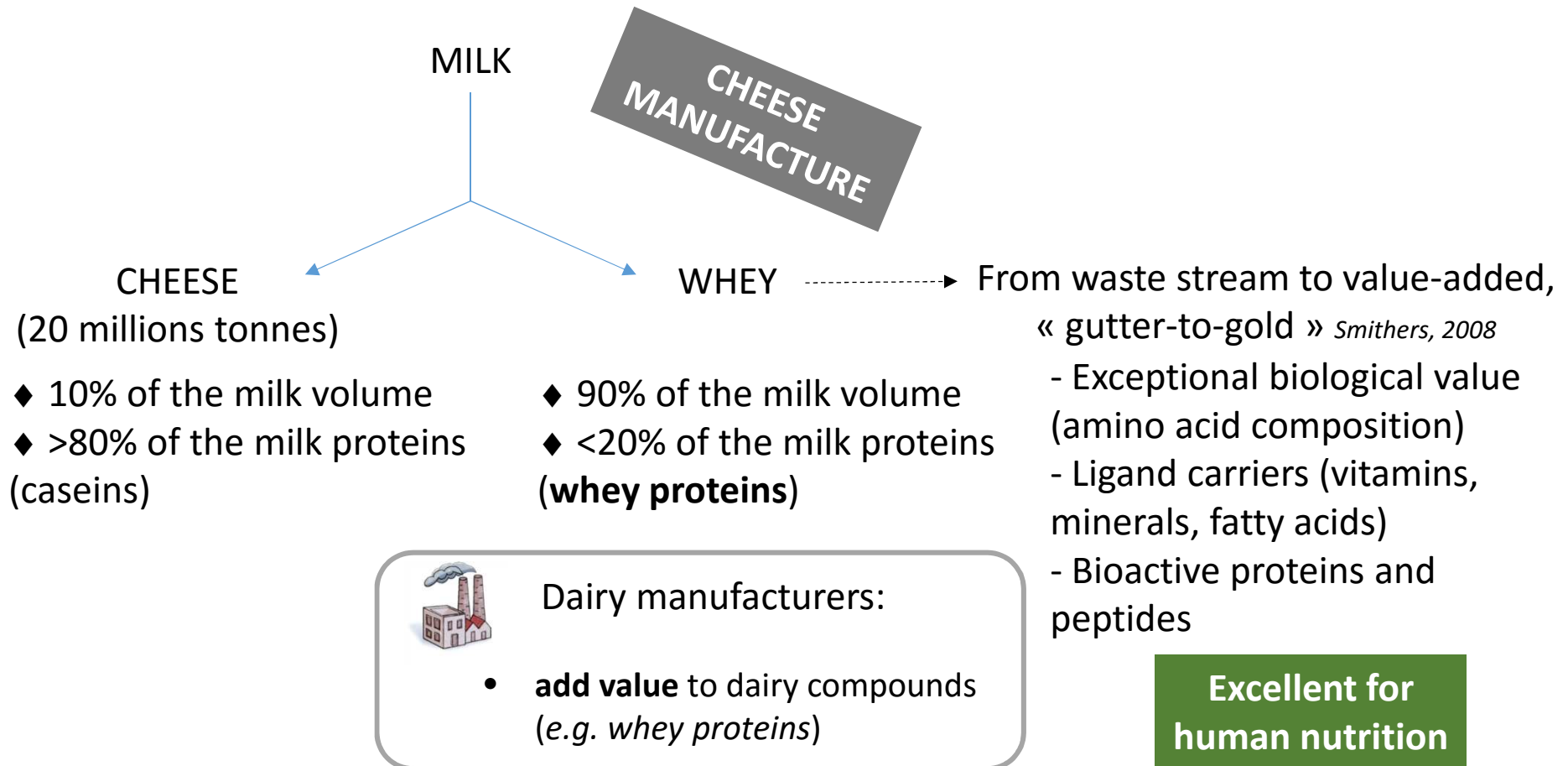
1. Design of fluid whey protein emulsions after heating at high whey protein concentrations
2. Preparation of texturized (gelled) whey protein emulsions at low whey protein concentrations

Conclusion

Acknowledgments

Introduction

Whey proteins : Large amount available around the world



Introduction

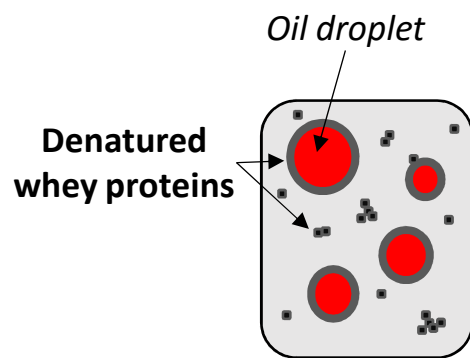
- Whey proteins :
 - natural emulsifiers (*adsorb to oil/water interface*)
 - heat-sensitive proteins (*heat treatments are required to extent food product shelf life*)
 - heat sensitive emulsions
 - texturized (gelled) emulsions



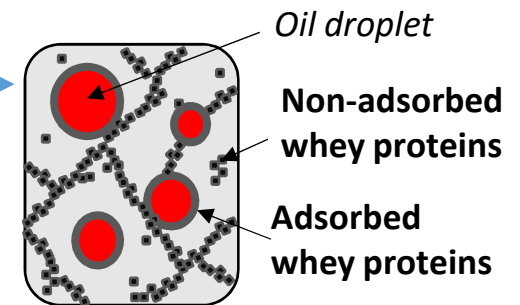
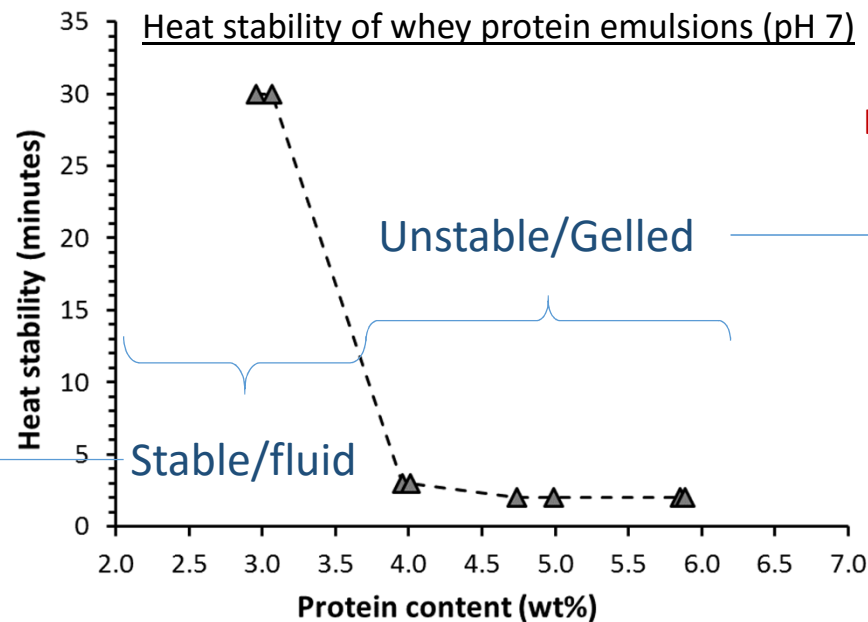
Fluid emulsions: Protein amount too low to build a continuous network



Gelled emulsions : Network of proteins entrapping oil droplets



Gelled emulsions obtained by using non-dairy **gelling agents**



fluid emulsions obtained by using non-dairy **stabilizing agents**

Dairy industries

Introduction

- New trends in Europe driven by consumer's expectations

- **More natural and healthier food products**
- **100% milk products**
(without non-dairy additives)
- **Innovative products**
(new uses and consumption habits)



Research Questions



- How to design whey protein emulsions at high protein concentrations that are fluid after heating without non-dairy additives?
- How to obtain gelled whey protein emulsions at low protein concentrations without non-dairy additives ?

Whey protein emulsions: how to control texture in a large range of protein concentration ?

Introduction

1. Design of fluid whey protein emulsions after heating at high whey protein concentrations
2. Preparation of texturized (gelled) whey protein emulsions at low whey protein concentrations

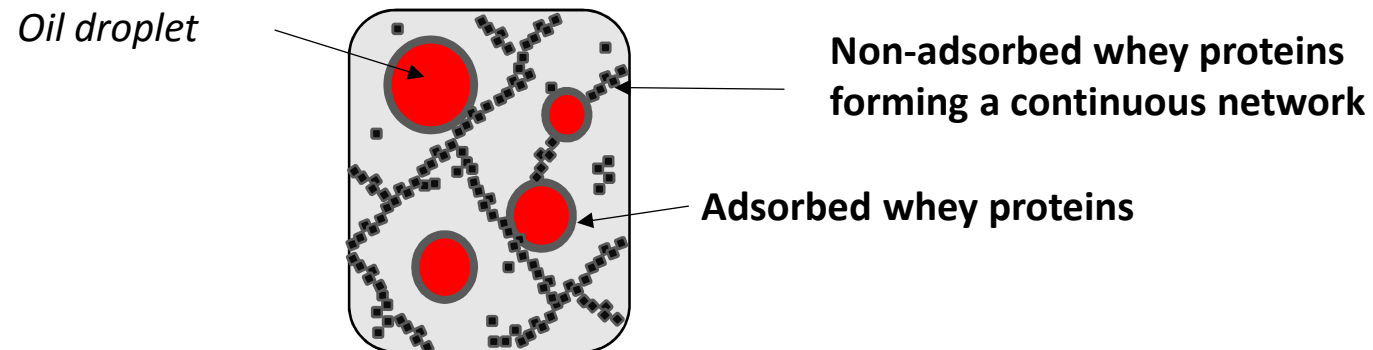
Conclusion

Acknowledgments

1. Design of fluid whey protein emulsions after heating

Emulsion gelation results from the establishment of **interactions between whey proteins**

- Whey proteins denature and aggregate during heating
- A gel is formed when the whey protein concentration is enough (critical gelation concentration)











To prevent emulsion gelation:

- Limit the interactions between proteins at the interface of oil droplets and proteins in the continuous phase
- Reduce the interactions between the proteins in the continuous phase

Objective : designing fluid emulsions at protein concentration higher than 4%

1. Design of fluid whey protein emulsions after heating

a. Have a look on scientific bibliography

-  • Whey protein aggregates are more heat stable in solution than native whey proteins (number and reactivity) *Ryan et al., 2012* 
-  • A combination of whey protein aggregates and native whey proteins improves emulsion heat-stability *Çakır-Fuller, 2015* 
-  • Emulsifier properties of whey protein aggregates are reduced, compared to native proteins *Kiokias et al., 2006* 
-  • Interfacial whey protein aggregates induce oil droplet flocculation on heating *Sarkar et al., 2016* 

Whey protein aggregates are heat stable in solution (i.e. continuous phase of emulsion), but destabilize oil droplets (poor emulsifiers, bridging between droplets)

1. Design of fluid whey protein emulsions after heating

a. Have a look on scientific bibliography



- Caseins are heat stable and gives heat stable emulsions

(Hunt & Dalgleish, 1995; Srinivasan et al, 2002)



- Caseins adsorbed preferentially at fat droplet surface, compared to whey proteins.

Srinivasan et al., 1996



- Caseins improve the heat stability of whey protein emulsions (casein covered oil droplets do not contribute to whey protein network)

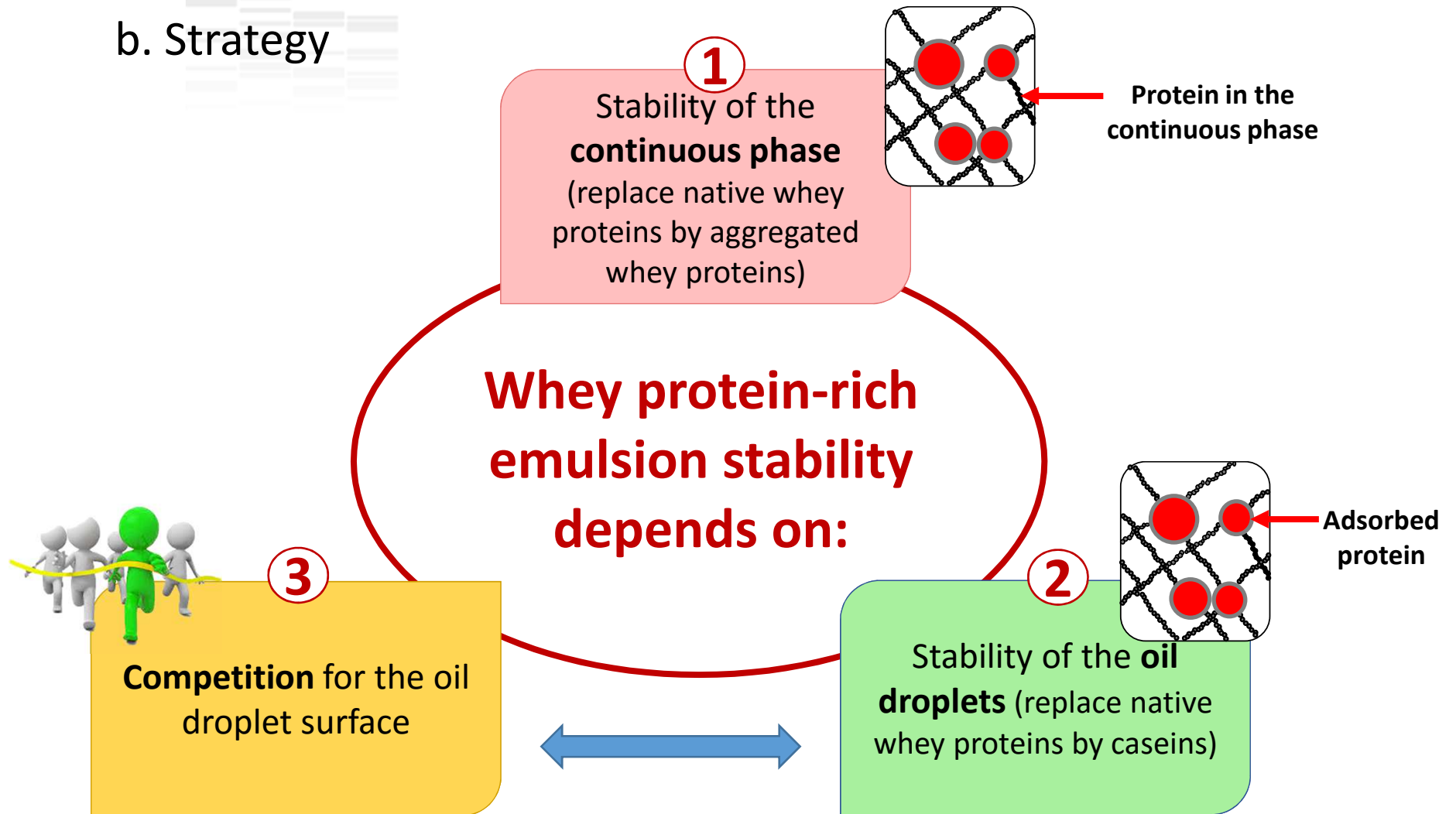
Dickinson & Parkinson, 2004; Parkinson & Dickinson, 2004



Caseins are good protector for oil droplets

1. Design of fluid whey protein emulsions after heating

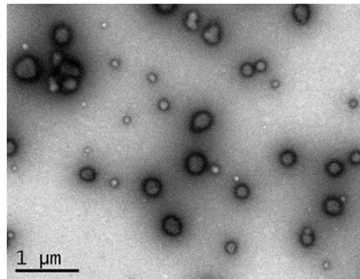
b. Strategy



1. Design of fluid whey protein emulsions after heating

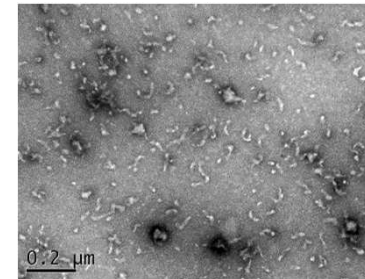
b. Strategy

What type of whey protein aggregates?

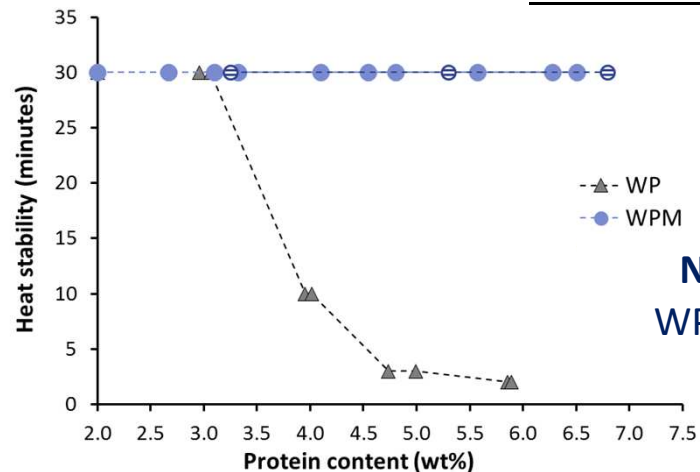


← Whey protein microgels
(dense aggregates of $\phi \sim 300\text{nm}$)

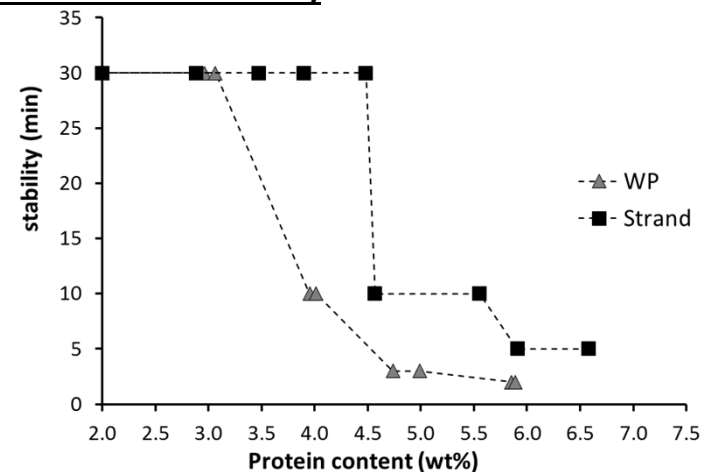
Whey protein strands
(low density aggregates of $\phi \sim 70\text{nm}$) →



Heat stability of the native whey proteins (WP), whey protein microgels (WPM) and whey protein strands in solution (= continuous phase of the emulsion)



Number/reactivity:
WP \gg strands \gg WPM



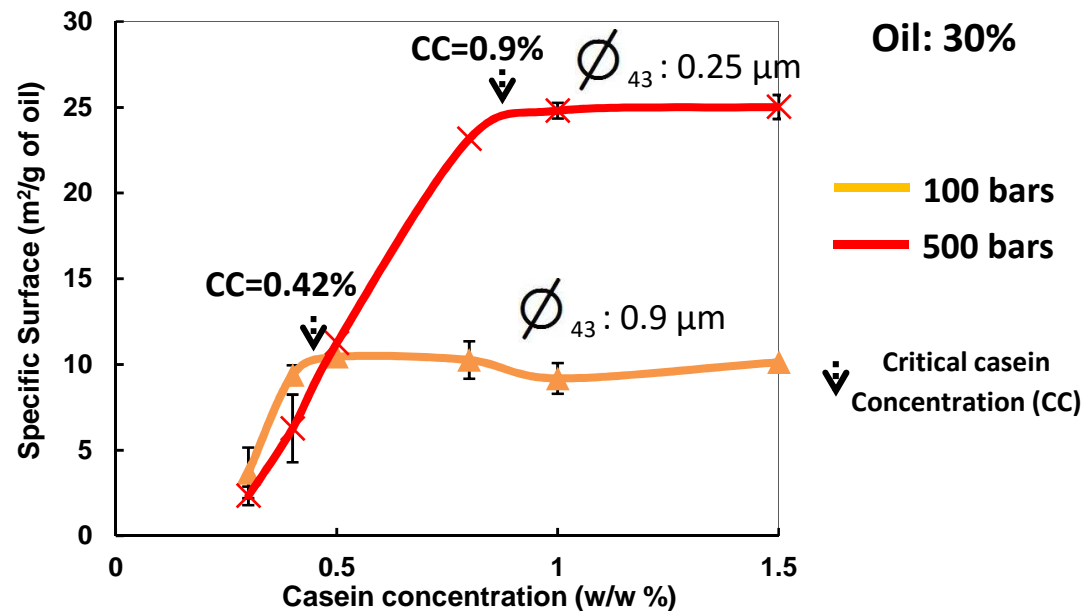
Whey protein microgels should be extremely stable in the continuous phase of the emulsion

1. Design of fluid whey protein emulsions after heating

b. Strategy

What amount of caseins in the emulsion ? (depend on the surface of the oil droplets)

Surface of the oil droplets depends on - amount of oil in the emulsions
- size of the oil droplet (homogeneization pressure)



To have oil droplet fully covered by caseins:
Casein concentration > Critical casein concentration

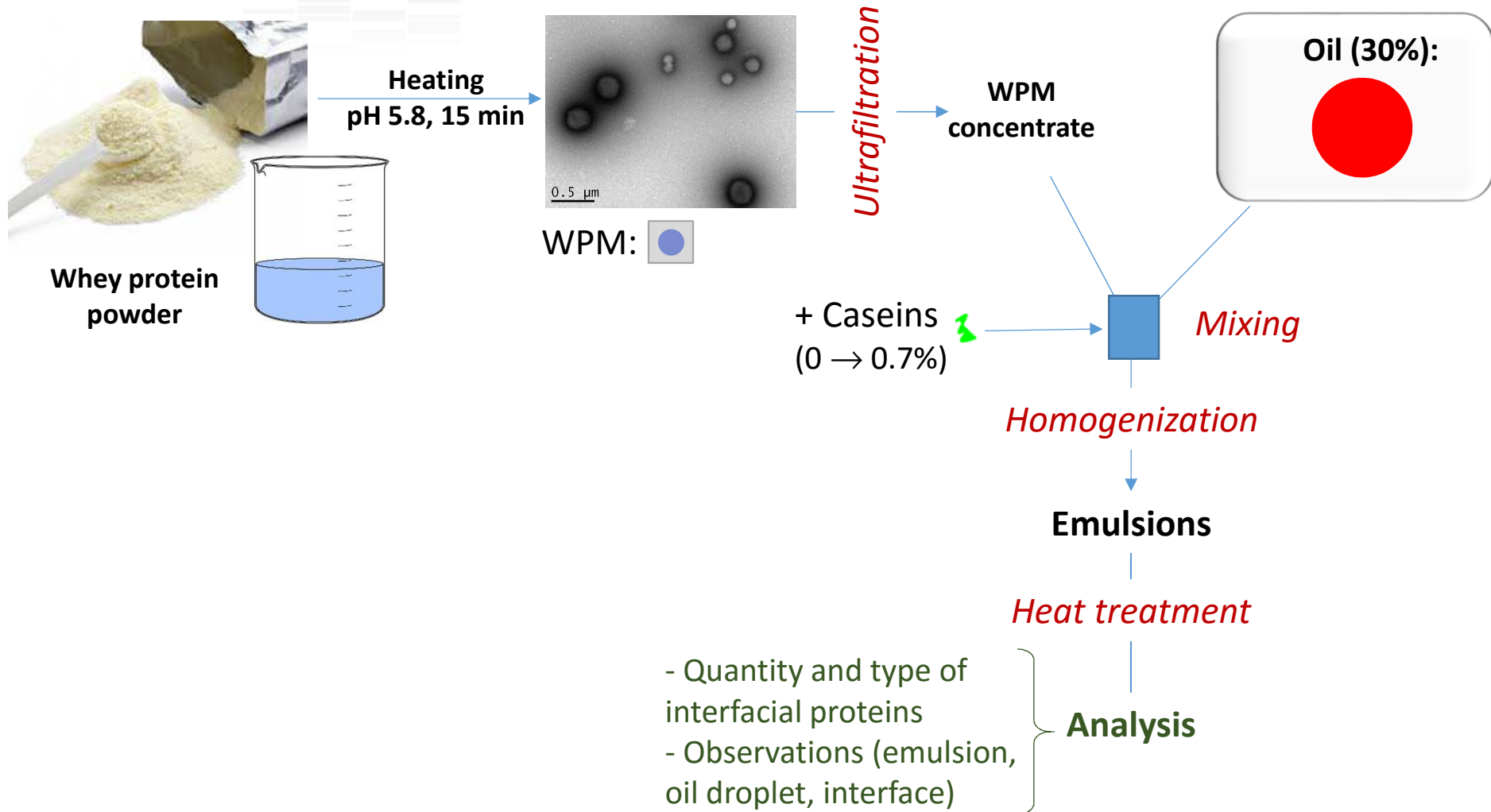
1. Design of fluid whey protein emulsions after heating

c. Hypothesis to test

- ◆ **Above the critical casein concentration**, the whey protein aggregates are released in the continuous phase, the oil droplets are covered exclusively by caseins and the **emulsions are stable** on heating
- ◆ **Below the critical casein concentration**, some whey protein aggregates adsorb at oil droplet surface and **destabilize the emulsions** on heating (casein amount is not enough to fully cover the oil droplet surface)

1. Design of fluid whey protein emulsions after heating

d. Materials and methods



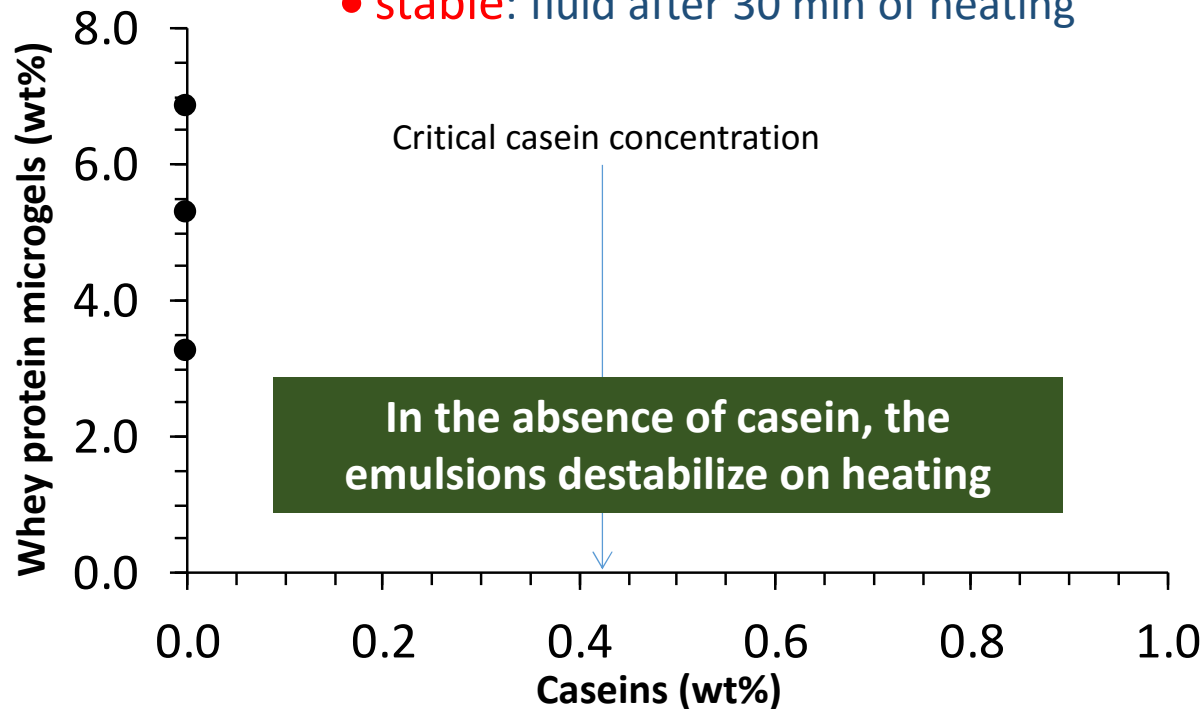
1. Design of fluid whey protein emulsions after heating

e. Results

- Emulsions **below the critical casein concentration** at different whey protein microgel concentrations

Test of heat stability: heating at 120°C up to 30 min

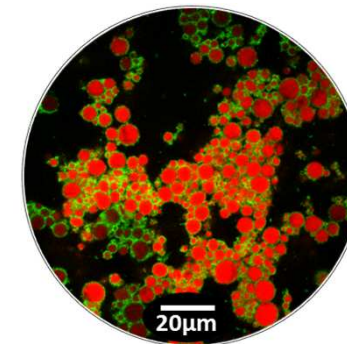
- **unstable:** gelled before 5 min of heating
- **stable:** fluid after 30 min of heating



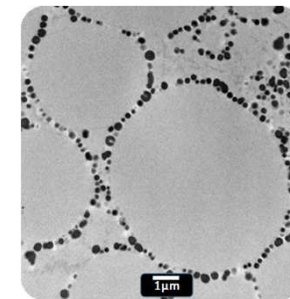
Observations (after 1 min of heating)



Emulsion scale



Oil droplet scale



Oil droplet surface scale

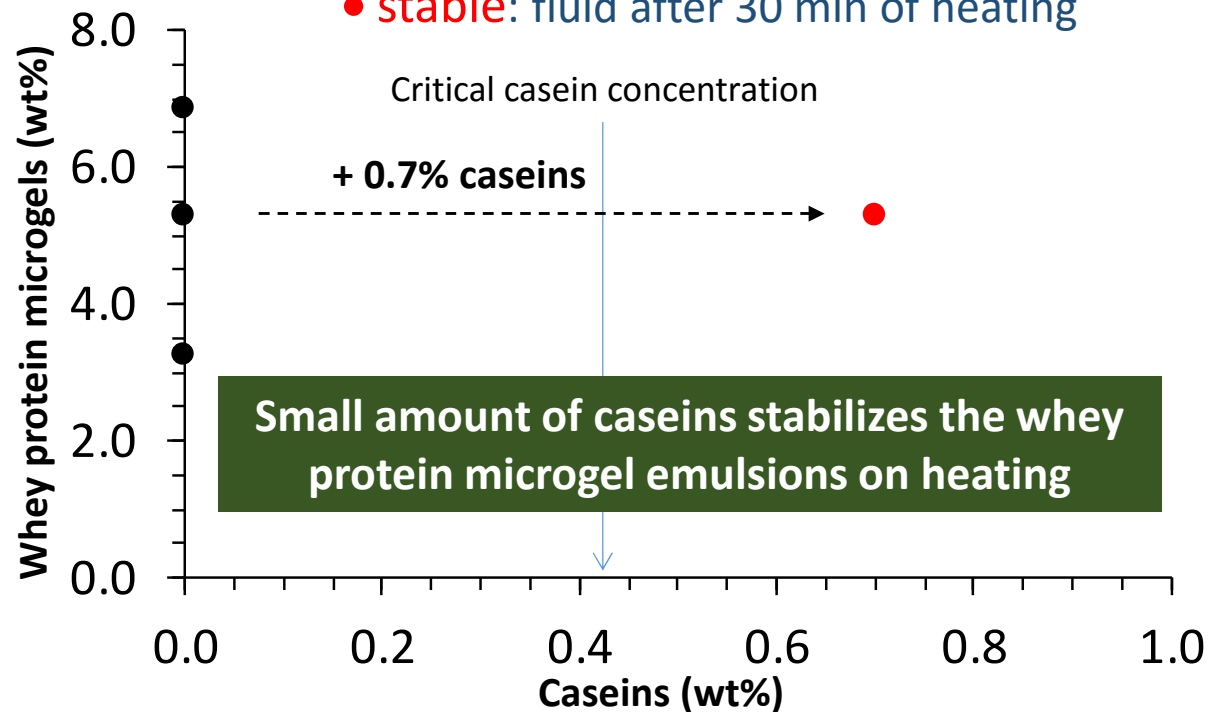
1. Design of fluid whey protein emulsions after heating

e. Results

- Emulsions above the critical casein concentration: +0.7% caseins

Test of heat stability: heating at 120°C up to 30 min

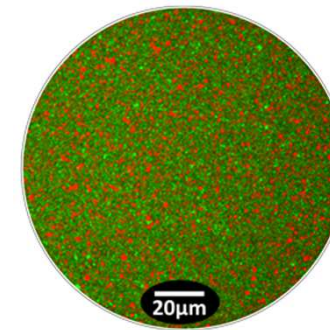
- unstable: gelled before 5 min of heating
- **stable:** fluid after 30 min of heating



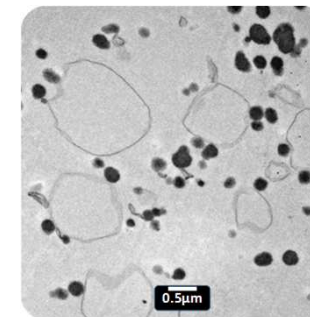
Observations (after 30 min of heating)



Emulsion scale



Oil droplet scale

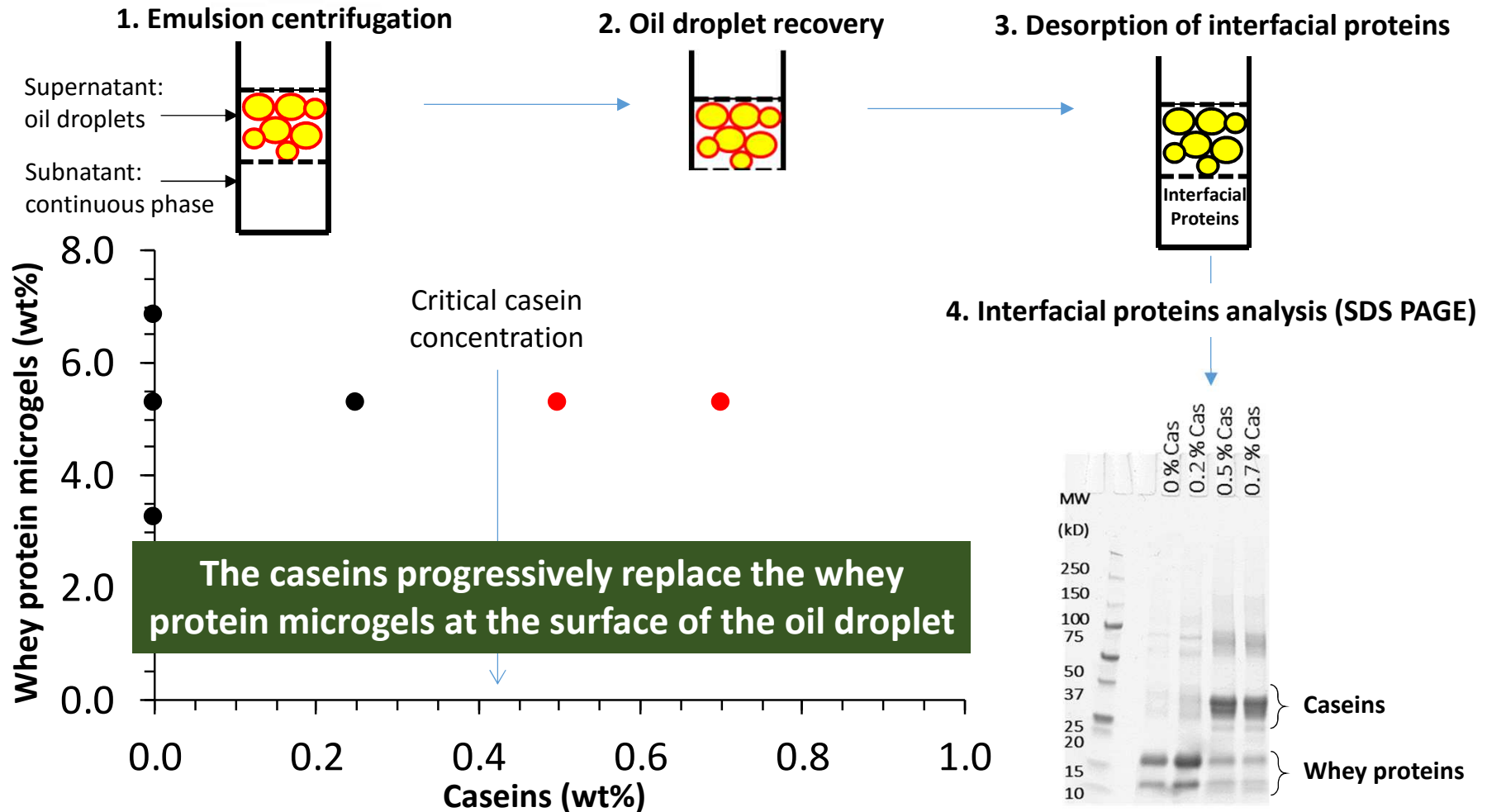


Oil droplet surface scale

1. Design of fluid whey protein emulsions after heating

e. Results

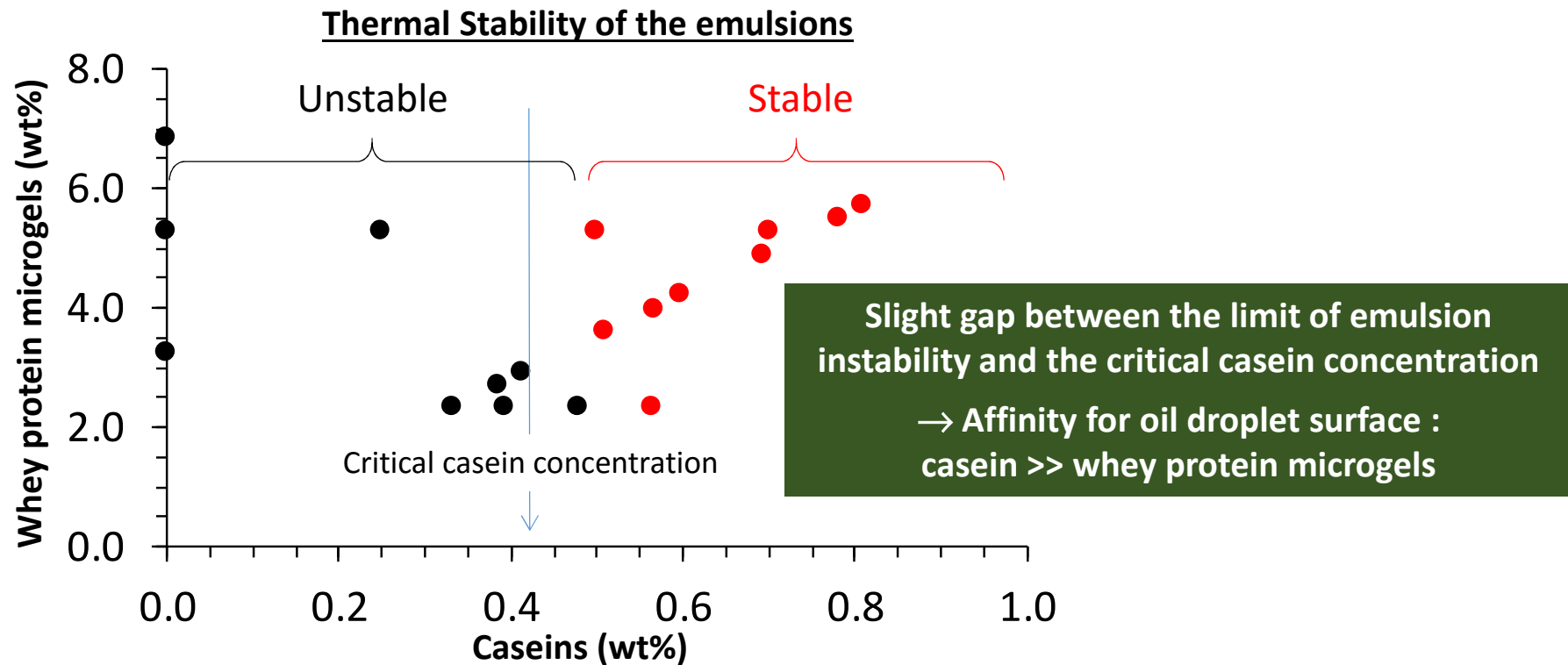
- Emulsions at different casein concentrations: **analysis of the fat droplet surface composition**



1. Design of fluid whey protein emulsions after heating

e. Results

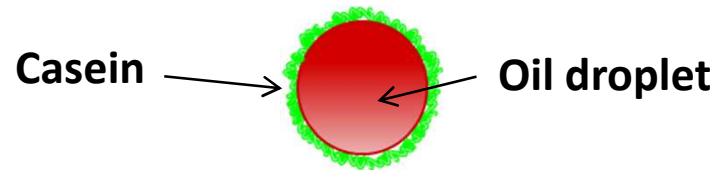
- Generalization for emulsions at different concentration of caseins and whey protein microgels in order to support the hypothesis



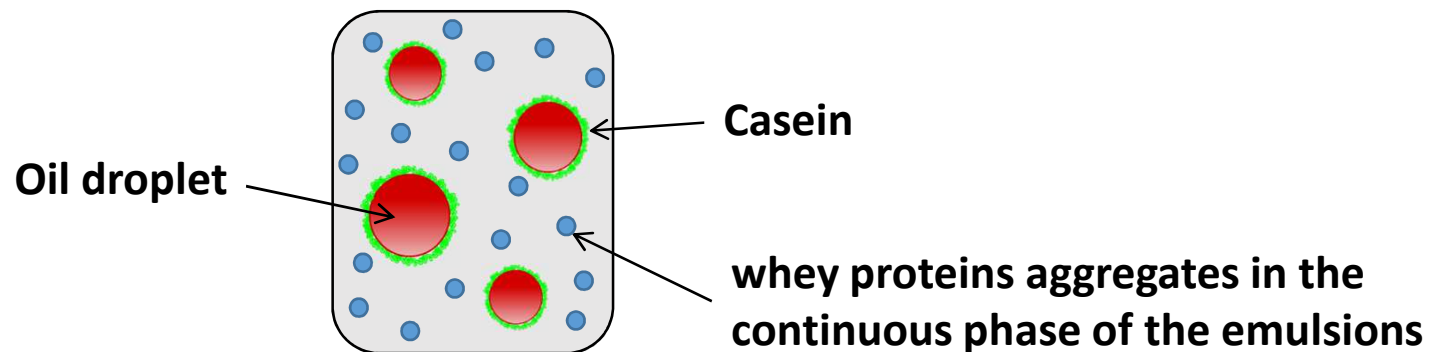
1. Design of fluid whey protein emulsions after heating

How to design whey protein emulsions at high protein concentrations that are fluid after heating in the absence of non-dairy additives?

- by adding sufficient amount of caseins to cover oil droplet surface
→ estimated value: $\text{mass of oil (g)} \times \text{specific surface (m}^2/\text{g of oil)} \times \text{protein interfacial load (g/m}^2)$
(protein interfacial load $\sim 2\text{mg/m}^2$ for caseins)



- By selecting large and dense whey protein aggregates (*small number and low reactivity on heating*)



Whey protein emulsions: how to control texture in a large range of protein concentration ?

Introduction

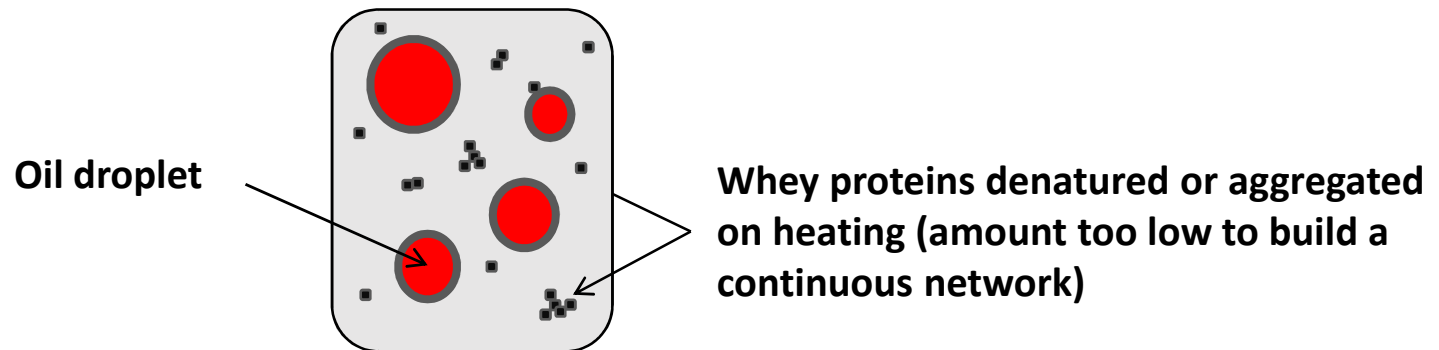
1. Design of fluid whey protein emulsions after heating at high whey protein concentrations
2. Preparation of texturized (gelled) whey protein emulsions at low whey protein concentrations

Conclusion

Acknowledgments

2. Design of texturized whey protein emulsions

- ◆ At **high protein concentration** → emulsions of native whey proteins gelled on heating
- ◆ At **low protein concentration** → not enough whey proteins to form a continuous network



Objective : designing texturized emulsions at protein concentration lower than 4%

2. Design of texturized whey protein emulsions

a. Literature review



- Protein aggregates are able to connect adjacent oil droplets

Surel et al., 2014

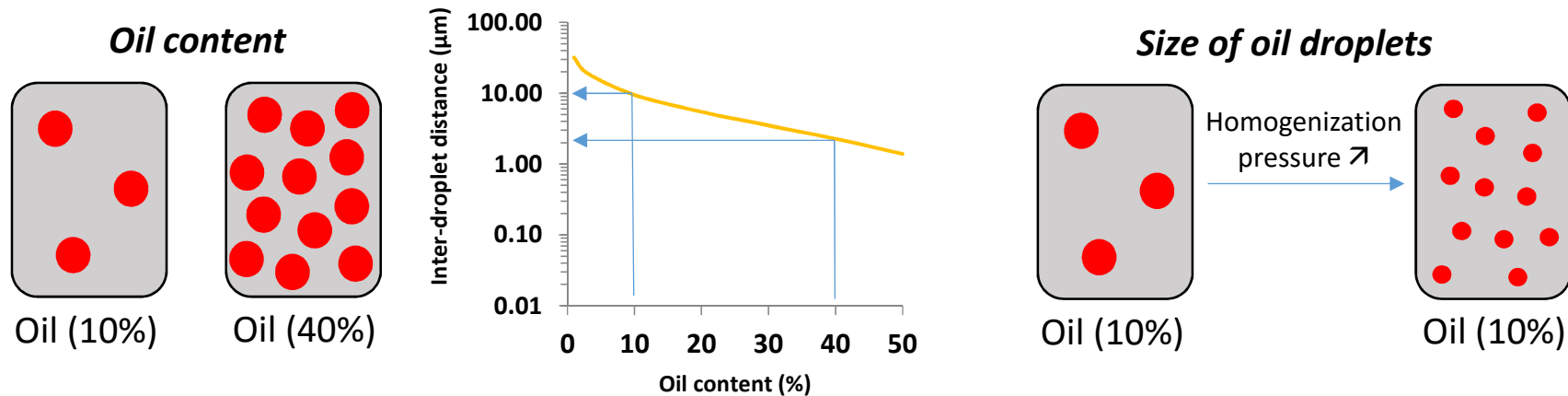


→ Distance between oil droplets is of tremendous importance ... (the size of the aggregates also!)



- Distances between oil droplets depend on **oil content** and the **size of the oil droplets**

Jost, 2006; Dickinson, 2003; Jafari, 2008; Dickinson, 2010

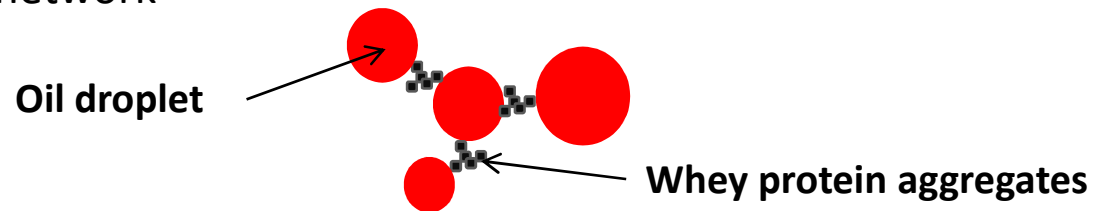


2. Design of texturized whey protein emulsions

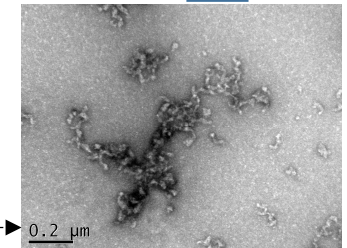
b. Strategy

Connect the oil droplets in the emulsion in order to obtain a **continuous network (gel)** at **low protein concentrations** without non-dairy gelling agents

- Using **whey protein aggregates** to connect the oil droplets for obtaining à continuous network

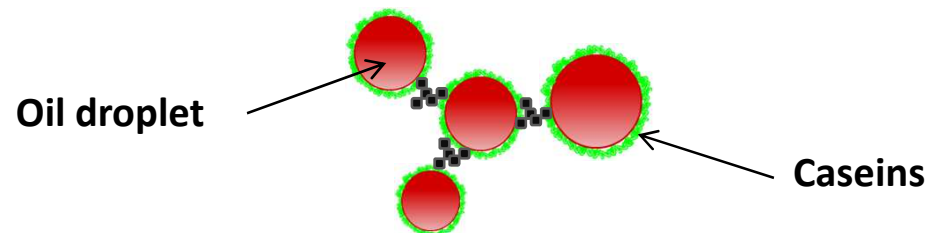


Strands 



For structuring whey protein emulsions at low protein concentrations the aggregates have to be of low density → **whey protein strands**

- Control of the size (distance between oil droplets) of the oil droplets by using caseins



Casein amount < critical casein concentration in order to allow the **adsorption of whey protein strands at oil droplet interface**

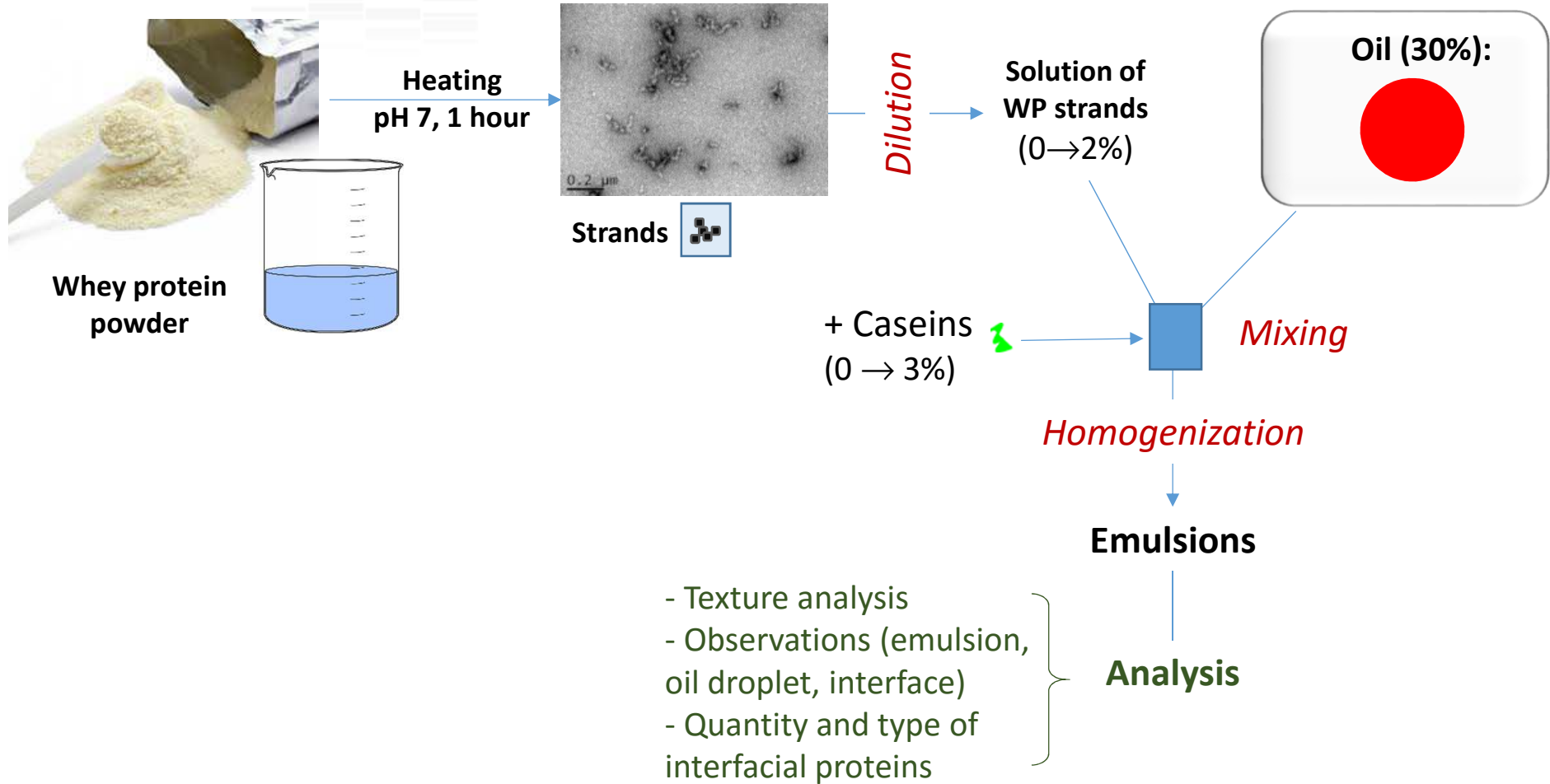
2. Design of texturized whey protein emulsions

c. Hypothesis to test

- ◆ The **whey protein strands** can **connect the oil droplets** in order to obtain a continuous network (as whey protein microgels can do below the critical casein concentration, *see section 1.*)
- ◆ The **whey protein emulsions will be texturized** (gelled) only if the whey protein strands are adsorbed at the oil droplet surface (**below the critical casein concentration**)
- ◆ **Above the critical casein concentration** the whey protein strands are discharged in the continuous phase of the emulsions and are not able to connect oil droplets → **fluid emulsions**

2. Design of texturized whey protein emulsions

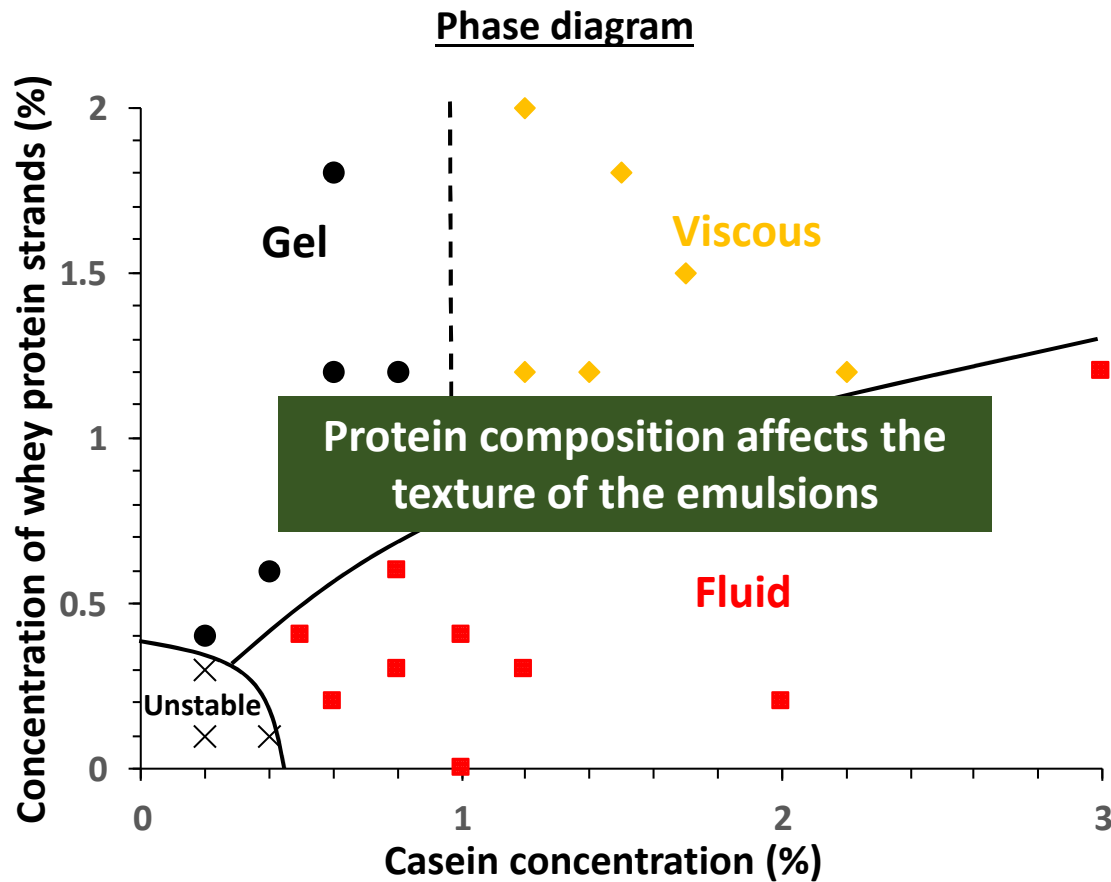
d. Materials and methods



2. Design of texturized whey protein emulsions

e. Results

Screening of the emulsion texture according to protein composition in the emulsions



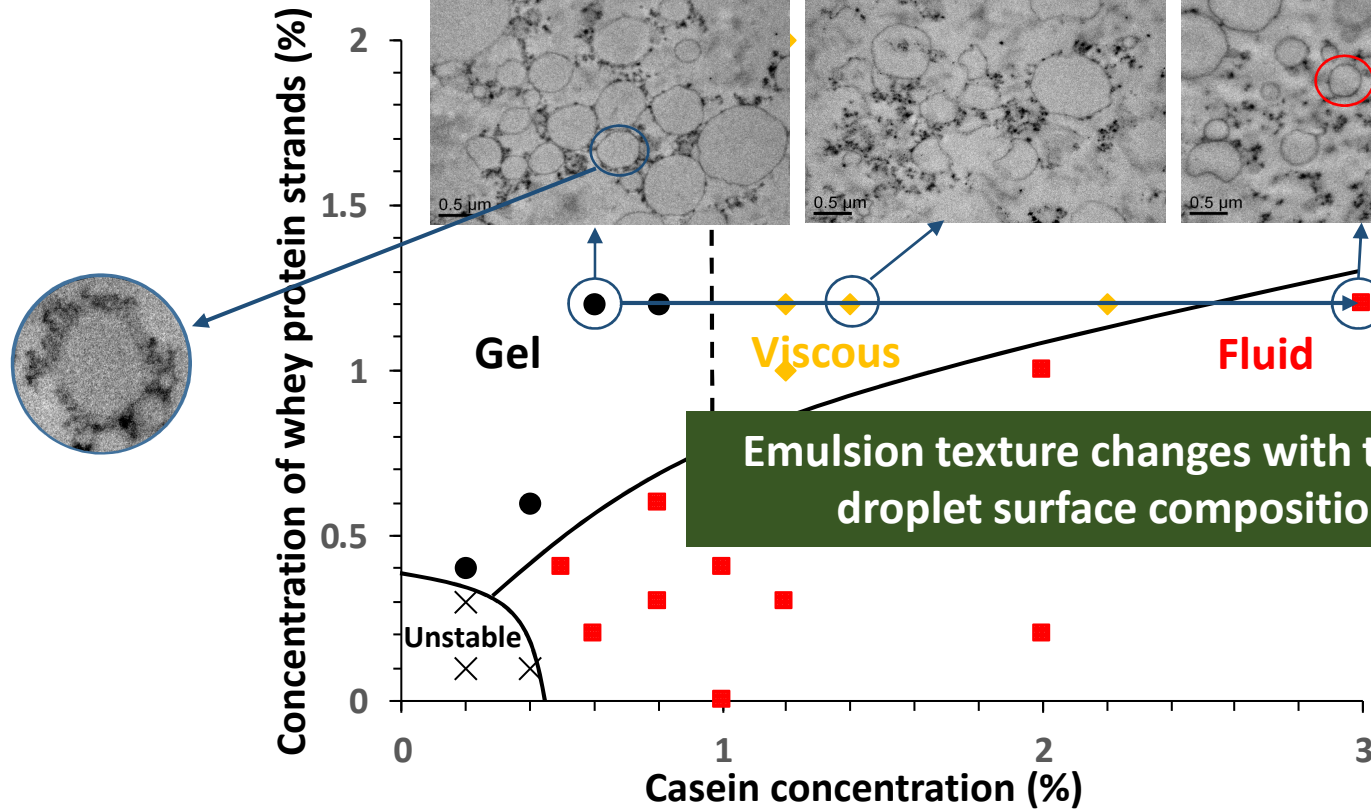
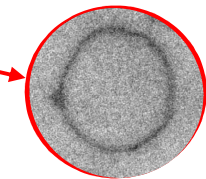
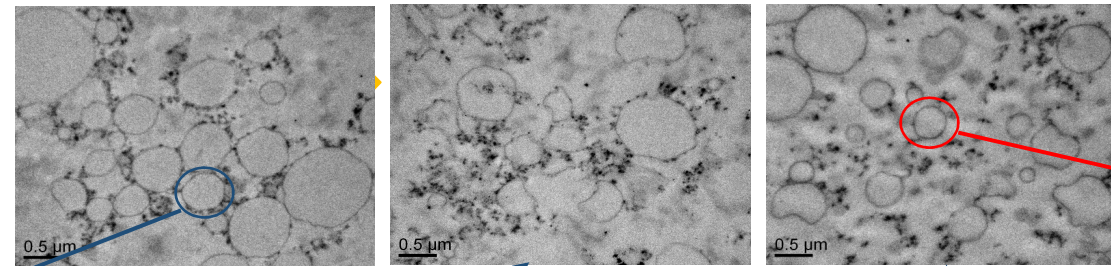
2. Design of texturized whey protein emulsions

e. Results

Observations:

- Emulsion scale

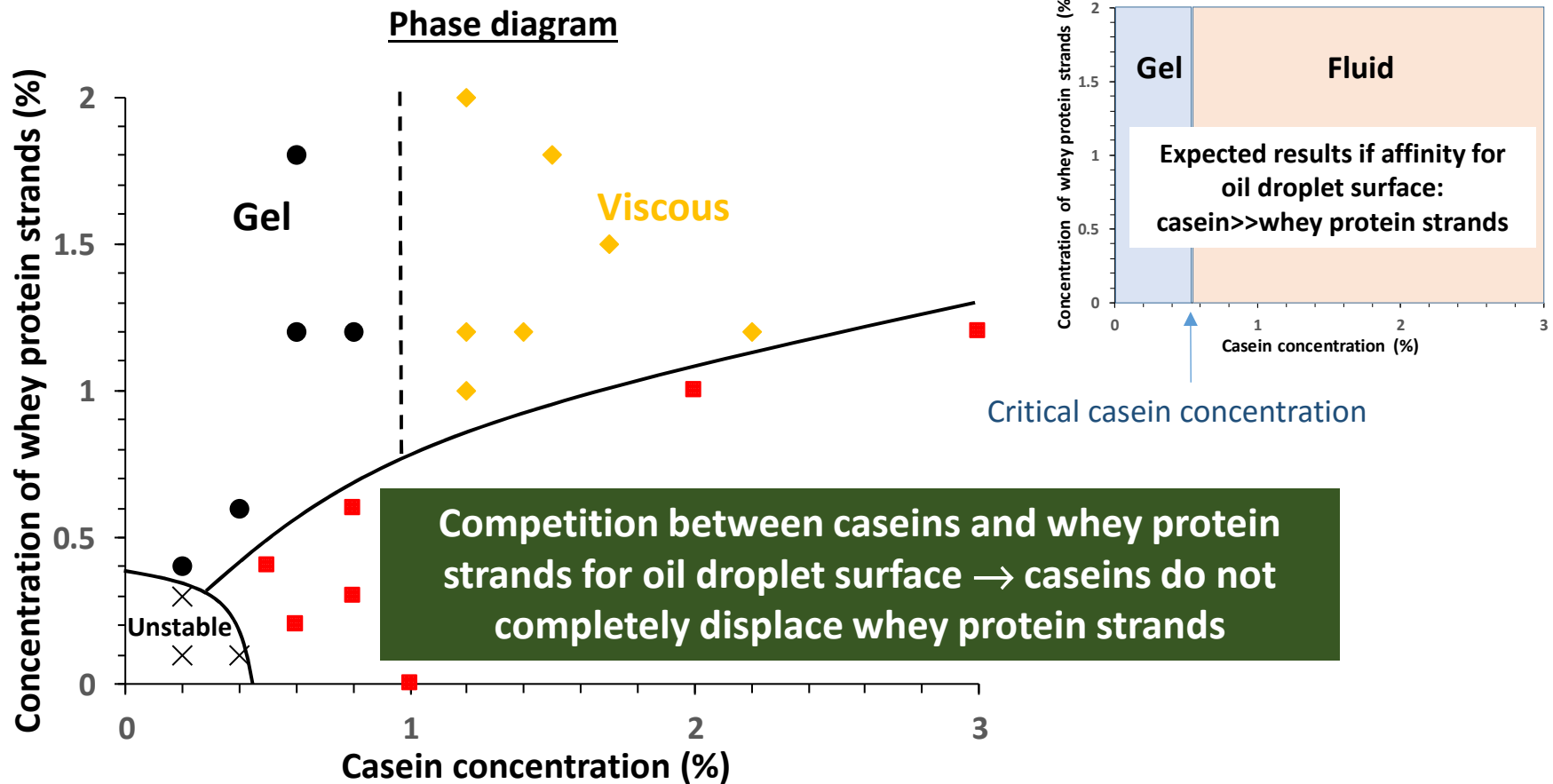
- Interface scale



2. Design of texturized whey protein emulsions

e. Results

Results of emulsion texture were not obvious regarding the **critical casein concentration**

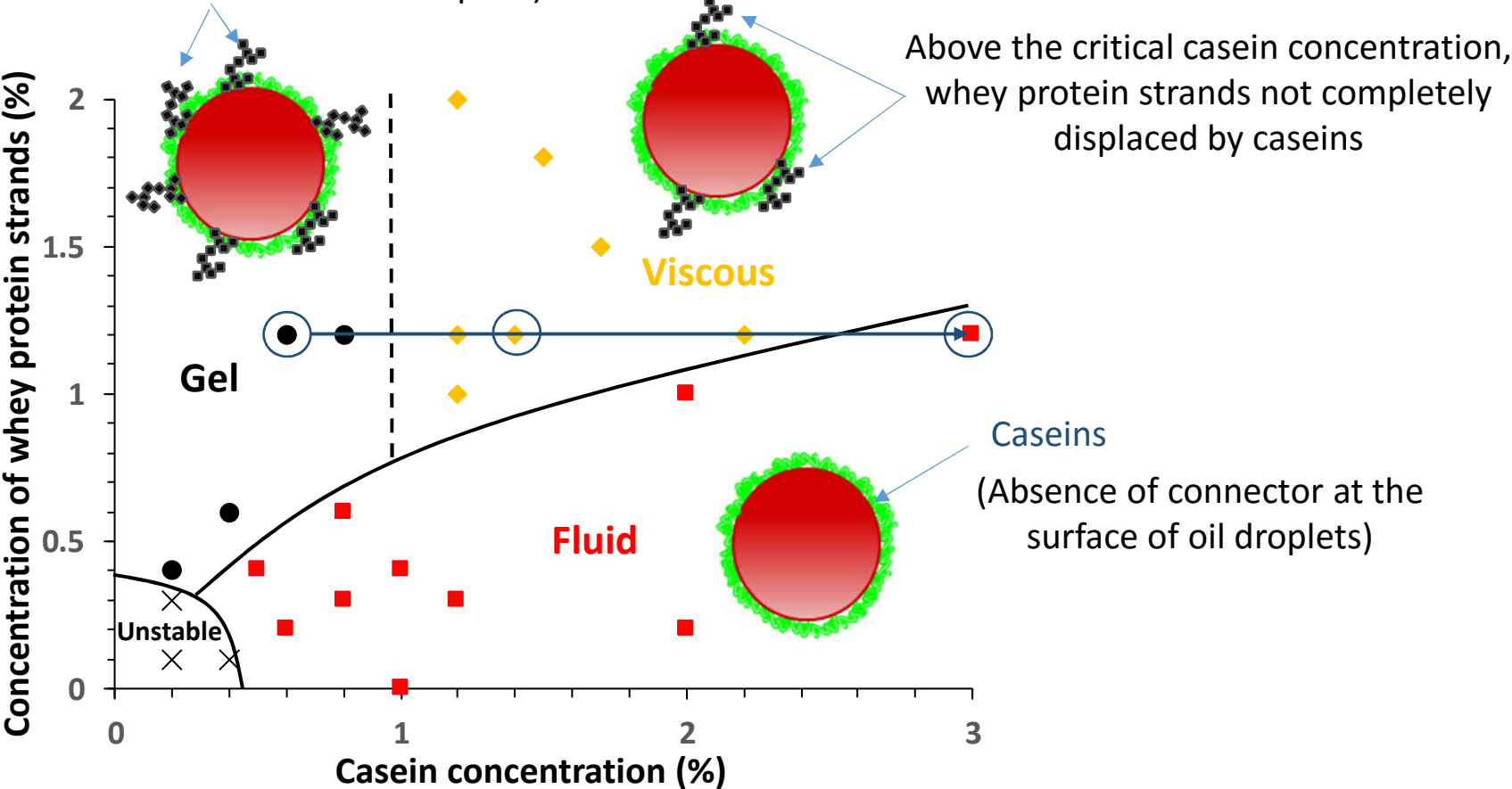


2. Design of texturized whey protein emulsions

e. Results

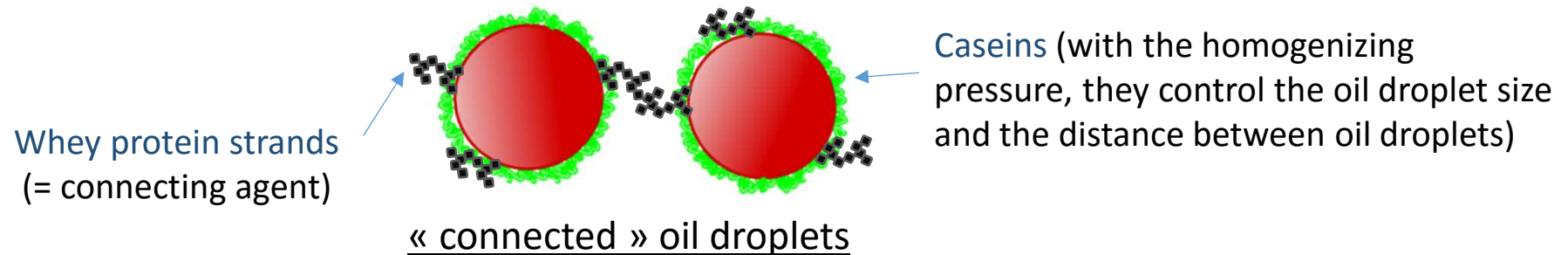
Structure of the oil droplet surface (schematic representation)

Whey protein strands
(Connector at the surface of oil droplets)



2. Design of texturized whey protein emulsions

- How to obtain texturized (gelled) whey protein emulsions at low protein concentrations (below 4%) without non-dairy additives ?
 - Select aggregates of low density (whey protein strands)
 - Use whey protein strands as « connector » at the surface of the oil droplets (size of the aggregates ~ distance between oil droplets)
 - In combination with the homogenizing pressure, use caseins as emulsifiers to control the size of the oil droplets (distance between oil droplets)

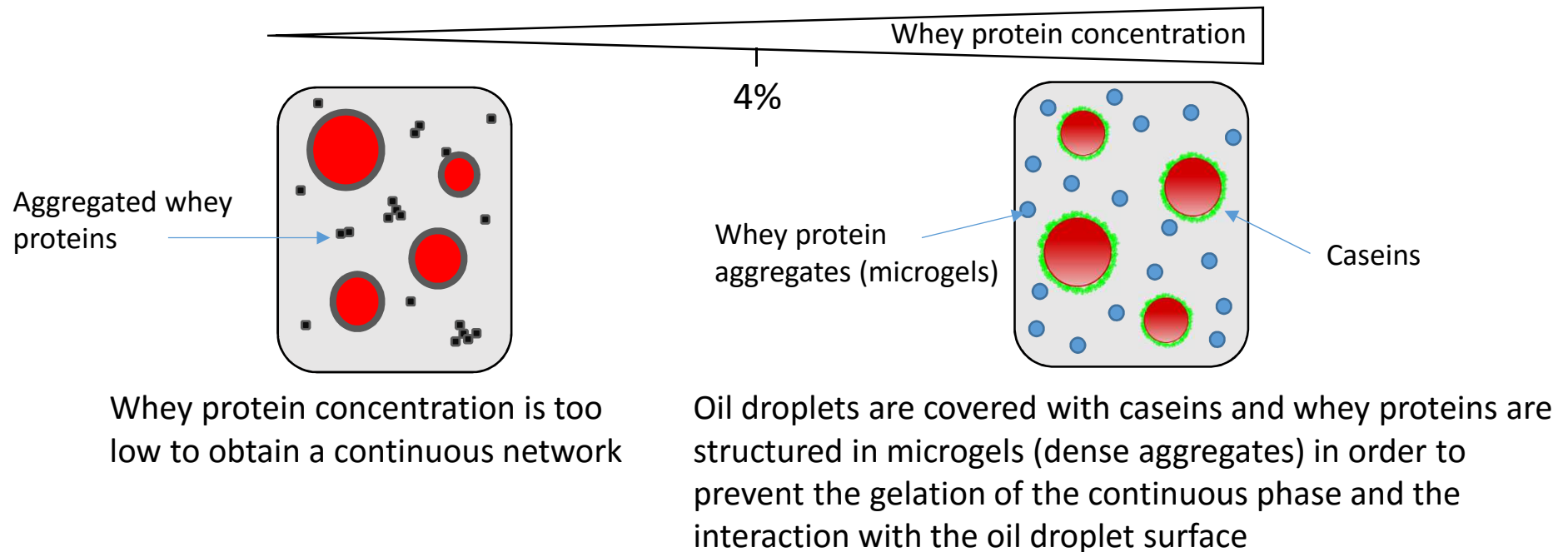


The number of « connectors » defines the texture of the emulsions (gel, viscous solution, fluid)

Conclusion

To design fluid heat stable emulsions:

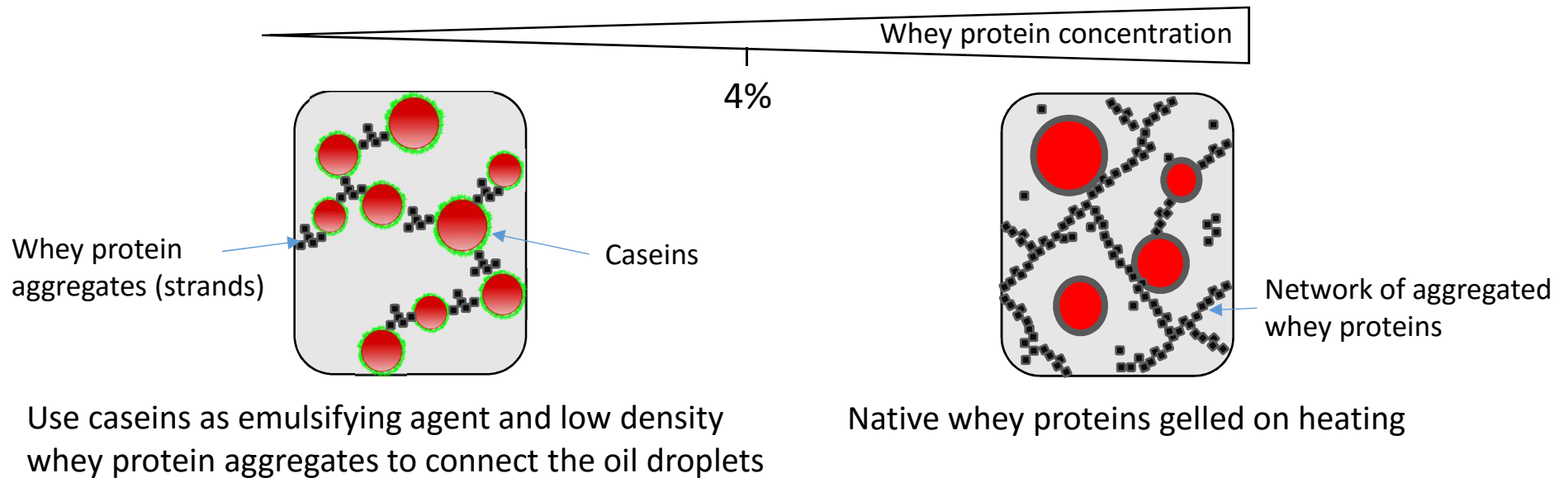
- ◆ At low protein concentrations → **native whey proteins**
- ◆ At high protein concentrations → whey protein aggregates (**microgels**)
+ **casein > critical concentration** to cover the oil droplet surface



Conclusion

To design texturized (gelled) emulsions:

- ◆ At low protein concentration → whey protein aggregates (**strands**) + **casein** < **critical concentration** to cover the oil droplet surface
- ◆ At high protein concentration → **native whey proteins**





Acknowledgments

STLO: Pascaline HAMON, Maryvonne PASCO, Florence ROUSSEAU,
Chantal CAUTY

BIA: Valérie BEAUMAL, Camille JONCHERE, Elisabeth AVID-BRIAND,
Genevieve LLAMAS, Véronique SOLÉ, Bérénice HOUINSSOU
HOUSSOU, Agnes ROLLAND-SABATÉ, Sophie GUILOIS

Interregional project **PROFIL** (supported by BBA
industrial association and managed by Pôle
Agronomique Ouest)

- Regional councils of Brittany (grant n°13008651)
- Pays de la Loire (grant n°2014-07081)
- INRA (Joelle LEONIL, project coordinator)