

➤ A RESEARCH UNIT, located at Lille, centered on materials science hosting agents coming from 4 establishments



UMET is composed of 207 members

-> 110 permanent agents

->97 contractual agents 74 phd, 17 post-doctoral positions, 6 technical staff

The head of UMET is Patrice Woisel, assisted by two Deputy directors Frederic Affouard and Guillaume Delaplace

Common point of all the join research : Elaborate/study/improve soft or hard materials to characterize and to understand their properties for different applications



Biomedical applications



Transportation



Building



Planets



Nuclear Plant



Food sector

Director : Patrice WOISEL
Deputy Director: Frédéric AFFOUARD
Deputy Director: Guillaume DELAPLACE

Project manager:
Sébastien Merkel Communication
Sophie Duquesne Scientific animation
Franck Beclin Ressources optimization

RESEARCH TEAMS

Ingénierie des Systèmes
Polymères
ISP
Serge Bourbigot

Matériaux Moléculaires et
Thérapeutiques
MMT
Alain Hédoux

Métallurgie Physique et Génie
des Matériaux
MPGM
Ingrid Proriot Serre
Ludovic Thuinet

Matériaux Terrestres et
Planétaires
MTP
Jannick Ingrin

Plasticité
PI
Patrick Cordier

Processus aux Interfaces et
Hygiène des Matériaux
PIHM
Guillaume Delaplace

SCIENTIFIC AND TECHNICAL SUPPORT

Addad Ahmed : Plateforme ME
IgR en Microscopie Electronique
Bachelet Pierre : ISP
IgE, Développement Tests "feu"
Bellayer Séverine : ISP
IgR Responsable Microsonde Electronique
Blanchenet Anne-Marie : Plateforme ME
ASI en Microscopie Electronique
Bouvier Laurent : PIHM
IgE. en Calcul Scientifique
Candelier Catherine : ISP
ASI en Chimie Analytique
Chantel Julien : MTP
IgR en Minéralogie haute pression
Creton Damien : MPGM
Technicien métallographe
Danède Florence : MMT
IgE Responsable DRX et ATG
Daubias Patrick : ISP
ASI en chimie
Descamps Amandine : PIHM
IgE Interfaces bactéries /surfaces
Dhénin Jean-François : Plateforme ME IgE
Dir. Adjt du Centre de Microscopie électronique
Golek Jocelyn : MPGM
IgE Ingénieur essayiste mécaniques
Lemy Christelle : PIHM
Technicienne Microbiologie
Malfait Aurélie : ISP
IgE Analyses SEC
Marin Adeline : ISP/MTP
ASI Déformations Mécaniques
Moreau Anne : PIHM
Technicienne Laboratoire
Paccou Laurent : MMT
IgE Spectroscopie Raman
Six Thierry : PIHM
ASI Interfaces aliments/surfaces
Staelens Jean-Noël : ISP
Technicien chimiste
Tahon Jean-François : ISP
IgE Composites Polymères
Ternel Valentin : ISP
Adj.-T. Principal en chimie
Wauquier Laurent : PIHM
Adj. T. P. Interfaces bactéries /surfaces

Administrative and
Financial Management and
Human resource manager

Henry Corinne: head
Dufourmantelle Christophe PIHM
Duveau Danièle MMT, Plasticité
Henry Corinne ISP, SG
Marchant Angélique ISP, MMT, SG
Samain Isabelle ISP, MPGM, MTP et PL,
Correspondant Formation

Computer service
Sénéchal Michel, IgR Info. Scientif. CSSI
Hue Benoit, ASI Parc informatique

Mechanical Design
Hue Benoit, ASI
Wauquier Laurent, Adj. T. Principal

Buiding maintenance
Deraedt Michel, Adj. T. Principal
Deregnacourt Christelle, Adj. Technique

SHARED SERVICES

Safety
Bachelet Pierre C7 AP
Cordier Catherine C6 PCR
Creton Damien C6 Habilité Electrique
Danède Florence C6 et P5 PCR
Deraedt Michel C6 HE
Golek Jocelyn C6 AP
Jacob Damien C6 SST
Malfait Aurélie C6 AP
Marin Adeline C6 AP
Moreau Anne PIHM AP
Paccou Laurent P5 AP et Laser
Samain Isabelle C6 SST
Staelens Jean-Noël C6 SST et HE
Tahon Jean-François P5 AP et PCR
Touzin Matthieu C6 SST

1. PIHM: Position in UMET

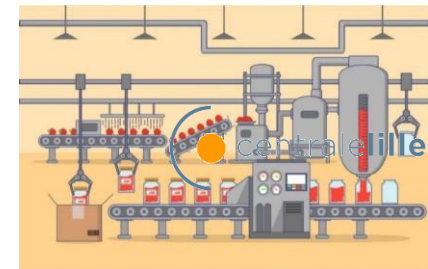
Unité Matériaux Et Transformations

- > **MMT** Matériaux Moléculaires et Thérapeutiques (leader A. Hédoux)
- > **ISP** Ingénierie des Systèmes Polymères (leader S. Bourbigot)
- > **PM** Matériaux Terrestres et Planétaires (leader P. Cordier)
 - > **PI** Plasticité (leader J. Ingrin)
 - > **MPGM** Métallurgie Physique et Génie des Matériaux (leader L. Thuinet)
- > **PIHM** Processus aux Interfaces et Hygiène des Matériaux (leader G. Delaplace)

PIHM



A team of UMET, containing INRAE 's agents, which investigates food processing in reactors and bioadhesion of soil in food process equipments



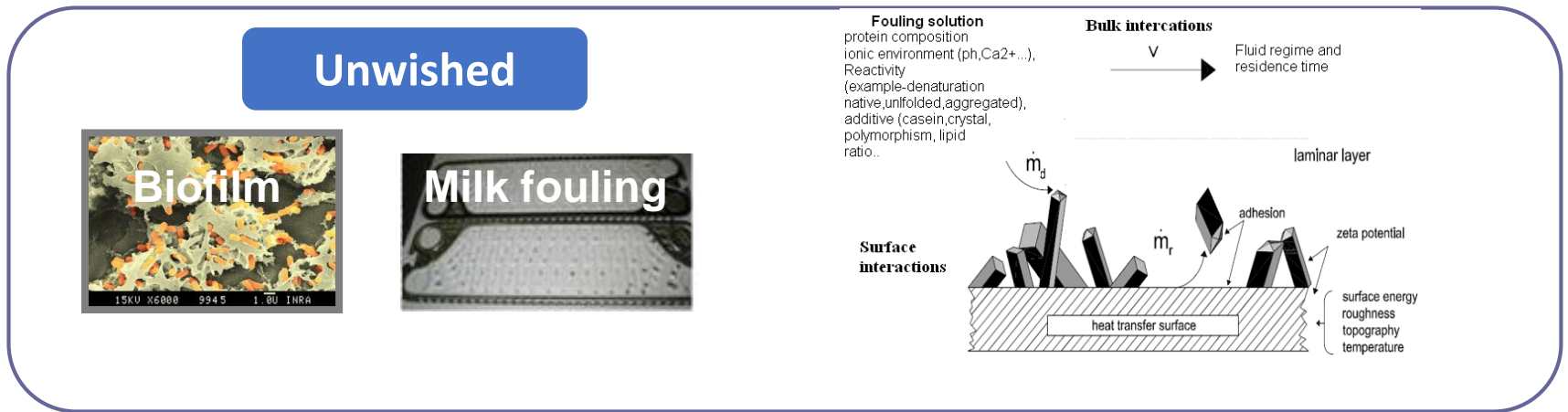
is France's National Research Institute for Agriculture, Food and Environment. It is Europe's top research institute in this field.

Learn more : <https://www.inrae.fr/en>

2. PIHM's research objectives

Understanding the mechanisms governing

- i) food process in reactors
- ii) contamination of surface in agro-food industry (protein fouling, adhesion of spores & food bacteria and biofilm formation) with the aim of improving cleaning of food processing lines

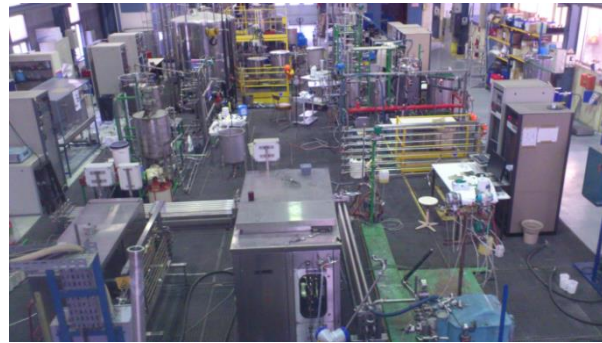


Issues : Food Safety / Quality / Sustainability of food processing => Meeting INRAE's objectives

3. PIHM's staff

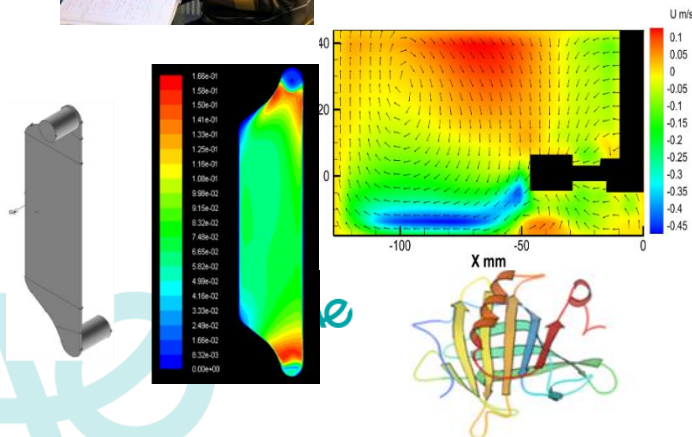
19 permanent agents (7 researchers INRAE+ 3 Professors+1 Assistant professors - 8 technical staff, among them 2 administrative agents)

18 non permanent agents (13 cosupervised PhD, 3 Post-doctorant positions, 1 apprentice, 1 temporary Engineers)+ short internship students



Experimental approach and Numerical simulations

- **Specific microbiology laboratory: GMO and containment –level 2**
- **Technological hall**
- **Metrology workshop**
- **Computational resources for modelling (molecular or process scales)**



PiHM staff: 37 agents (without short internship students)

permanent agent 19

>permanent agent from INRAE 15

T Six, AI; Protin TR (admin); L Wauquier TR; C Dufourmantelle TR (admin), C Lemy TR
Laurent Bouvier IE, Amandine Descamps IE, **Dylan Caron TR (Sept. 2021)**

Paulo Peixoto CRCN, Thomas Dubois CRCN, Pascal Blanpain-avet CRCN, **Anne-Laure Fameau CRCN (Oct 2021)** G Delaplace, DR; T Benezech, DR; C Faille, DR

>Permanent agent coming from other partner 4

M Jimenez, Pr Ulille; N-E Chihib, Pr Ulille; C Andre, prof YNCREA; C Gruescu, MdC Ulille,

Non-permanent agent 18

>Temporary engineer 1

M. Delplace (FEFS)

>Apprentice 1

T. Danel

>coSupervised PhD students 13

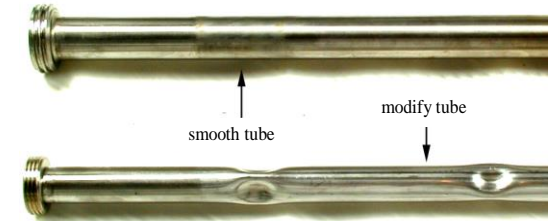
Manon Saget (ECONOMICS), Henni Dallagi (Veg-i-tech), Audrey Hamiot, Weiji Liu (LIA FOODPRINT), Hage M, Yammine J (PHC Liban), Mechmechani S, Angella Velasquez (Proteinolab), L Gustavo (LAI SAMBA), Elfannassi Y (PHC Maroc), Swati Vershnez (PHC india), Kevin Dourgaparsad, **Carolina Dari (Oct. 2021)**

>Post doctoral position 3

Luisa Scudeller (ETUVE), Marwan Abdhallah (Proteinolab), Sakr Alhtulhali (Transform/Imp College london)



3. PIHM facilities: Technological hall



800m² research workshop house platforms for the thermal treatments of food products (batch and continuous processes- pilot plant scale) and automated cleaning in place stations

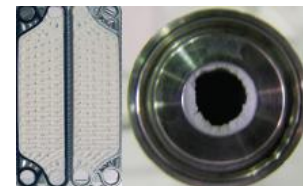
3. UMET facilities : Microscopies and Spectroscopy allowing characterisations from macroscopic to nanoscopic scale

Molecular and submolecular

Microscopies: EPMA, SEM with EDX, TEM AFM,
Spectroscopy NMR, XRD, XPS, ToF SIMS, FTIR/ATR, Mass, SDS HPLC
(Protein conformation, composition, structure)

Macroscopic

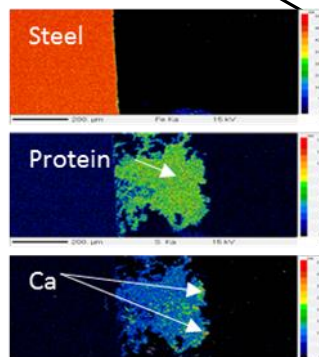
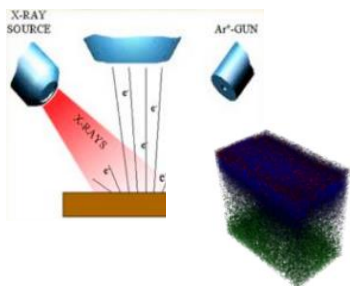
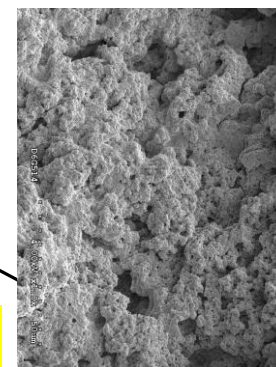
Weight, thickness



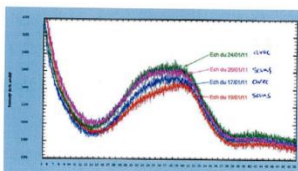
scale

Microscopic

SEM



Vert : Fe, bleu / protine, rouge le calcium



4. Collaborations

PHM steering committee UMR presentation

Academic

Local



National



International



Industrial



4. Collaborations

using various contractual frames for collaborative research project

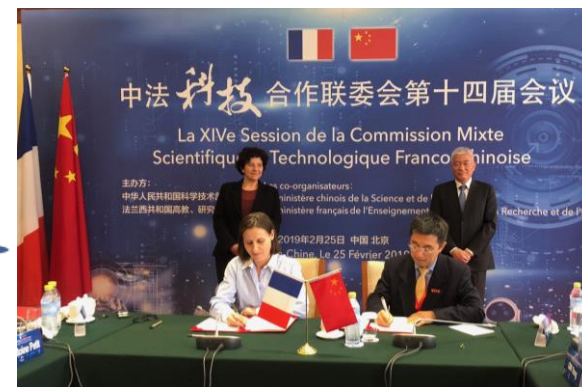
- Regional Council: ARCIR, CPER
- INRAE proposal: internal call
- Industrial: **multi-partners research program or Bilateral Agri-food Processor (Bongrain, CNIEL, Roquette,), Manufacturer (VMI, PCM...), Technical Center**
- National : Generic calls
- International : ERC, 2020

Members of various professional networks

- GDR SLAMM,
- GDR SOLVATE
- RMT CHLEAN

4. Collaborations: insight of international Frames

- **FOODPRINT LIA** Laboratory International Association « FOOD engineering for nutrition and health: Phenomena Related to INTERfaces”



- **SAMBA LAI** *Laboratoire Associé International* **BioEcoAgro** UMET- univ. Federal de Viçosa (Etatde Minas Gerais)« **Valorisations des microorganismes d'Amazonie : Recherche de molécules bioactives & ingrédients** »
Partenaires P. Peixoto coord. D. Drider

BioEcoAgro

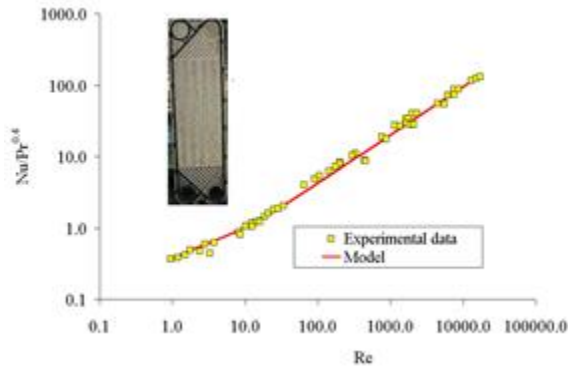


INRAE

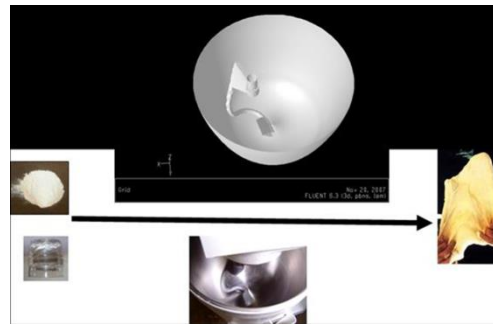


5. Typical projects carried out

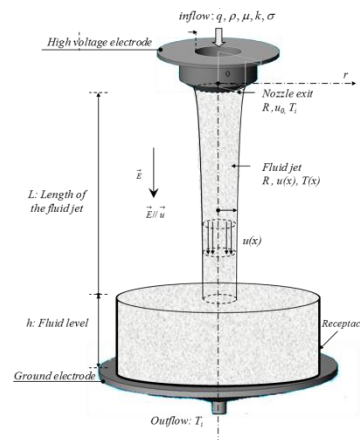
⇒ Investigations in order to quantify momentum/heat/mass transfers in food process equipments (Tubular and Plate heat exchangers, Ohmic heaters, Stirred vessels...)



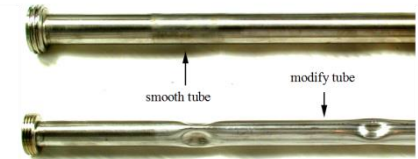
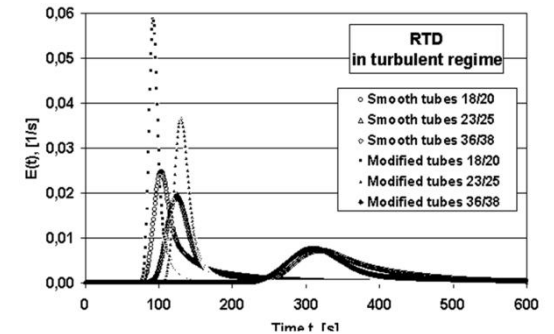
Heat transfer coefficient



Shear rate distribution



Thermal profile

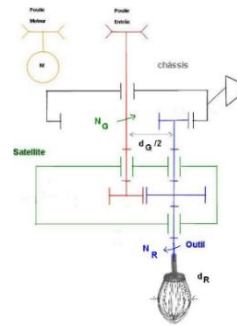
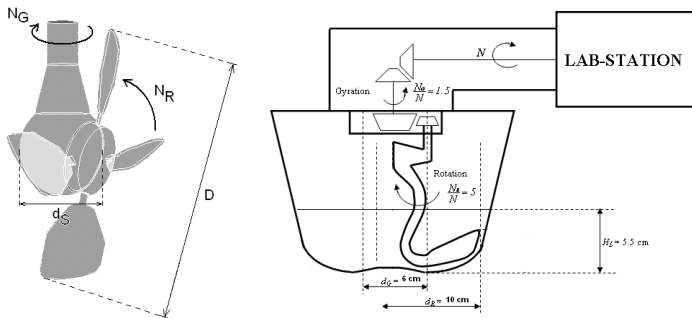


Residence time distribution

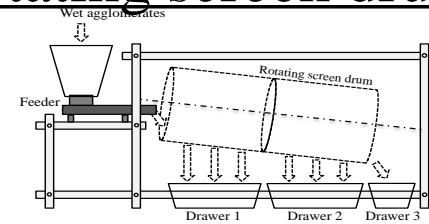
5. Typical projects carried out

⇒ Models in order to establish a link between the outputs of the system and operating conditions

Planetary mixers



Rotating screen drums



Influence of tilt angle, flow rate, rotational speed on agglomeration/separation

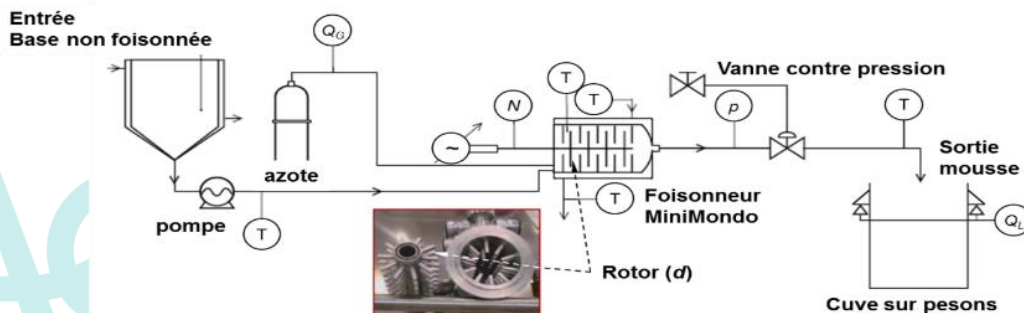
Bellocq et al., J of food eng. 2017

Influence of the combination of motions allowed by the impeller on the mixing time

Delaplace et al., Exp. In Fluids 2004; AIChE J. 2005; Chem. Eng. Sci. 2007; J. of food Eng. 2012,2013; Chem. Eng. J. 2012; Powder tech. 2015

Continuous rotor-stator mixer

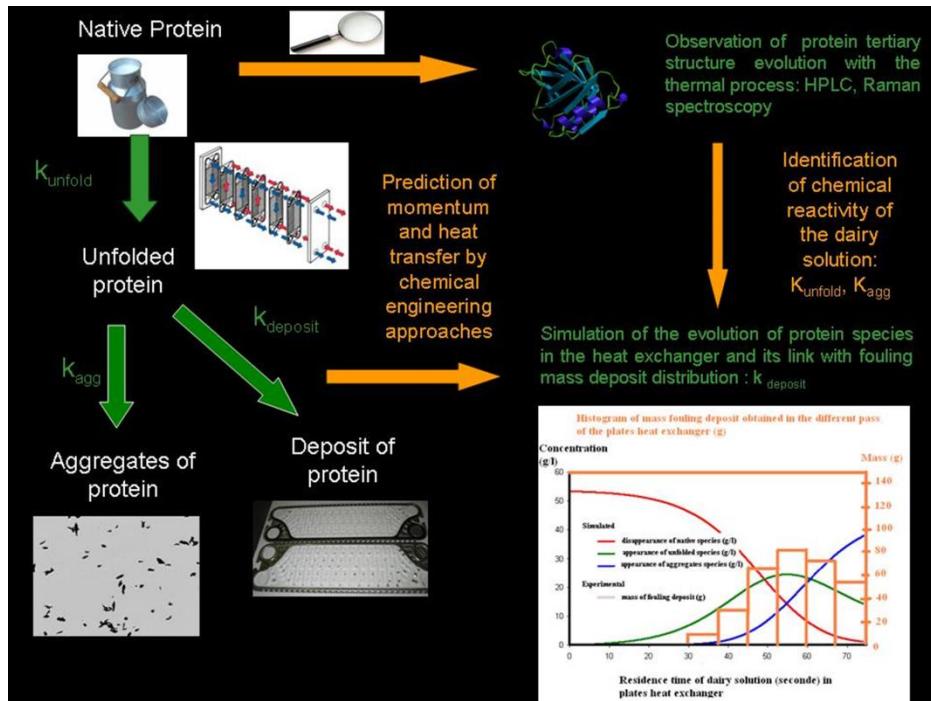
Influence on flow rate, pressure, rotational speed on foaming ability



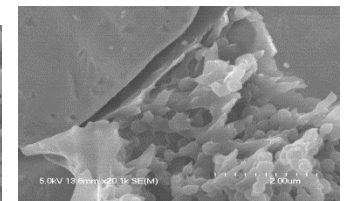
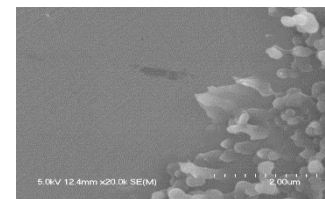
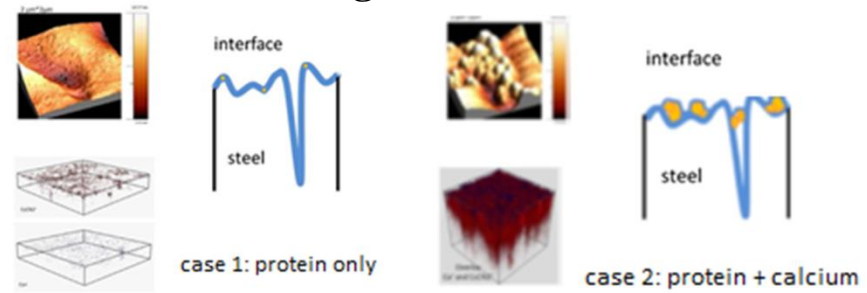
Mary et al. Chem Eng Res. AndDes. 2013

5. Typical projects carried out

⇒ Investigations in order to understand destabilizing phenomena and **fouling kinetics of whey protein solutions onto various surfaces of process equipment**



Role of soil/wall surface interaction in fouling growth

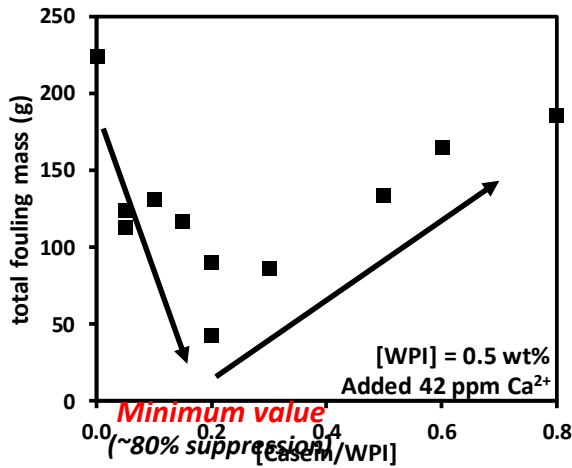


Population balance 1D or 2D induced by temperature profiles and corresponding fouling deposit mass

5. Typical projects carried out

⇒ Investigations in order to understand destabilizing phenomena and fouling kinetics of whey protein solutions onto various surfaces of process equipment

Role of caseins in Fouling

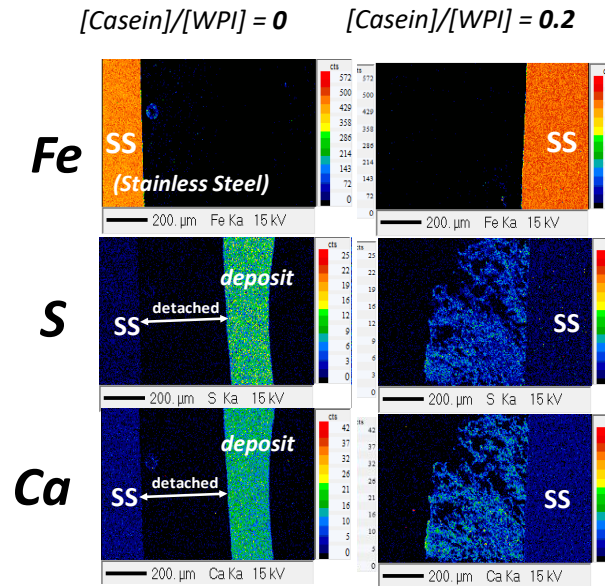


[Caseine/WPI] influences Deposit mass



Liu, W., et., al. (2021). Journal of Food Engineering **289**, 110175

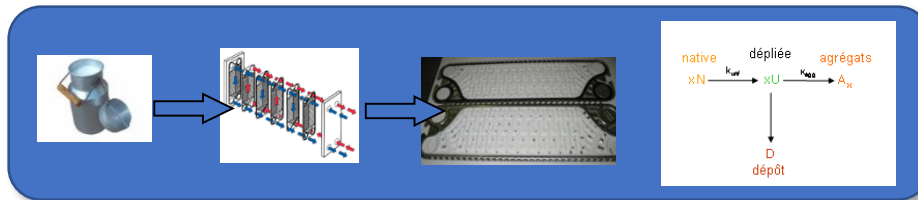
Fouling layer composition



[Caseine/WPI] affects structure and dynamics

5. Typical projects carried out

⇒ Development of Fouling deposit mass models for Whey protein solutions ?



Mecanistic models

Empirical models based on dimensional analysis

⇒ calcium content as inlet variable (*Khaldi et al., J. of Food Eng. 2015*) as

⇒ Denaturation constant as inlet variable (*Petit et al., J. of Food Eng. 2013*),

=> for given WPI solutions

(*Gu et al., Food control 2019*)=> for various WPI solutions

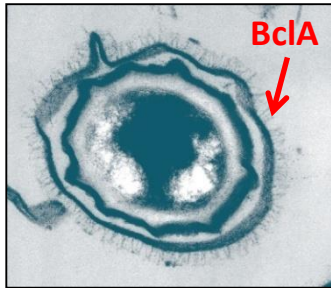
=> Mechanistic model based on CFD simulations describing denaturation reactions => for given WPI solutions (*Bouvier et al., J. of Food Eng. 2014*)

=> Mechanistic model coupled with IA (collaboration with Imperial college of London)

(*Wilfred Kwabena Darko et al., Proc 31 st EUROPEAN SYMPOSIUM ON COMPUTER AIDED PROCESS ENGINEERING, 2021*)

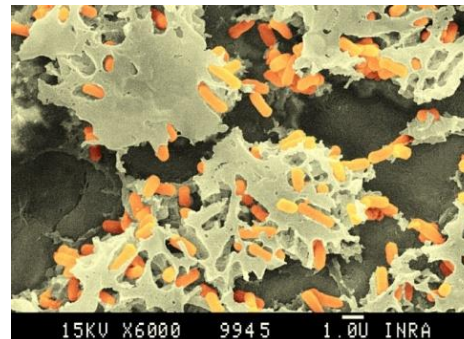
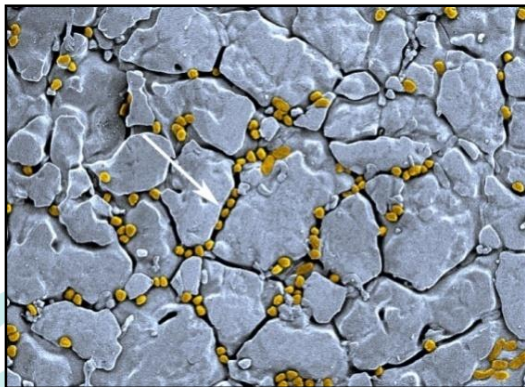
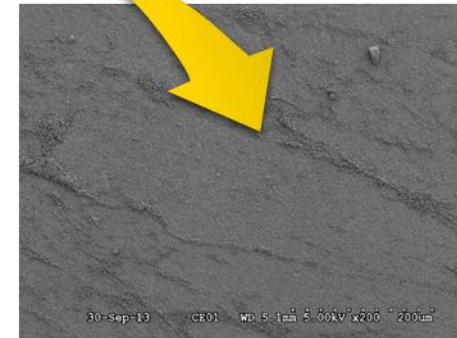
5. Typical projects carried out

⇒ Investigations in order to understand **adhesion of spores & food bacteria and biofilm formation**



Role Played by exosporium glycoproteins in the surface properties of Bacillus cereus spores and in their adhesion to stainless steel

Biofilms grown under static / dynamic conditions

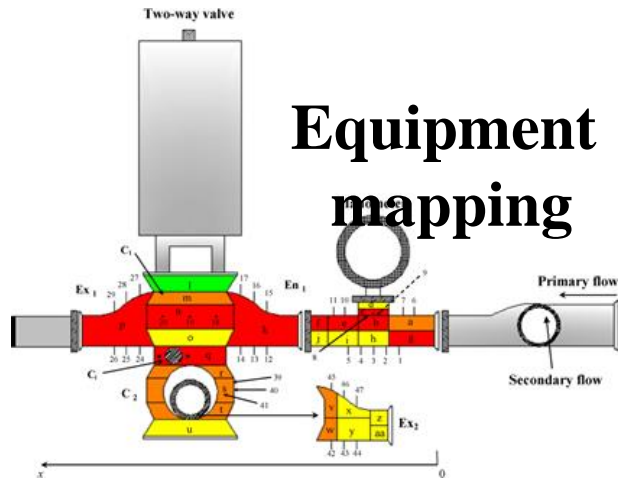


Sporulation of Bacillus spp. within biofilms: A potential source of contamination in food processing environments

5. Typical projects carried out

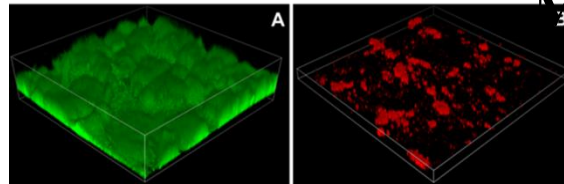
⇒ Investigations in order to understand **cleaning/disinfection mechanisms and hygienic design**

Equipment mapping

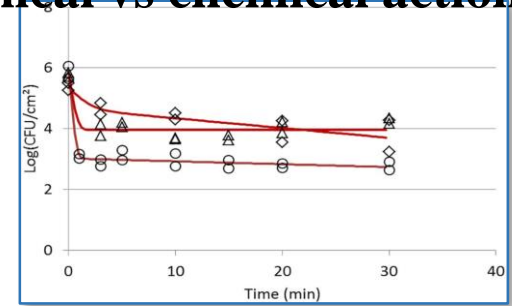


Detachment mechanisms

Mechanical vs chemical actions

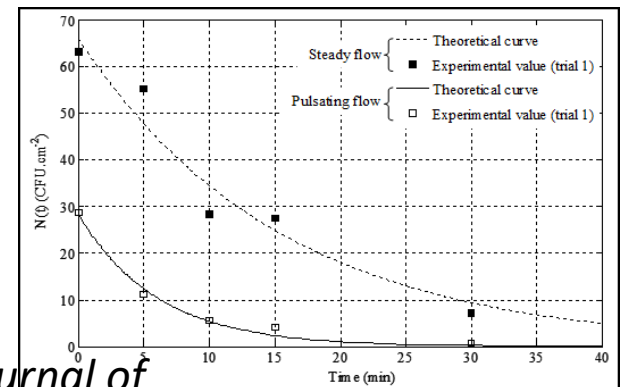
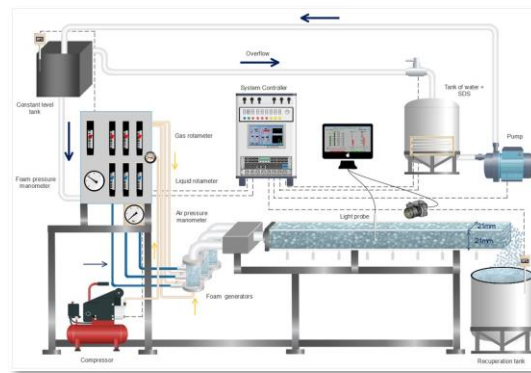


Biofilms grown at 20°C on stainless steel before A) and after B) exposition to P2 disinfectant.

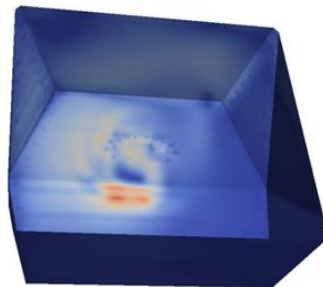


Steady flow vs pulsed flow

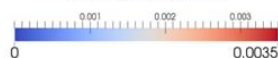
Foam cleaning



[Ahmad Al Saabi et al. \(2021\). Journal of Food Engineering, 110273](#)



Wall shear stress (mPa)

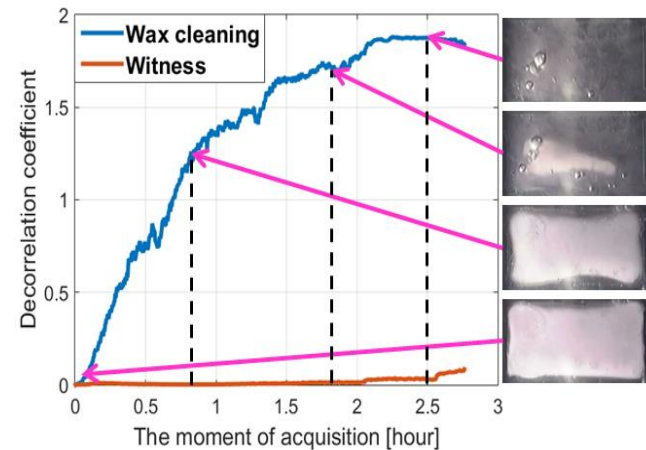
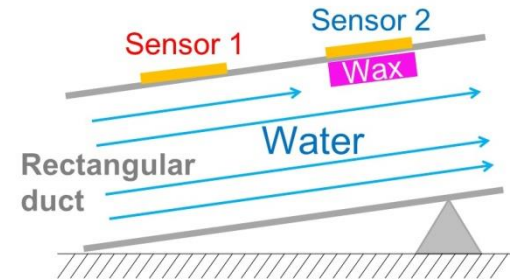
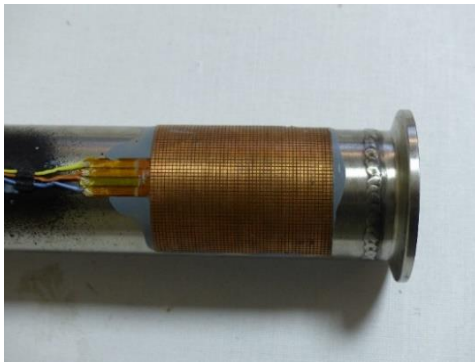


5. Typical projects carried out

PIHM's team of INRAE in UMET: presentation

⇒ **Development of sensors and software respectively**

i) to monitor food structure change under real-time conditions ii) to follow fouling rate and adhesion level of a deposit onto surface

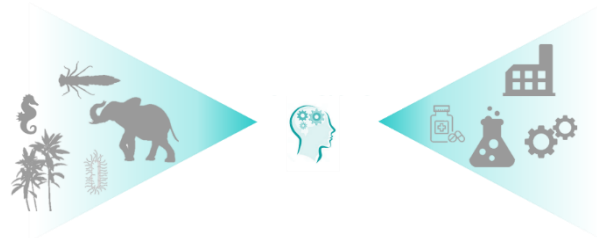


L. Bouvier, G Delaplace, S Lalot. Continuous Monitoring of Whey Protein Fouling Using a Nonintrusive Sensor, *Heat Transfer Engineering Journal*, vol 41 1-26 (2020),

Phd B. Chen, 2019
B. Chen, D. Callens, P. Campistron, E. Moulin, P. Debreyne, G. Delaplace, Monitoring cleaning cycles of fouled channel by ultrasonic Coda Wave Interferometry (CWI) (*Ultrasonics* 2018)

5. Typical projects carried out

⇒ Elaborating surfaces with antifouling & hygienic properties



Biomimetic surfaces for fouling control



Slippery liquid infused surfaces

Smooth and hydrophobic

Zouaghi et al. (2017) ACS Applied Materials and Interfaces.



Silane-based coatings by plasma spraying

Nanotextured and hydrophobic

Zouaghi et al. (2018) Applied Surface Science.



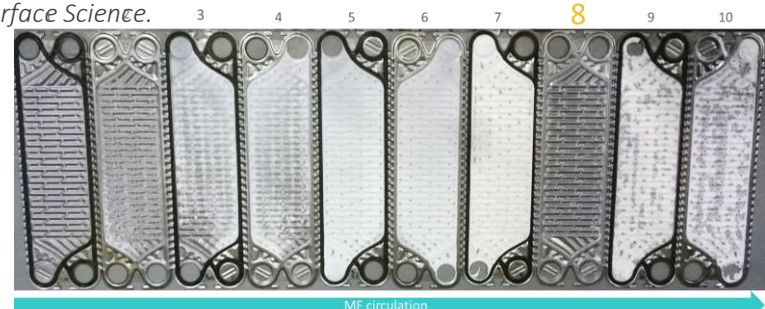
Amphiphilic smart coatings

Superhydrophilic

No fouling for 5 consecutive pasteurization cycles

Conclusive test on real heat transfer surface

• **S. Zouaghi**
Hygienic Study Award
As PhD thesis 2018
Nov. 2018, London
EHEDG World Congress



Zouaghi et al. (2019) Biofouling.



6. Main and current projects

- **Veg-i-tech Projet INTERREG** - Mise en réseau transfrontalier de centres techniques et de compétences pour une recherche appliquée et le développement de méthodes de transformation / nettoyage des légumes et des pommes de terre ; **janv 2018-2022**; **coord. Française T. Benezech**



- **ECONOMICS ANR Grand défis 2017** - Elaboration de surfaces et matériaux aux propriétés anti-encrassantes (au lait et œufs) et résistants aux procédures de nettoyage; **avr. 2018-avril 2022**;

coord. M. Jimenez



- **SOCORRO2 Projet INTERREG** - Seeking out corrosion - before it is too late **Mai 2022-2024**; **Coordination Antwerpen Univ, 16 Partenaires G. Delaplace**



- **FEFS ANR Grand défis 2018** - Dessiccation des souillures bactériennes dans les agro-industries et ses conséquences sur leur résistance au nettoyage; **Mars 2019-2023** ; **C Faille (WP leader)**; IEMN (coordination);

6. New accepted and starting projects

- **FAIRCHAIN Projet H2020 2021-2025;** - Innovative technological, social and organisational solutions for a FAIRer distribution among actors of the agri-food value CHAIN; Partenaires T. benezech coord. Genevieve Gezan-Guiziou
- **SOGLOSSI ANR JCJC “Seeking Out GLycans of B. subtilis mOdulating Spore - Surface Interactions to make food industries more sustainable ” coord. T Dubois 48 mois (2022-2026)**



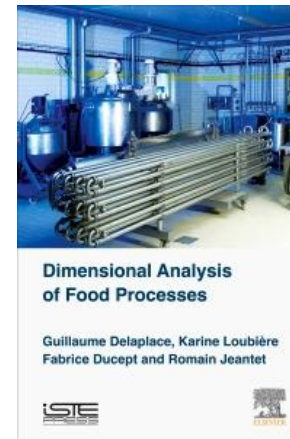
- **ProteinoPeps ANR Chaire industrielle “Seeking Out GLycans of B. subtilis mOdulating Spore - Surface Interactions to make food industries more sustainable ” coord. G Delaplace Partenaire R Ravellec (2022-2026)**

BioEcoAgro



6. PIHM: a team which carried out both applied and academic research on food processing and hygiene

- Writing educational Books



- Organizing conferences Fouling and Cleaning in Food Processing 2022: Sustainability and shifting to a circular economy 28th-30th March Université de Lille, France

<https://fcfp2022.symposium.inrae.fr/>



➤ Thank you for your attention

