

# **GREEN Extraction Team**

**G**roupe de **R**echerche en  
**E**co **E**xtraction des produits **N**aturels

**BILAN 2016-2022**



**Co-animation Farid CHEMAT - Anne-Sylvie TIXIER - Maryline VIAN**

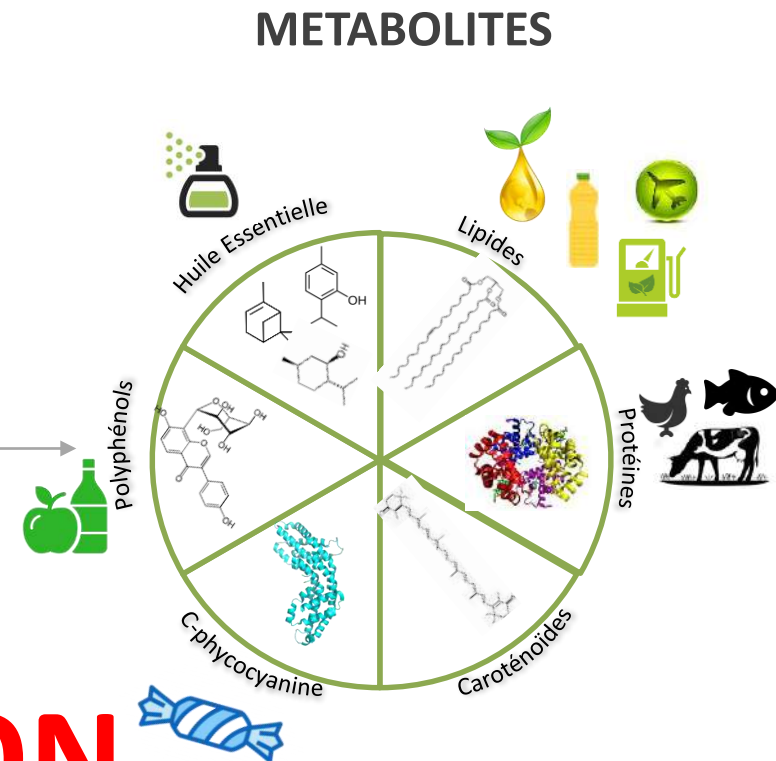
**4 EC HDR** Sandrine Perino - Anne-Sylvie TIXIER - Maryline VIAN & Farid CHEMAT – 1 IE K. ruiz) – 1 AI E. Petitcolas)

**6 Post Docs (FUI - ANR+ Industriels) + 3 Post Doc 2.0**

**10 Thésards (ANR – Region – Cotutelle - CIFREs (Tous insérés PRO (J+3mois) – Givaudan (4) et Pennakem (4) CELABOR (BL) – ALGAMA...**

# Vers une chimie verte 2.0 - sans pétrole - grâce aux bio-ressources

## BIORESSOURCE(S)



## ECO - EXTRACTION

# RESEARCH THEMES

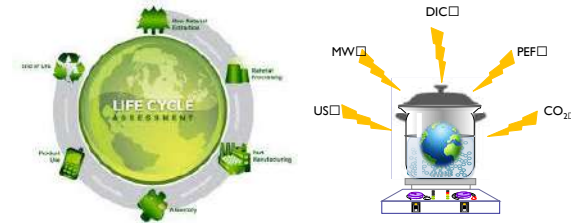
## ALTERNATIVE SOLVENTS FOR EXTRACTION OF NATURAL PRODUCTS AND FOOD INGREDIENTS *(Dr HDR Vian)*

- ⇒ Prediction of Solvent-Solute interaction
- ⇒ Combination with intensification techniques
- ⇒ Synthesis of new bio-based solvents



## GREEN EXTRACTION, TOOLS FOR SUSTAINABILITY *(Dr HDR Tixier)*

- ⇒ Intensification techniques, drivers for extraction
- ⇒ Life Cycle Assessment
- ⇒ Databases for solvent selection, Extractothèque



## PROCESS INTENSIFICATION : SCALE-UP, QUALITY, AND SAFETY CONSIDERATIONS *(Dr HDR Perino)*

- ⇒ Scale-up and Scale-Down
- ⇒ HACCP (Hazard Analysis and Critical Control Point)
- ⇒ HAZOP (Hazard Analysis and Operability)



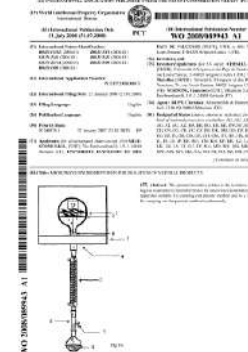
# EQUIPEMENT REALISATION : Examples

Overcoming technology limitations by creating devices for our research and education



From primary school  
to Master degree

**SOCIETE** Legallais  
Fournitures pour laboratoires



**MILESTONE**  
HELPING  
CHEMISTS



# SPECIFIC EQUIPEMENTS

## Green Extraction of Natural Products

### Ultrasound Extraction Reactors

Lab reactors  
 Hielscher UIP 1000 (20kHz, 1000W) 1 L or 40 L per h  
 REUS (25 kHz, 200 W, 3 L)

Pilot Plant  
 Hielscher (20kHz, 4000W) 1000 L per h  
 REUS (25 kHz, 800 W) 30 L

### Microwave Extraction Reactors

Lab reactors

Pilot Plant

NEOS-GR

### Green Solvents

Solvent free extraction

Green solvent  
H<sub>2</sub>O

Supercritical fluid  
CO<sub>2</sub>

Natural solvent  
Vegetable oil  
Alcohol

Eco-solvent  
Glycerol,  
Limonene

Petroleum sourced  
volatile organic solvent  
Methanol, Hexane

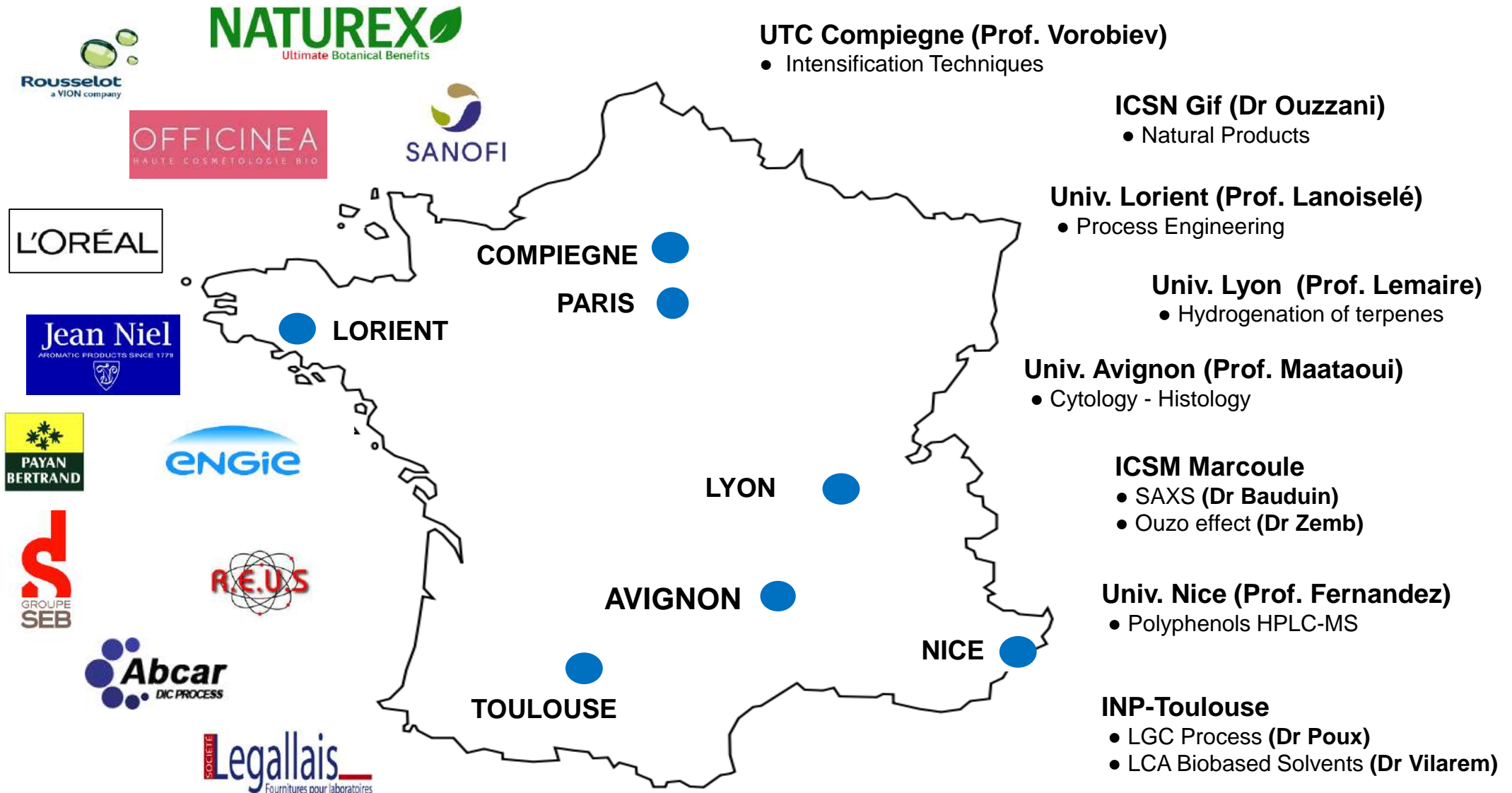
**COSMOthermX**  
 Version C39\_1301  
 ©2012 COSMOlogic GmbH & Co. KG

**COSMOlogic** GmbH & Co. KG  
 Chemische Technologie und Pilot-Pharmazie

### Compressed Fluid as Green Solvents

# NATIONAL COLLABORATIONS

## INDUSTRY and ACADEMIA



# INTERNATIONAL COLLABORATIONS

## ACADEMIA and INDUSTRY



Prof. Strube  
Germany



UNIVERSITÀ  
DEGLI STUDI  
DI TORINO

Prof. Cravotto  
Italy



**MILESTONE**

H E L P I N G  
C H E M I S T S



Prof. Ashokmar  
Australia



Prof. Meireles  
Brasil



暨南大學  
JINAN UNIVERSITY

Dr Li  
China



Prof.  
Touabia  
Canada



Prof. Ksouri  
Tunisie



Prof. Pharkphoom  
Thailand



Prof. Meklati  
Algeria



Prof. Farah  
Marocco

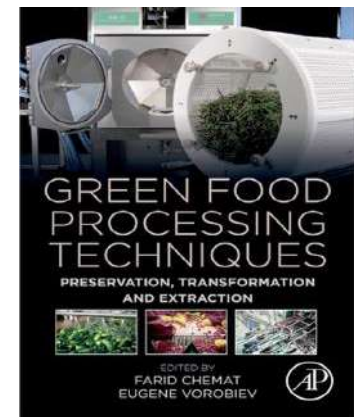


Firmenich



# HIGHLIGHTS 2016-2022

**5** Books  
**100** Articles  
**20** Plenary Conf.  
**20** Patents (10 Licences)  
**5** Projects (ANR, FUI, EU)  
**12** Industrial Projects



**High Cited Researcher 2018-2022**  
**Agricultural Sciences**





# Green Extraction ANALYSIS: TECHNOLOGY READINESS LEVEL?

Academia

Platforms

Manufacturers

INDUSTRY

Knowledge Development

Technology Development

Business Development

TRL1

TRL2

TRL3

TRL4

TRL5

TRL6

TRL7

TRL8

TRL9

Basic technology research

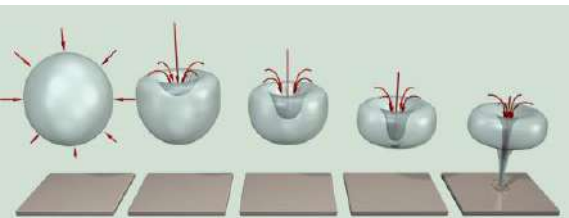
Research to prove feasibility

Technology demonstration

Technology development and prototypes

Pilot plan and scale up

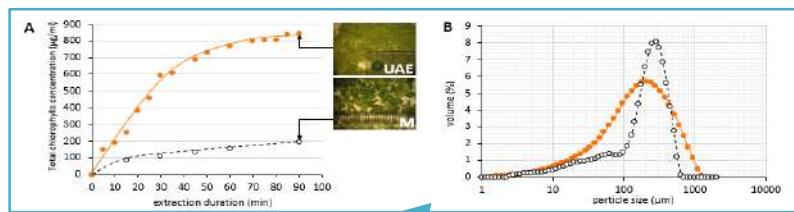
Market launch and commercialisation





**Exemple 1**  
**Ultrasound Technology**  
**from Fondamental research**  
**to Industrial Applications**

# Towards understanding ultrasound impacts on vegetal tissues



fragmentation

US impact on a material

biological material

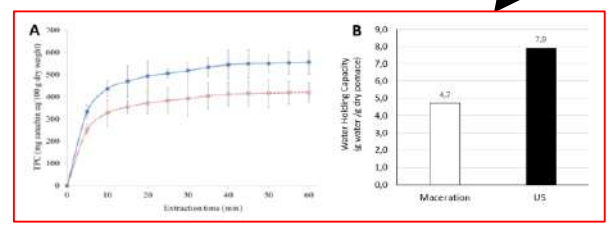
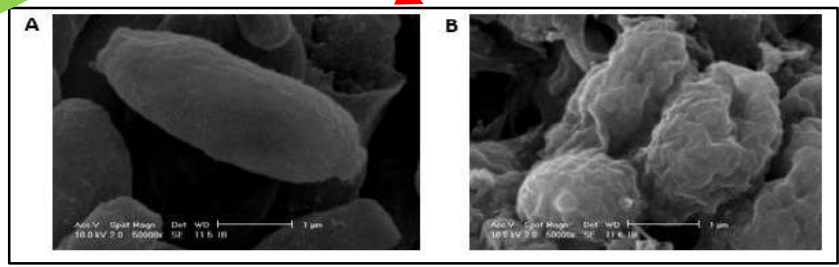
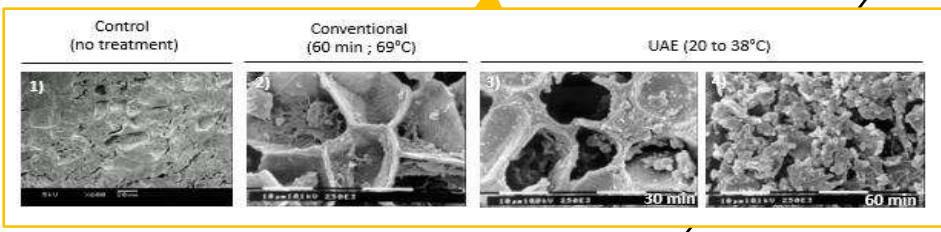
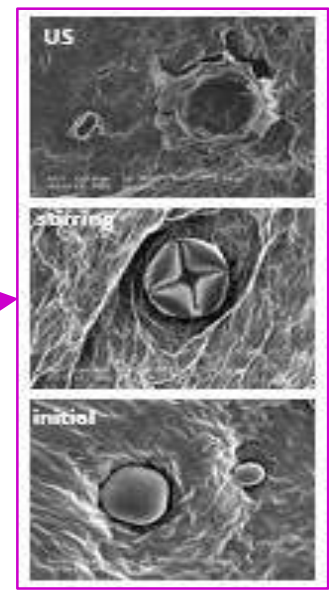
local shear effects

erosion

destruction

sonoporation

sono-capillarity



Ultrasonics Sonochemistry 18 (2011) 813–835

Contents lists available at ScienceDirect

**Ultrasonics Sonochemistry**

journal homepage: [www.elsevier.com/locate/ultsonch](http://www.elsevier.com/locate/ultsonch)




Applications of ultrasound in food technology: Processing, preservation and extraction

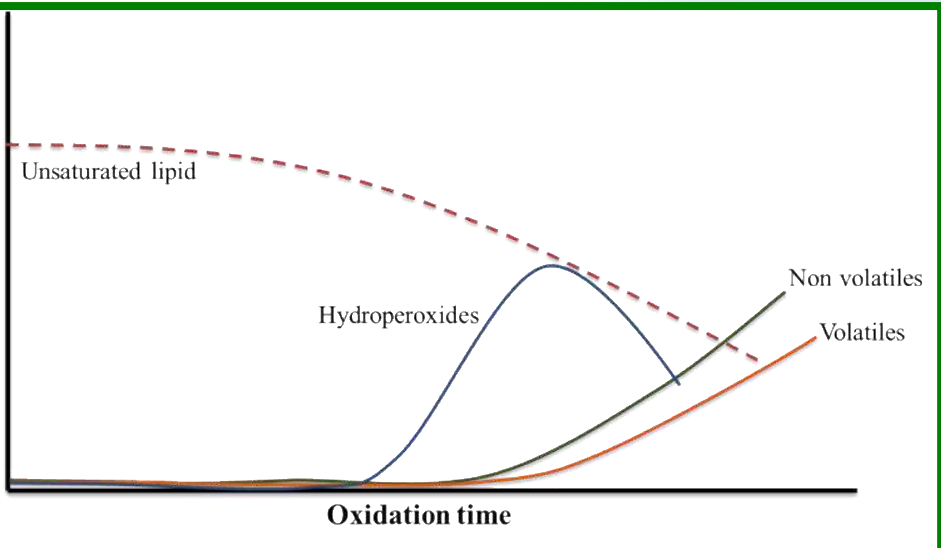
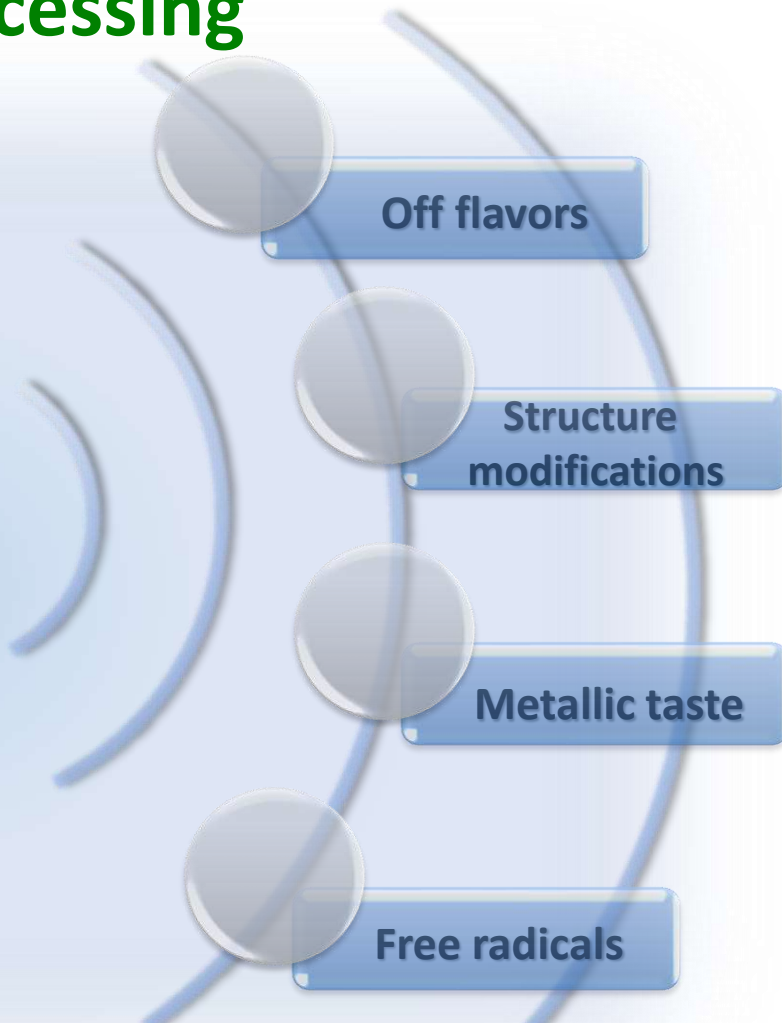
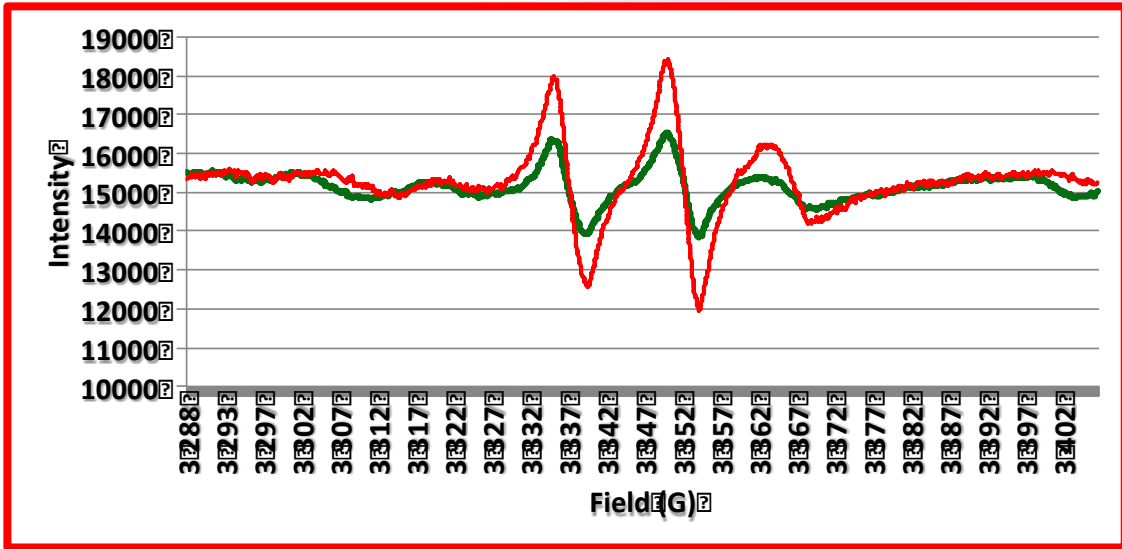
Farid Chemat\*, Zill-e-Huma, Muhammed Kamran Khan

Université d'Avignon et des Pays de Vaucluse, INRA, UMR408, Sécurité et Qualité des Produits d'Origine Végétale, F-84000 Avignon

Cited: 1500 times

# Degradations during ultrasound food processing

## Electron paramagnetic resonance (EPR)



Food Control 31 (2013) 593–606

Contents lists available at SciVerse ScienceDirect

**Food Control**

journal homepage: [www.elsevier.com/locate/foodcont](http://www.elsevier.com/locate/foodcont)

ELSEVIER

CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL

Review

Degradation during application of ultrasound in food processing:  
A review

Daniella Pingret, Anne-Sylvie Fabiano-Tixier\*, Farid Chemat

Cited: 150 times



# Ultrasound extraction of Nutraceutical and Pharmaceuticals

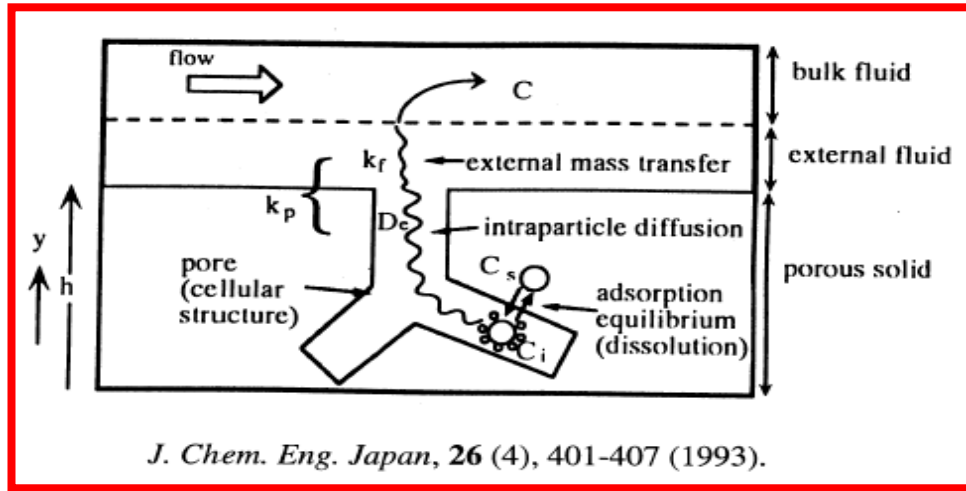




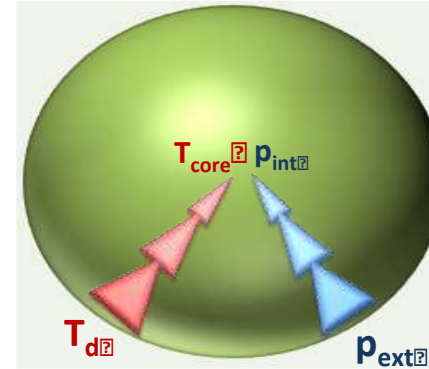
**Exemple 2**  
**Microwave Technology**  
**from Fondamental research**  
**to Industrial Applications**

# Solid-liquid Extraction Process

## Mechanism(s): Which Transfer mode ?

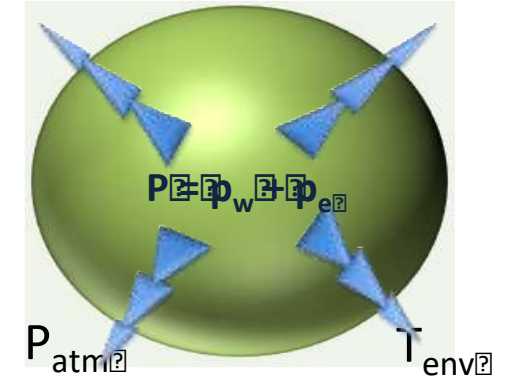


What we have



Fick Transfer

What we want



DARCY Transfer

Mass transfer

2 main transfer: convective and diffusion ; in extraction, mass transfer is predominantly ruled by molecular diffusion/ 2<sup>nd</sup>e Fick's law

$$\frac{\partial X}{\partial t} = -D_x \nabla^2 X$$

Heat transfer

Impacts on the matrix and rate of extraction/ Fourier's law

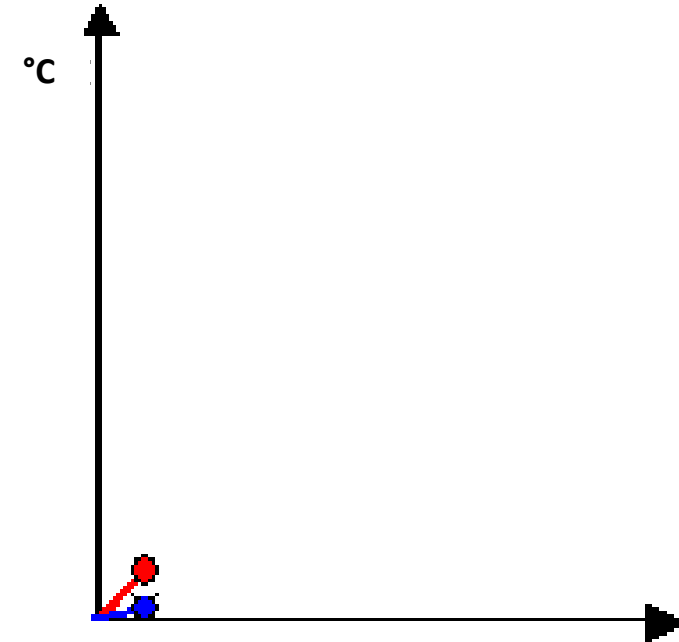
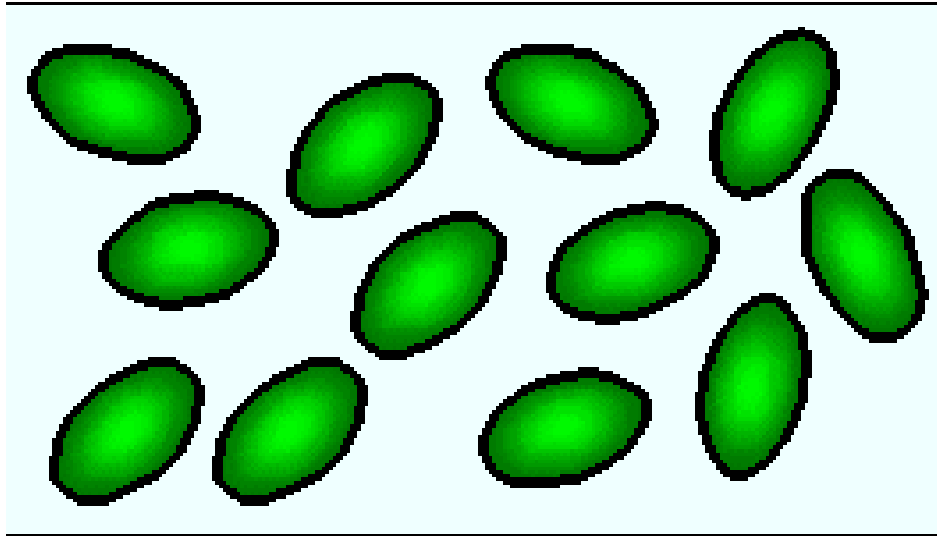
Momentum transfer

Taking into account the media's rheology and momentum (mixing...) brought to the extraction media / application of Newton's and Darcy's Law

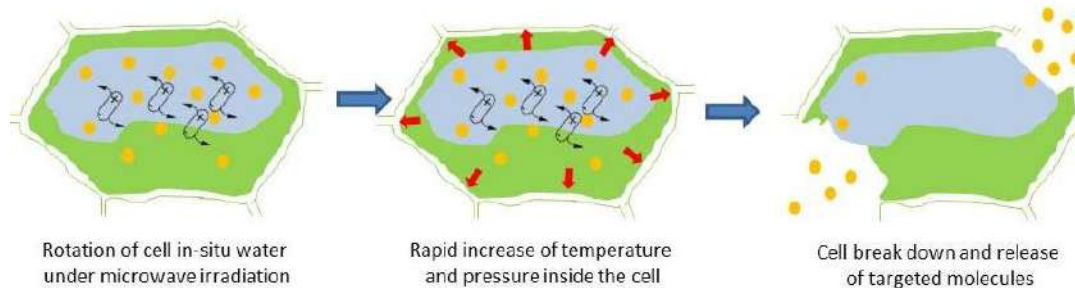
# SELECTIVE MICROWAVE HEATING OF NATURAL PRODUCTS



## EXTRACTION IN A MW-TRANSPARENT SOLVENT (Vegetable Oil)



### WHAT HAPPENS?



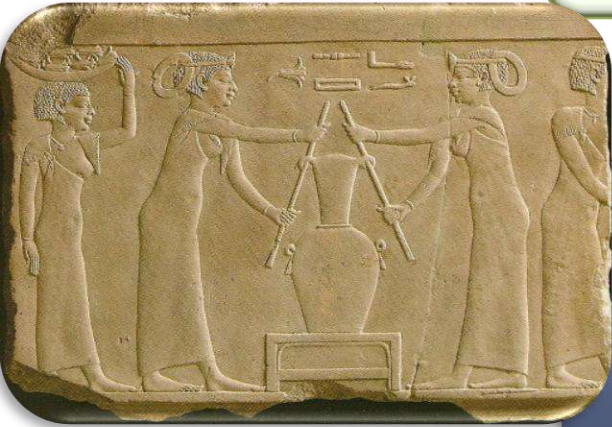
Time sec.





# Industrial Success Stories

## Microwave Extraction



# **GREEN Extraction Projects**

**2024-2029**

Présentation de pré-dépôt de dossier de candidature 2020

Appel à Projet Démonstrateur : BIOENV

# Projet EcoXtract Protéines

Démonstrateur de l'utilisation du solvant biosourcé  
EcoXtract® pour l'extraction de graines oléoprotéagineuses  
et substrats biologiques



**Document confidentiel**

**Projet ADEME 2022-2029**

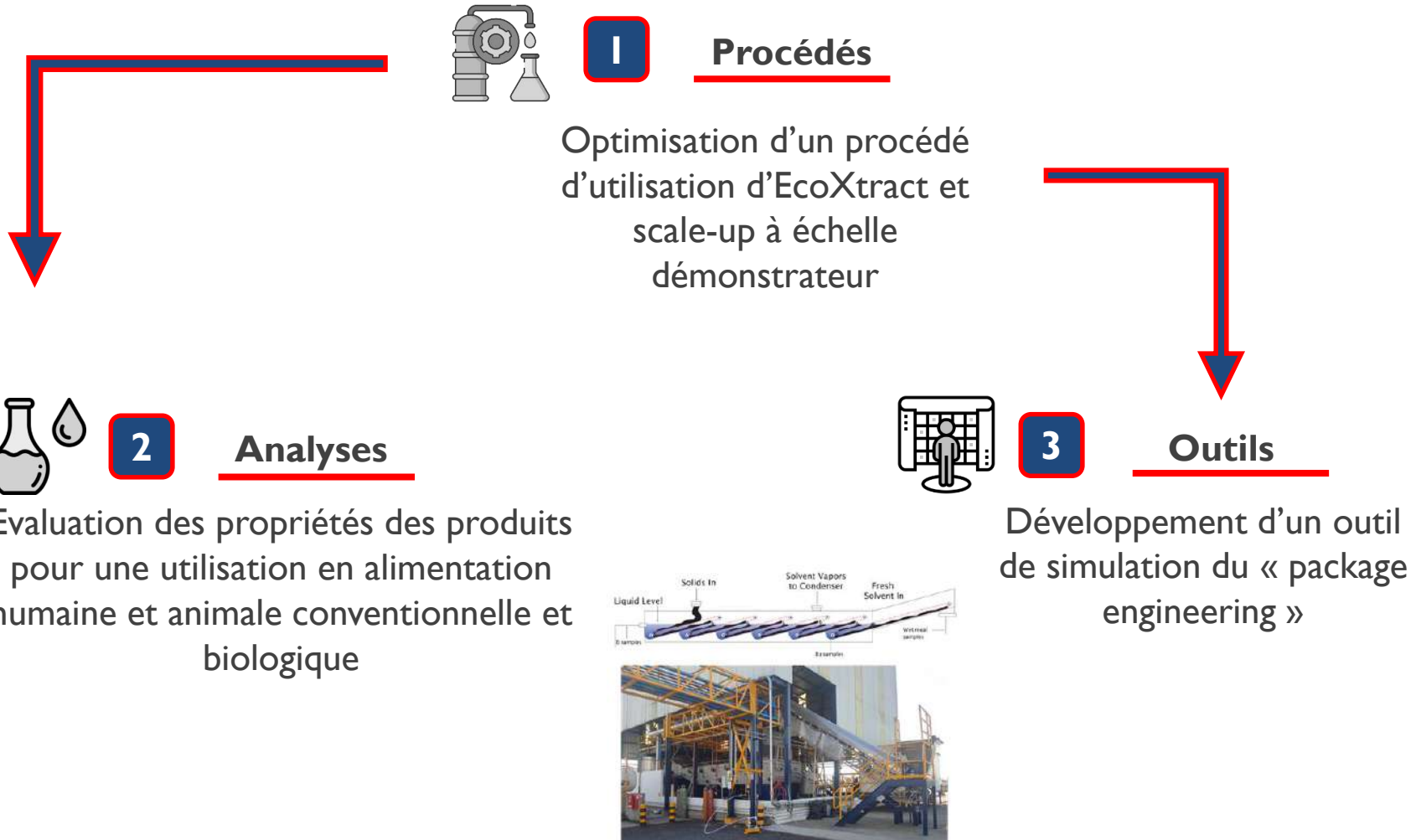
# Projet ECOXTRACT® Protéines

<b>Coordinateur</b>	<b>Objectif du projet</b>	<ul style="list-style-type: none"><li>■ Mise au point et validation d'un procédé d'extraction de tourteaux, isolats protéiques et huiles à partir d'un solvant biosourcé, EcoXtract®</li><li>■ Valorisation des produits et co-produits d'extraction obtenus à partir d'EcoXtract®</li></ul>
<ul style="list-style-type: none"><li>■ PENNAKEM EUROPA (ETI)</li></ul>	<b>Éléments clés</b>	<ul style="list-style-type: none"><li>■ Coût total : environ 9 600 k€</li><li>■ Durée : 42 mois</li><li>■ Localisations projet : Avignon, Dunkerque, sites de l'INRAE</li><li>■ Location industrialisation : Bordeaux</li></ul>
<b>Partenaires (Max 4)</b>	<b>Solutions</b>	<p><b>Solutions développées dans le cadre du projet :</b></p> <ul style="list-style-type: none"><li>■ Procédé éco-efficient d'extraction des oléo-protéagineux à échelle démonstrateur et process book pour l'utilisation industrielle</li><li>■ Produits de l'extraction validés sur les marchés du food et du feed conventionnels et biologiques</li></ul> <p><b>Produits commercialisés à l'issue du projet :</b></p> <ul style="list-style-type: none"><li>■ Protéines et huiles végétales pour le Feed et le Food conventionnel et biologiques ainsi que pour les produits cosmétiques</li><li>■ Package engineering à destination des industriels utilisateurs d'hexane pour la conversion à EcoXtract®.</li><li>■ Licences d'utilisation de la technologie d'extraction basée sur le biosolvant EcoXtract®</li></ul>
<ul style="list-style-type: none"><li>■ INRAE (LP)</li><li>■ Avignon Université (LP)</li></ul>		

Date de démarrage du projet : 01/01/2022



# 3. Solution proposée : les 3 axes de travail



# CHAIRE UNIVERSITAIRE UNESCO

## 2022-2026

