Workshop
VALORIZZAZIONE DEI PRODOTTI DELLA PESCA DELLA CAMPANIA
FEAMP 2014/2020 MISURA 1.26 «INNOVAZIONE»

Le nuove tecnologie per migliorare la shelf life dei prodotti ittici

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Outline

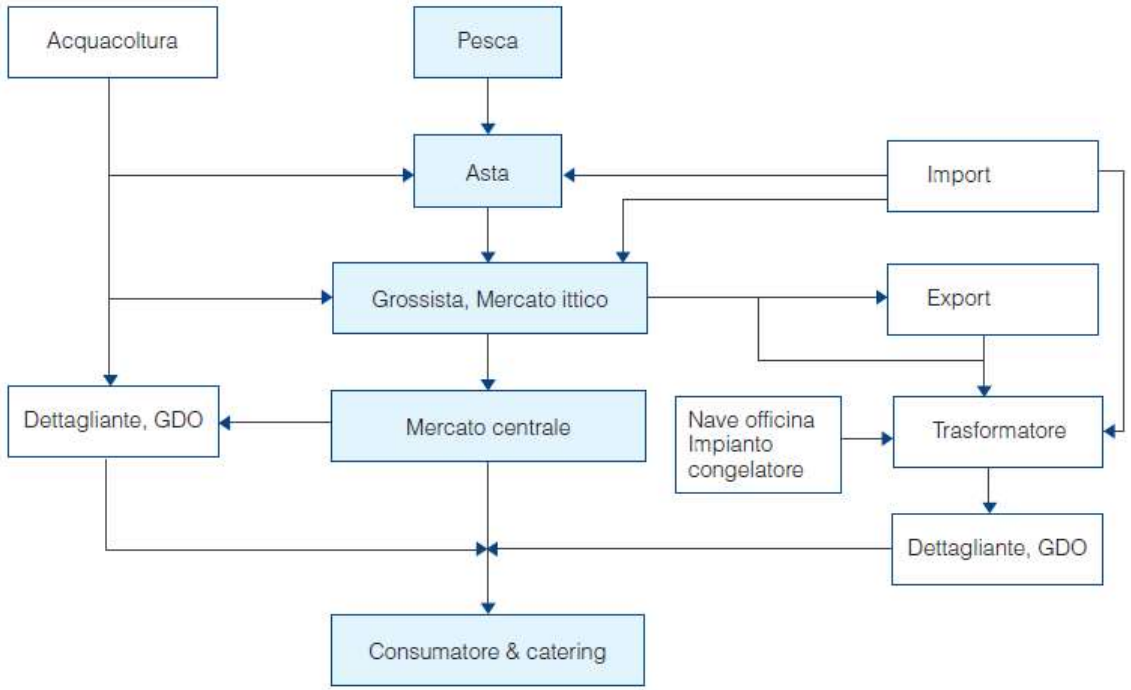
- La shelf life dei prodotti ittici
- La filiera ittica e le nuove tecnologie di produzione
  - Sanificazione
  - Conservazione
- Acqua attivata al plasma
- Coating attivi a base di biopolimeri
- Conclusioni

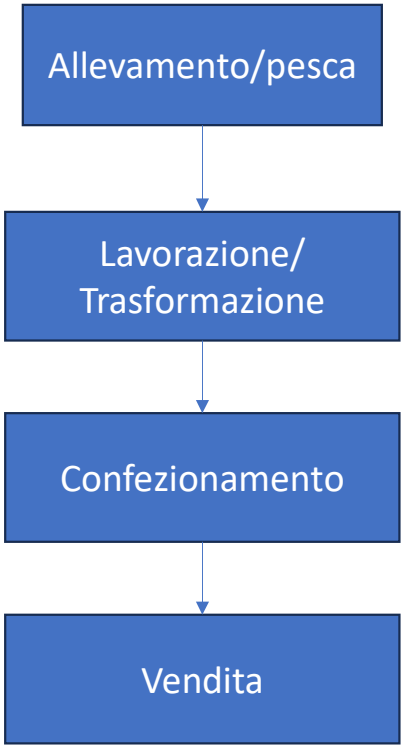
Shelf life dei prodotti ittici

- Il periodo di tempo, in specifiche condizioni di conservazione, tra la produzione e la vendita, durante il quale l'alimento è sicuro* e di qualità accettabile per il consumatore in termini di proprietà chimiche, fisiche, sensoriali e funzionali (Robertson, 2010).

  - REQUISITI PER I PRODOTTI DELLA PESCA TRASFORMATI
    - Requisiti microbiologici in base al regolamento 852/2004 e 853/2004
    - Caratteristiche organolettiche
    - Istamina
    - Azoto volatile totale
    - Parassiti
    - Tossine

La filiera ittica





Le nuove tecnologie

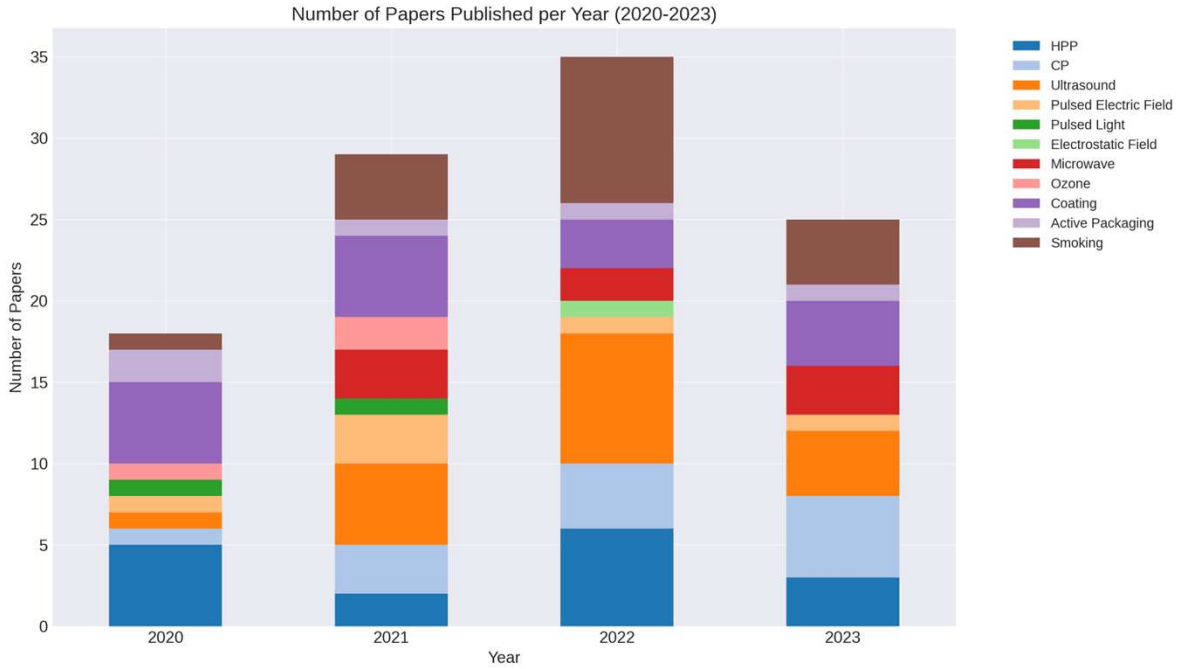
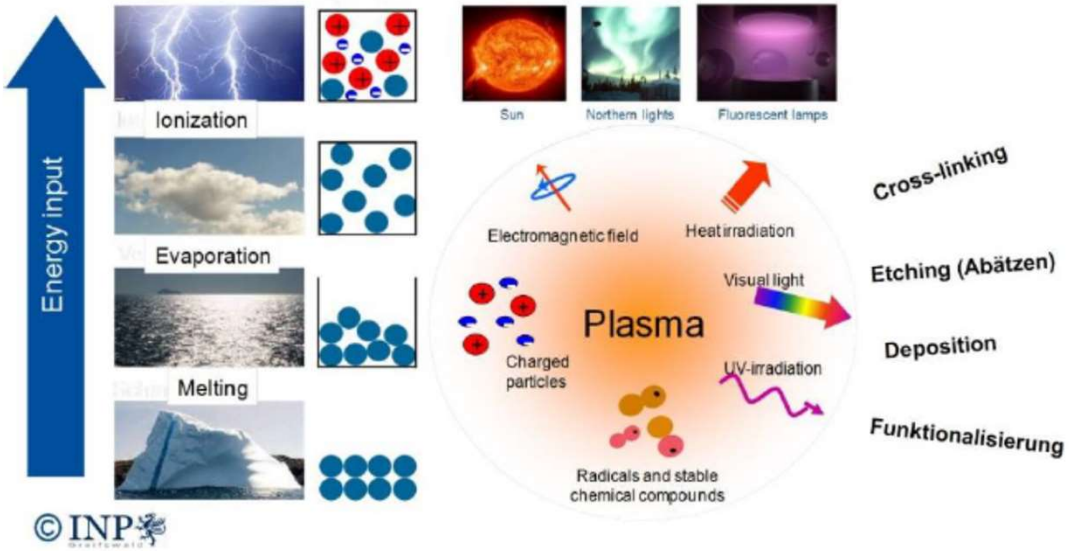


Figure 1. Annual publication count by technology (2020-2023) applied for seafood products based on Scopus and Web of Science database (822 documents results).

Metodi di sanificazione

Acqua attivata al plasma

Acqua attivata al plasma



- ✓ Il plasma è il IV stato della materia
- ✓ Il plasma si ottiene per ionizzazione dei gas e generazione di specie reattive (ROS e RNS)
- ✓ L'attività e la funzionalità del plasma può essere catturata nell'acqua

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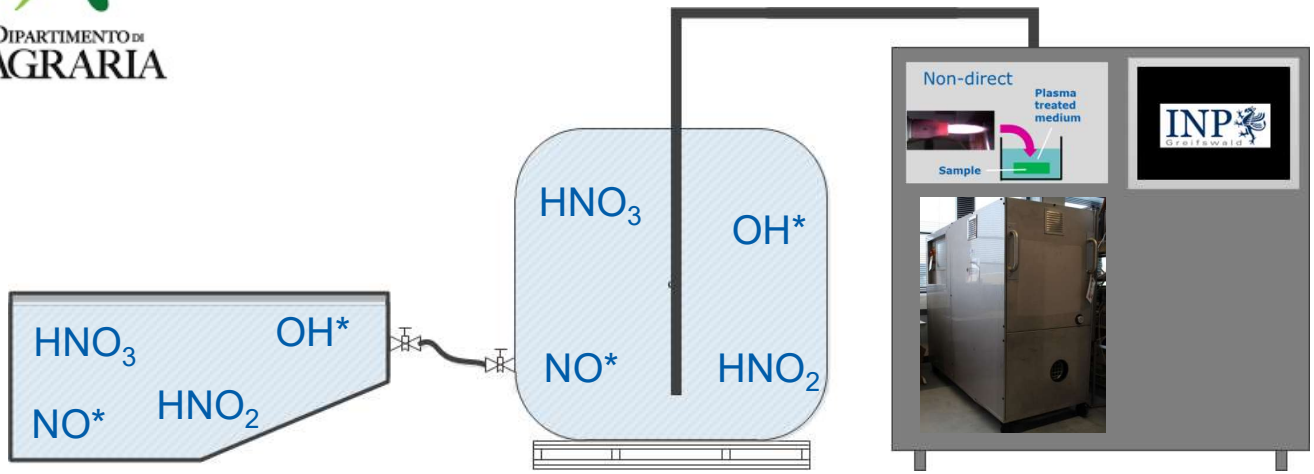
PLASMA

Technology applied	Specie studied	Key findings
Plasma activated water	Sea bream (Sparus aurata)	Extension of shelf life of 2.8 days using plasma processing technologies respect standard procedures
Cold atmospheric plasma	Golden pomfret (Trachinotus ovatus)	Improvements in the color parameters, hydration properties, and textural property parameters of muscle proteins
Cold atmospheric plasma with helium	Sea bass (Dicentrarchus labrax)	He-plasma treatments were found to suppress the growth of psychrophilic bacteria more effectively after 5 days of cold storage
Cold atmospheric plasma	Bolti fish (Tilapia nilotica)	Extension of tilapia fish shelf life up to 10 days, respect to the 4 days of control specimen.
Atmospheric pressure plasma jet	Salmon (Salmo salar)	Treatment with N_2 plasma for 12 minutes reduced the NoV viral load from an initial inoculum of 2.7×10^4 copies/g to 2.17×10^4 copies/g. Air-based or O2-based plasma treatments for 9–12 minutes were even more effective, reducing the viral load to undetectable levels (below 100 copies/g). TBARS values in the sashimi, remained within acceptable levels for salmon sashimi.

Acqua attivata al plasma



Serbatoio di raccolta dell'acqua attivata al plasma

Acqua attivata al plasma

Table 2
Chemical reactions taking place during PAW generation resulting in the formation of ROS and RNS. Adapted from Pârvulescu, Magureanu, and Lukes (2012) by courtesy of John Wiley & Sons.

$H_2O + e \rightarrow OH\bullet + H\bullet + e^-$	(1)
$H_2O + e \rightarrow H^+ + OH\bullet + 2\,e^-$	(2)
$H_2O + e \rightarrow H\bullet + O\bullet + H\bullet + e^-$	(3)
$O_2 + e \rightarrow O^+ + O + 2e$	(4)
$O_2 + e \rightarrow O^- + O$	(5)
$O + O_2 \rightarrow O_3$	(6)
$O_3 + NO \rightarrow NO_2 + O_2$	(7)
$N + O_2 \rightarrow NO + O$	(8)
$O + N_2 \rightarrow NO + N$	(9)
$O + NO_2 \rightarrow NO + O_2$	(10)
$2\,NO + O_2 \rightarrow 2NO_2$	(11)
$NO_2 + OH \rightarrow HNO_3$	(12)
$H_2O_2 + h\nu \rightarrow OH\bullet + OH\bullet$	(13)
$3\,NO_2 + H_2O \rightarrow 2\,HNO_3 + NO$	(14)
$H_2O_2 + H^+ + NO_2^- \rightarrow ONOOH + H_2O$	(15)
$OH\bullet + OH\bullet \rightarrow H_2O_2$	(16)
$NO + NO \rightarrow N_2 + O_2$	(17)
$NO + OH\bullet \rightarrow HNO_2$	(18)
$HNO_2 + OH\bullet \rightarrow NO_2 + H_2O$	(19)
$NO_2 + h\nu \rightarrow NO + O\bullet$	(20)
$NO_3 + h\nu \rightarrow NO + O_2$	(21)
$NO_2 + NO_3 \rightarrow N_2O_5$	(22)
$N_2O_5 + H_2O \rightarrow 2HNO_3$	(23)
$2\,NO_2 + H_2O \rightarrow NO_2^- + NO_3^- + 2H^+$	(24)
$3\,NO_2^- + 3\,H^+ \rightarrow 2\,NO + NO_3^- + H_3O^+$	(25)
$OH + NO_2 \rightarrow [O{=}N{-}OOH] \rightarrow O{=}N{-}OO^- + H^+$	(26)

Thirumdas et al., (2018). Plasma activated water (PAW): Chemistry, physico-chemical properties, applications in food and agriculture. Trends in Food Science & Technology, 77, 21-31.

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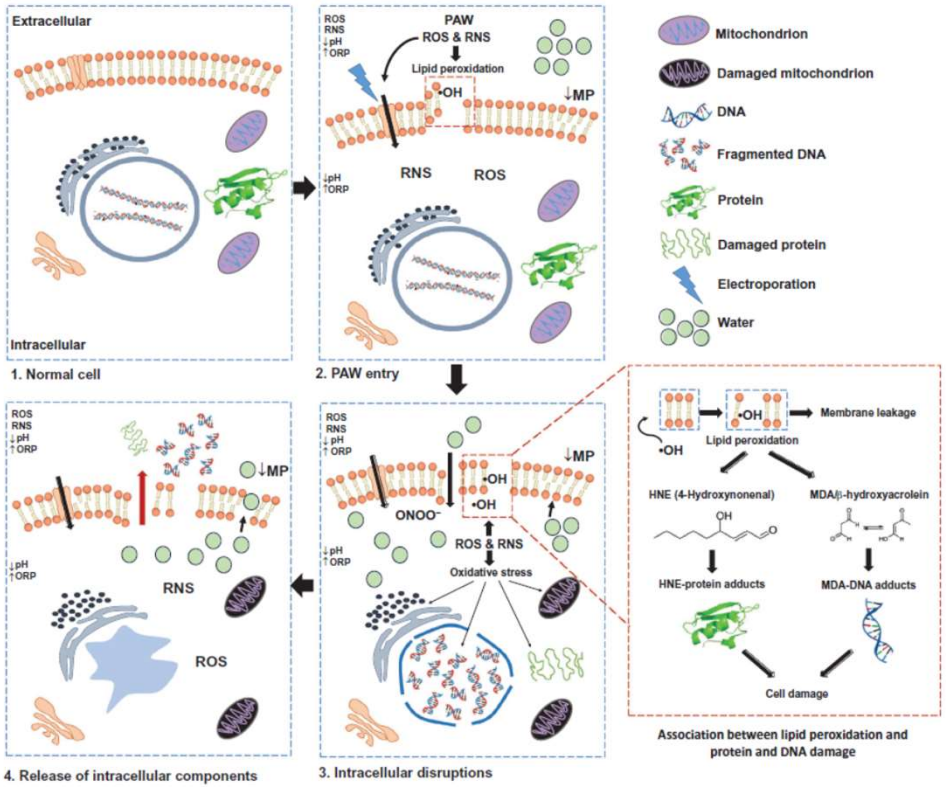

FIGURE 2 Mechanism of microbial inactivation by PAW divided into three main stages, including cell membrane disruption, disruption of intracellular components, and release of the intracellular materials and components

Meccanismo di inattivazione microbica:

- Distruzione della membrana cellulare
- Distruzione dei componenti intracellulare
- Rilascio dei componenti cellulari

Herianto et al., (2020). Non-thermal Plasma activated water: A Comprehensive review of this new tool for enhanced food safety and quality. Comprehensive Review in Food Science and Food Safety , 20, 583-626.

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Inattivazione di microrganismi con PAW

Table 4
Key findings of inactivation of microorganism using PAW.

Microorganism	Mode of activation	Activation time (min)	Storage period (day)	Treatment time (min)	Inactivation (in Log_{10} CFU/mL or CFU/g)	Form of cells	Reference
E. coli	Plasma discharge over the water surface	20	0	15	5.6	Planktonic cells	Traylor et al. (2011)
	Plasma discharge over the water surface	15	–	0.5, 1, 1.5	1, 2, 5	Planktonic cells	Shainsky et al. (2012)
	Plasma discharge over the water surface	7	–	15	7	Planktonic cells	Oehmigen et al. (2010)
Aerobic bacteria	Plasma plume touching the water surface	20	1	5, 10	0.22, 1.5	Surface attached cells	Xu et al. (2016)
S. aureus	Plasma plume touching the water surface	20	0, 1	20	6, 2	Planktonic cells	Zhang et al. (2016)
	Plasma discharge inside the water	20	1, 3, 7, 15, 30	20	1.9,1, 0.25, 0.3, 0.7	Planktonic cells	Shen et al. (2016)
	Plasma discharge over the water surface	10	0	5, 10, 15	1.5, 1.6, 1.9	Surface attached cells	Ma et al. (2015)
		10	4	5, 10, 15	1.7, 2.0, 2.25	Surface attached cells	
	Plasma discharge inside the water	5, 10	–	10	4.1, 5,7	Planktonic cells	Zhang et al. (2016)
	Plasma discharge inside the water	5, 10, 15, 20	–	20	3.5, 3.6, 4.5, 5.0	Planktonic cells	Tian et al. (2015)
H. alvei,	Plasma discharge over the water surface	5	–	10, 20, 30	1.84, 3.16, 5.36	Adherent cells	Kamgang-Youbi et al. (2009)
S. cerevisiae					0.52, 1.27, 3.07		
L. mesentroids					3.52, 3.98, 4.69		
H. alvei	Plasma discharge over the water surface	5	–	5, 10, 20	6.8, 5.7, 2.5	Adherent cells	Naitali et al. (2010)
B. subtilis	Plasma discharge inside the water	20	–	2, 4, 6	3.2, 3.6, 4.0		Sun et al. (2012)

Efficacia su Alimenti

TABLE 2 (Continued)

Devices	Physicochemistries of PAW	Microorganism concern	Classification	The treated foods	Treatment time	Microbial reduction (maximal reduction)	References
		Penicillium chrysogenum	Fungi	Korean rice cake	40 min	~2.0 log CFU/g	Han et al. (2020)
		Candida albicans	Fungi	Korean rice cake	40 min	~2.0 log CFU/g	Han et al. (2020)
APPJ with single electrode	pH 3.7 ORP = 467 mV EC = 218 μS/cm	Total bacteria	Bacteria	Button mushroom	5, 10, and 15 min	1.5 log CFU/g	Xu et al. (2016)
		Fungi	Fungi	Button mushroom	5, 10, and 15 min	0.5 log CFU/g	Xu et al. (2016)
Application of PAW as thawing media on meat products							
APPJ	n/a	Total viable count (TVC)	–	Beef	–	1.62 log CF/g	Liao et al. (2020)
		Fungi and yeast	Fungi	Beef	–	1.76 log CF/g	Liao et al. (2020)
Application of PAW ice on the preservation of aquatic products							
DBD	pH 3.04 ORP = 485 mV EC = 427 μS/cm H_2O_2 = 2.15 mg/mL NO_3^- = 78.2 mg/mL O_3 = 8.60 mg/mL	Total viable counts (TVC)	–	Shrimps	9 days	2.1 log CFU/g	Liao, Su, et al. (2018)

Note: n/d: not detected; n/a: nonavailable;

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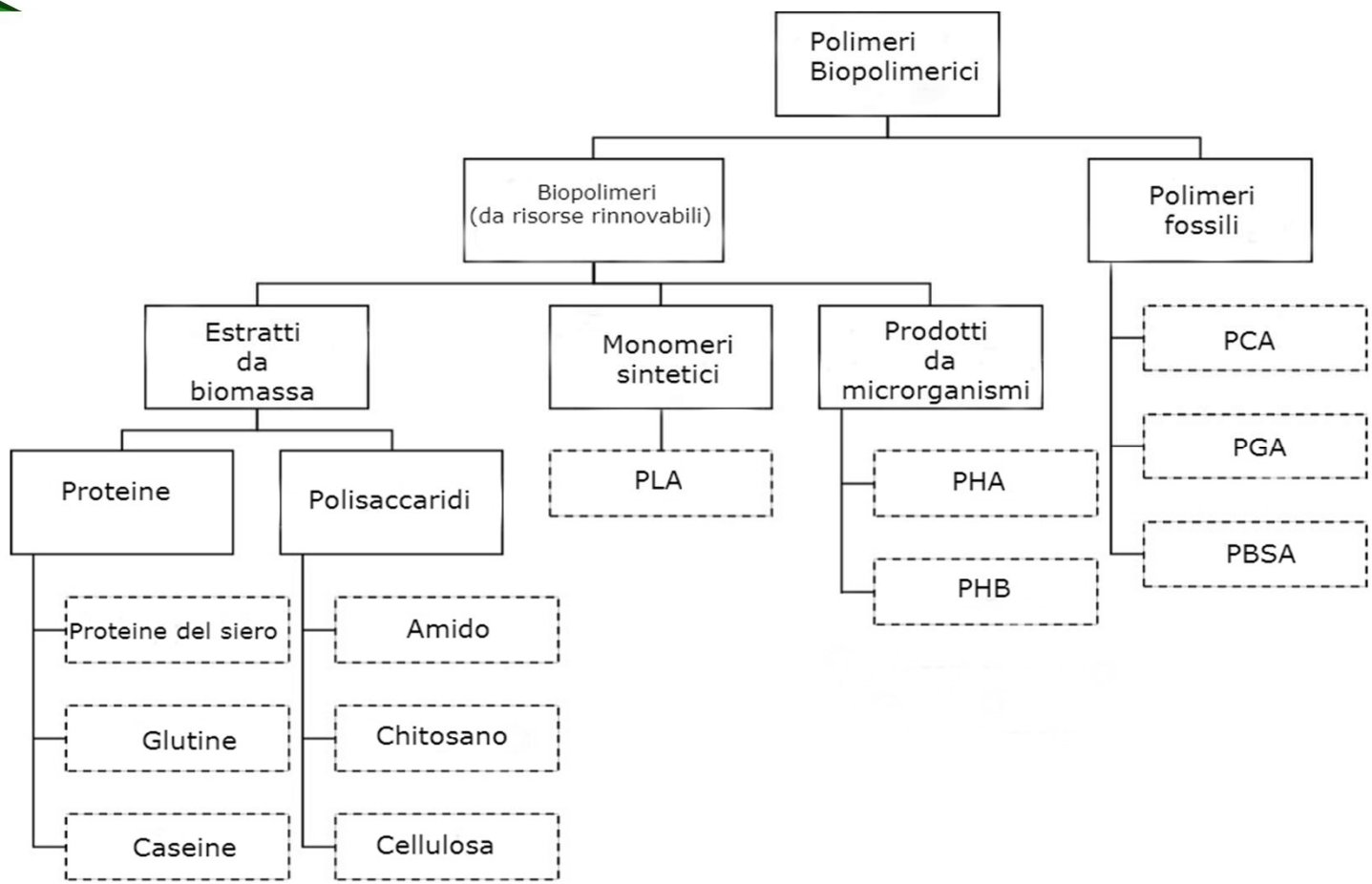
Metodi conservazione

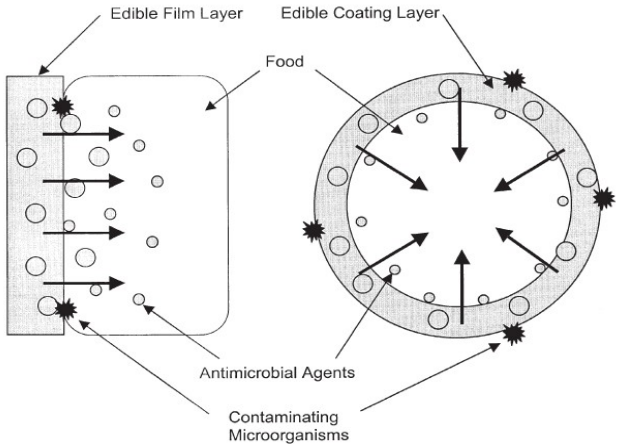
Coating attivi a base di biopolimeri

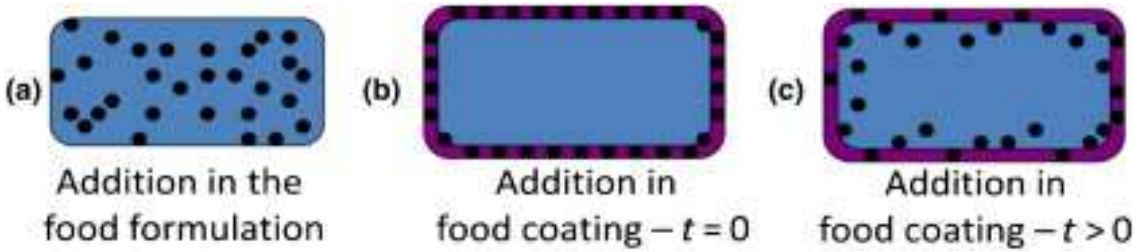

Polimeri Biopolimerici
Biopolimeri (da risorse rinnovabili)
Polimeri fossili
Estratti da biomassa
Monomeri sintetici
Prodotti da microrganismi
PCA
PGA
PBSA
Proteine
Polisaccaridi
PLA
PHA
PHB
Proteine del siero
Glutine
Caseine
Amido
Chitosano
Cellulosa

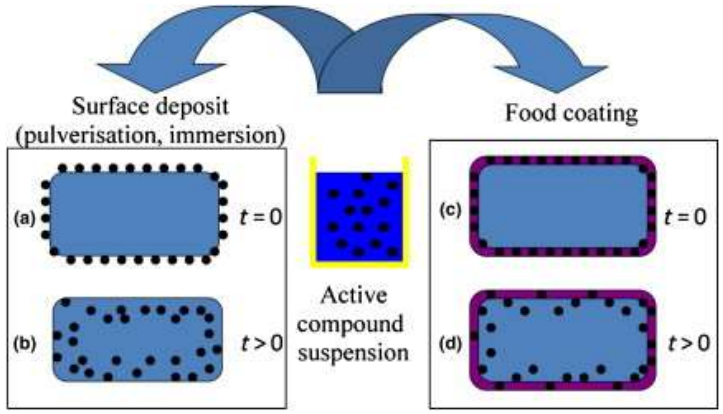
Coating *attivi* a base di biopolimeri

Carrier di sostanze attive:

- Antimicrobiche
- Antiossidanti







Coating attivi

Biopolymer	Active compound	Fish species	Key findings	
Chitosan or chitosan nanoparticle	Clove oil (1.5%)	Grey mullet (Mugil cephalus) steaks	A combination of nanochitosan and clove oil treatment prolonged the shelf life of mullet steaks to 24 days at refrigeration temperature, by preserving the chemical, microbiological and sensory characteristics of the fresh fish steaks.	2022)
Gelatine from salmon fish bone + chitosan	Gallic acid or clove oil	Salmon fillet	The combination of gelatine, chitosan, gallic acid and clove oil had the best performance on salmon fillet preservation and prolonged the shelf life for at least 5 days.	(Xiong et al., 2021)
Sodium alginate	Postbiotics + probiotic bacteria cells	Salmon fillets	The fortified coating significantly inhibited the proliferation of psychrophilic bacteria, Pseudomonas spp., Enterobacteriaceae, as well as the spiked Listeria monocytogenes on the salmon fillets during a refrigeration storage of 9 days	(Hua et al., 2022)
Alginate/protein-based coating	Antimicrobial agents	Sturgeon fillets	Composite coatings can be used as a multifunctional coating material for freshness preservation of sturgeon fillets to improve quality and extend shelf life.	(Tan et al., 2022)
Alginate	Carum copticum essential oil (CEO)	Fish burger	The study demonstrated that solid lipid nanoparticles with CEO enhanced fish burger shelf life at 4°C, reducing lipid oxidation, microbial growth, and total volatile basic nitrogen production more effectively than free CEO. The results support the use of nanoencapsulated CEO in food preservation.	(Hashemi et al., 2023)

Technology used	Shelf life results	Reference
Plasma	Control: 5 days Treated samples: 20 days	(Chaijan et al., 2021)
	Control: 4 days Treated samples: 10 days	(Mohamed et al., 2021)
	Control: 4.7 days Treated samples: 7.5 days	(Chanioti et al., 2023)
	Control: 9 days Treated samples: 21 days	(Olatunde et al., 2020)
	Control: 6 days Treated samples: 18 days	(Shiekh, Benjakul, et al., 2021)
	Control: 5 days Treated samples: 7-8 days	(Giannoglou et al., 2021)
Edible coatings	Control: 6 days Treated samples: 9 days	(Hua et al., 2022)
	Control: 10 days Treated samples: 15 days	(Xiong et al., 2021)
	Control: 4 days Treated samples: 12 days	(Agdar GhareAghaji et al., 2021)
	Control: 15 days Treated samples	(Chaijan et al., 2022)

Conclusioni

- Le nuove tecnologie mostrano evidenti vantaggi nel preservare la sicurezza dei prodotti ittici e prolungare la shelf-life;
- L'acqua attivata al plasma necessita di ulteriori studi per garantire la sua approvazione a livello legislativo;
- I coating edibili hanno elevate potenzialità ma la loro efficacia è fortemente legata alle specificità del prodotto;
- Inoltre, studi sistematici sull'effetto dei coating sulle proprietà sensoriali dei prodotti alimentari e sull'accettabilità del prodotto da parte dei consumatori sono necessari;
- La combinazione di più tecnologie consente di ottenere risultati desiderabili senza impattare negativamente sulla qualità del prodotto

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