Seafood product innovation by using emerging/non-thermal technologies

Innovazione dei prodotti ittici mediante utilizzo di tecnologie emergenti e non-termiche

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Motivation for new technologies

- New products /consumer expectation

- Quality
  - Health benefits
  - Sensory attributes

- Food safety

- Economic advantage
  - Cost (energy)
  - Time
  - Efficiency

- Waste reduction/reuse, sustainability

Critical Factors in Seafood preservation

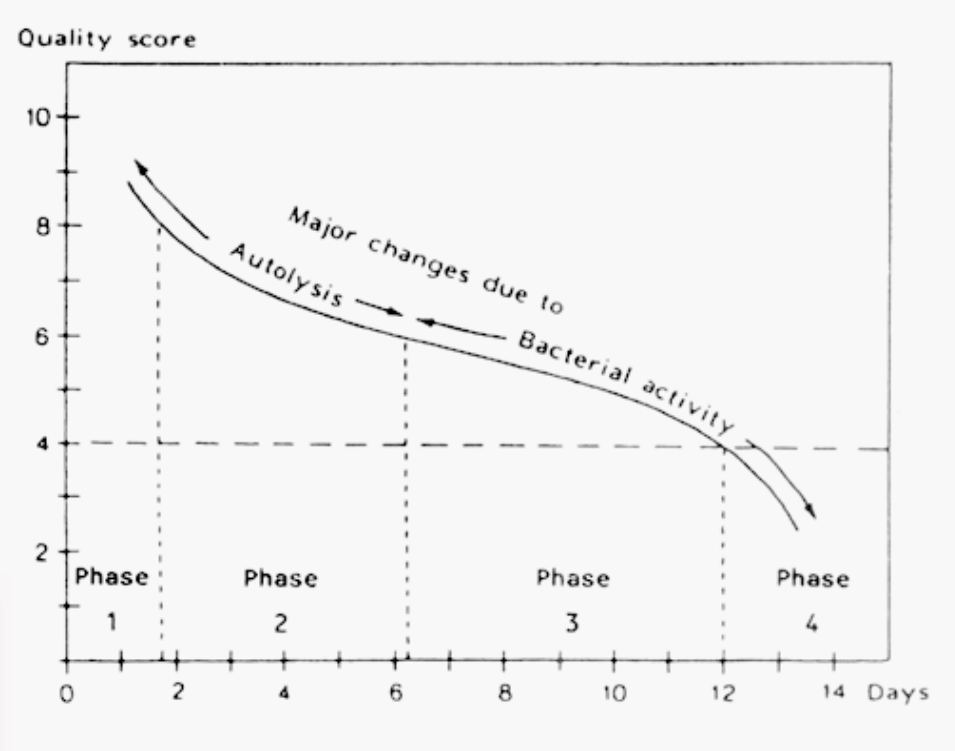
Fish products in general have a high degree of perishability due essentially to:

High content of spoilage bacteria

Presence of autolytic enzymes

pH ≈ low acid

High water activity (a_w)

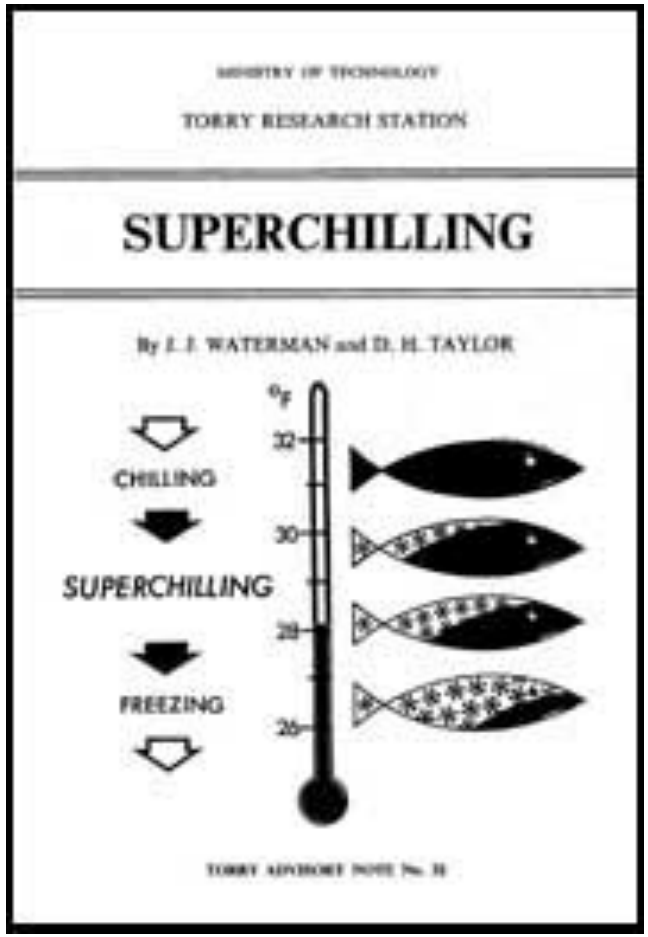


Factors favorable to microbial development and degradative reactions

Fresh-like quality and cold chain

Fresh-like quality and cold chain

Superchilling



Superchilling causes the fish to be cooled down to -2.5 ° C just below the temperature at which it begins to freeze.

At this temperature it is frozen only on the surface and therefore preserves its freshness qualities and will not be perceived as a frozen product

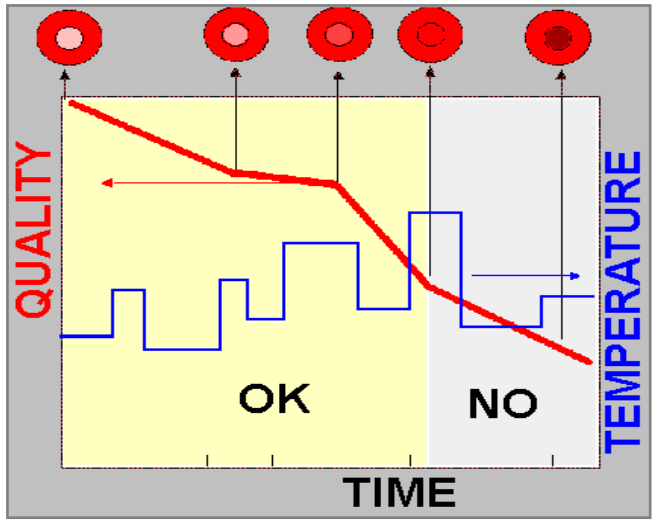
- The fish keeps its freshness longer, up to 30 days
- Shelf Life prolongation without significant changes
- This means less CO2 emissions
- Long shelf-life also means less food waste

Real needs *vs.* reality!

Primary transport	4°C	24-48 h
Distribution platform	4°C	12 h
Secondary transport	6°C	12 h
Unloading point of sale	12°C	4 h
Storage point of sale	6,5°C	3 d
Consumer transport	20°C	2 h
Home refrigeration	7,5°C	End of shelf-life

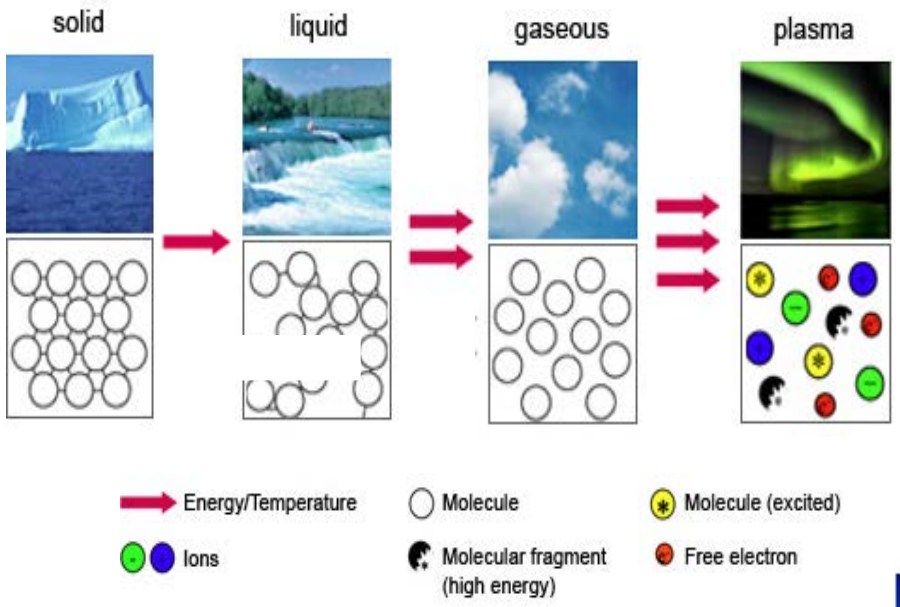
Intelligent packaging

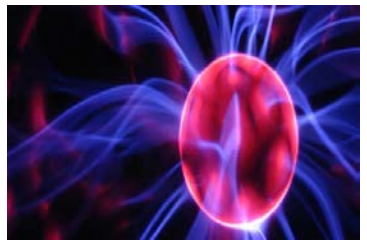
- Time-temperature integrators



Why not?

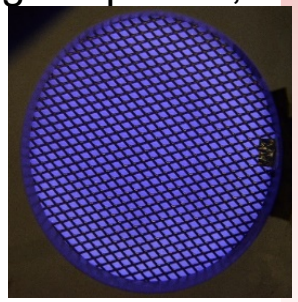
Atmospheric pressure cold plasma

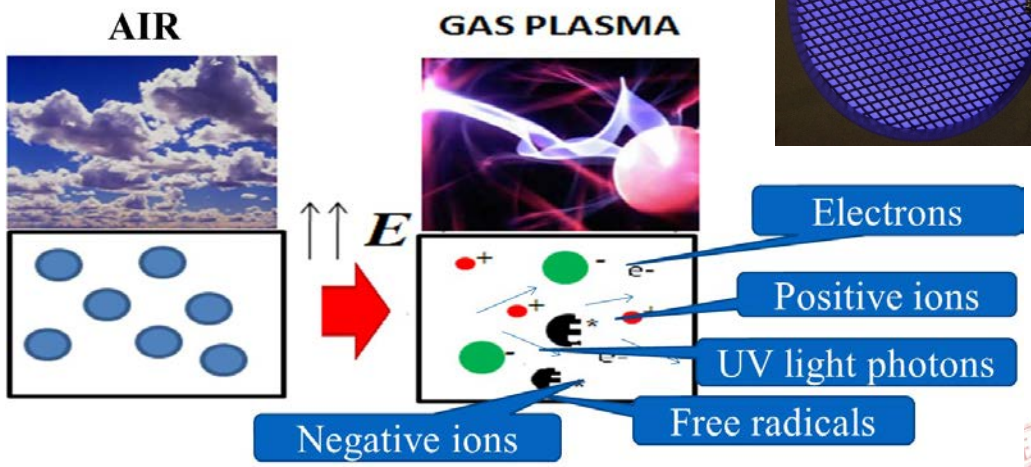




Ionized gas obtained by applying energy to a gas mixture

Contains: reactive oxygen and nitrogen species, radicals, electrons, ions, UV …





Main effect in Food

- Microbial decontamination
- Enzymatic inactivation
- Effect on living tissue metabolism
- Oxidation of fat and bioactive compounds

Atmospheric pressure cold plasma

Mackerel fresh fillets
Albertos et al (2017)
DBD 70-80 kV
Treatment time: up to 5 min

Dried filefish
Park et al (2015)
Treatment time up to 20 min

Results:
Spoilage bacteria was significantly reduced as DBD voltage-time increased.
Colour parameters not affected by DBD.
Lipid oxidation increased after DBD exposure.

Promising treatment for microbial inhibition in fish products
Necessary to tailor treatment parameters for each specific products

Atmospheric pressure cold plasma

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

High voltage cold atmospheric plasma: Antibacterial properties and its effect on quality of Asian sea bass slices

Oladipupo Odunayo Olatunde, Soottawat Benjakul*, Kitiya Vongkamjan

POSITIVE RESULTS

- HVCAP had a pronounced influence on the inhibition towards Vibrio parahaemolyticus, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Listeria monocytogenes
- The rate of reduction was higher for Gram-negative bacteria (Vibrio parahaemolyticus, Escherichia coli, and Pseudomonas aeruginosa) than Gram-positive bacteria (Staphylococcus aureus and Listeria monocytogenes).
- Microbial population was generally decreased as treatment time increased
- Enterobacteriaceae were not detected in samples treated with HVCAP generated for 5, 7.5 and 10 min

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Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

In-package cold plasma technologies

N.N. Misra[a,*], Ximena Yepez[b], Lei Xu[b], Kevin Keener[a,c]

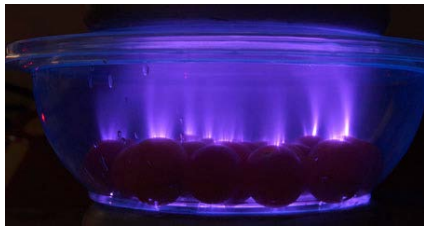
- The in-package volume DBD plasma has been shown to **reduce the population of the spoilage bacteria (total aerobic psychrotrophs**, Pseudomonas sp. and lactic acid bacteria) by ca. 1 log10 at 80 kV in fresh mackerel (Scomber scombrus) fillets (Albertos et al., 2017a,b).
- However, no effect on aerobic mesophilic counts
- an increased oxidation of the lipids poses question over the suitability of cold plasma treatments under these conditions.

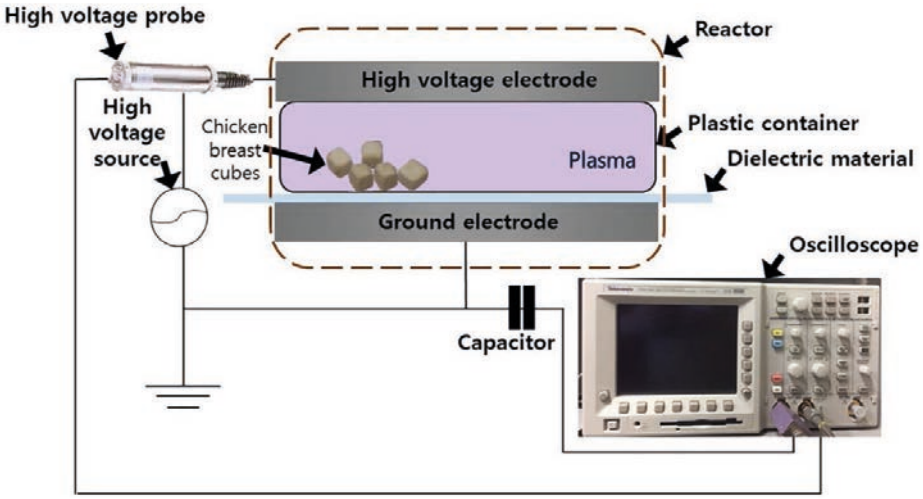
NEGATIVE RESULTS

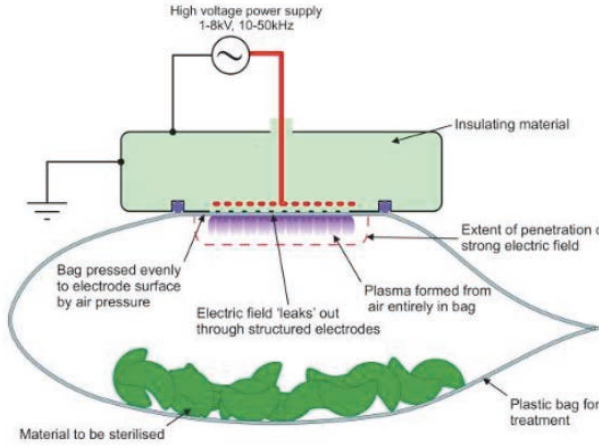
- Reactive species generated during HVCAP can induce lipid oxidation
- TBARS value rapidly in- creased as HVCAP treatment time increased with values ranging from 0.19 to 1.86 mg MDA/kg
- An increase in lightness (L*) and a decrease in redness (a*) were obtained for Asian sea bass slices treated with HVCAP as treatment time increased

Atmospheric pressure cold plasma

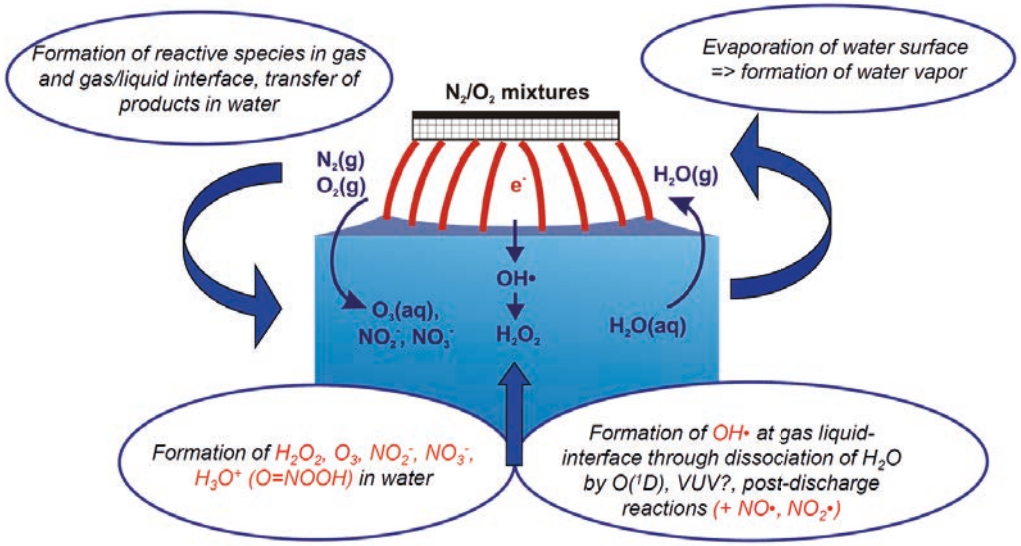
In-Package Plasma Generation



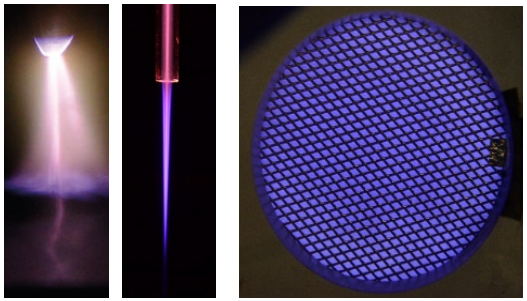




Plasma Activated Water (PAW)



Plasma discharges



Chemical composition of PAW

Hydrogen peroxide [µM]	Nitrites [µM]	pH
242	86	2,5

$$NO_2^- + H_2O_2 + H^+ \rightarrow O{=}NOOH + H_2O$$

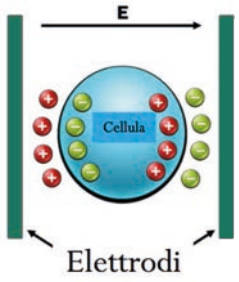
Peroxynitrous acid: strong antimicrobial agent

Antimicrobial activity on 10^4 CFU/ml of *Candida albicans* and *Staphylococcus aureus*

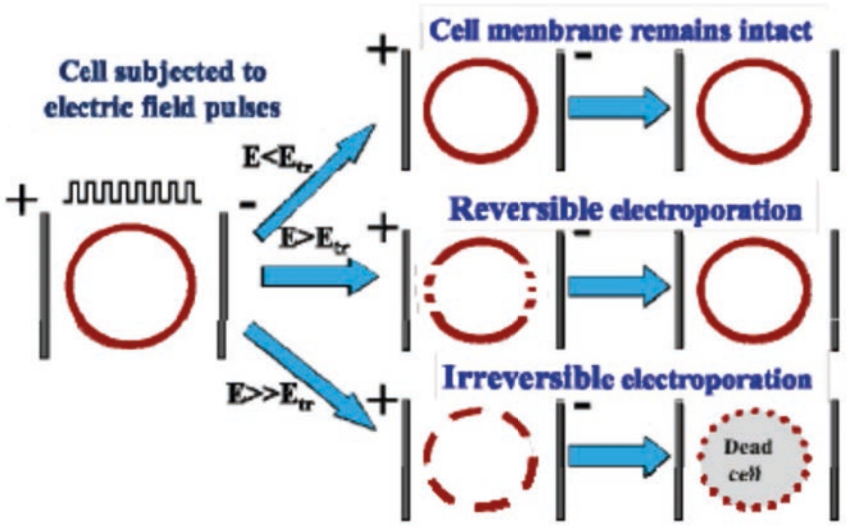
Contact time 5 min

Pathogen	Log R
Candida albicans	3,5 ± 0,4
Staphylococcus aureus	3,98 ± 0,1

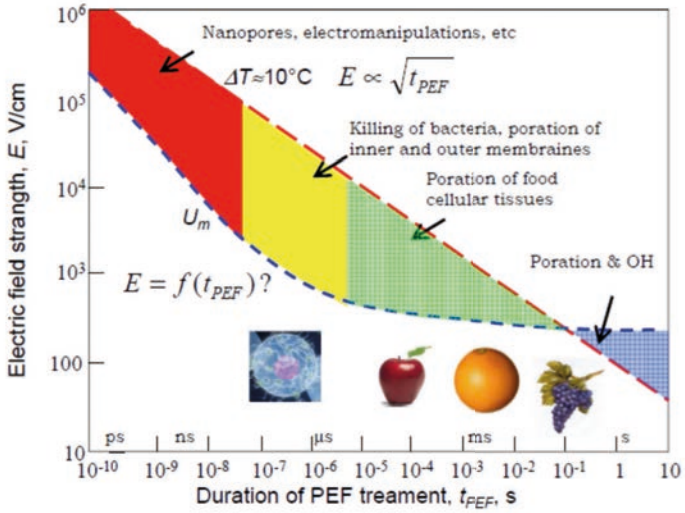
Pulsed Electric Fields (PEF)



Three possible actions following PEF application

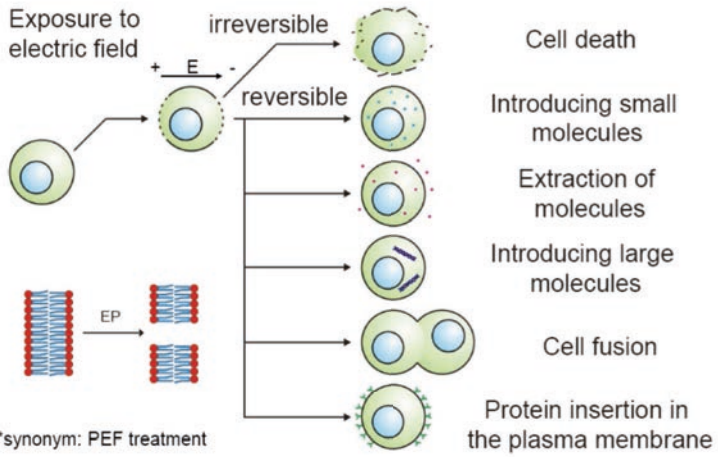


Range **di applicazioni del PEF**



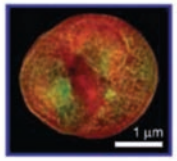
Karl H. Schoenbach, Robert H. Stark and Stephen j. Beebe "Bioelectrics-new applications for pulsed power technology", in Pulsed Power Plasma Science, 2001. PPPS-2001. Digest of Technical Papers. 2001.

Applications of Electroporation*



*synonym: PEF treatment

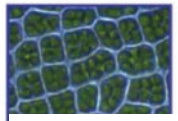
$E_c = U / 1.5\ R \cos\theta$



Microbial cells

R: 1 - 10 µm

Ec: 5 - 50 kV/cm



Tissue cells

Vegetable tissue cells

R: 10 - 100 µm

Ec: 0.5 - 5 kV/cm

Pulsed Electric Fields (PEF)

Mass transfer enhancement

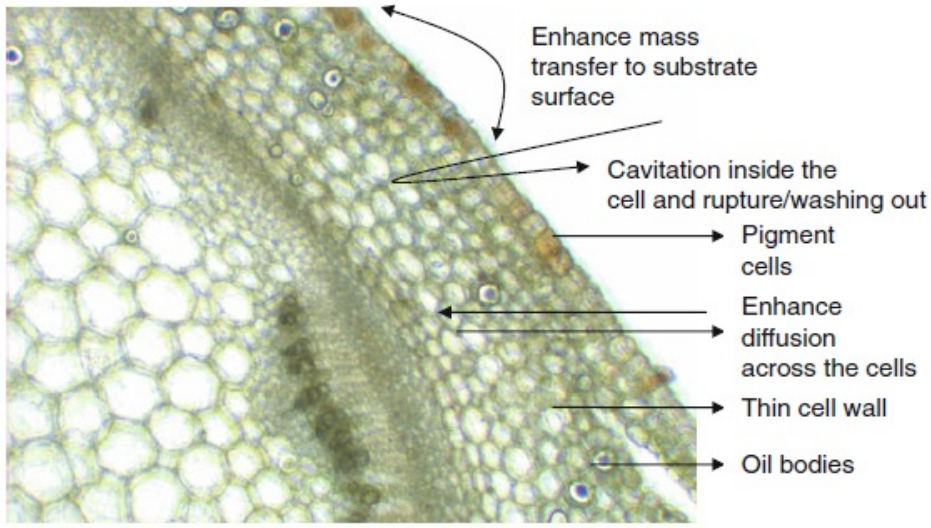
- Various processes in food production governed by mass transfer
- Mass transfer resistances limit yield and production rates

Ultrasound:

- **Acoustic streaming**
- **Cavitation**
- **Interparticle collisions**
- **Particle breakdown**

Processes:

- **Extraction**
- **Drying**
- **Brining**
- **Osmotic dehydration**
- **Enzyme activation**



Vilkhu et al. (2011)

Pulsed Electric Fields (PEF)

PEF equipments

Modular Lab Scale plant

Industrial scale

Benefits PEF in Fish Processing

- Enhanced drying, brining and marinating processes
- Improved micro-diffusion of brine and marinade in the fish tissue
- Improved water binding due to the interaction between protein, salt and phosphate
- Inactivation of parasites in fish fillets
- Reduced labor costs

Effects on Fish Quality

- product structure modifications
- tenderization
- safety
- improved water binding (particularly interesting for cooking operation)

Pulsed Electric Fields (PEF)

PEF assisted brining

Quality parameters of sea bass subjected to pulsed electric field (PEF) treatment and brine salting

Janna Cropotova, Jessica Genovese, Silvia Tappi, Pietro Rocculi, Luca Laghi, Marco Dalla Rosa, Turid Rustad

Winner of BEST POSTER presentation at

Raw material

Sea bass fished in the Adriatic sea in May 2019
Filleted and skinned
Cut in 2x2x2 cm pieces

Salting parameters

- NaCl: 5, 10%
- Time: 2, 5 and 8 days

PEF parameters

Field strenght 300, 660 V/cm

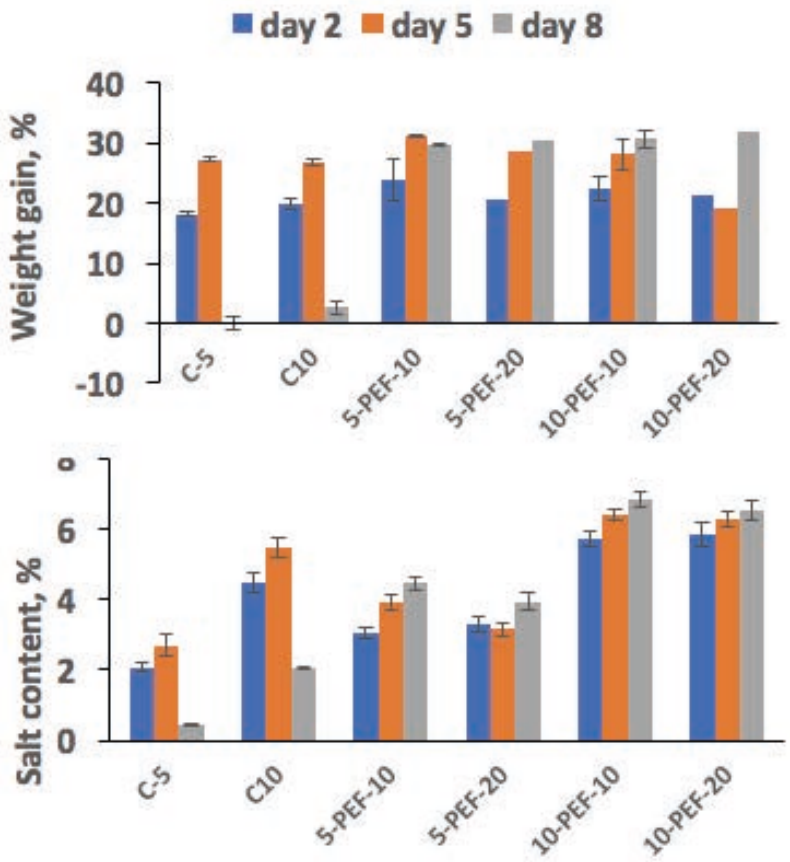
Full Factorial Design (18 samples)

Analytical Determinations:

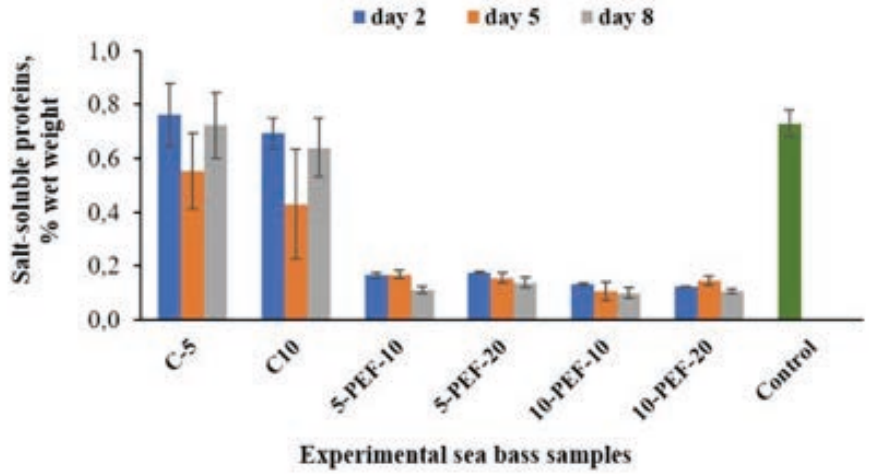
- Weight gain (%)
- Salt content (%)
- Color (L* and a*)
- Water Holding Capacity (WHC)
- Water activity (a_w)
- Lipid oxidation
- Protein Denaturation and solubility

Pulsed Electric Fields (PEF)

Main Results

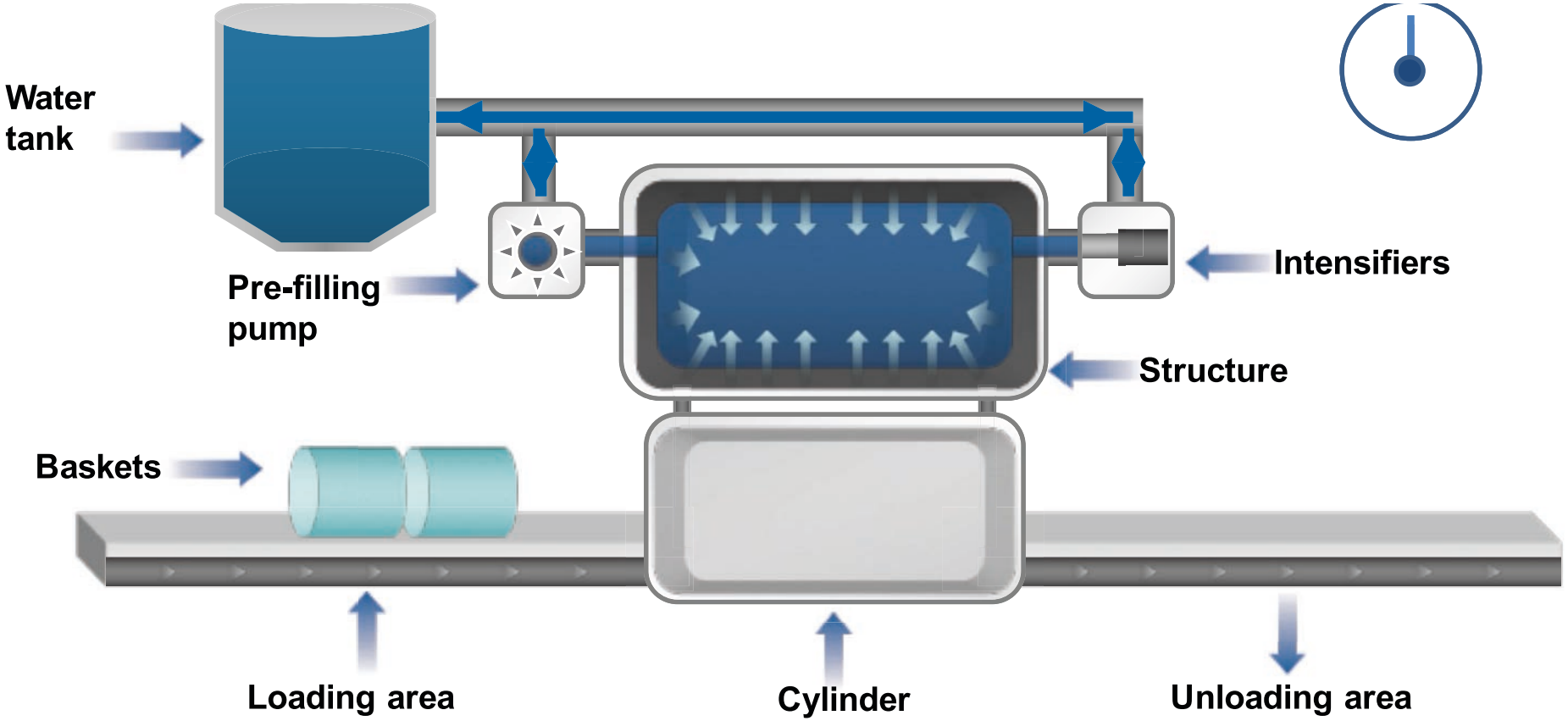


- PEF allowed to *increase salt distribution* in the fish tissue.
- *Solubility of miofibrillar protein* was significantly affected



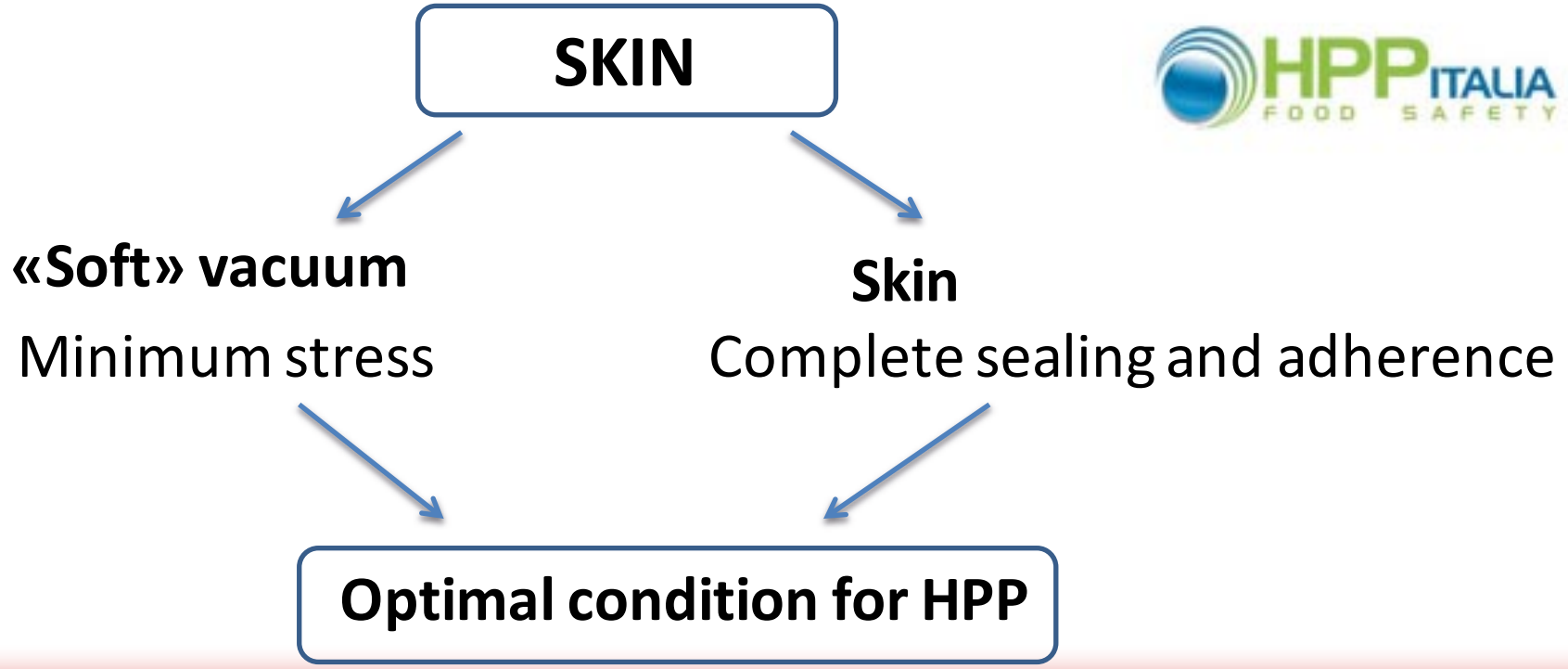
High hydrostatic pressure (HPP)

Maintenance



High hydrostatic pressure (HPP)

- HPP work with **flexible packaging** (and *water friendly labels*) => no glass, no canned foods
- **Vacuum packaging is the optimal condition**



High hydrostatic pressure (HPP)

Shrimp sausage

Shrimp sausage + seaweed

PRE-HPP (SL = 8 d)

POST-HPP (SL > 30 d)

No detectable differences!

Prinz Gourmet Italia

Salmon sausage

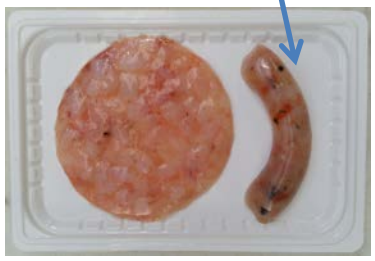
PRE-HPP (SL = 8 d)

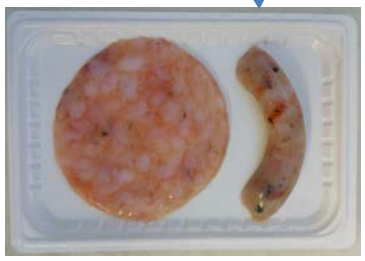
POST-HPP (SL > 21 d)

Detectable colour modification!

Shrimp burger

Shrimp sausage



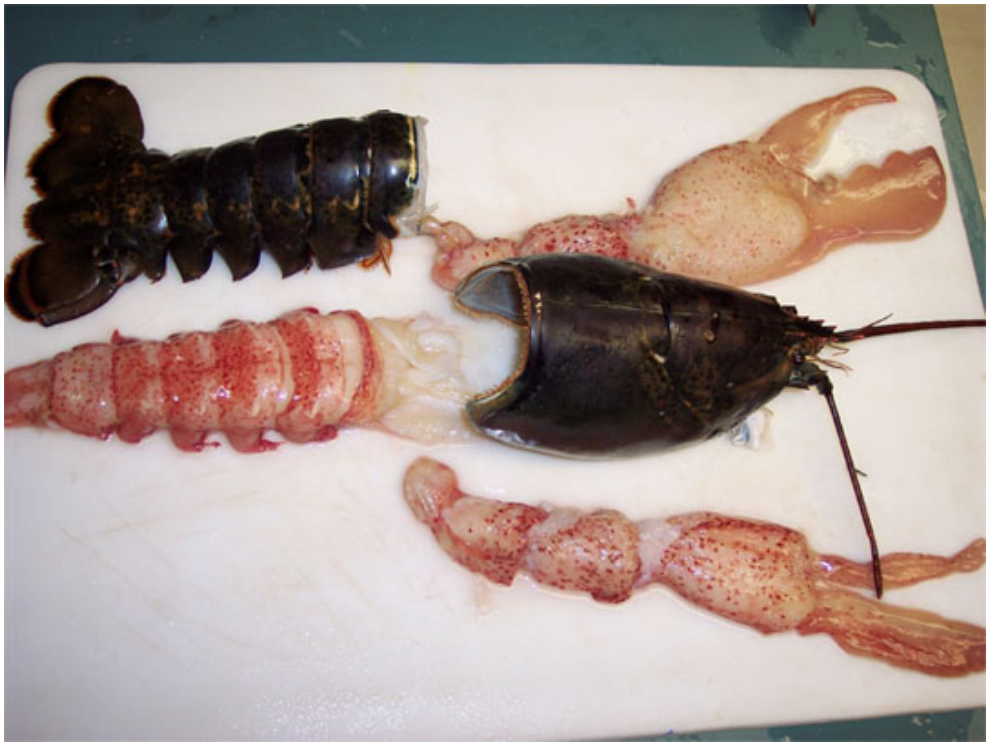


PRE-HPP (SL = 8 d)

POST-HPP (SL > 30 d)

No detectable differences!

High hydrostatic pressure (HPP)



Lobster: Complete flesh separation

THE EASY LOBSTER
..the complete lobster without its jacket!

Easy to get the full lobster-meat in 3 steps…

Put lobster on plate

step 1

step 2

step 3

and ready..! For bake, grill, steamed, butter poached, sous-vide …

High hydrostatic pressure (HPP)

High Pressure Plants & Products

Microbial load reduction

Shelling processing

- Pacific oyster (*Crassostrea gigas*) optimal shucking was 300 MPa for 2 min.
- Shelf-life of oysters treated by HP extended from 6–8 days to 12 days under refrigerated condition

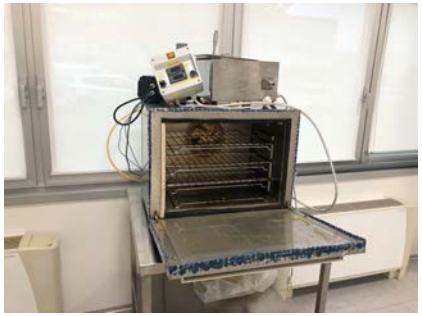
Modified atmosphere processing and packaging

Cryo-smoking – set up of procedures

Equipment, developed and in the process of patenting by CS

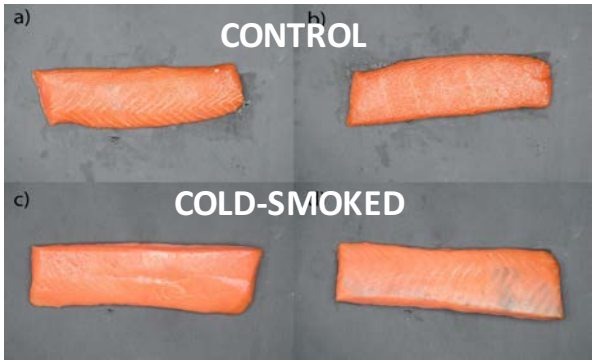
Smoking

- 30 °C (without ice) 1-2 h Smoking: Chippings Beech Tree
- 1°C Carrier gas: Cold Nitrogen 1-2 h Smoking: Chippings Beech Tree



AIM

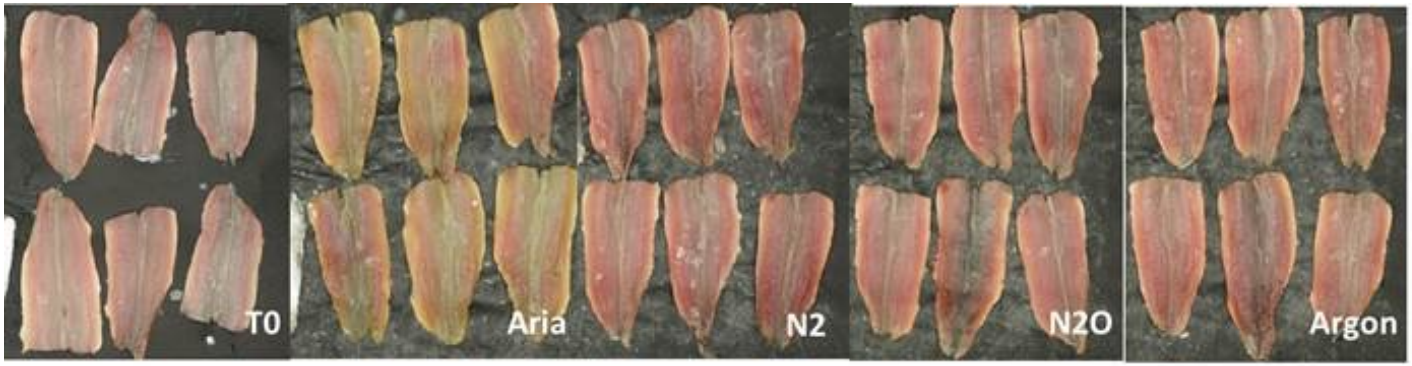
obtain smoked salmon with improved quality and nutritional characteristics compared to the traditional method



Preliminary tests

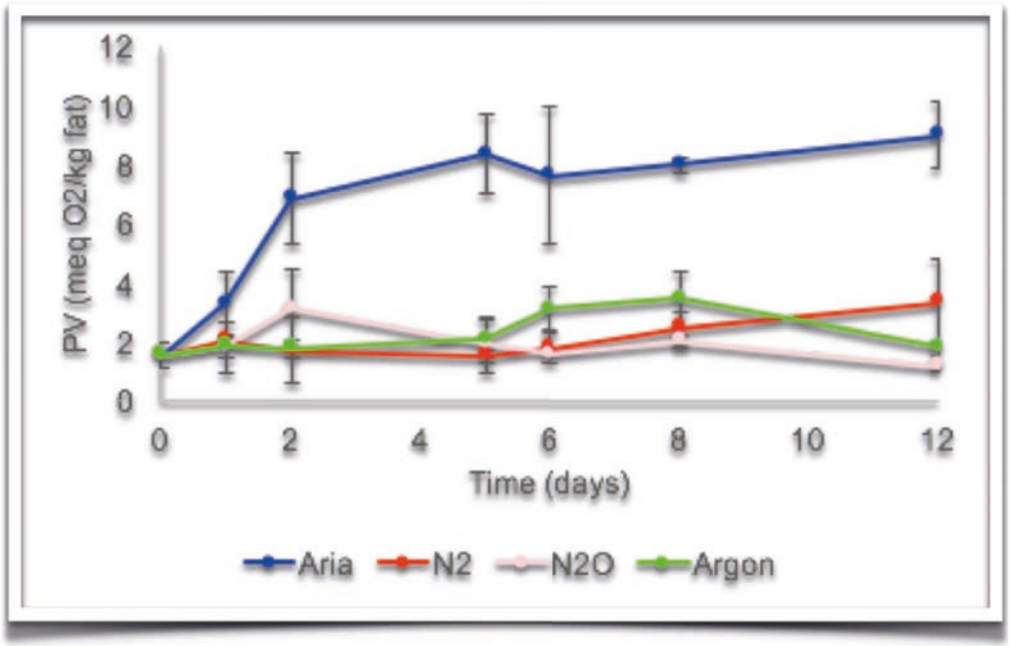
	Color			a_w	Hardness	Dry matter
	L*	a*	b*		(N)	(%)
Control	38,68 ^{a} (± 1,24)	15,13 ^{a} (± 0,54)	20,73 ^{b} (± 1,75)	0,894 ^{a} (± 0,006)	22,36 ^{b} (± 1,93)	45,51 ^{b} (± 1,18)
Cryo-Smoked	41,39 ^{b} (± 1,37)	16,73 ^{a} (± 1,00)	15,84 ^{a} (± 2,85)	0,950 ^{b} (± 0,003)	12,42 ^{a} (± 1,22)	38,19 ^{a} (± 0,61)

Modified atmosphere processing and packaging



Colour was affected by MAP and resulted in higher L* and lower a* values in Air sample

Fat oxidation was inhibited by MAP as shown by PV values.



Tappi et al., 2018, FoodOmics Conference, Cesena (ITA)

Optimization of technologies for **seafood processing and by-products valorisation**

Squilla mantis

Mechanical separation

Shells

Flesh

Frozen and stored for 12 months

Tappi et al., 2018, FoodOmics Conference, Cesena (ITA)

Carapace

Chitin

Chitosan

Antimicrobial and antioxidant properties

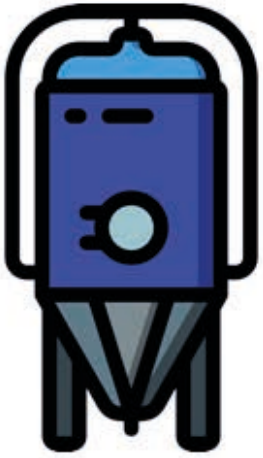
Creation of added value products

Optimization of technologies for **seafood processing and by-products valorisation**

Biotechnological processes to obtain functional ingredients from solid fish by-products

Solid Fish by-products

Safe and robust selected yeast strains (i.e. *Y. lipolytica* strains)



Optimized and sustainable biotechnological processes

Multiple functional ingredients

Most relevant research projects

- **PRIZEFISH** – *Piloting of eco-innovative fishery supply-chains to market added-value Adriatic fish products*. Project Interreg Italy-Croatia, European Regional Development Fund (2018-2021).

- **FUTUREUAQUA** – *Future growth in sustainable, resilient and climate friendly organic and conventional European aquaculture*. Project H2020. Call: H2020-BG-2018-2020 (Blue Growth). Taype of action: IA (2018-2022).

- **NEWTECHAQUA** - *New Technologies, Tools and Strategies for a Sustainable, Resilient and Innovative European Aquaculture* H2020-BG-2018-2020 (Blue Growth) Type of action: IA (2019-2022)

- **PLASMAFOOD** – *Study and optimizazion of cold atmospheric plasma treatment for food safety and quality improvement.* PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE (2018-2021).

From research to commercial products!

Research

DIPARTIMENTO DI SCIENZE E TECNOLOGIE AGRO-ALIMENTARI

OCEM POWER ELECTRONICS

HPP ITALIA FOOD SAFETY

microglass

ALINTEL

Cibo&Salute

Plant producers and users

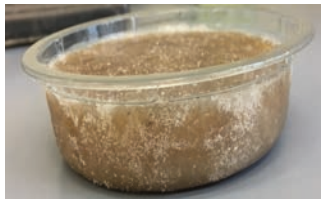
Seafood products

ECONOMIA DEL MARE

Tagliapietra
LE ECCELLENZE DEL MARE

O.P. BIVALVIA VENETO s.c.

From research to commercial products!



Il CIRI Agroalimentare

Struttura indipendente:

Via Quinto Bucci 336, Cesena (FC) → 950 m^2

Spazi condivisi:

Firmati accordi di condivisione spazi con

BIGEA	→ 15	m^2
FABIT	→ 100	m^2
DEI	→ 15	m^2
CHIM	→ 63	m^2
STAT	→ 12	m^2
DISTAL-CES	→ 607	m^2
DISTAL-BOL	→ 216	m^2
DICAM	→ 82	m^2

Il CIRI Agroalimentare

Organizzazione e personale

Struttura:

Consiglio di CIRI
- Direttore – Vicedirettore
  - Resp. gestione qualità
- Giunta esecutiva

Responsabile Amministrativo
- Amministrazione comune

5 Unità operative
- Sicurezza e autenticità
- Produzione primaria sostenibile
- Qualità, nutrizione e salute
- Processi e prodotti alimentari
- Consumo e mercati

Personale: (2019)

Ricercatori afferenti	113
Assegnisti	14
Contratti co.co.co.	4

DISTAL, Campus of Food Science and Technology, *Alma Mater Studiorum*,
Università di Bologna

E-mail: pietro.rocculi3@unibo.it

Thanks for your attention !!