Innovations in Food Loss and Waste Management
Ancona, 23-25 January 2024



The PRIMA project Fedkito: FrEsh FooD sustainable pacKaging in the cIrcular economy

Priscilla Farina, Barbara Conti

Department of Agriculture, Food and Environment, University of Pisa

priscilla.farina@agr.unipi.it

Fedkito

FrEsh fooD sustainable pacKaging In The circular ecOnomy

Prof. **Barbara Conti**
University of Pisa
Project Coordinator

Starting date: 15th September **2020**
Ending date: 14th September **2023**

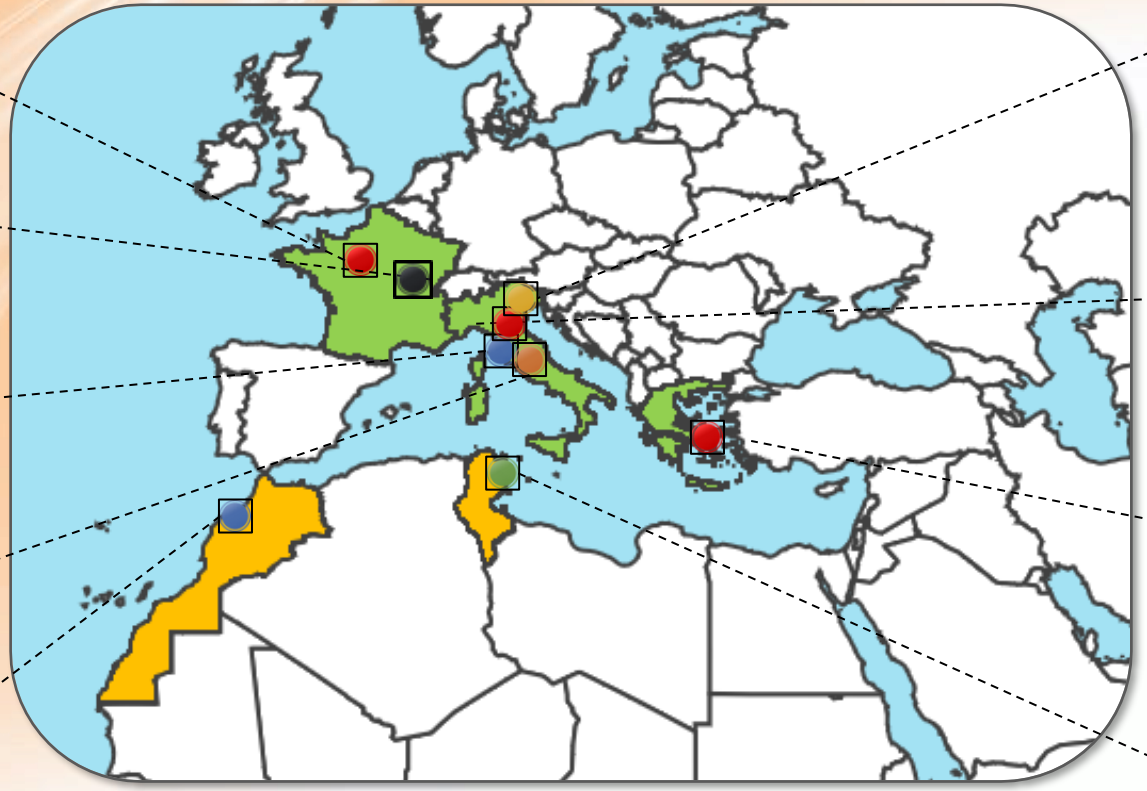
Budget: 1.755.416,00 €
Donor: Partnership on Research and Innovation in the Mediterranean Area (**PRIMA**) and Italian Ministero dell'Università e della Ricerca (**MUR**)

Experts involved: entomologists, mycologists, chemists, sensory analysts, material engineers, fresh food producers, economists, communication experts, and data analysts

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

SORBONNE UNIVERSITÉ
Azienda Agricola Salvadori Furio s.s.a.
UNIVERSITÀ DI PISA
AIMPLAS PLASTICS TECHNOLOGY CENTRE
Université Hassan II Casablanca
GUSTO PARMIGIANO BUONO - SANO - EMILIANO
CBBC
UNIVERSITY OF THESSALY
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

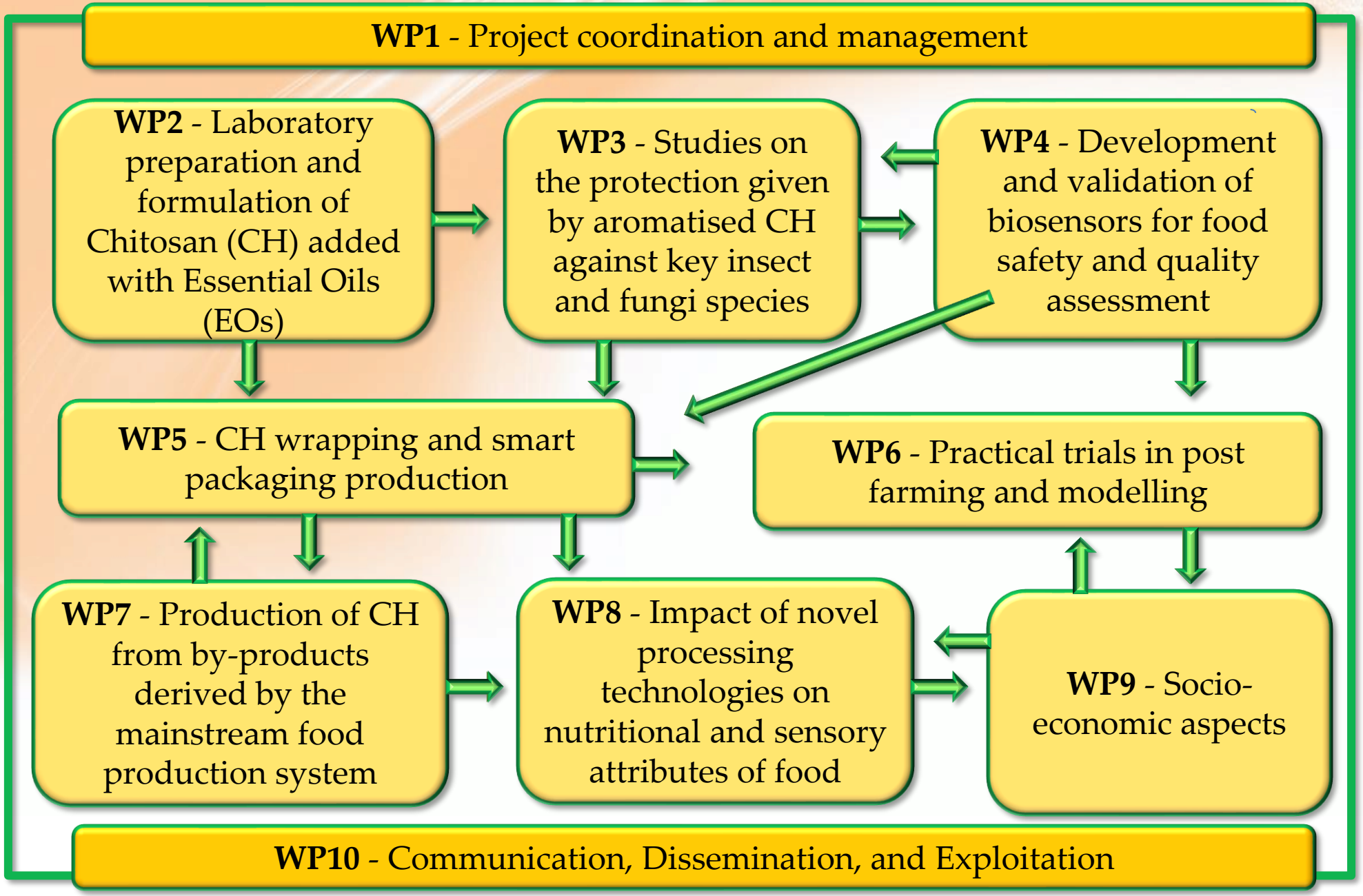
Fedkito Consortium



- **Italy** (University of **Pisa** and **Bologna** and 2 **SMEs**)
- **France** (**Sorbonne** Université and Centre Tecnique Industrial de la Plasturgie et des Composites **IPC**)
- **Greece** (University of **Thessaly**)
- **Morocco** (Université Hassan II de **Casablanca**)
- **Tunisia** (Centre de Biotechnologie de Borj Cédria **CBBC**)

Fedkito three main goals

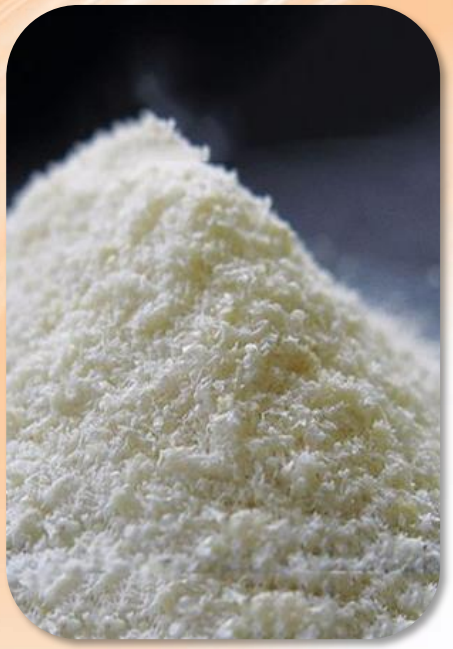
Fedkito Work Packages (WPs)



WP2 - Laboratory preparation and **formulation** of **Chitosan** (CH) added with **Essential Oils** (EOs)

Chitosan (CH):

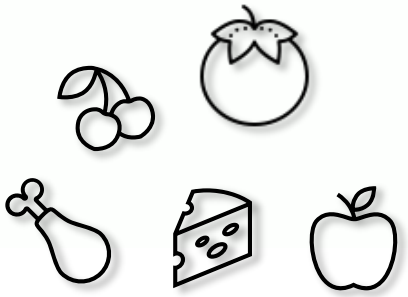
- **Polysaccharide** (D-glucosamine and N-acetyl-D-glucosamine)
- Currently extracted from crustacean shells and fungi
- **Antimicrobial** and **antifungal** activity, low gas permeability



Essential Oils (EOs):

- Complex **mixtures of secondary metabolites**
- Extracted from more than 17,000 aromatic plants
- Well known **antioxidant**, **antibacterial**, **antifungal**, **insecticidal**, and **repellent** properties

Most suitable **CH concentrations**: from 1.0 to 2.0% (based on the food matrix) in acidified water



EOs selected by the trained **sensory analysts**:

- *Citrus reticulata* (**mandarin**) and *Cinnamomum verum* (**cinnamon**) EOs to protect **fruit**
- *Piper nigrum* (**black pepper**) and *Laurus nobilis* (**bay**) EOs to protect **meat** and **dairy** products
- *Citrus lemon* (**lemon**) and *Ocimum basilicum* (**basil**) to protect **vegetables**

WP3 - Studies on the protection given by aromatised CH against key **insect** and **fungi** species

Fruits

Drosophila suzukii

Ceratitis capitata

Meat

Calliphora vomitoria

Piophila casei

Vegetables

Spodoptera littoralis

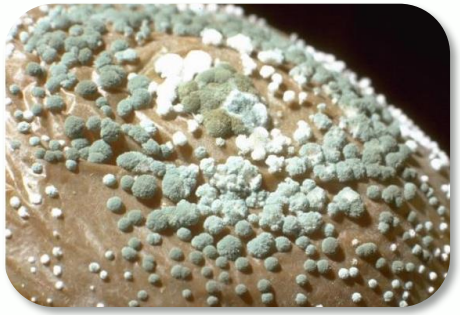
Meat

Cheese

Target species

Penicillium digitatum

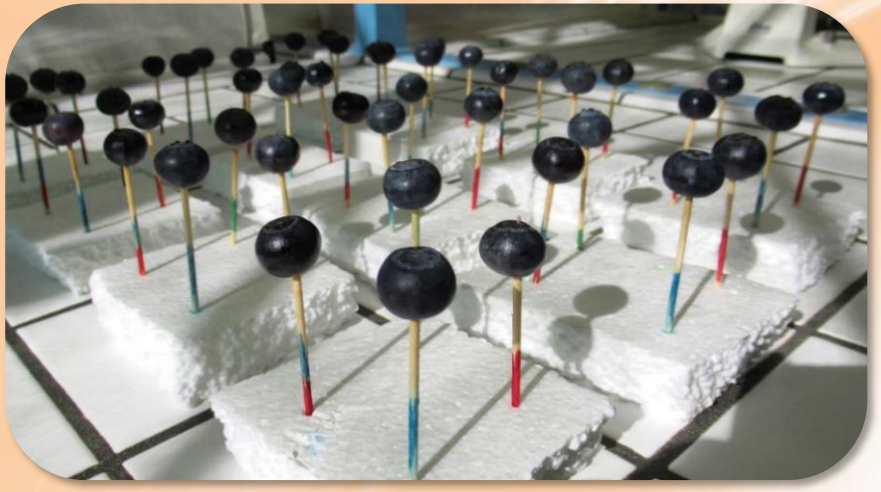
P. italicum



P. expansum

Mould agents and mycotoxins producer (patulin and citrinin from *P. expansum*)

WP3 - Studies on the protection given by aromatised CH against key **insect** and fungi species



Blueberries for the trial with *D. suzukii*

Beef meat for the trial with *C. vomitoria*

Evaluation of the **protection** given against the **oviposition** of:

- *Drosophila suzukii* on **blueberries**
- *Ceratitis capitata* on **kumquats**
- *Calliphora vomitoria* on raw **beef meat**
- *Piophila casei* on ripening **cheese** and curing **ham**

Using **CH**, the selected **EOs**, and the **mixtures** of the two compounds

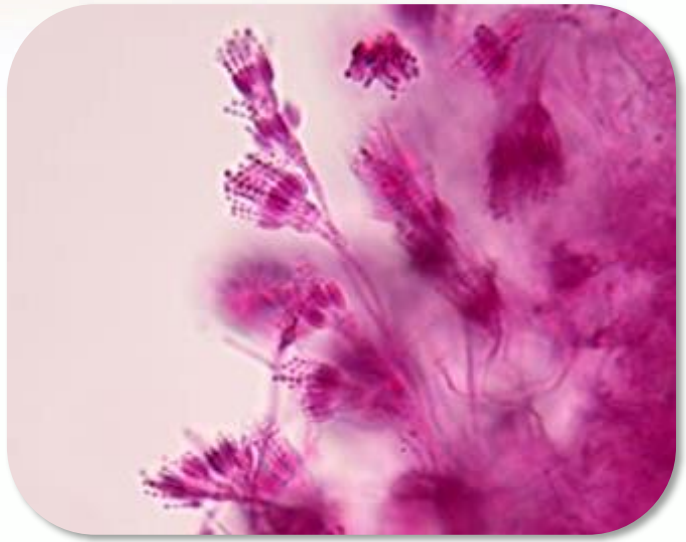
The **mixtures** (with different EOs concentrations) gave up to **96 hours** of **protection** under **laboratory conditions**

Kumquats for the trial with *C. capitata*

WP3 - Studies on the protection given by aromatised CH against key insect and **fungi** species

Isolation of *Penicillium* spp. fungi from affected apples and citrus fruits:

- Superficial sterilisation of fruits in NaClO or EtOH
- Plating of fruits with signs of mould
- Single spore cultivation
- Morphological and molecular identification of the selected species
- Establishment of a **fungal collection** deposited at the Plant Pathology & Mycology Laboratory of DAFE

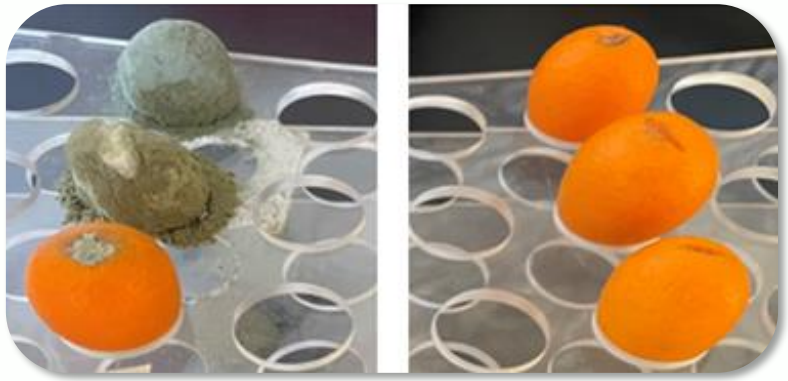


In vivo (on citrus fruits) and ***in vitro*** (on solid an liquid media) tests about ***Penicillium digitatum, P. italicum,*** and ***P. expansum***:

- Mycelial growth
- Spore germination and sporulation
- Minimum Inhibitory Concentration (MIC)

Using **CH**, the selected **EOs**, and the **mixtures** of the two compounds

The **mixtures** (1.0% CH + 1.0% mandarin EO) completely **inhibited** the **spore germination** and **fungal growth**



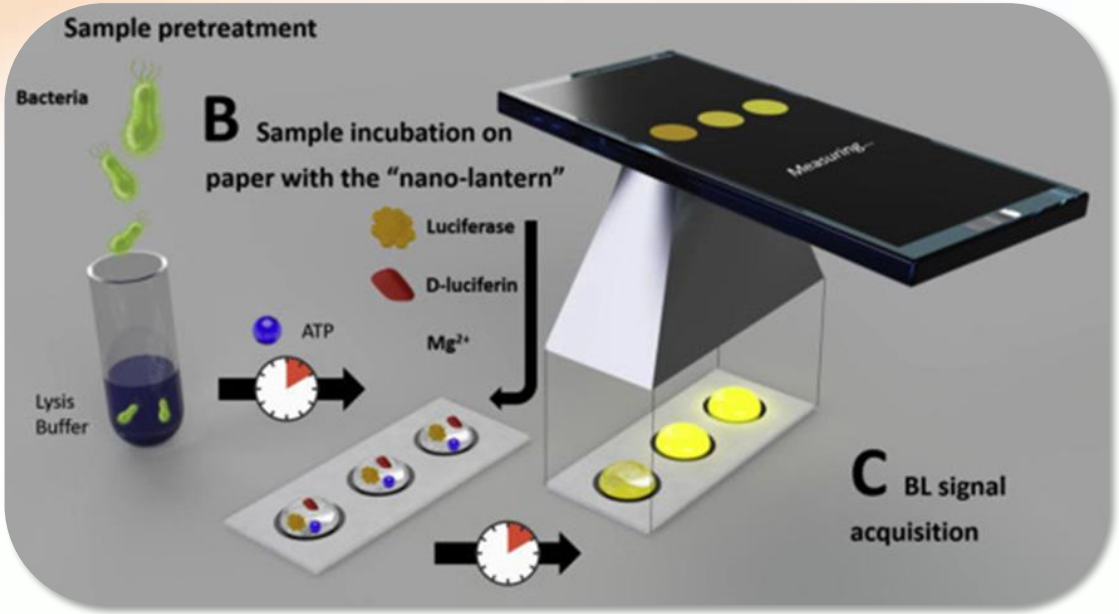
P. digitatum control

P. digitatum CH + EO

WP4 - Development and validation of biosensors for food safety and quality assessment

Development of **low-cost** and **user-friendly biosensors** for **rapid** and **easy monitoring** of **food safety** and **quality**:

- Detection through **colourimetric**, **chemiluminescent**, **bioluminescent**, and biorecognition elements (**enzymes**, purified proteins) methods
- **Screen-printed** electrodes and origami **paper-based** biosensors
- 3D-printed case for **smartphone signal acquisition**



Biosensors for the **detection** of:

- **Heavy metals** (mercury) through bioluminescent and colorimetric methods on a paper sensor
- **Bisphenol A** through a magnetic molecularly imprinted polymer as adsorbent coupled with a spectrophotometric method
- **Pesticides** (with action on the enzyme acetylcholinesterase) through a luciferase/luciferin system on an origami sensing paper
- **Metabolic activity** of **microbial contaminants** through an ATP-sensitive paper
- **Biogenic amines** through a colourimetric method on a paper sensor
- **Mycotoxins** (citrinin) using graphene nanoflakes on screen-printed electrochemical sensor

WP5 - CH wrapping and smart packaging production

Composition of the new **packaging materials**:

- **PBSA** (Polybutylene succinate-co-butylene adipate), a **biodegradable**, soft, and **flexible** semi-crystalline **polyester**
- **PLA** (Polylactic acid), a **biodegradable**, hydrophobic, and **stiff** thermoplastic **polyester**
- **CH** and bay, black pepper, or mandarin **EOs**

Extrusion technologies:

- **Blow extrusion** of the matrix with **PBSA** to obtain the transparent **wrapping film**
- **Thermoforming** of the matrix with **PLA** in a mould through pressure to obtain the rigid **trays**

Performances and **mechanical properties**:

- **FILM**: thermal stability, lower glass transition and crystallisation temperatures, stable oxygen permeability and water vapour permeability, and bacterial inhibition (on *E. coli* and *S. aureus*)
- **TRAY**: lower glass transition temperature, lower tensile strength, stable strain at break, higher oxygen permeability, and stable water vapour permeability

WP7 - Production of CH from by-products derived by the mainstream food production system

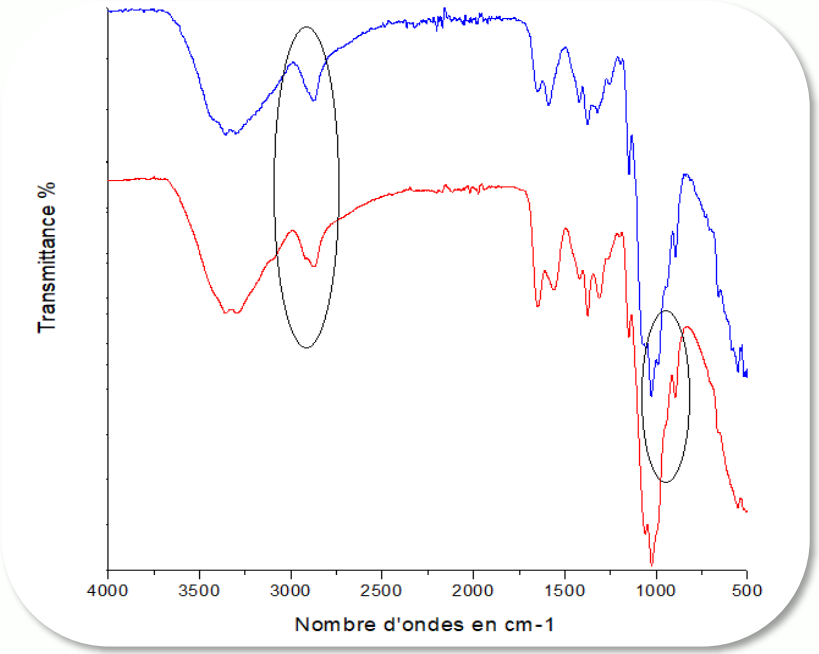
Black soldier fly

Hermetia illucens (Diptera: Stratiomyidae):

- Adults do not bite, sting, nor represent a nuisance
- Larvae digest more than twice their weight per day
- **Larvae bioconvert** every kind of **organic matter** (also by-products and waste from mainstream food production)

CH extraction from **pupae** and **characterisation**:

- **Chitin** extraction (demineralisation + deproteinisation)
- **CH** extraction (deacetylation + discolouration)
- **Morphological** and **chemical** characterisation and **comparison** with **commercial CH** from shellfish through UV spectroscopy, infra-red, X-ray, TEM, and SEM

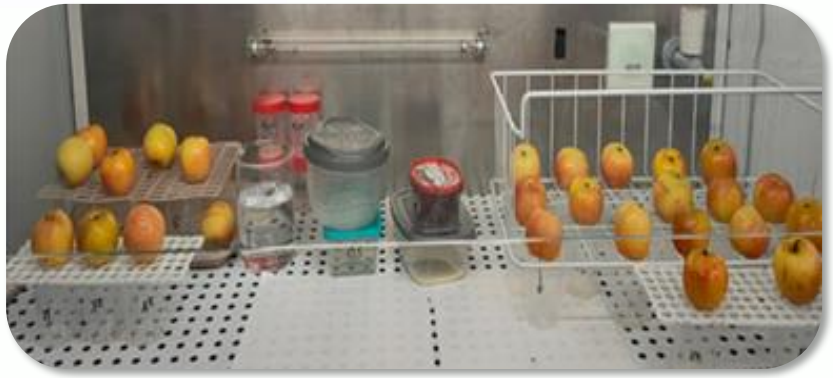


FTIR spectrum of commercial (blue) and insect (red) CH

WP8 - Impact of novel processing technologies on nutritional and sensory attributes of food

Characterisation of **food products protected** with **CH + EOs**:

- Quantification of **health-promoting compounds**
- Assessment of marketable quality, **shelf-life**, and **sensory profiles** (olfactive and visual) during the **storage time**



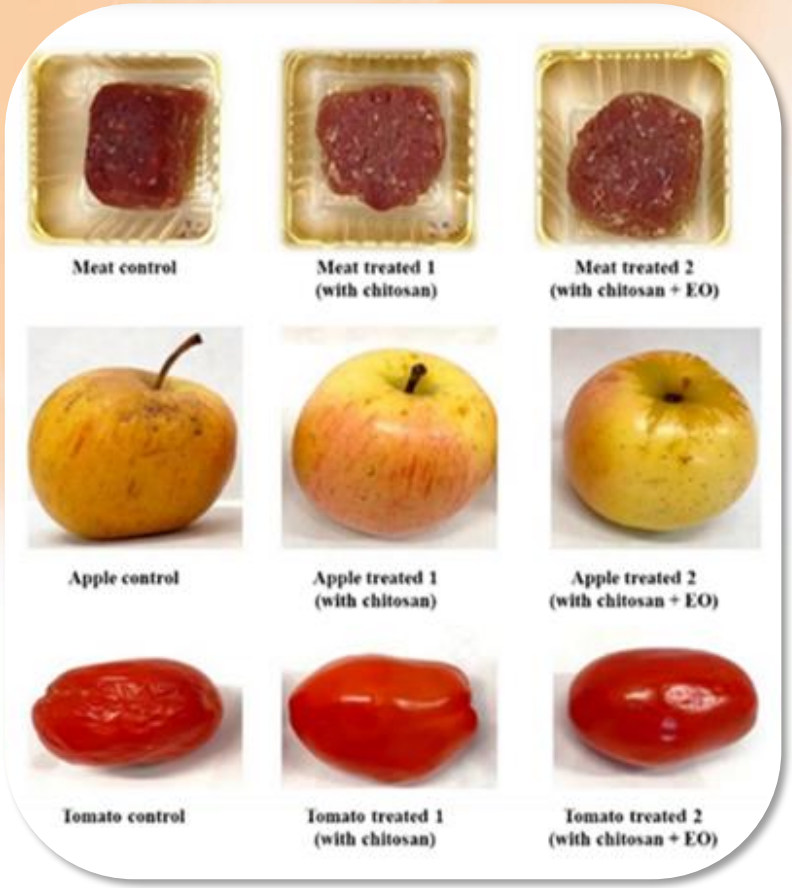
Results:

- CH + cinnamon EO-treated **apples**, during **30 days of storage**, showed **lower weight loss**, stable pH and titratable acidity, **higher phenol** and **flavonoid** content, and **antioxidant activity**
- CH + laurel EO-treated **tomatoes**, during **21 days of storage**, showed stable pH, **higher phenol**, **flavonoid**, **soluble sugar**, and **lycopene** content, and reduced microbial growth
- CH + clove EO-treated **beef meat**, during **10 days of storage**, showed stable pH around 5.4-5.7, **higher water-holding capacity**, stable protein and fat content, **lower lipid oxidation, higher** antioxidant activity, and reduced microbial growth

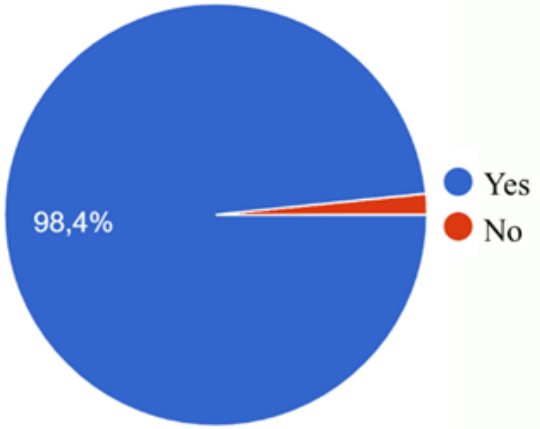
WP8 - Impact of novel processing technologies on nutritional and sensory attributes of food

Characterisation of **food products protected** with **CH + EOs**:

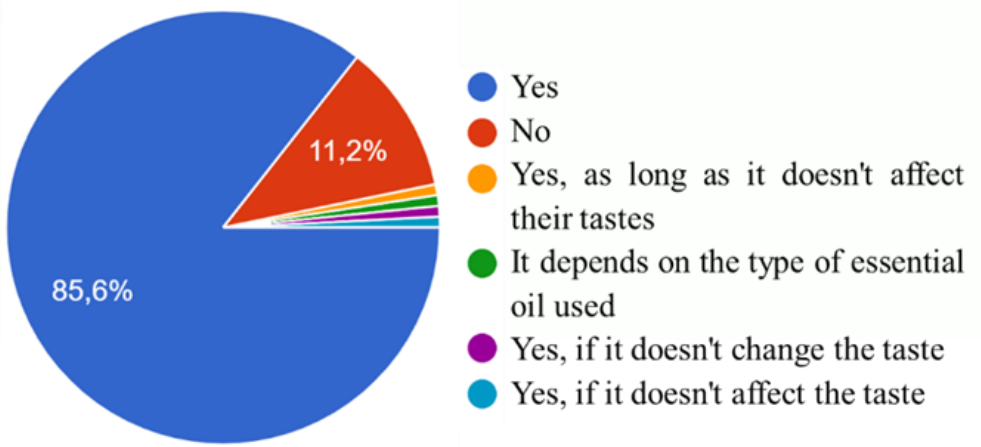
- **125 surveys** involving **general consumers** to verify the **acceptability** of treated apples, tomatoes, and beef meat according to their preferences and eating habits



Would you use biodegradable packaging as an alternative to conventional packaging?



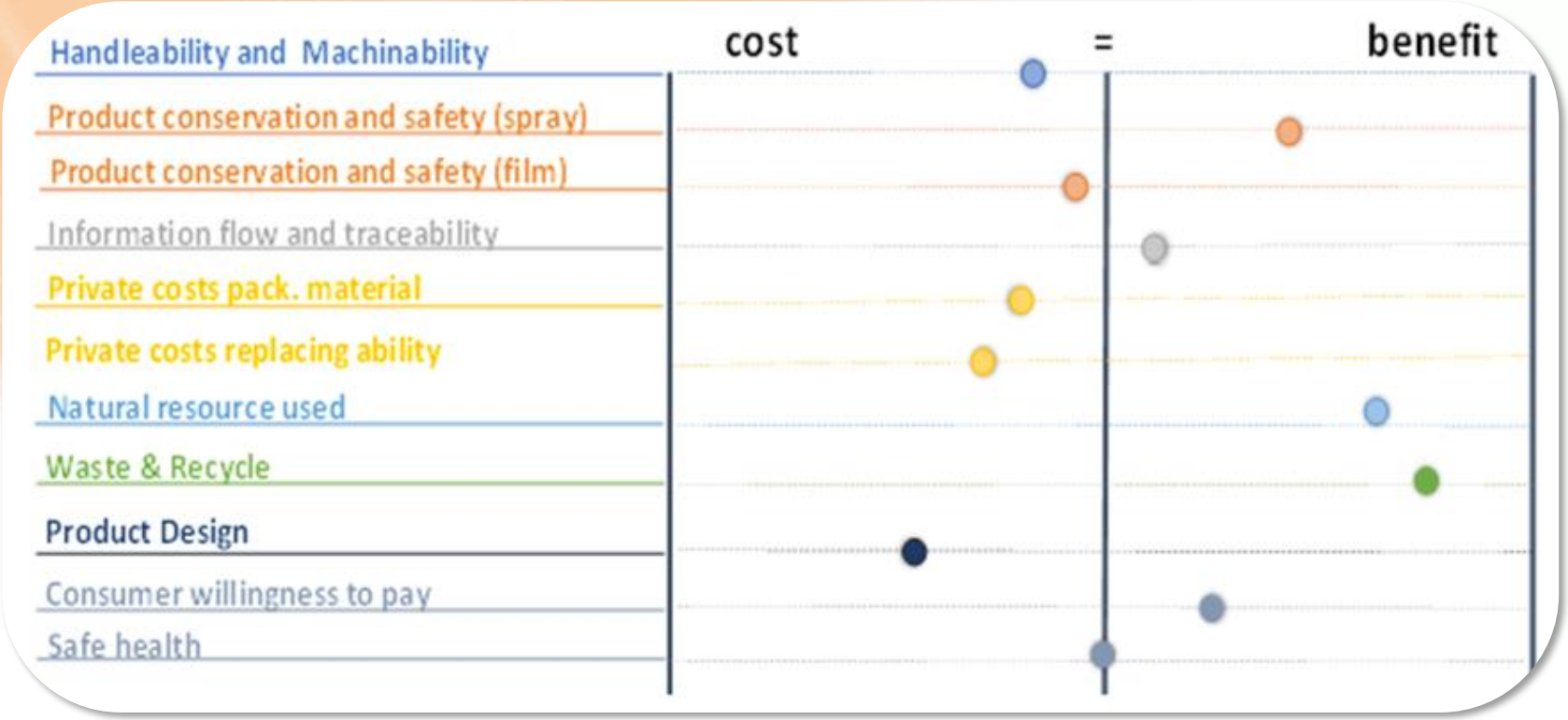
Would you consume meat, apples and tomatoes enveloped using biodegradable packaging containing an essential oil?



WP9 - Socio-economic aspects

Socio-economic and **cost-effectiveness analyses** including:

- **Comparison** between the common and the CH + EOs packaging solution (cost and benefits, environmental and social impact)
- Collection of **academic papers** and **interviews** with key stakeholders about socio-economic aspects of the **transition** to **sustainable packaging**
- Definition of the **framework** of analysis



Negative outcome: for the moment, the industrial production of the proposed packaging materials is **expensive**, as it requires **changes** in the production lines

Positive outcome: the use of **natural resources** and the possibility of **recycling** and **reducing plastic** are warmly welcomed

WP10 - Communication, Dissemination, and Exploitation

http://fedkito.agr.unipi.it

5522 views

https://www.facebook.com/Fedkito

https://www.instagram.com/fedkito_project

https://www.linkedin.com/company/fedkito

https://twitter.com/fedkito

WP10 - Communication, Dissemination, and Exploitation

- **24** free-access **publications** within the 3 years + 3 published in the last months and 3 accepted
- 22 **congresses**
- 3 **living labs** (2 in Italy and 1 in France)
- 5 **webinars**
- 2 short **videos**
- 11 **lessons** for master and PhD students

WP10 - Communication, Dissemination, and Exploitation

Final Conference of the FEDKITO project

Towards circular economy in the agri-food sector: strategies and challenges

September 12th, 2023

Aula Magna of the Department of Agriculture, Food and Environment (DAFE)

Via del Borghetto, 80 - 56124 - Pisa

Thank you for your attention