

# How will the food of future be? Nanofood: augmenting nature

Prof. Lorenzo Pastrana



International Iberian Nanotechnology Laboratory



The INL International Iberian Nanotechnology Laboratory, having its headquarters in Braga (North of Portugal) was founded 2009 by the governments of Portugal and Spain under an international legal framework to perform interdisciplinary research, deploy and communicate nanotechnology for the benefit of society.



### INL IN NUMBERS



**+400**  
Researchers



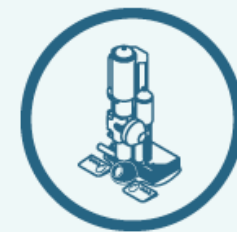
**+40**  
Nationalities



**100's**  
Collaborations with  
companies



**1000 m<sup>2</sup>**  
**State-of-the-Art**  
Cleanroom Facility



**State-of-the-Art**  
Electron Microscopy  
Imaging  
and Spectroscopy  
Facility



**State-of-the-Art**  
Nanophotonics  
Flagship Facility



**Health**

**Food & Environment**

**ICT**

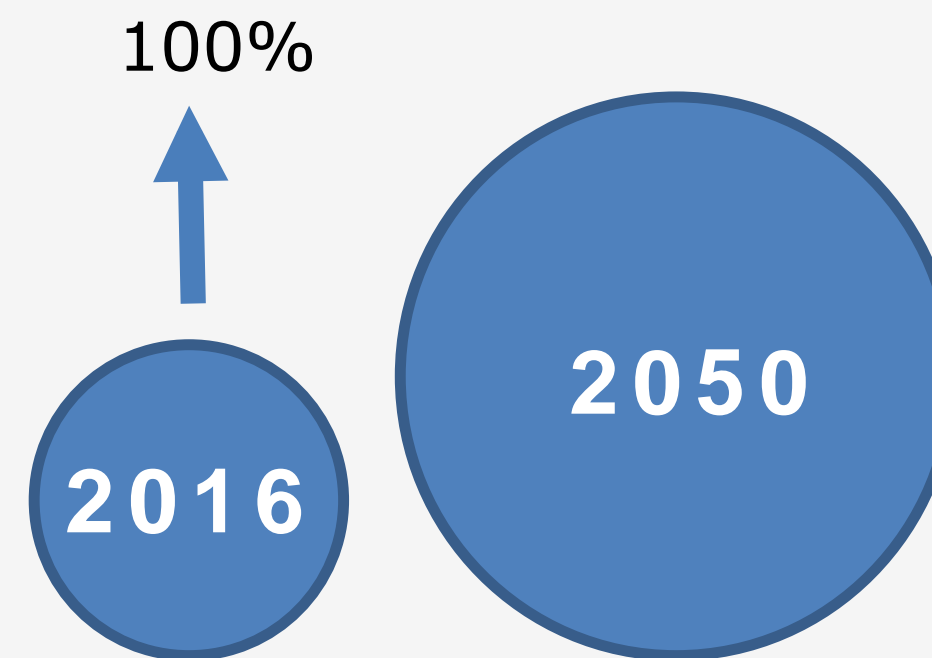
**Renewable Energy**

# Towards a new sustainable food system model

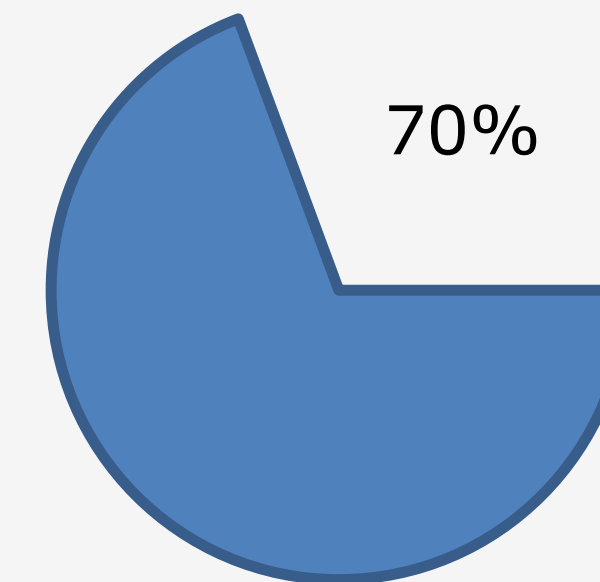
Traditional technologies have to be replaced for new disruptive technologies to face the new challenges in the food system



BY 2050  
POLULATION  
WILL REQUIRE



100% MORE FOOD



70% FOOD FORM  
MORE EFFICIENT  
TECHNOLOGIES

# In the future foods will be...

- Healthier and natural
- Sustainable
- Safer
- Tastier

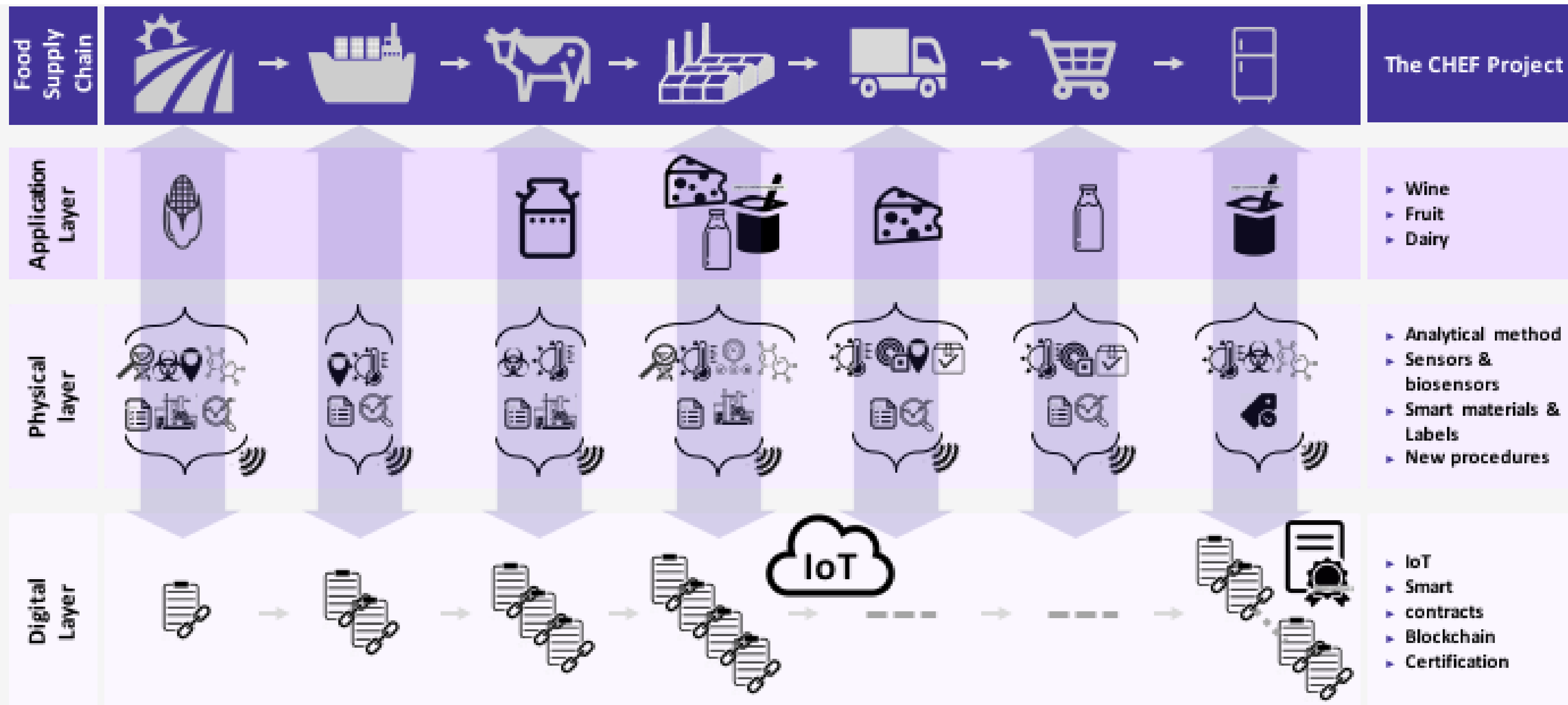
...and Nanotechnology makes it possible

# Sensorization



Blockchain

# Toward a digitalized food system



- Blockchain solutions
- IoT solutions
- Antifraud labels
- Regulatory issues and standardization
- Target and non target analytical methods
- Traceability sensors
- Biosensors based on DNA
- Sensors for allergens
- Traceability: Temperature and sensors for logistics
- Sensors for chemicals and pesticides
- Implementation of solutions
- Risk assessment & Analytical Procedures
- Minimization of risk: New processing technologies
- Minimization of risk: Active packaging

# i Grape Project

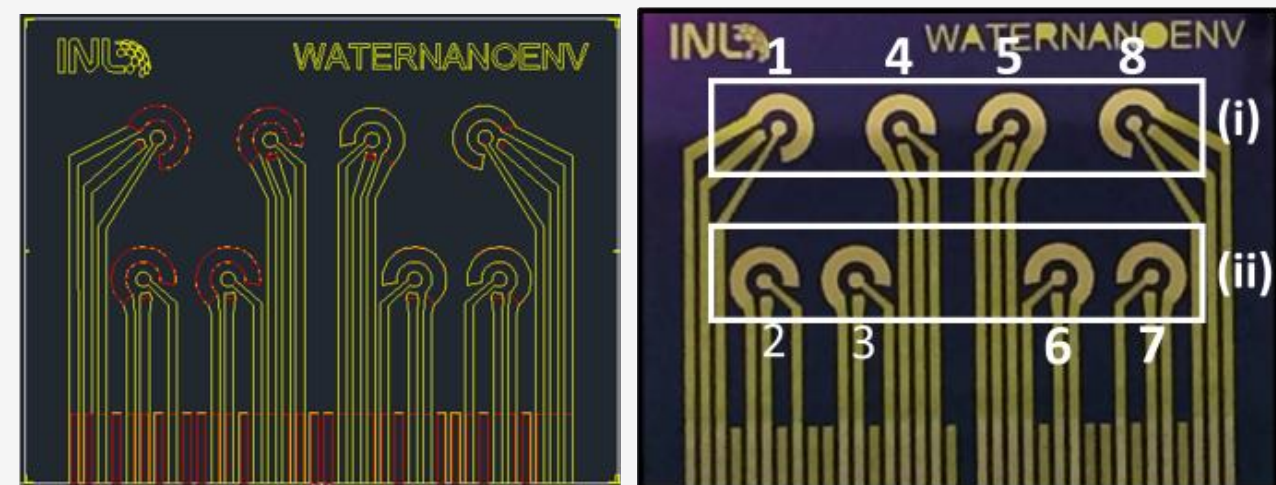
## Integrated low-Cost and Stand-Alone Micro-Optical System for Grape Maturation and Vine Hydric Stress Monitoring

It will consist of an optical detection head (flexible strip or transparent canopy) connected to the grape bunch, including power, signal pre-processing, and wireless communications. The detection head will be optically based (UV-VIS-NIR) using an integration of LED sources and photodiode/interference filter arrays at wafer level or wafer package level.



# Nanotechnology for a Safe and Sustainable use of Water Resources

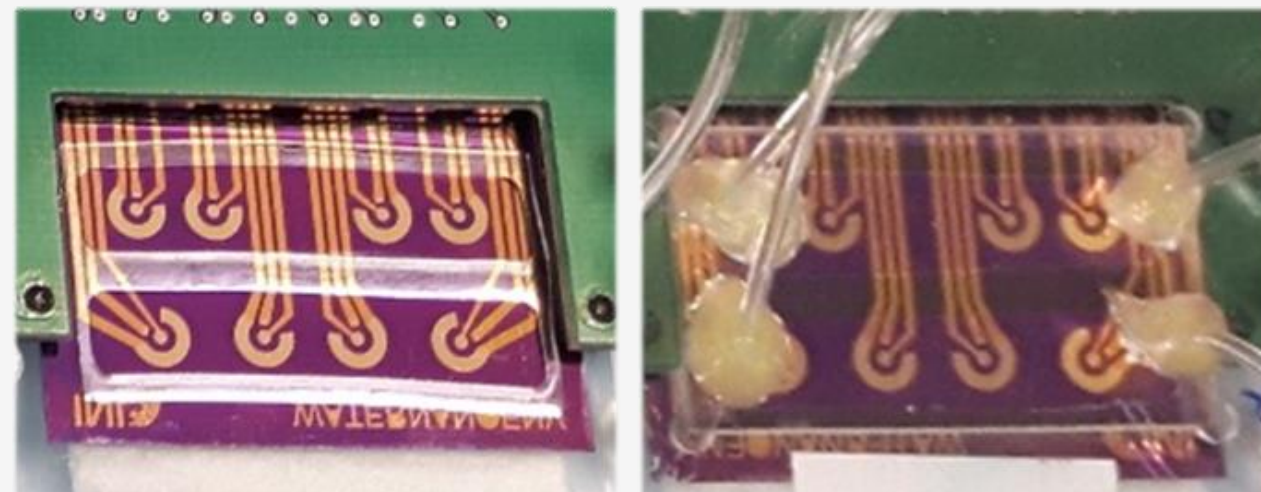
## Electrochemical sensors



Design

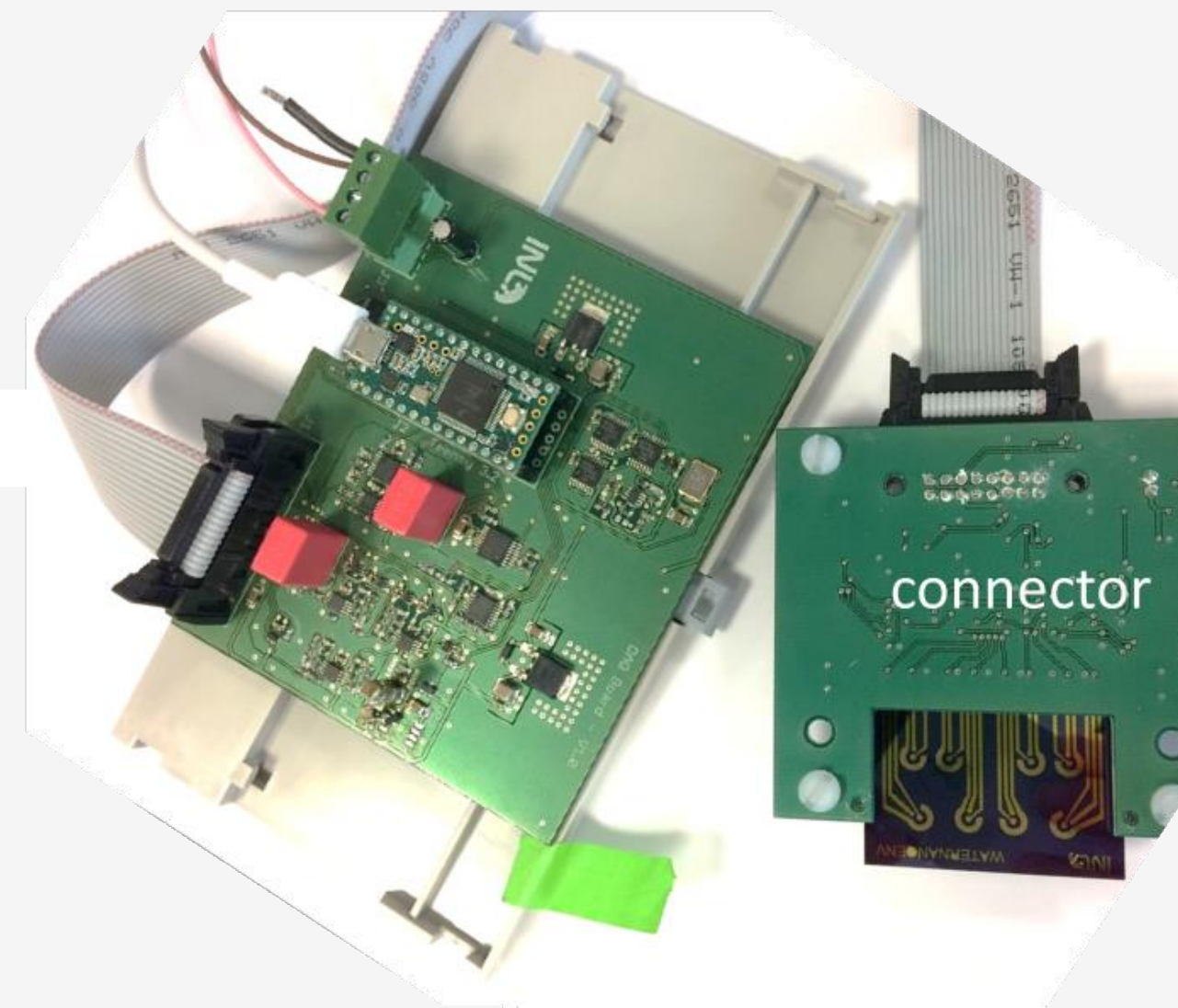
Fabricated chip (30x60mm)

## Detection system



Microfluidic reaction/measuring chambers

## Electrochemical impedance portable platform



INL INTERNATIONAL IBERIAN NANOTECHNOLOGY LABORATORY  
Systems Engineering Group

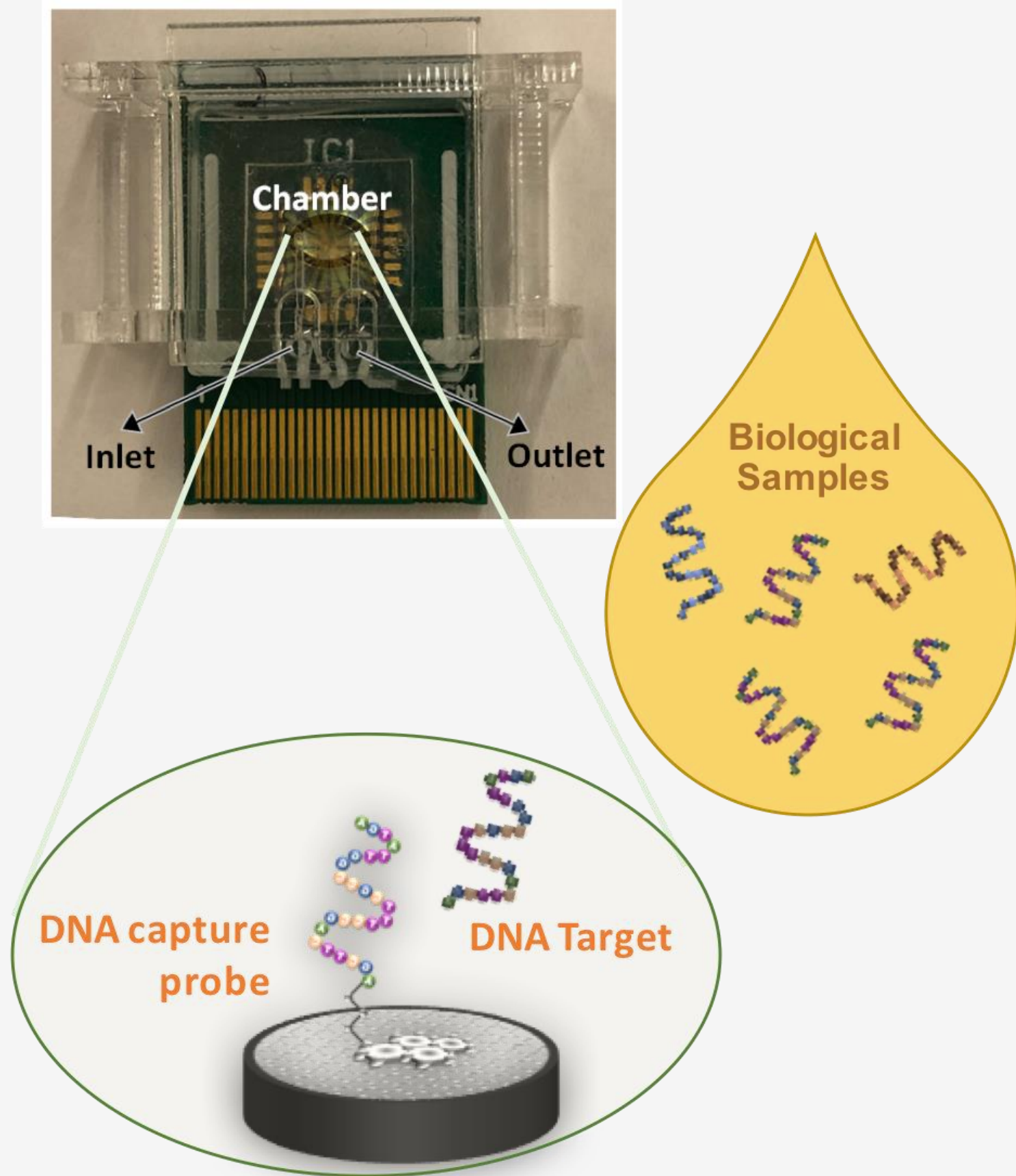


Beche's Dam ( La Coruña, Spain)

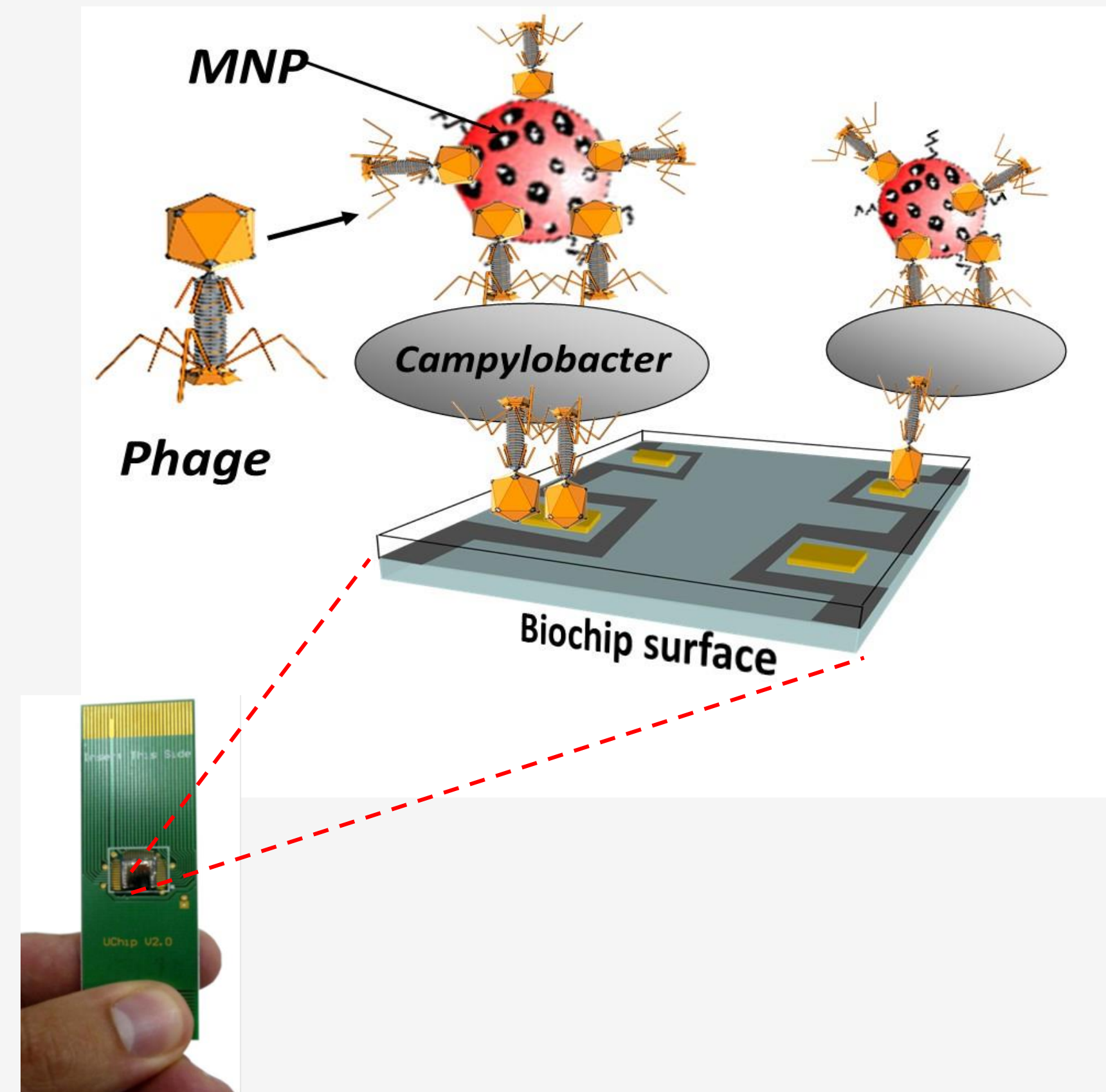


# DNA based sensors for food analysis

## Graphene biosensors



## Phage based biosensors



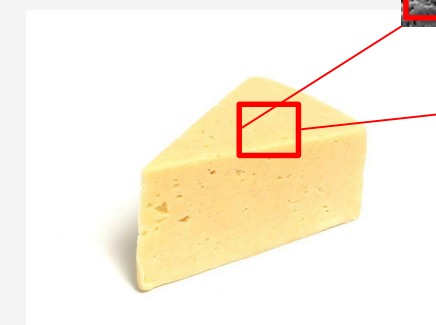
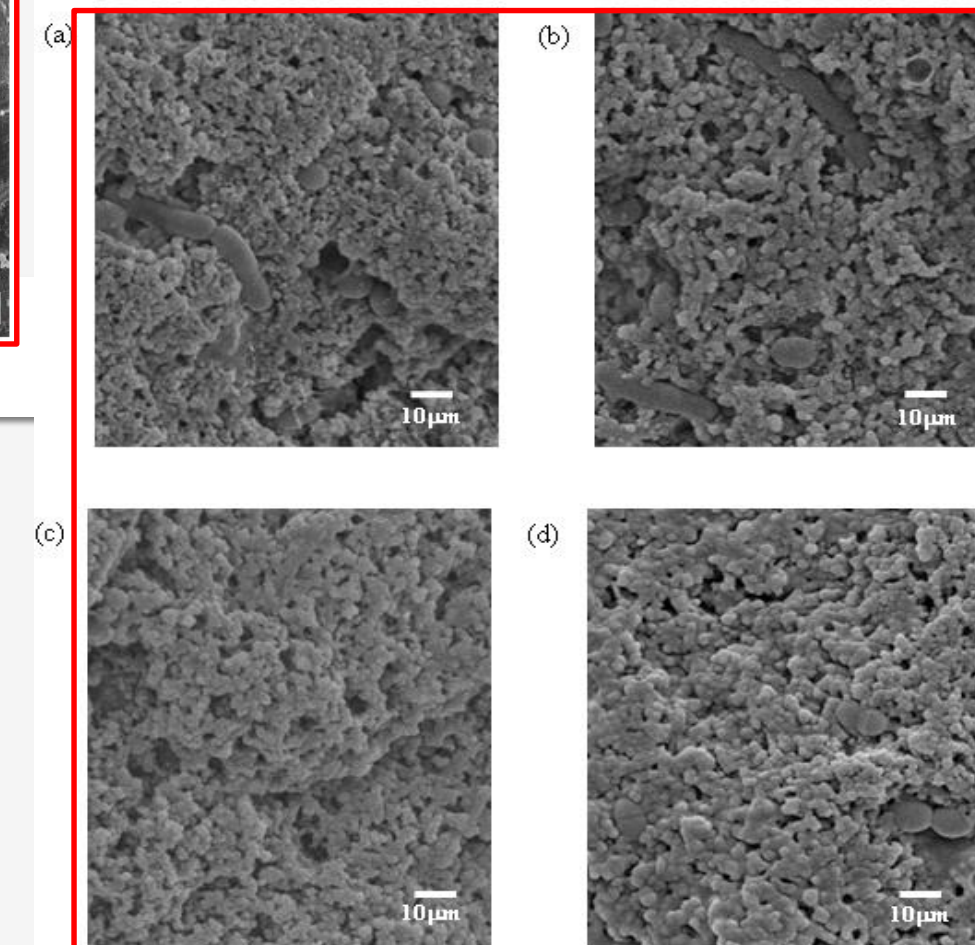
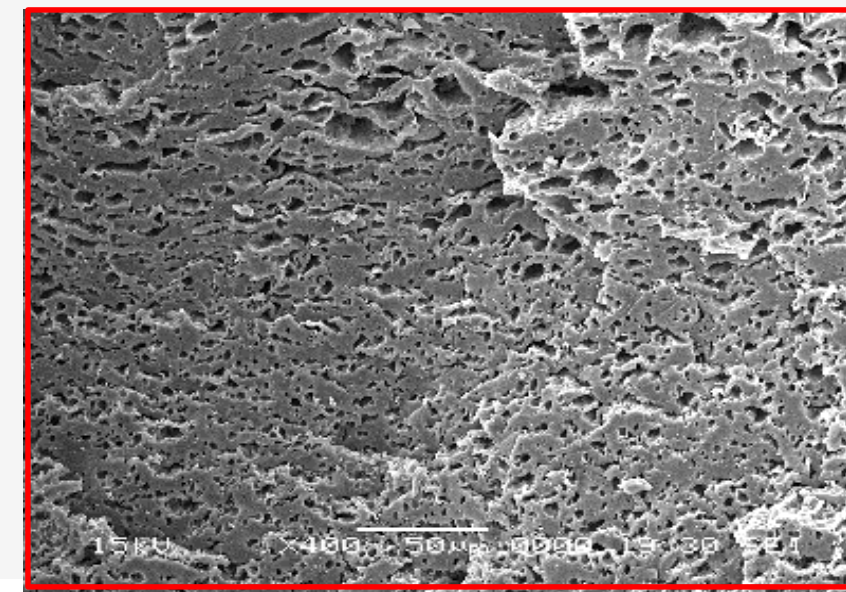
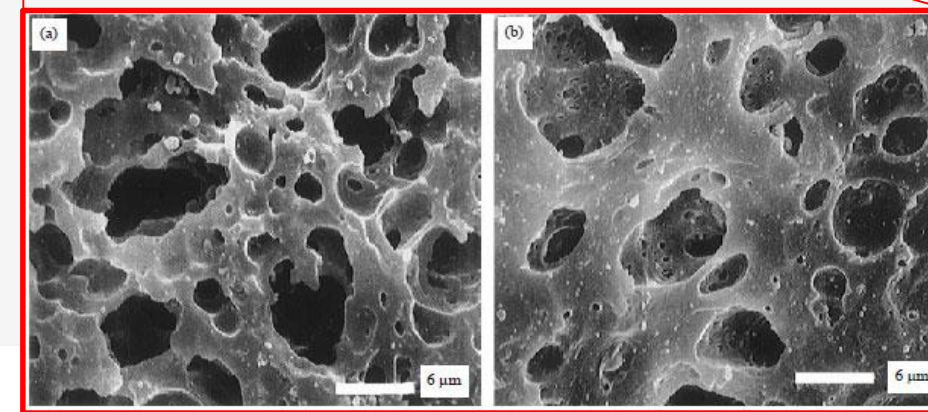
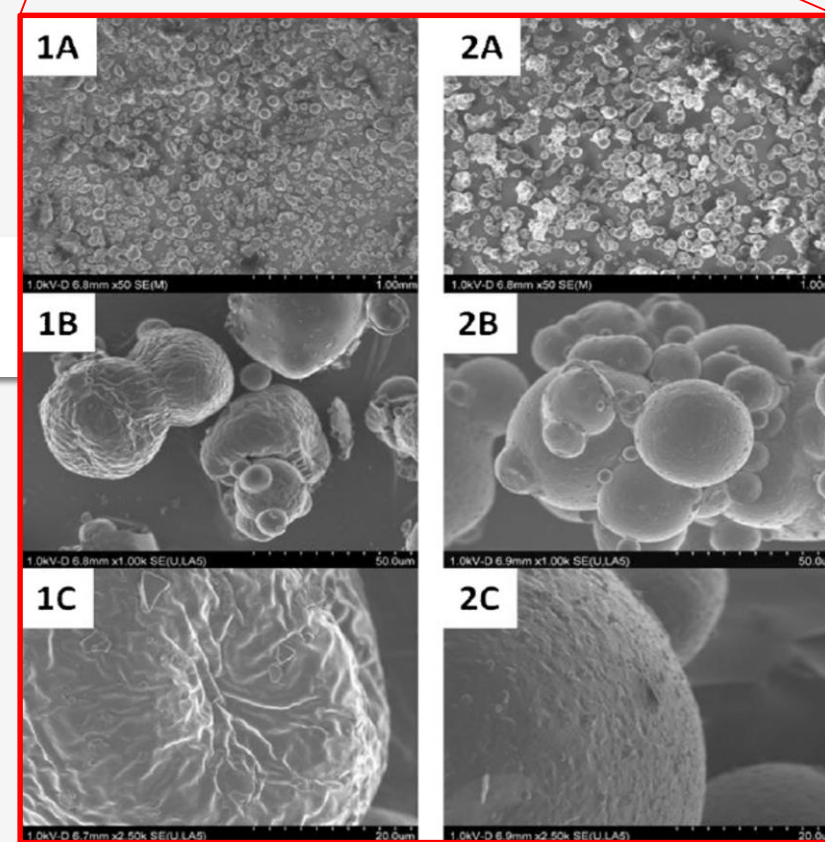
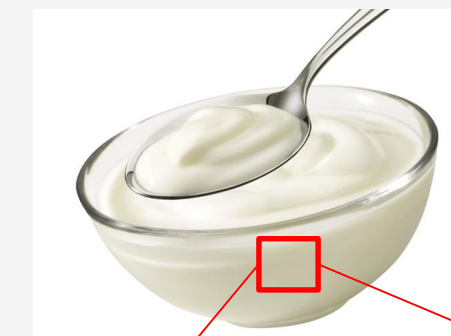
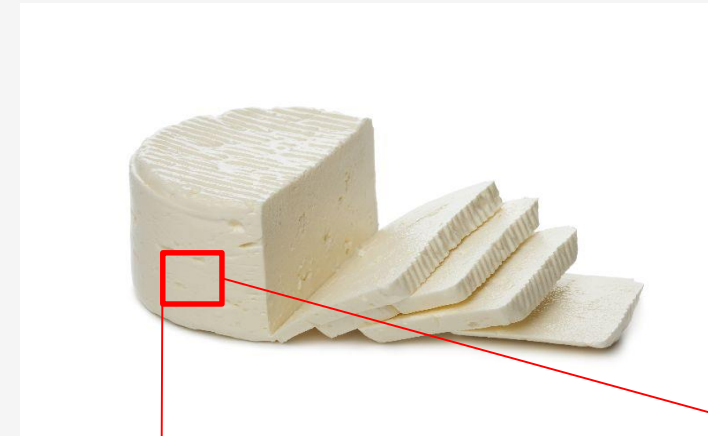
# BioNanoFactory



# The Nanoscale in Foods



# The Nanoscale of Foods



# Healthier Food



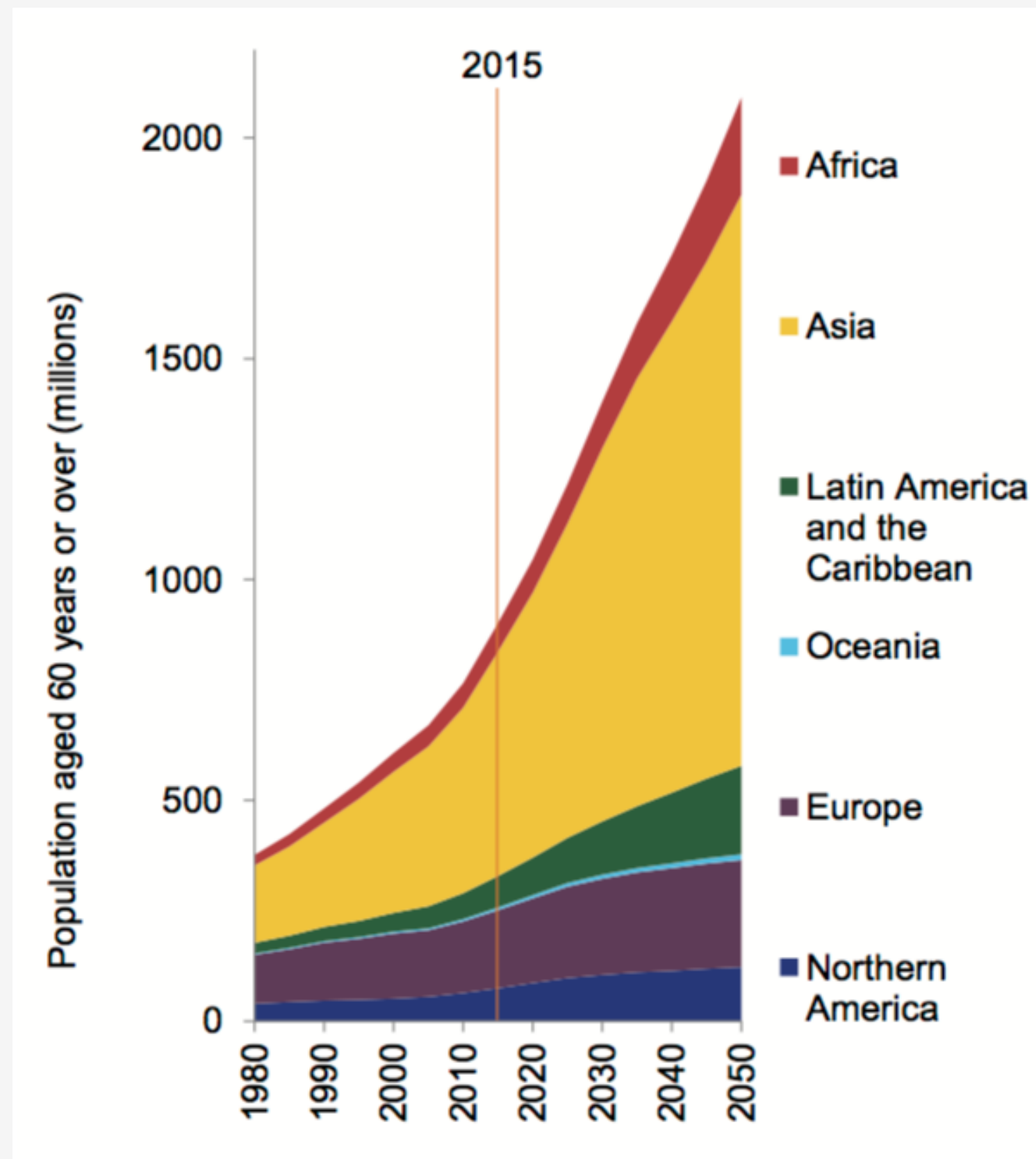
Bioactive encapsulation  
Food 3D-Printing

# Personalization



Food plays a variety of roles in peoples' lives

# Big Challenges for the XXI Century



2030	
Country or area	Percentage aged 60 years or over
Martinique	38.5
Japan	37.3
Italy	36.6
Germany	36.1
Portugal	34.7
China, Hong Kong SAR	33.6
Spain	33.5
Greece	33.2
Slovenia	32.7
Austria	32.4

Population growth and Ageing are increasing fast

# Less is More: Nano Sized Salt and Sugar

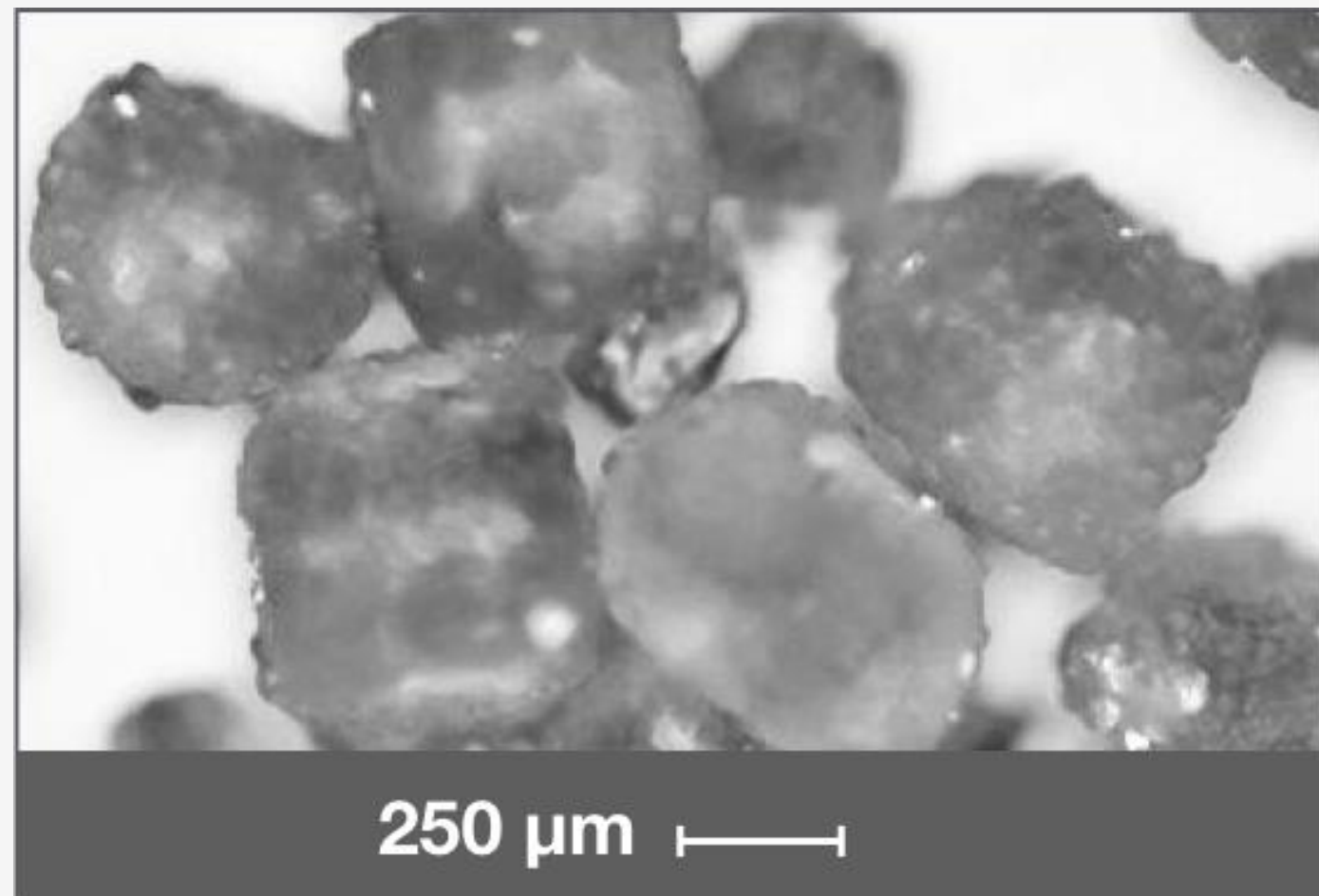
- 1.56 billion people worldwide will have hypertension by the year 2025
- It is expected to have 642 million people living with diabetes worldwide by 2040

Sodium-rich diets are a leading cause of hypertension, and a reduction on salt intake is advised  
(WHO - [http://www.who.int/elena/titles/sodium\\_cvd\\_adults/en/](http://www.who.int/elena/titles/sodium_cvd_adults/en/))

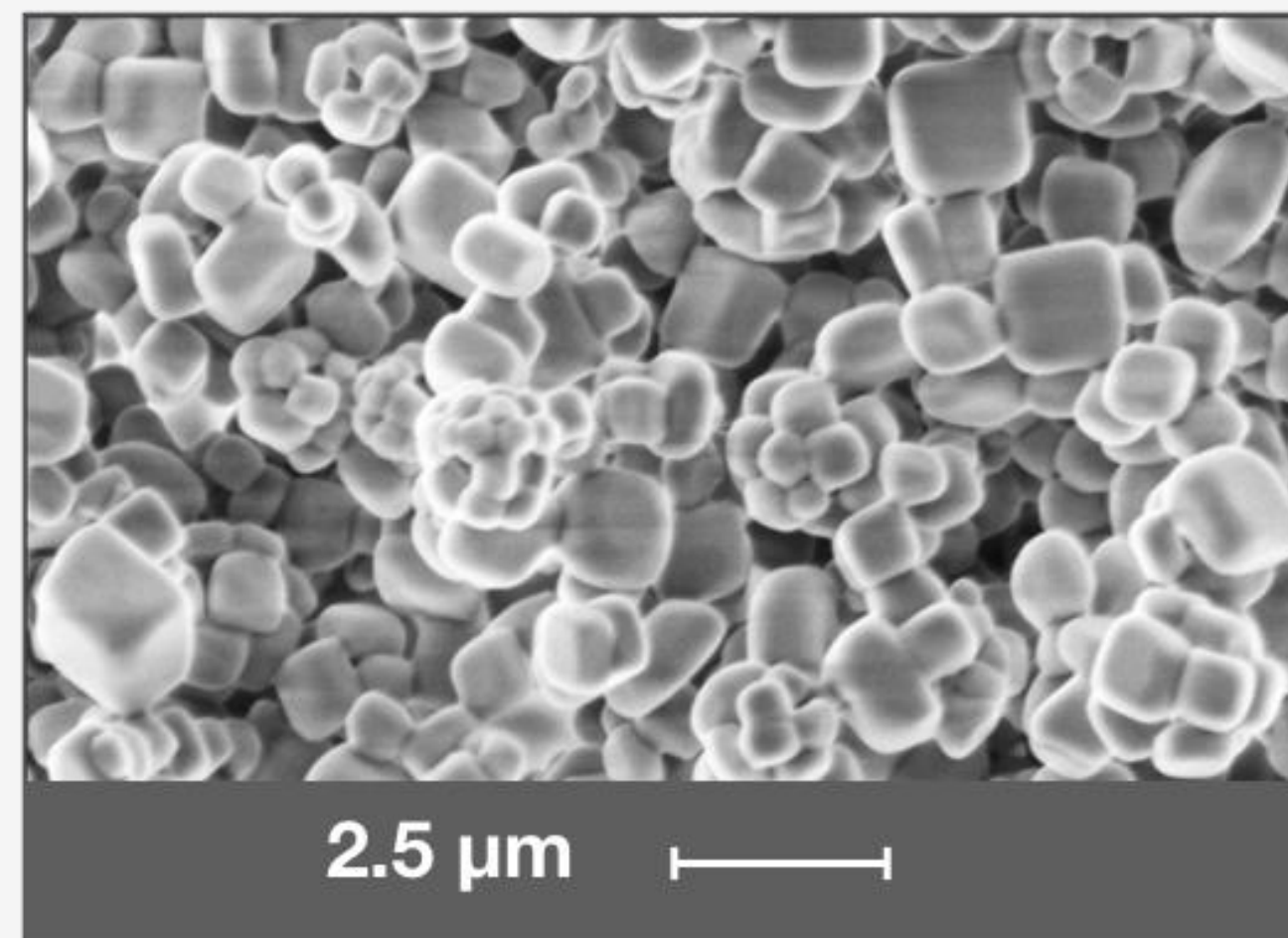


# Less is More: Nano Sized Salt and Sugar

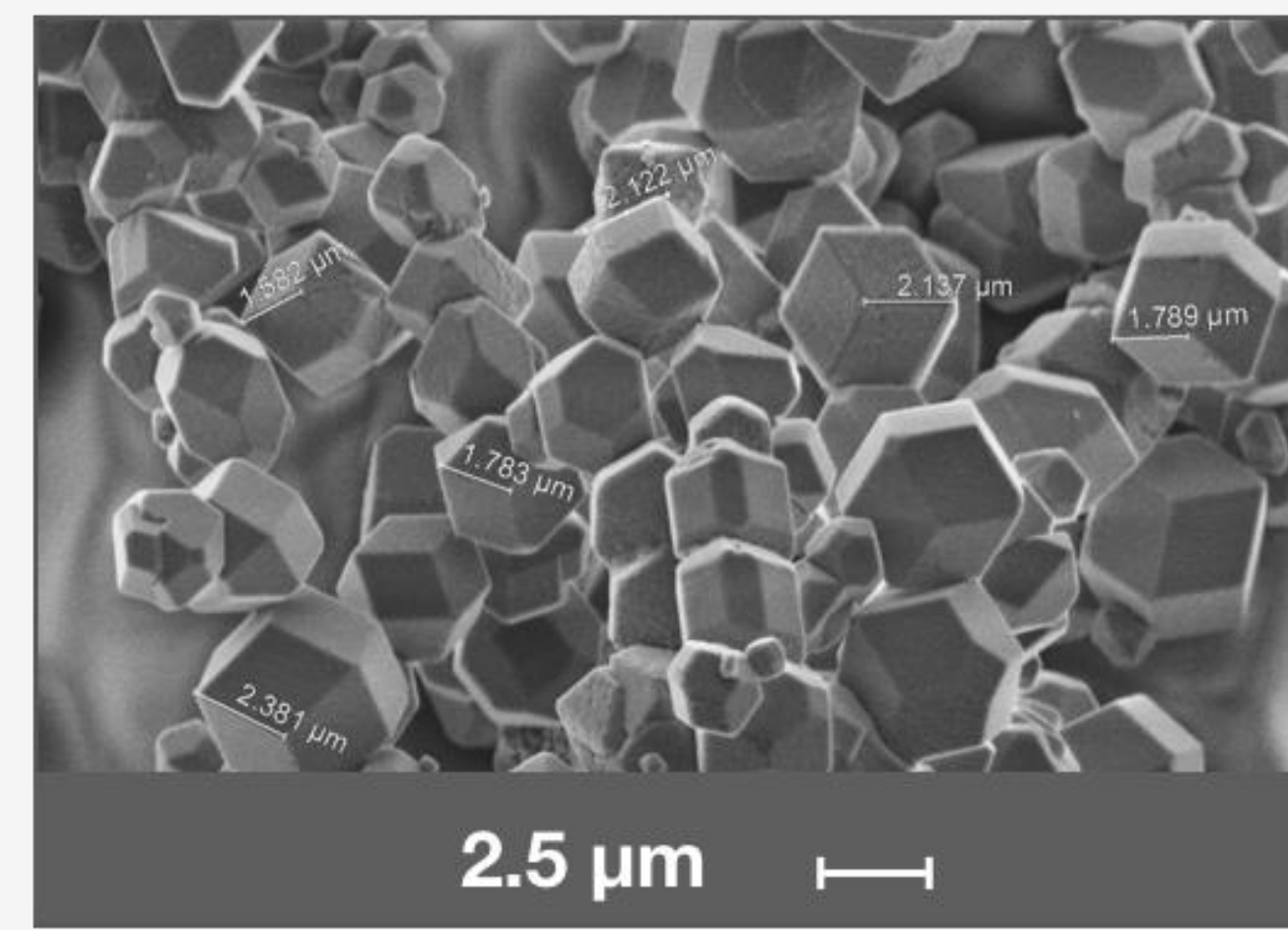
We have technologies suitable for producing salt particles in the range of 1-2  $\mu\text{m}$



A. Regular fine commercial salt (Sigma Aldrich)



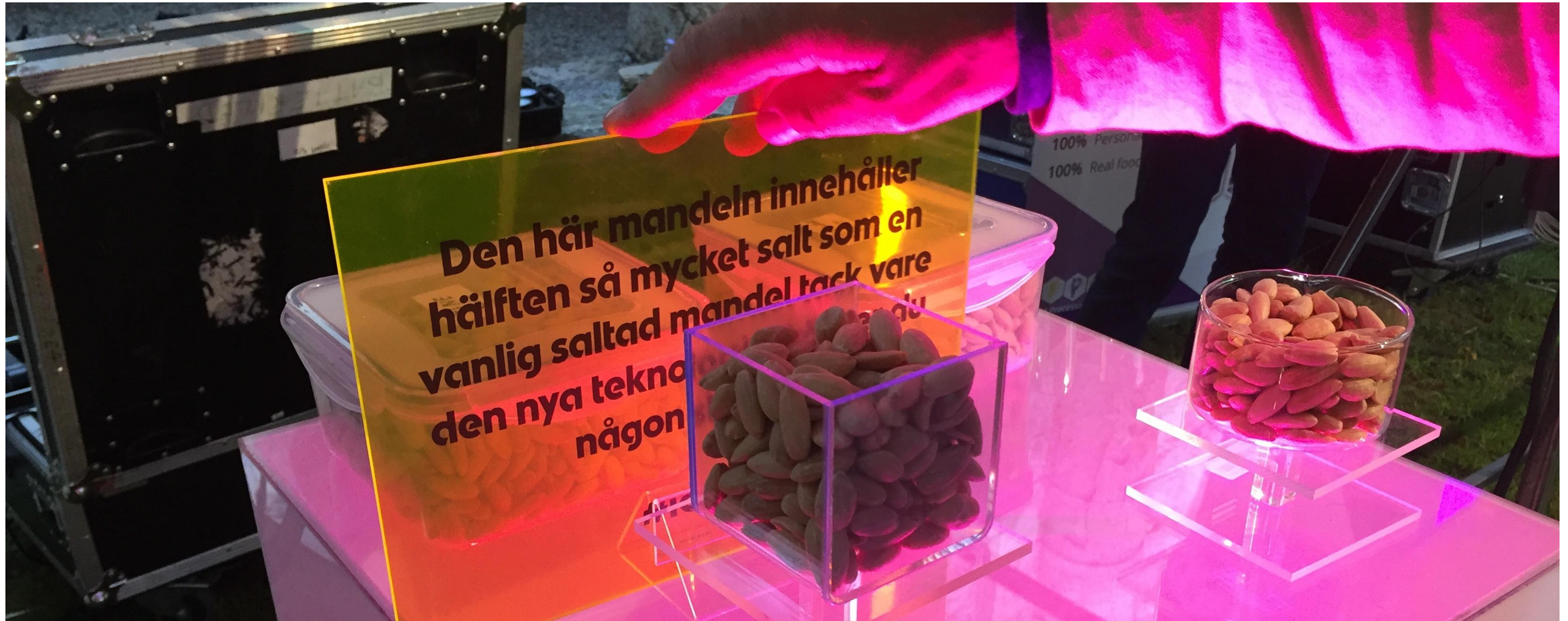
B. MicroSalt Formulation 1



C. MicroSalt Formulation 2

It is possible to reduce 50% amount of salt keeping the salty taste

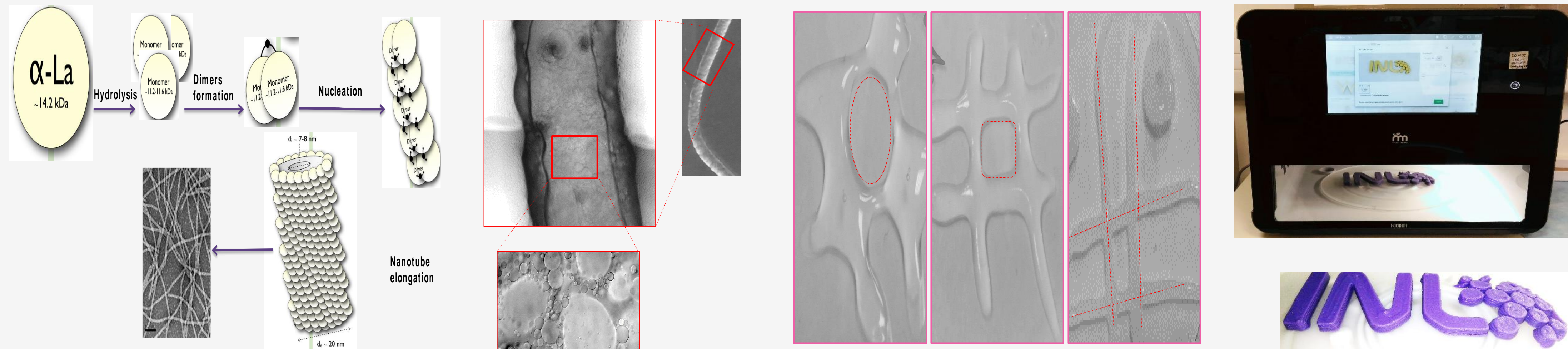
A proof of concept in Sweden, Summer 2017...



Healthier nanoengineered almonds with the same taste than regular snacks

# Swallowing difficulties (Dysphagia) and 3D Printed Food

- ▶ 45% seniors have symptoms of dysphagia
- ▶ Soluble proteins such as whey protein can be structured to obtain nanotubes
- ▶ Design meals for easy swallowing in dysphagia patients by using be printable proteins



# Functional Foods

- ▶ Malnutrition can affect 50% of the frailest elderly population
- ▶ Direct incorporation of micronutrients to the biscuit mass is not compatible with fabrication process and yield unacceptable quality and sensorial biscuits



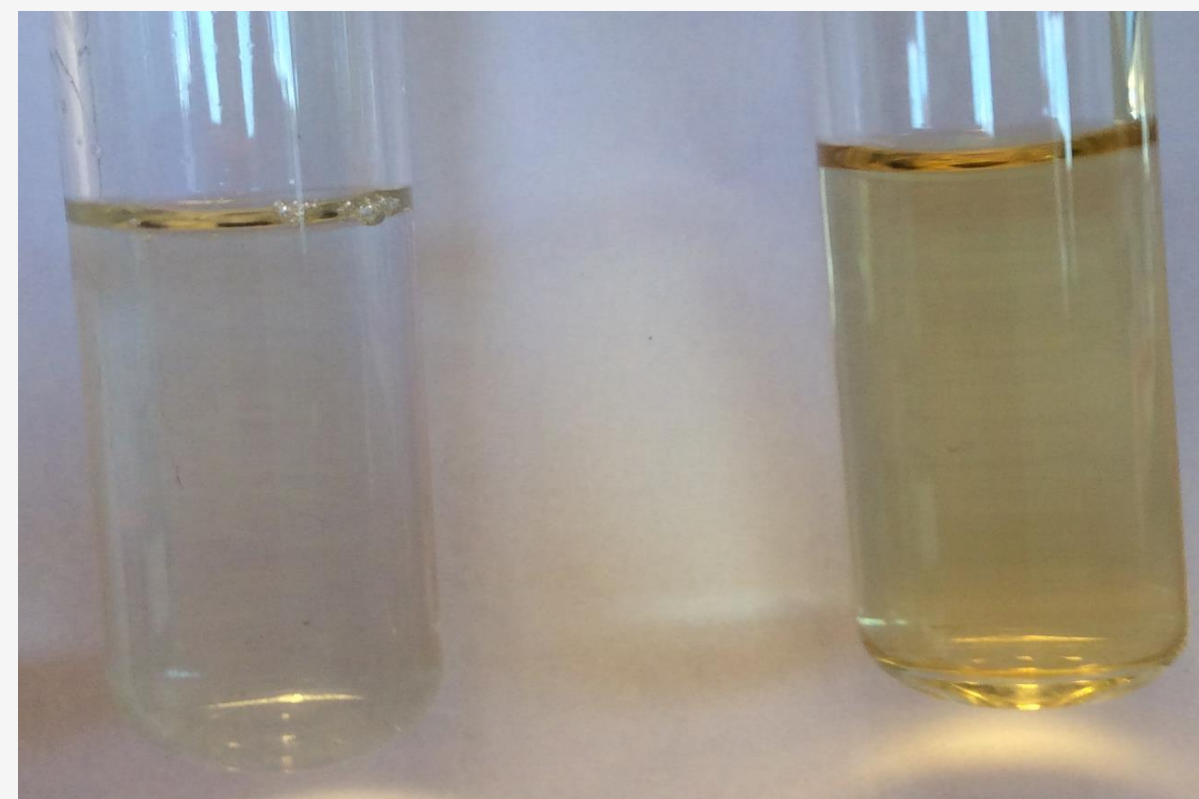
Control without Fe



Formulation with Fe

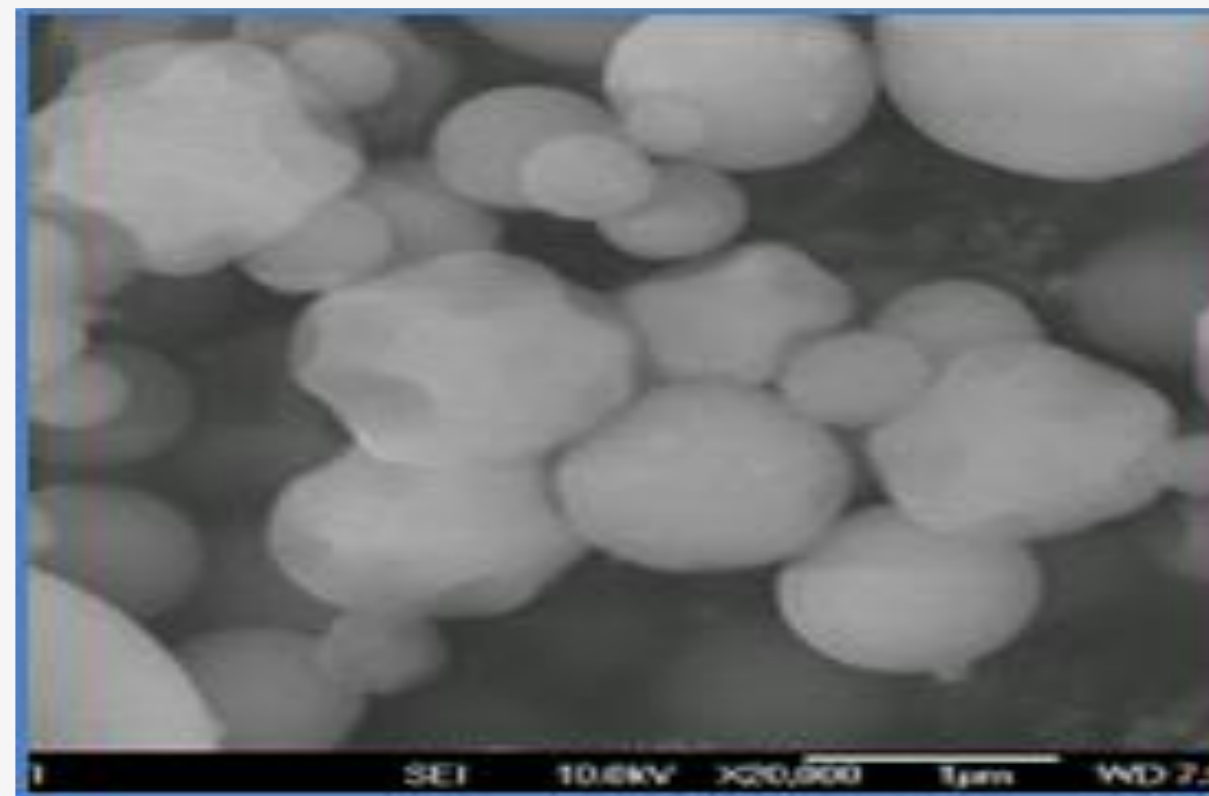
# Nano-encapsulation of micronutrients

- ▶ Fe, Ca and Se must be encapsulated to prevent their degradation, reduction of bioavailability
- ▶ Encapsulation of iron is technologically compatible and mask off flavours



Fe-Casein hydrolysate

Fe solution



# Sustainability



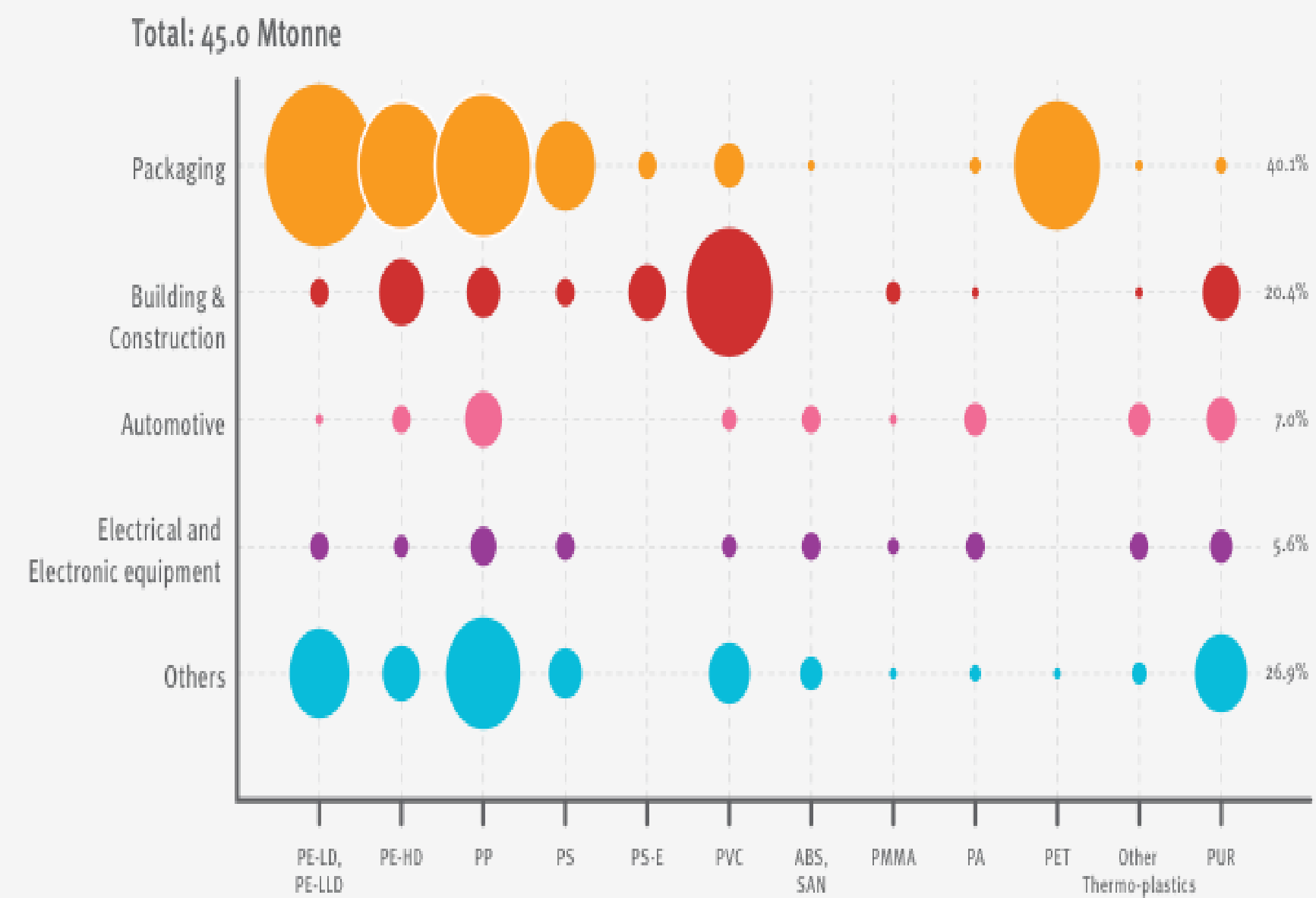
Food waste  
reduction

Active,  
Edible and  
Smart Packaging

# Replacing petrol based plastics

270 million tons of non-biodegradable/non-compostable plastics are produced annually

Packaging industry is the main user of synthetic plastics



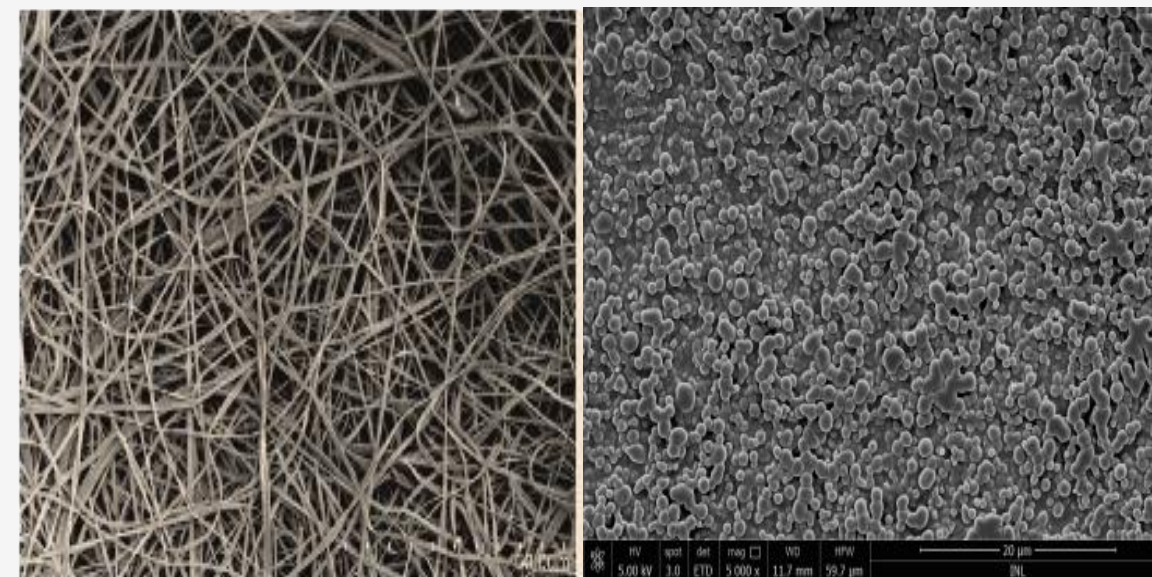
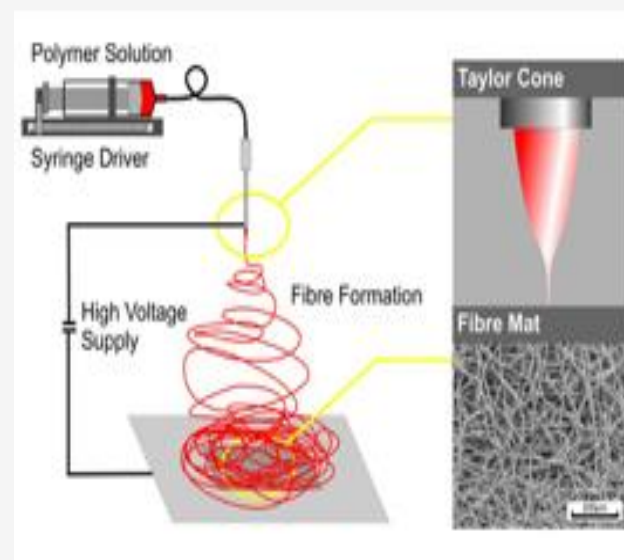
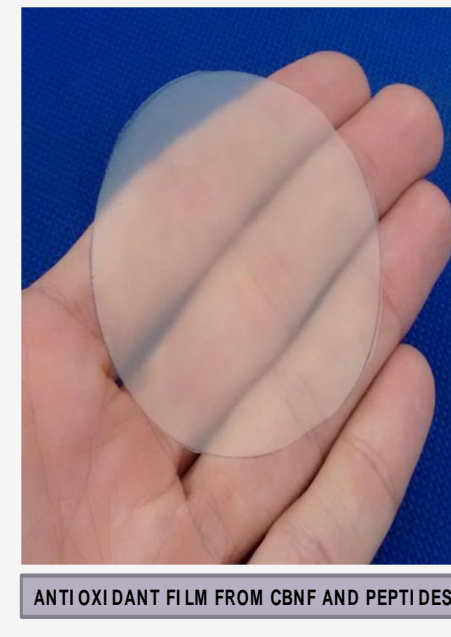
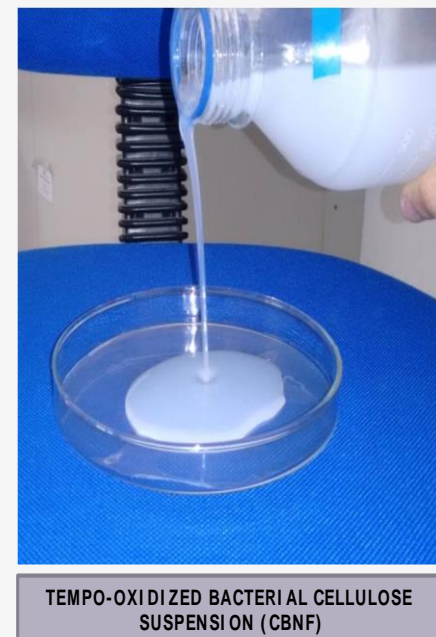
(1) [www.plasticseurope.org](http://www.plasticseurope.org); (2) <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home>; (3) <http://www.clal.it/en/index.php>

# Antioxidant and Antimicrobial edible coatings...

Based on blends of natural biodegradable food grade biopolymers

Made with bacterial cellulose, natural waxes, protein hydrolysates or polyphenols extracts

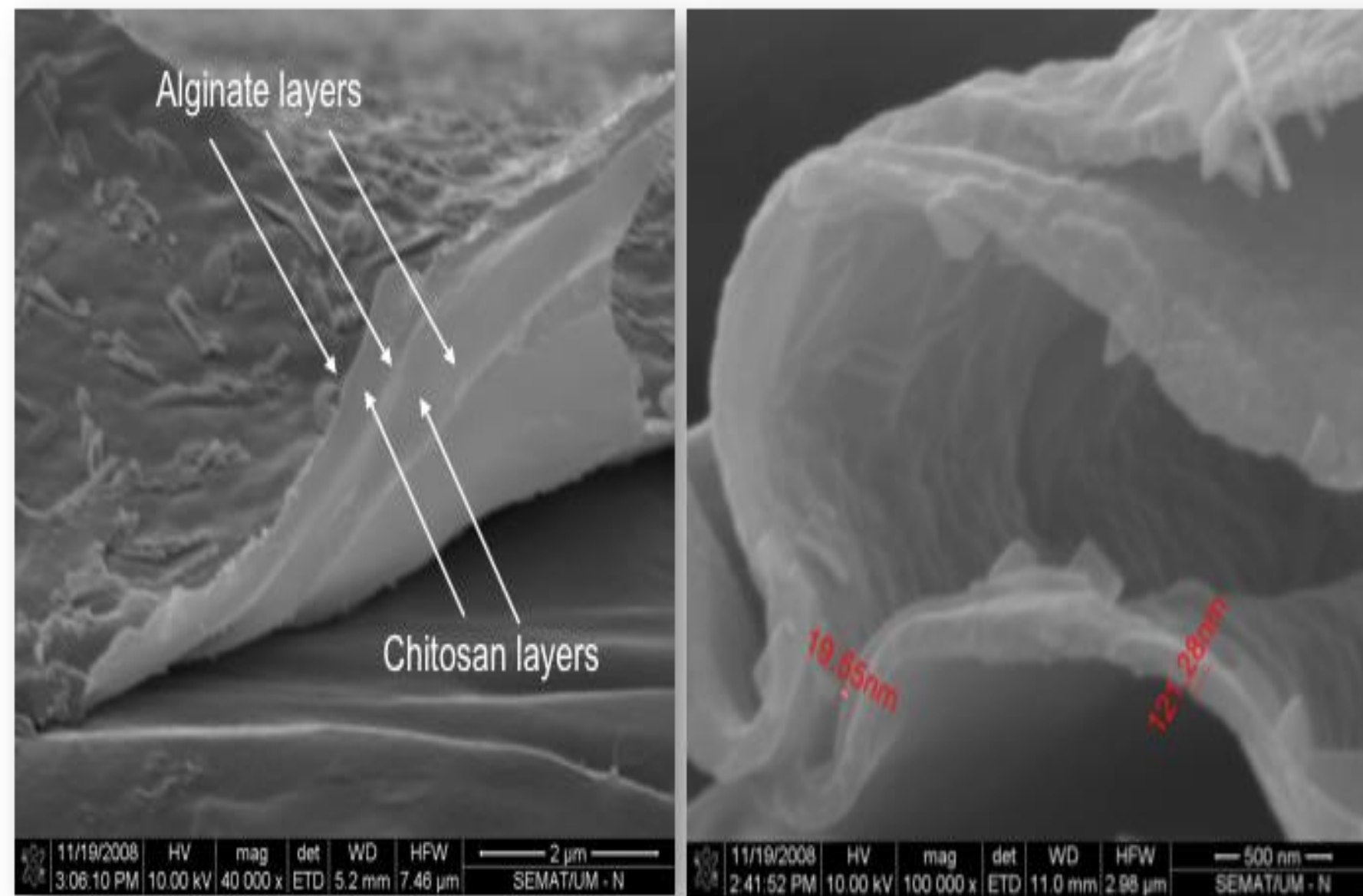
Layer-by-Layer  
Electrospinning



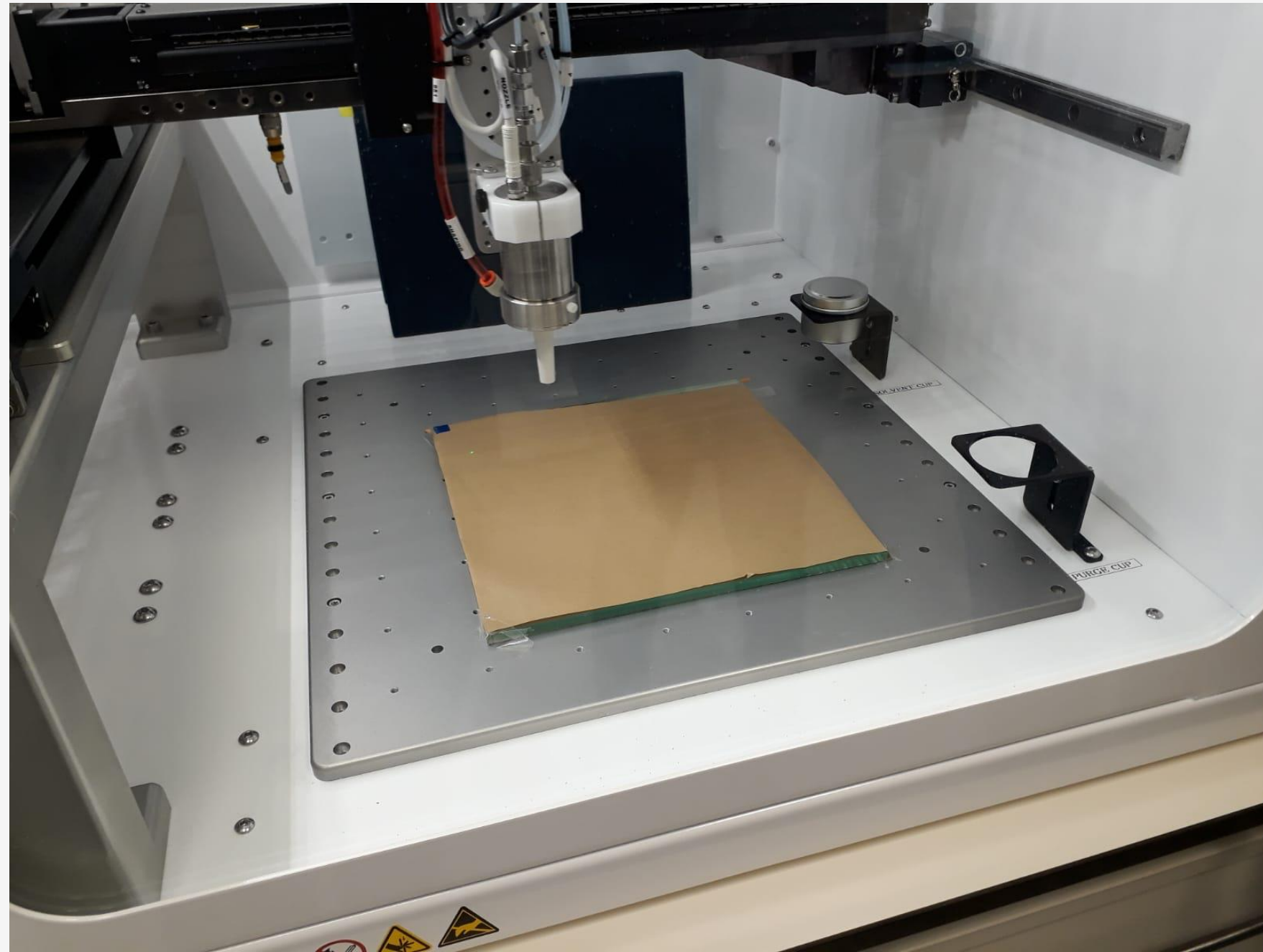


...and films

## Aginate-Chitosan active films



# Superhydrophobic and antimicrobial paper



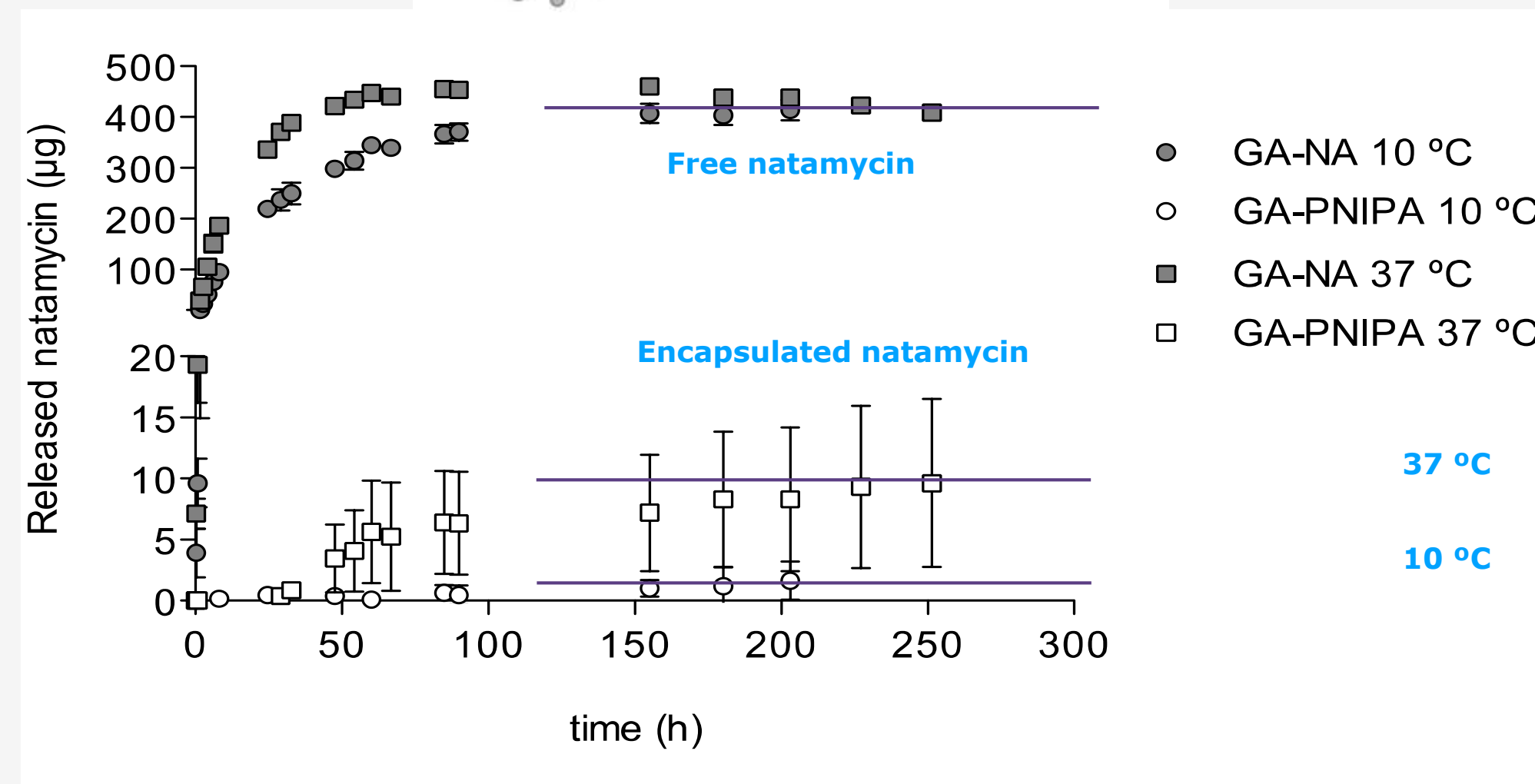
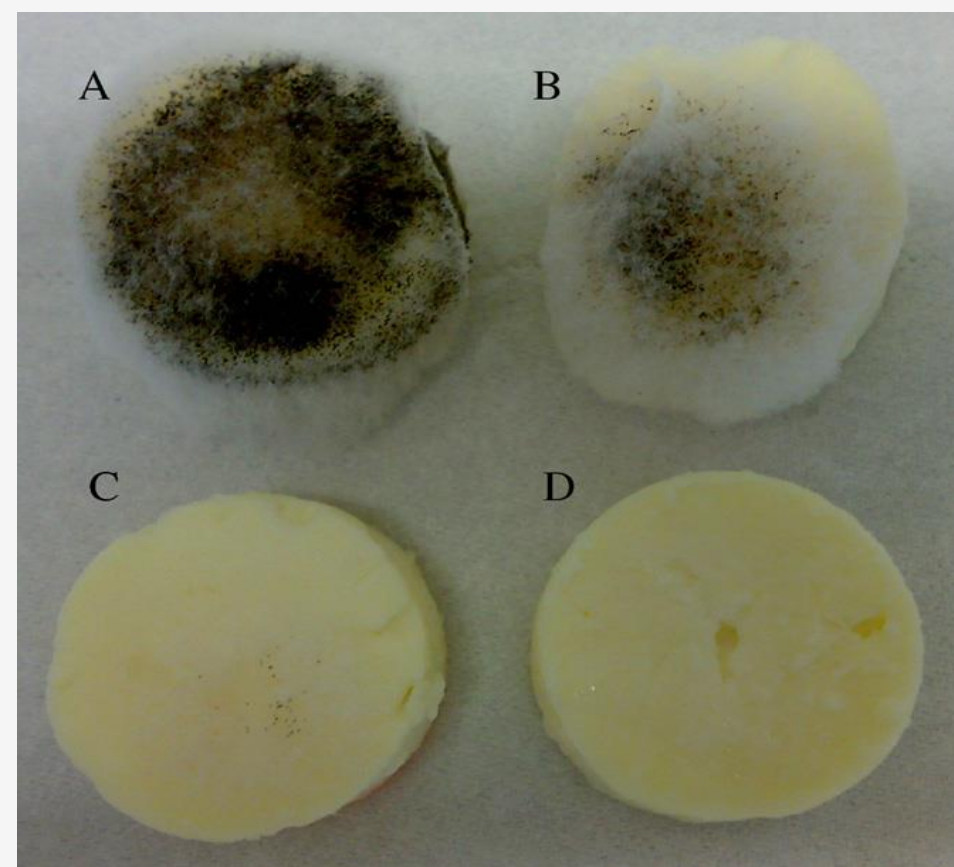
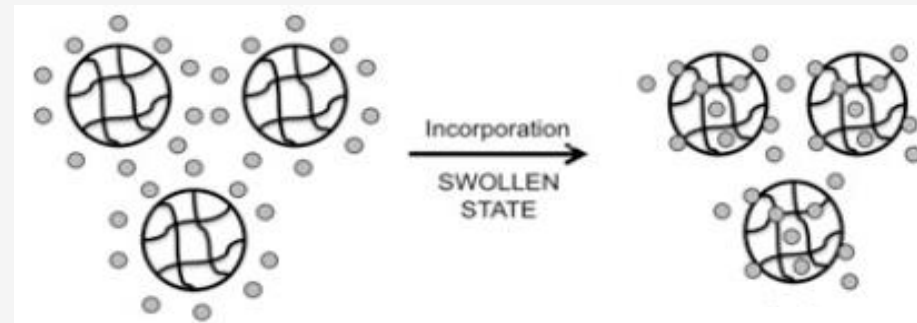
- **Superhydrophobic paper obtained by ultrasonic coating**

# Smart coatings...

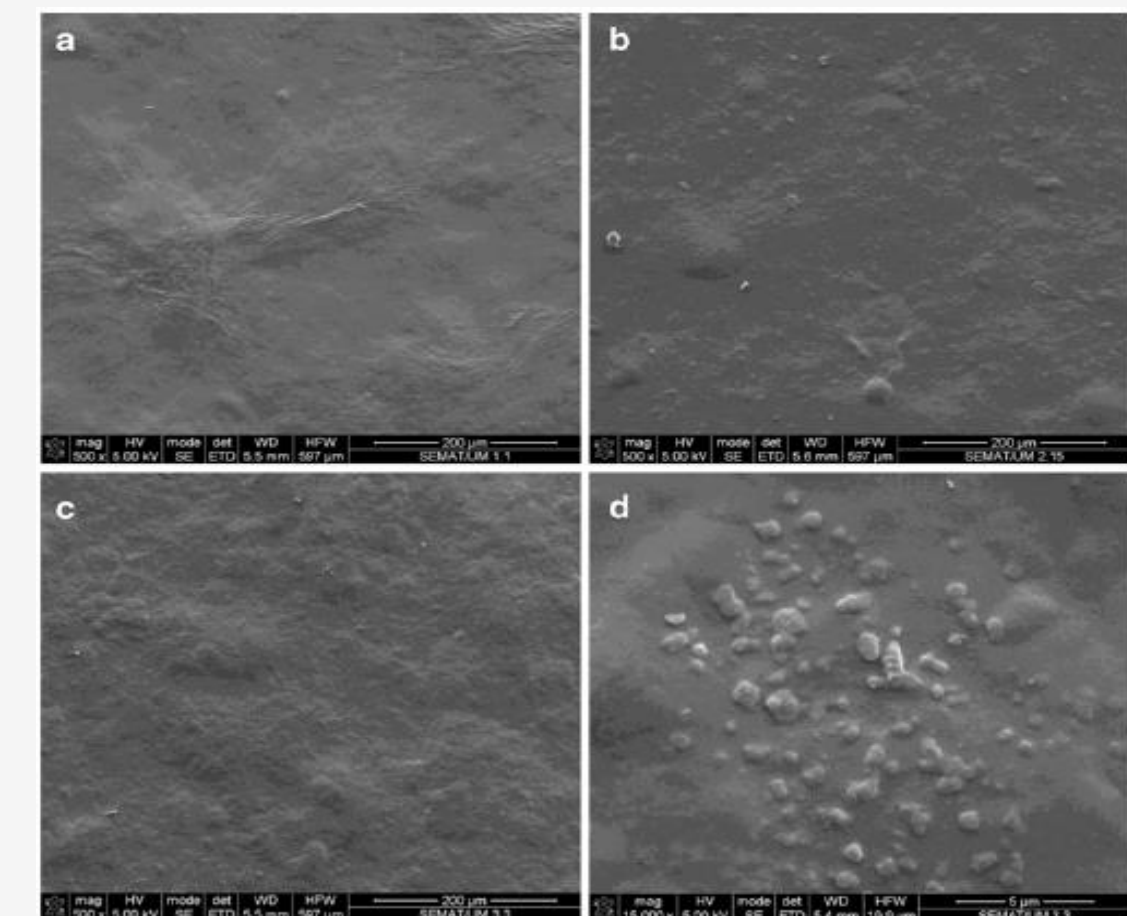
Based on blends of natural biodegradable food grade biopolymers

Made with bacterial cellulose, natural waxes, protein hydrolysates or polyphenols extracts

PNIPA - Poly(N-isopropylacrylamide)  
NA - natamycin

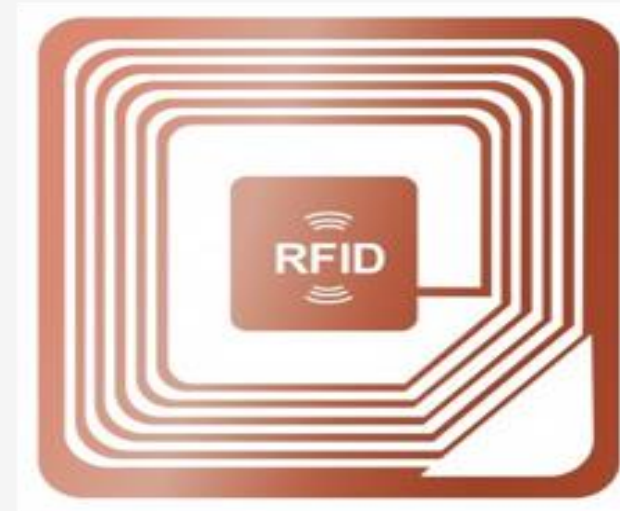


Cerqueira M.A. et al. (2014). Food and Bioprocess Technology. 7, 1472.



# ... and Smart Packaging

## Empowering the consumer



Nano-enabled Information and Communication Technologies (ICT) can improve consumers' information about what they eat

# Safer

Traceability,  
authenticity

Anticounterfeiting labels

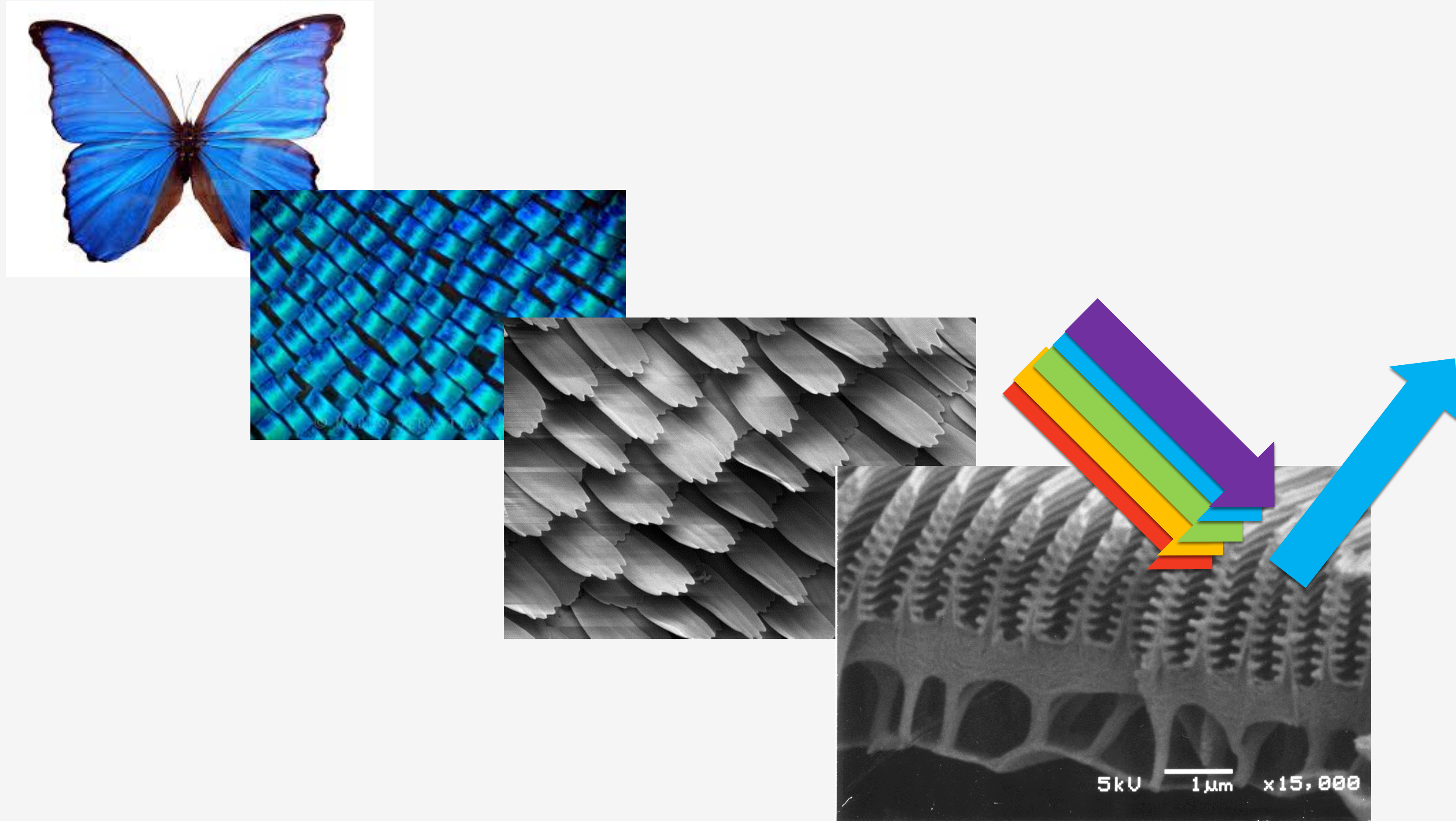
# Blockchain adapted edible packaging

Integrated, repeating watermark embedded in the edible packaging material making it technically and economically challenging to duplicate

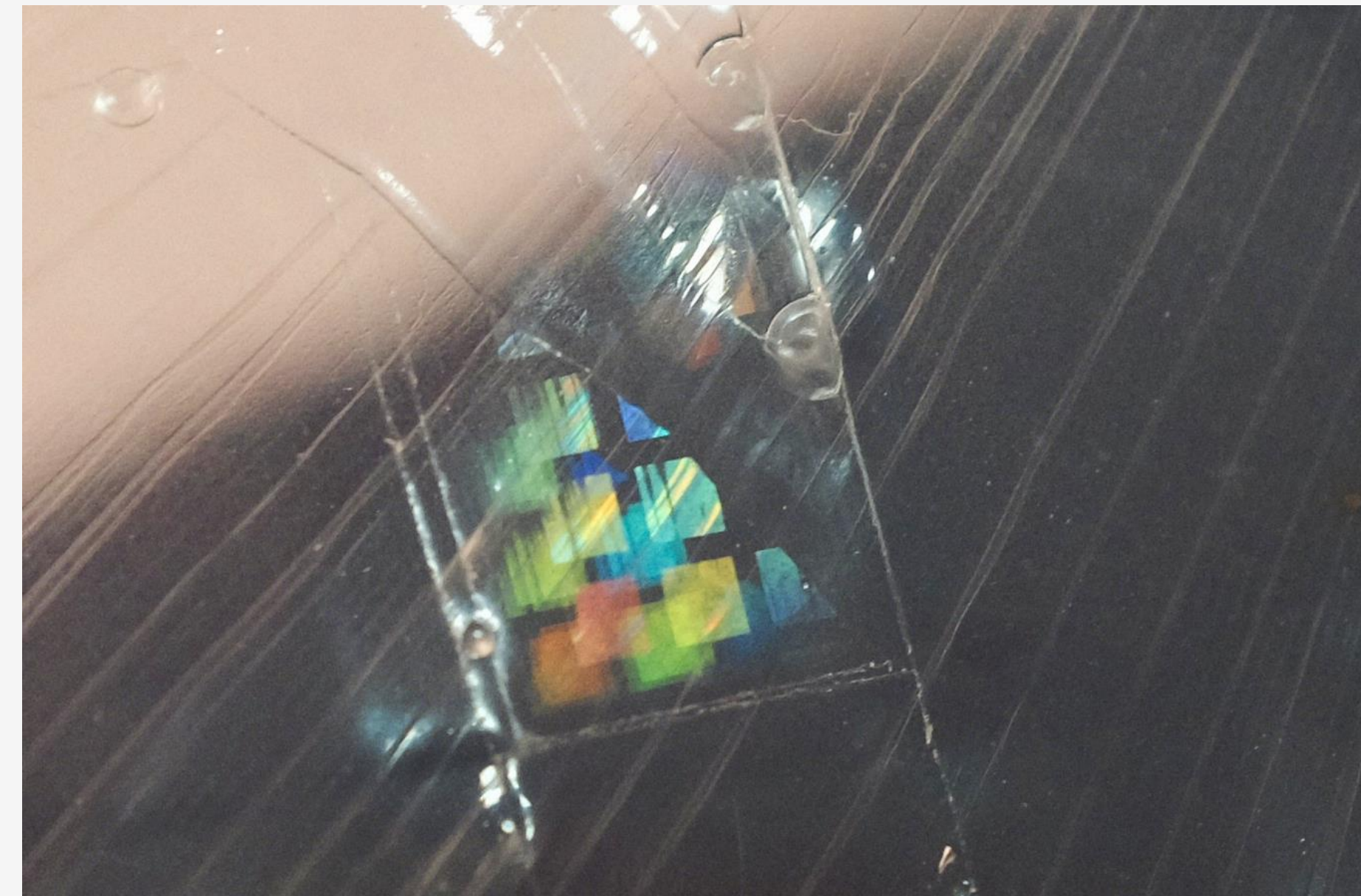


Electron beam induced photoluminescence

# Structural Color



# Labels, matermarks and stamps





# Tastier



Emotion

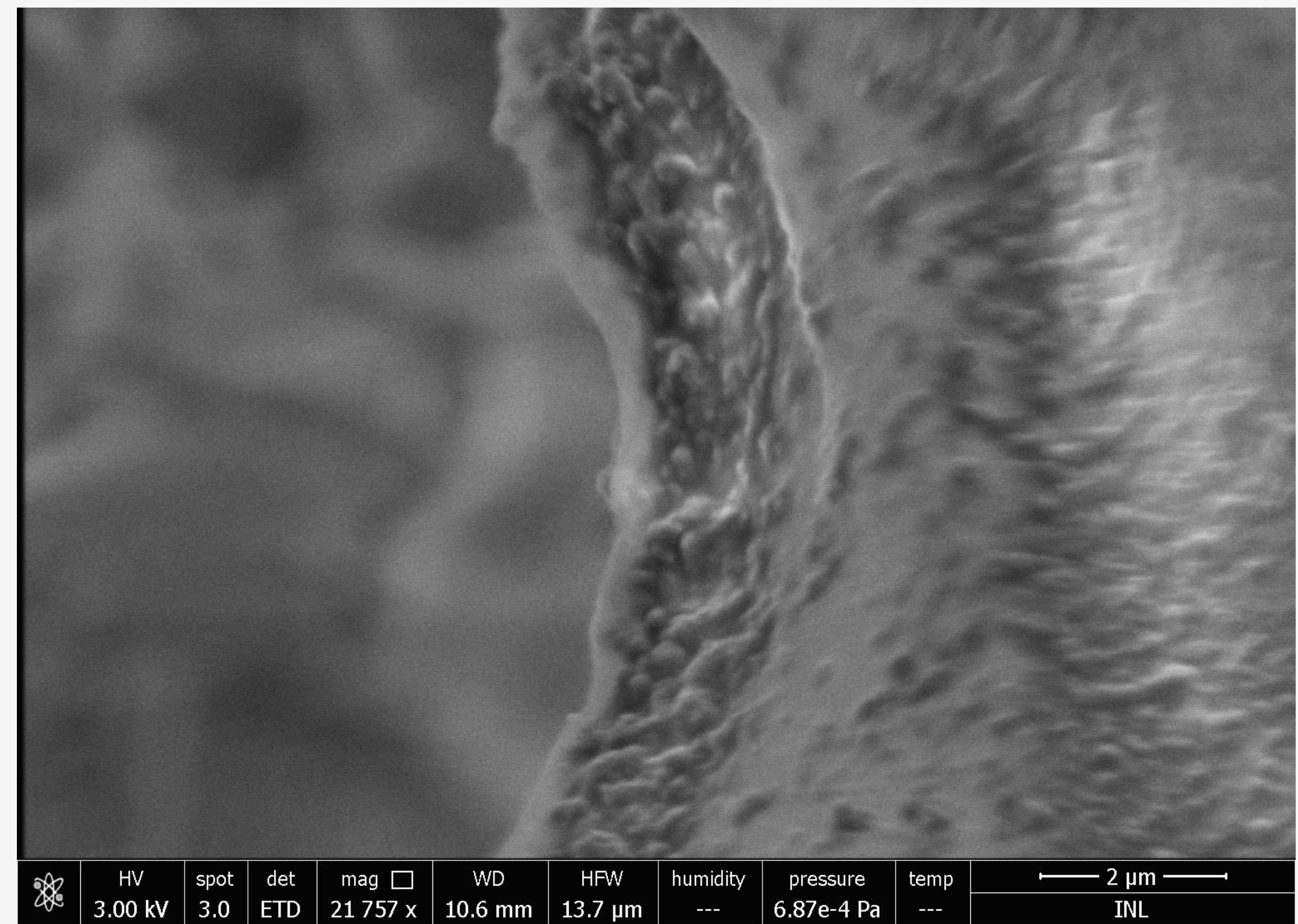
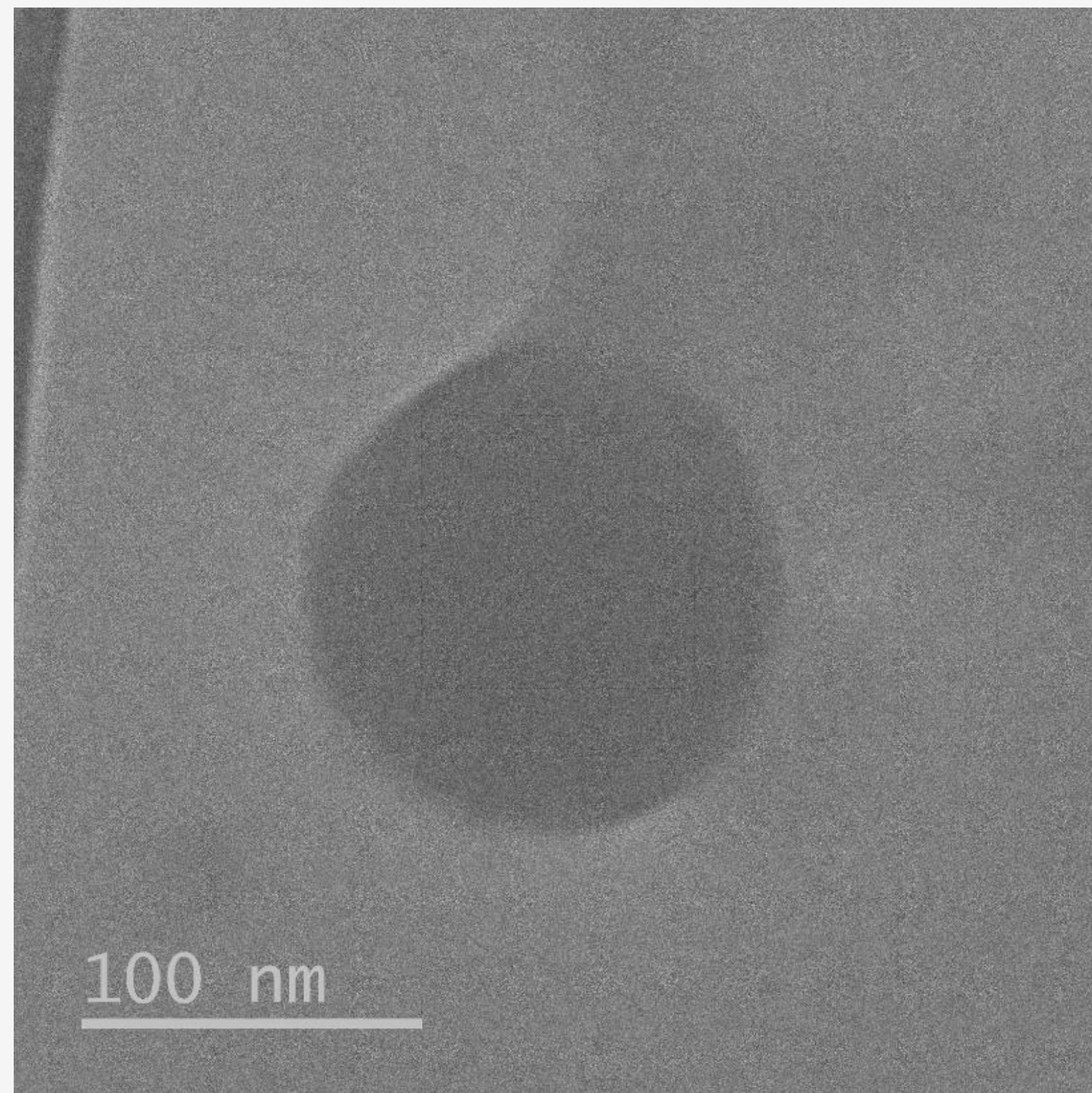
Authenticity  
New experiences

# Foams



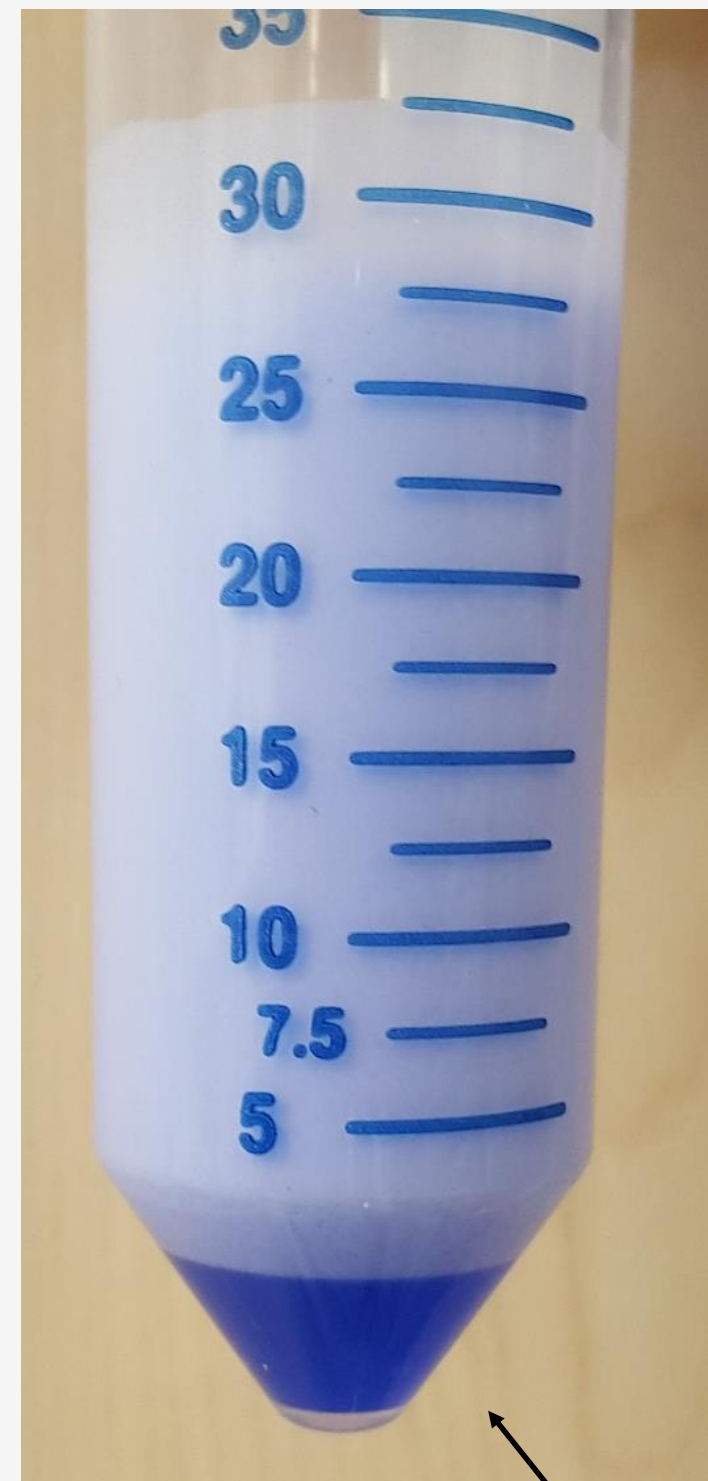
# Intensely coloured edible foams – Nano enabled solution

Encapsulating colorants in protein nanoparticles (coated with surfactants) and using these loaded particles for creating Pickering foams. The anchoring of the particles onto the air-water interface results in accumulation of the colorants in the foam phase.

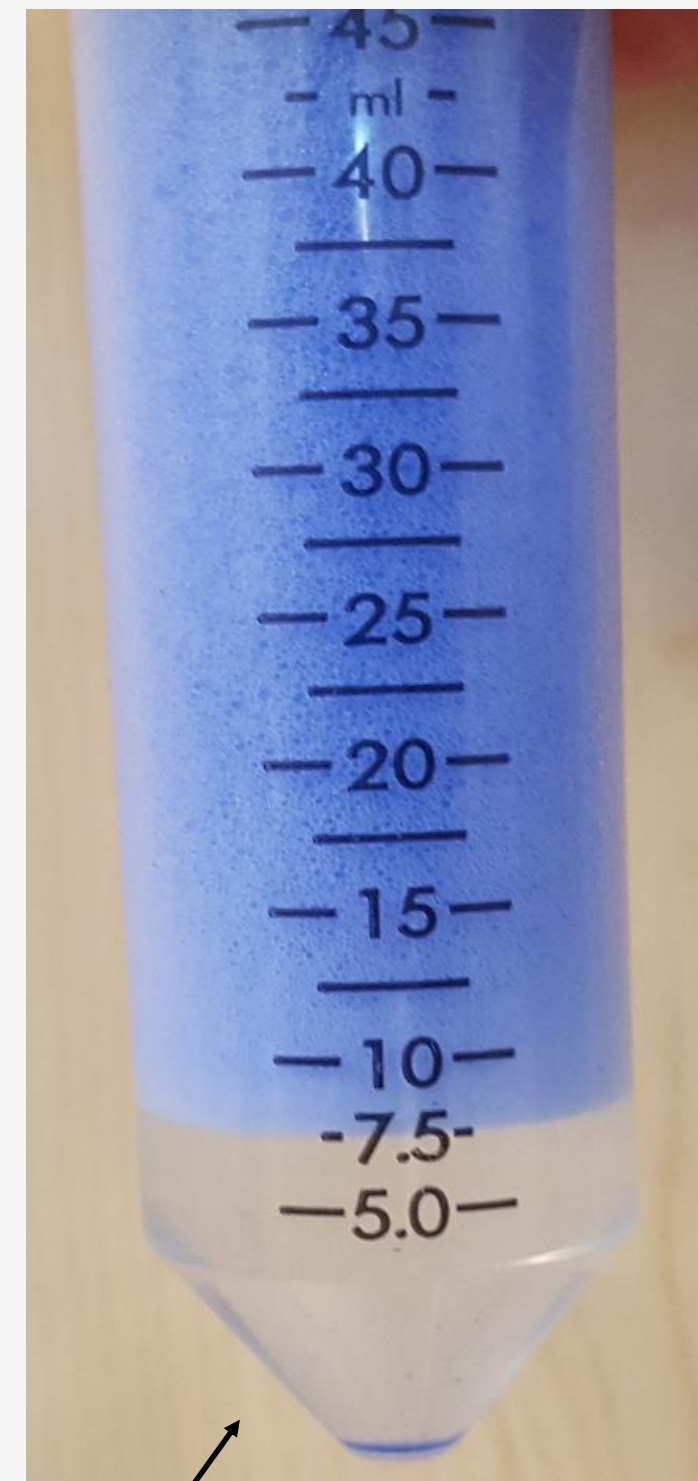


# Stabilized coloured edible foams

FDC blue coloured foam stabilized by sucrose ester alone.



Pickering stabilized foam using color loaded zein particles as stabilizers.

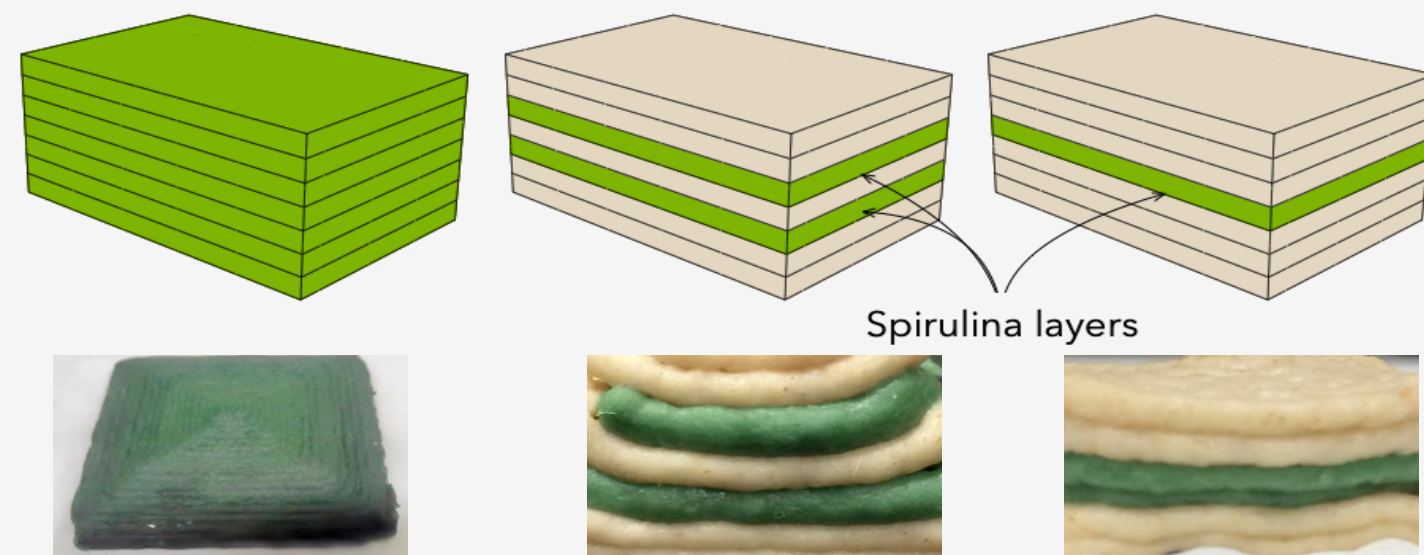
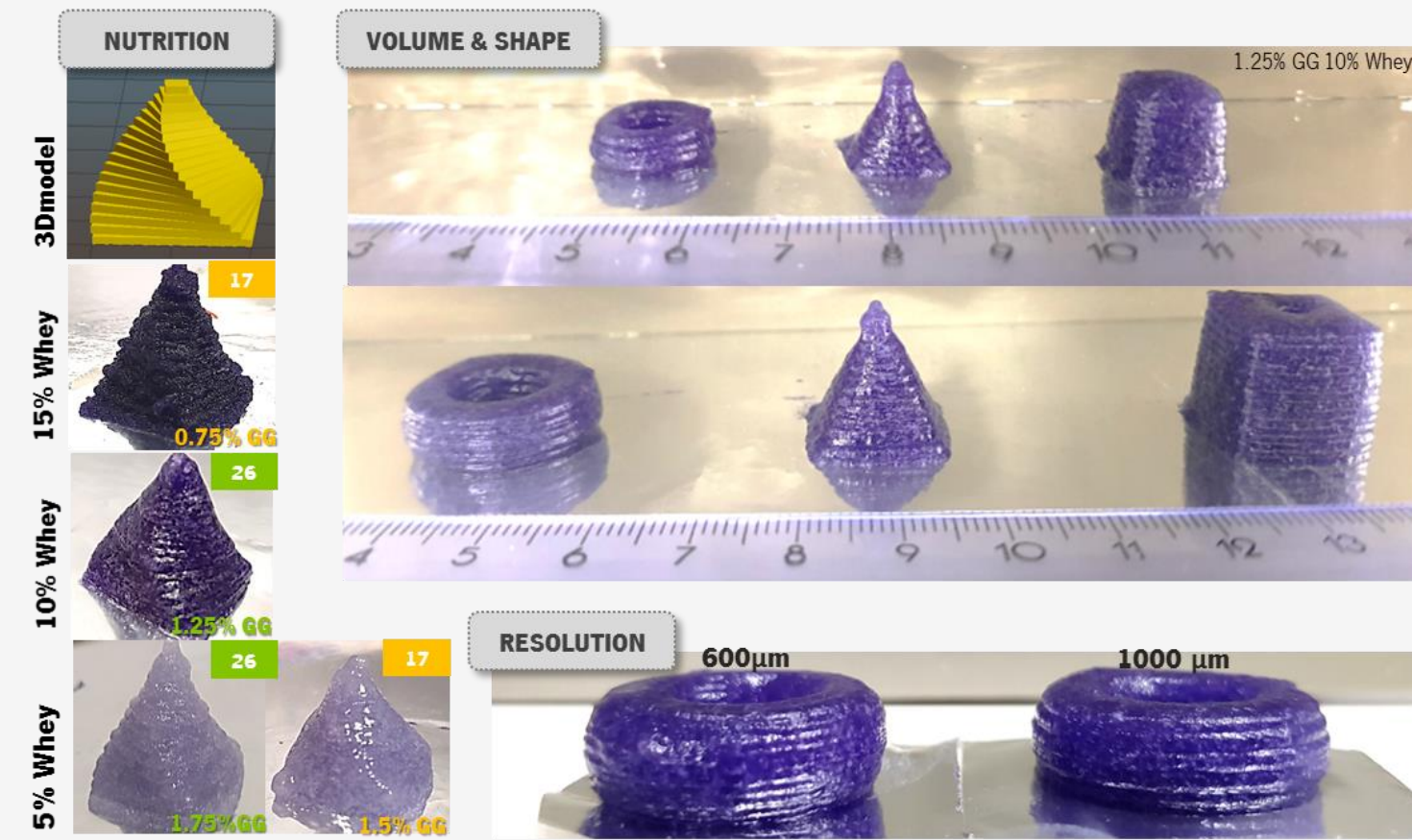
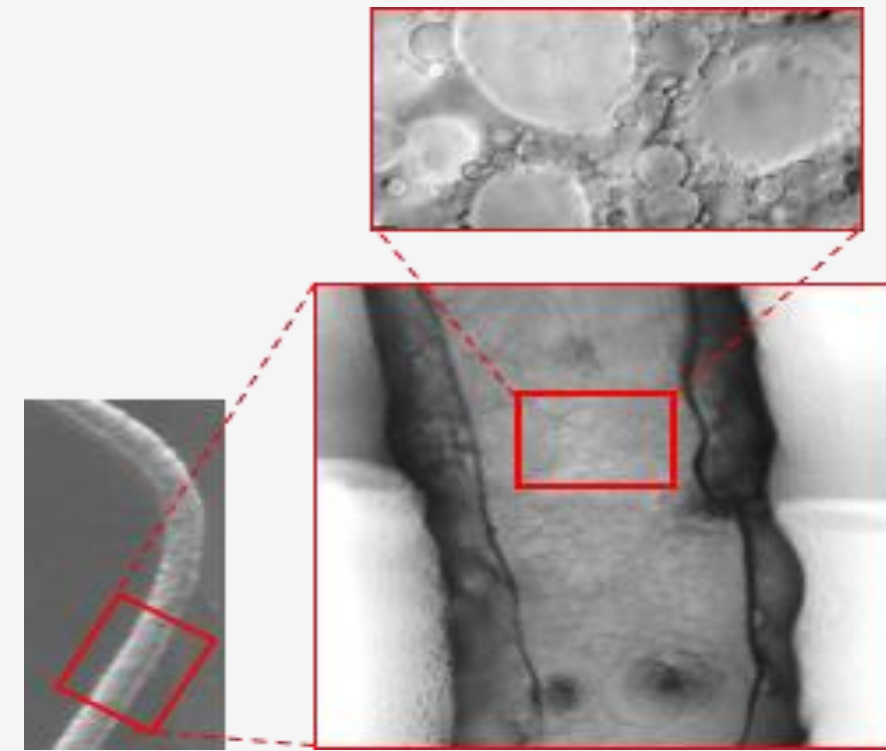


$\beta$ -carotene

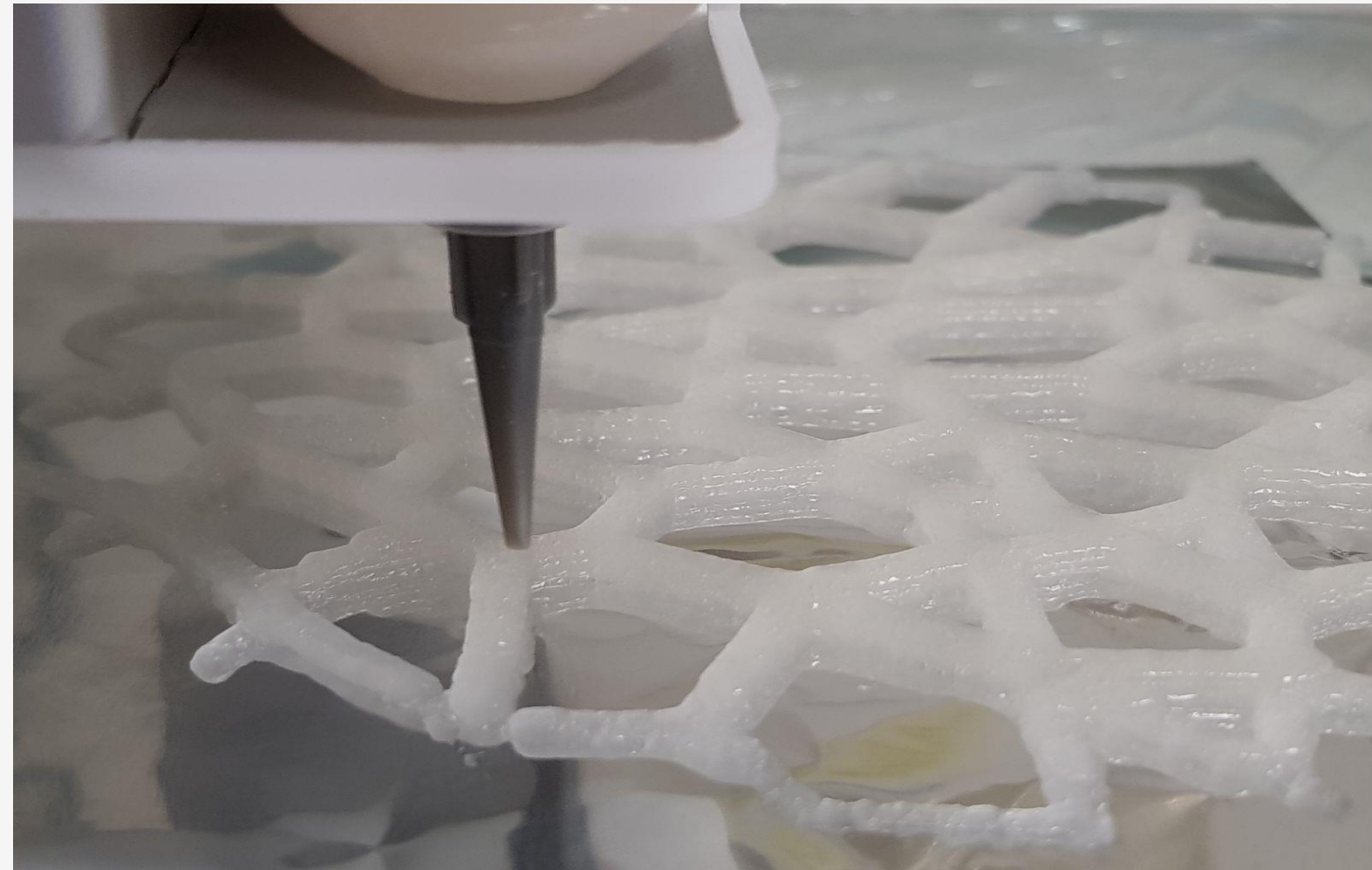


Notice the drainage of colour in the serum phase.

# 3D Printed Foods



# Shapes and flavors



# The Food NanoTeam at INL



# Nano food augmenting nature

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