ANTIFUNGAL EDIBLE COATINGS TO REDUCE DECAY AND MAINTAIN POSTHARVEST QUALITY OF CITRUS, PLUMS, AND POMEGRANATES

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Plan de Recuperación, Transformación y Resiliencia

Introduction

Fungicides

- Chemical residues on/in produce and released to the environment
- Legal restrictions in many countries
- Fungicide-resistant strains
- Consumer requirements, new markets

- Fresh products are highly perishable, with short shelf-lives, being postharvest diseases the main cause that contributes to food waste

Eco-friendly alternative strategies to control postharvest diseases and reduce losses

STOP MED WASTE

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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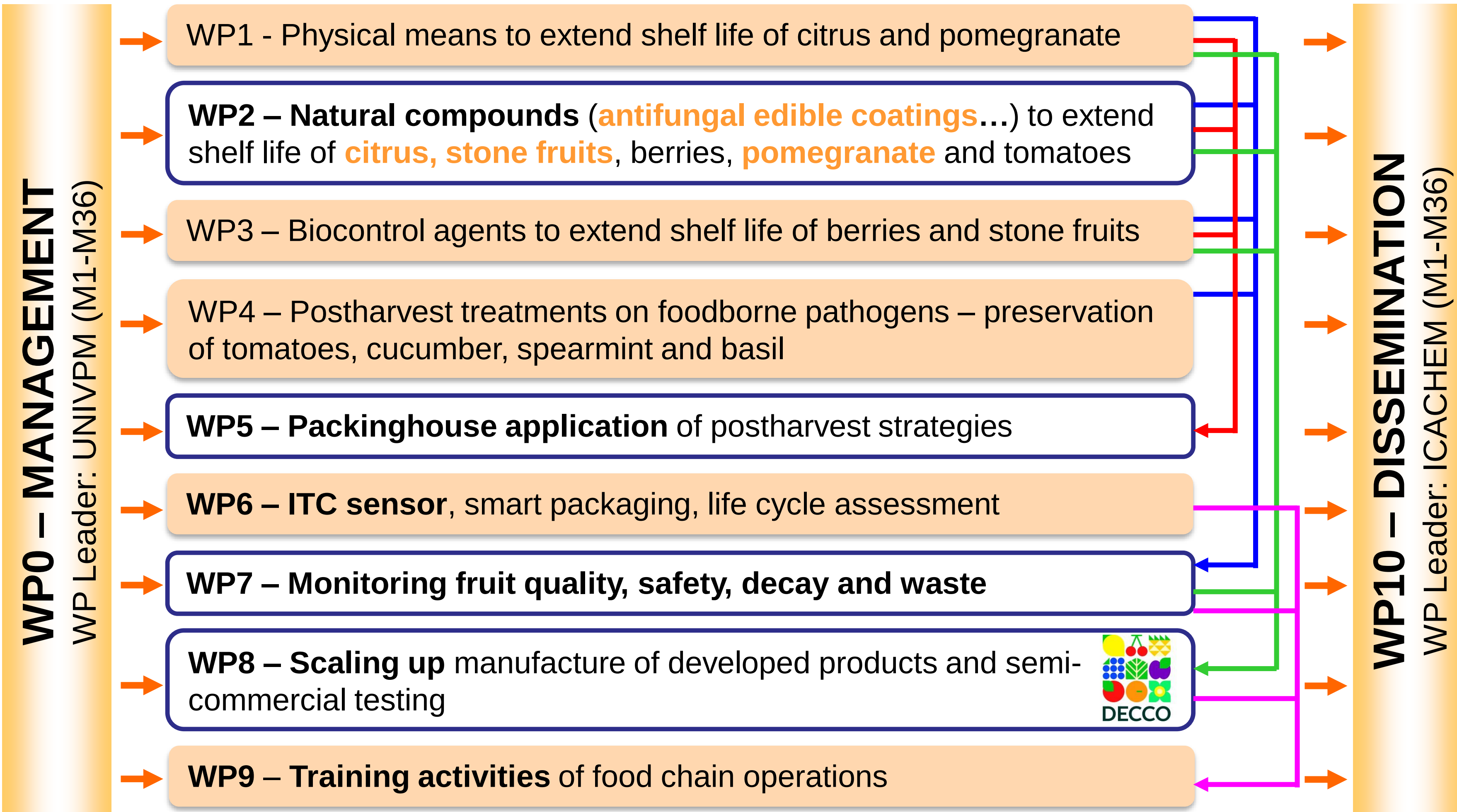
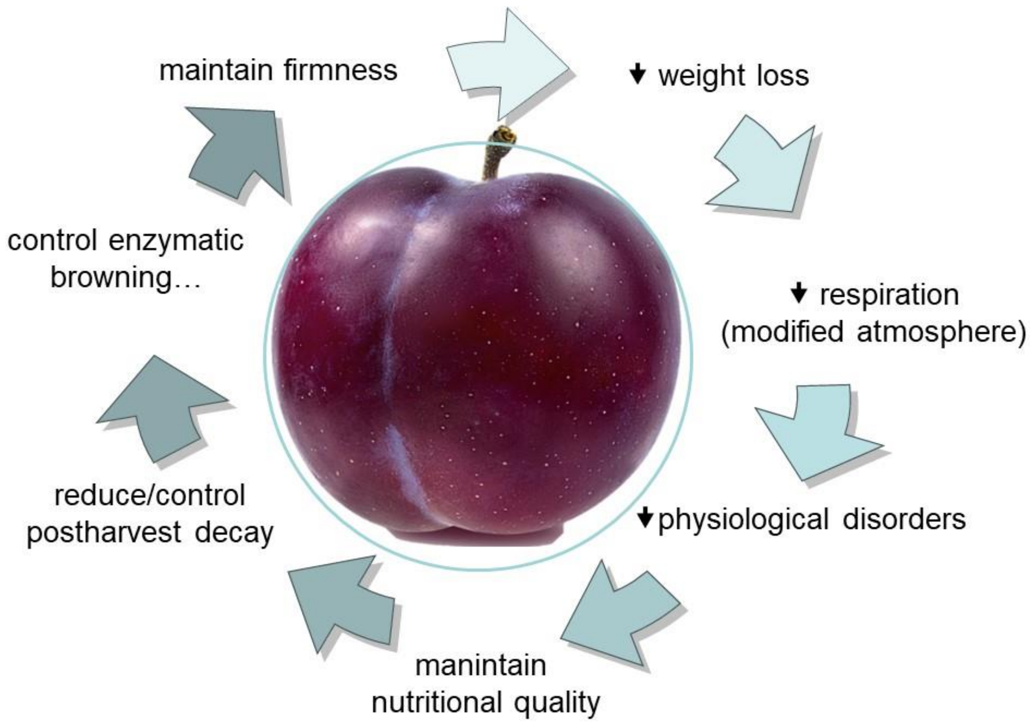
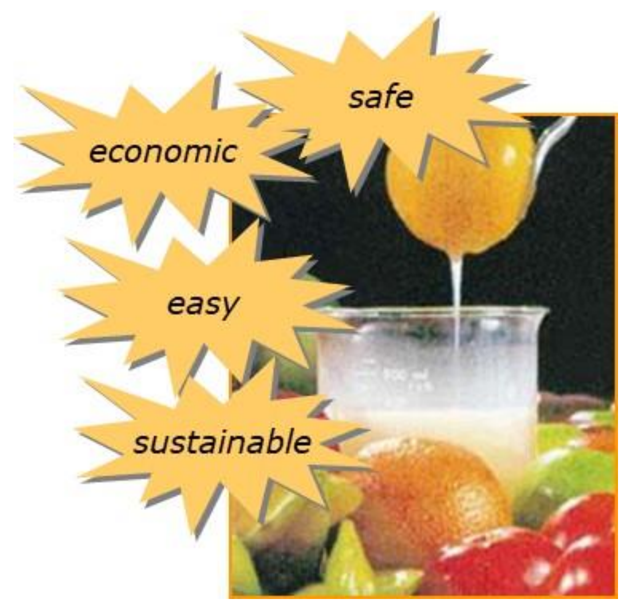


Edible coatings

Edible coating is a thin layer of edible ingredients, applied by immersion, spray,... that can be eaten with food

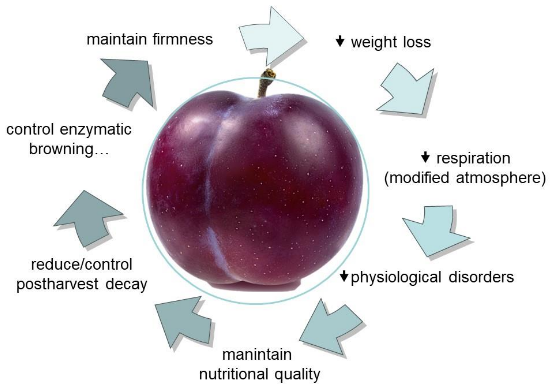
- Barrier to gases (O_2 y CO_2) and water vapor
- It allows the incorporation of active substances (antioxidants, antimicrobial agents, aromas, etc.)



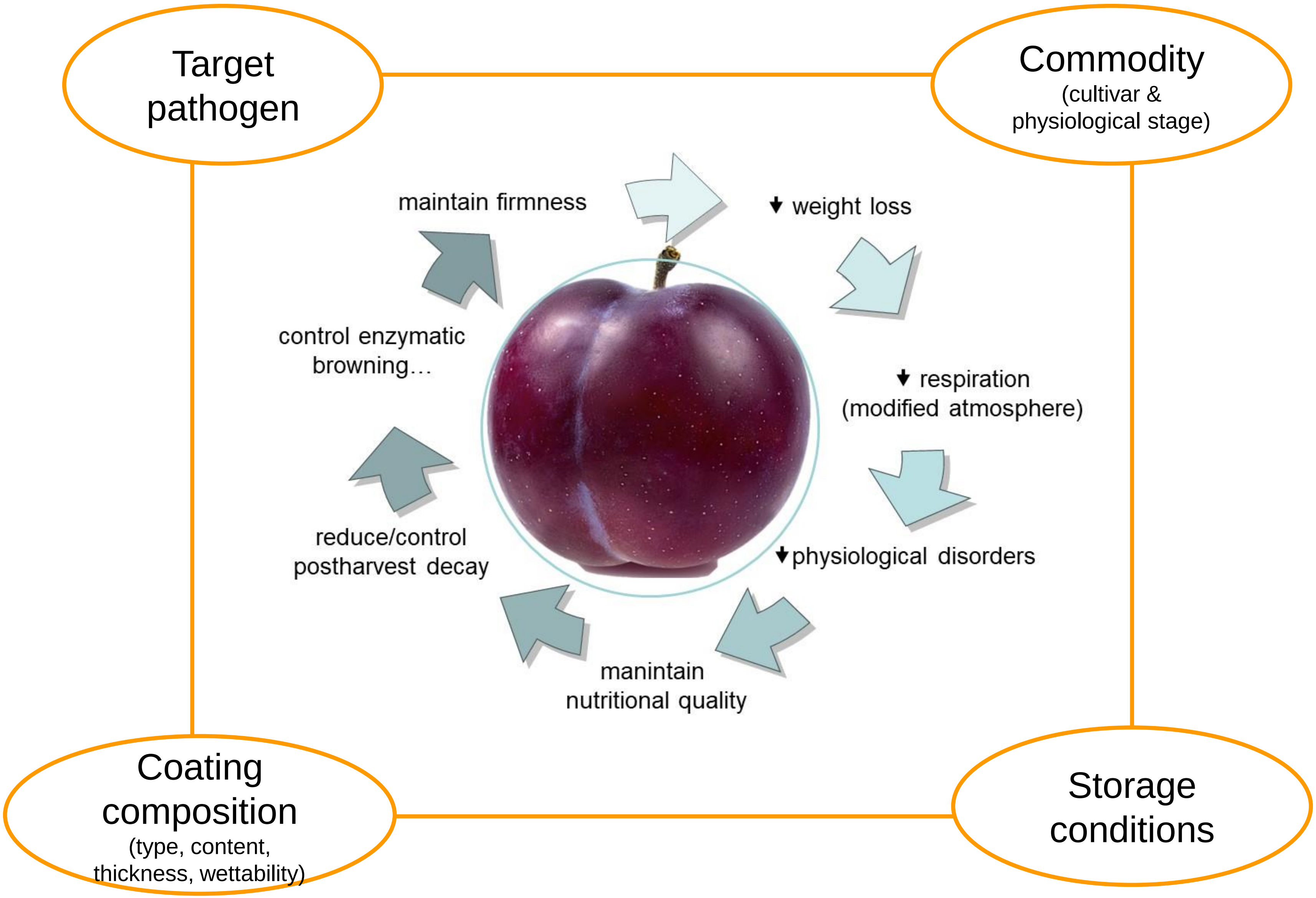


Antifungal edible coatings

- **Biopolymers with antimicrobial/antifungal activity**
  - chitosan, *Aloe vera*
- **Biopolymers require the incorporation of non-polluting antifungal ingredients**
  - Food additives and GRAS salts (Na, K, NH_4,…)
    - Organic salts: sorbates, benzoates, paraben, silicates,…
    - Inorganic salts: bicarbonates, carbonates,…
  - Natural compounds: essential oils, plant extracts,…
  - Antifungal proteins and peptides
    - Bacteriocins, lysozyme, nisin,…
  - Metal-based nanoparticles
    - Metals: Ag, Au,…
    - Oxides: ZnO, SiO_2, TiO_2, Al_2O_3, Fe_3O_4, Fe_2O_3,…
  - Biocontrol agents: antagonistic microorganisms



Development of antifungal edible coatings

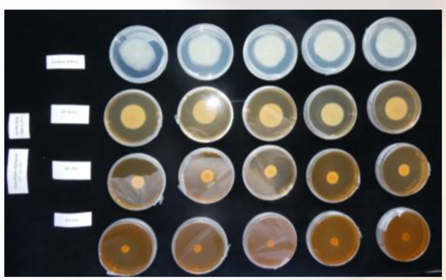


Objective

- To develop of novel antifungal edible coatings (AECs) for citrus, stone fruit and pomegranate able to control decay and maintain fruit quality during cold storage and shelf-life

In vitro screening of antifungal agents

Selection of essential oils (EOs), natural extracts, and GRAS salts to inhibit mycelial growth of target pathogens



Formulation

Optimization of coating formulations with selected agents

In vivo tests

Assessment of curative activity against postharvest diseases on artificially inoculated fruit incubated at 20ºC

Cold storage and shelf-life

- Assessment of selected AECs to control decay on inoculated fruit during cold storage.
- Quality evaluation of fruit during cold storage followed by a short commercial shelf-life period at 20ºC

Scaling up manufacture and packinghouse application of selected coatings

In vitro screening of antifungal agents

Volatile exposure method EOs and pure volatiles	
Satureja montana EO (AJ) Cinnamon EO (CN) Lemongrass EO (LG) Eugenol (EU) Geraniol (GE) Myrrh EO (MY)	5, 10, 20, and 40 µL
Controls	sterile distilled water

Agar dilution method Extracts and low volatility compounds	
Green tea (GT) Cinnamon ext. (CN EXT) Artichoke ext. (AF)	0.5, 1.0, and 2.0%
Vanillin (VA)	0.062, 0.125, and 0.25%
Propolis ext. (PPE)	0.5 and 1.0%
Myrrh EO (MY)	0.125, 0.25, and 0.5%
Controls	non-amended PDA plates

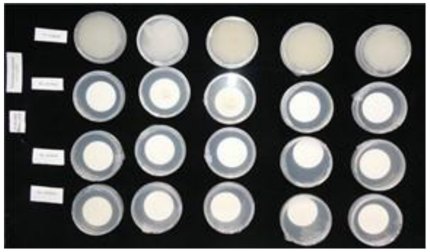
Agar dilution method GRAS salts	
Sodium metabisulfite (SMBS) Potassium metabisulfite (PMBS) Aluminum sulfate (AlS) Aluminum potassium sulfate (AlPS)	0, 10, 20, 30, 50, and 100 mM
Controls	Non-amended PDA plates

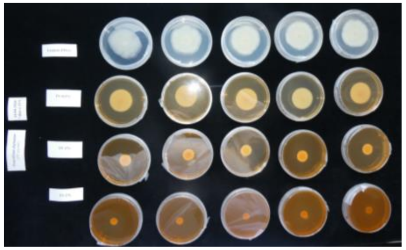
Inoculation of plates with 20 µL of *P. digitatum* (10^6 spores/mL)
P. italicum (10^6 esp/mL)
G. citri-aurantii (plug 5mm)
M. fructícola (10^4 esp/mL)

Incubation for 7 to 14 days at 25ºC

Evaluation: Radial mycelial growth in each plate of two perpendicular fungal colony diameters

% of mycelial growth inhibition = (dc-dt)/dc *100





In vitro screening of antifungal agents

- Essential oils (EOs), pure volatiles and plant extracts with concentrations selected to control major fungal pathogens of citrus and stone fruits

P. digitatum	
Cinnamon EO (CN)	20 µL
Satureja montana EO (SM)	20 µL
Eugenol (EU)	20 µL
Geraniol (GE)	20 µL
Propolis ext. (PPE)	0.5, 1.0%
Vanillin (VA)	0.062, 0.25%

P. italicum	
Cinnamon EO (CN)	10 µL
Satureja montana EO (SM)	10 µL
Lemongras EO (LG)	10 µL
Eugenol (EU)	10 µL
Geraniol (GE)	10 µL
Propolis ext. (PPE)	0.5, 1.0%
Vanillin (VA)	0.25%

M. fruticola	
Cinnamon EO (CN)	5 µL
Satureja montana EO (SM)	5 µL
Lemongras EO (LG)	5 µL
Eugenol (EU)	5 µL
Geraniol (GE)	5 µL
Vanillin (VA)	0.0625%
Myrrth EO (MY EO)	0.25%

G. citri-aurantii	
Cinnamon EO (CN)	20 µL
Satureja montana EO (SM)	20 µL
Lemongras EO (LG)	20 µL
Eugenol (EU)	40 µL
Geraniol (GE)	20, 40 µL
Vanillin (VA)	0.25%

- Sulfur-containing food additives and concentrations selected to control major fungal pathogen of stone fruits

M. fructicola	
Sodium metabisulfite (SMBS) Potassium metabisulfite (PMBS) Aluminum sulfate (AlS) Aluminum potassium sulfate (AlPS)	1, 5, 10, 50, and 100 mM

90-100% mycelial growth inhibition

AECs formulation for citrus

Formulation and selection of coating ingredients

Biopolymers: Hydroxypropyl methylcellulose (HPMC); Carboxy Methylcellulose (CMC); λ-Carrageenan (CARG); Starch (S); Citrus pectin (PEC)

Lipids: Beeswax; carnauba wax, mono-digliceride s of fatty acids (MDG)

Emulsifiers: stearic acid, palmitic acid, oleic acid, lecithin

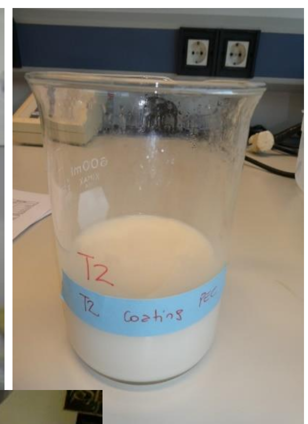
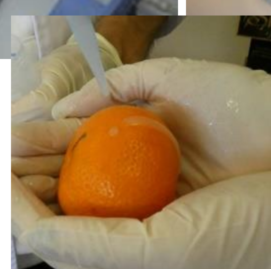
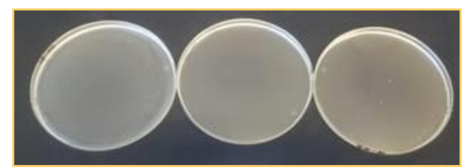
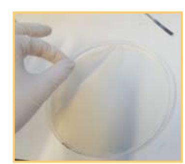
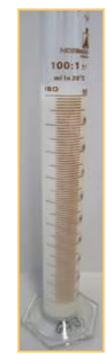
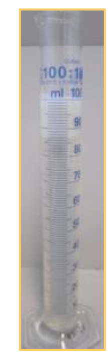
Antifungal agents: selected EOs and extract

Control (water)

PEC-BW (coating w/o antifungal)

AEC with antifungal	Concentrations
Cinnamon EO (CN) *Satureja montana* EO (SM) Eugenol (EU) Geraniol (GE)	0,2, 0,4, 0,8%
Propolis (PRO)	0,5, 1,0, 2,0%
Vanillin (VA)	0,25, 0,5, 1,0%
Myrrh EO (MY)	1,5%

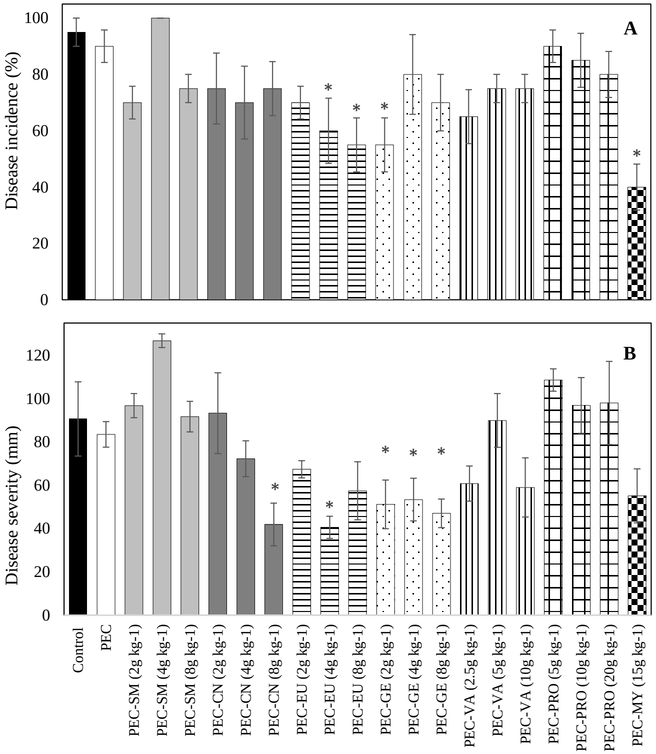


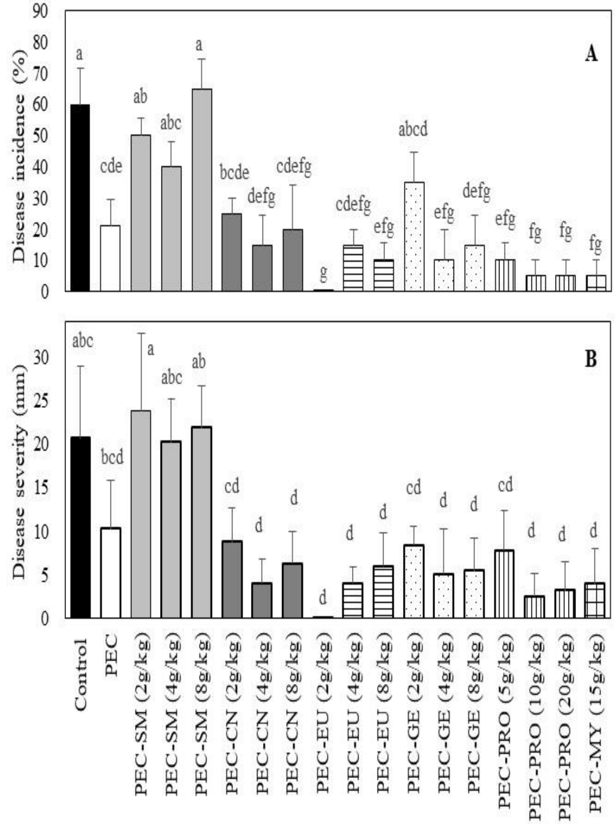
- ✓ Emulsion stability and viscosity
- ✓ Film forming properties
- ✓ Fruit wetting, tacking, and appearance

Main results in citrus

Penicillium digitatum – 8 days at 20 °C



Geotrichum citri-aurantia – 20 days at 20 ºC



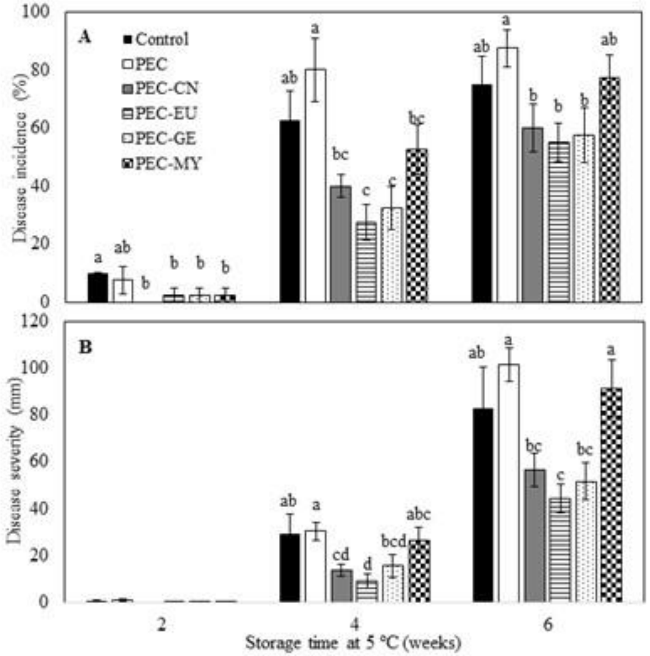
Effective AECs reduced **green mold** incidence and severity of 'Valencia' oranges in the range 38-40% and 40-55%, respectively, compared to control samples after 8 days at 20 °C

Effective AECs reduced **sour rot** incidence and severity by 75 to 100% compared to uncoated oranges after 20 days of incubation at 20 °C

In vivo assay – curative activity at 20 °C

Main results in citrus

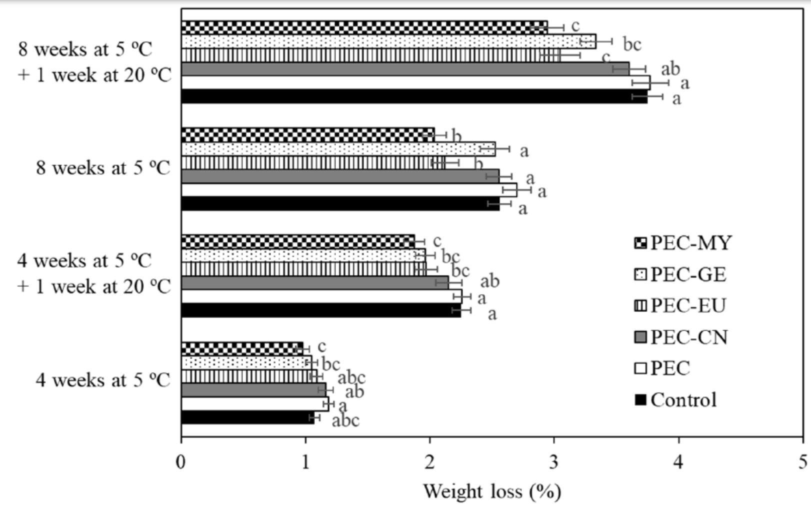
Penicillium digitatum – cold storage



In vivo assay –
curative activity at 5 °C

The most effective coatings reduced **green mold** incidence and severity of 'Valencia' oranges in the range 35-50% compared to control samples after 6 weeks of cold storage

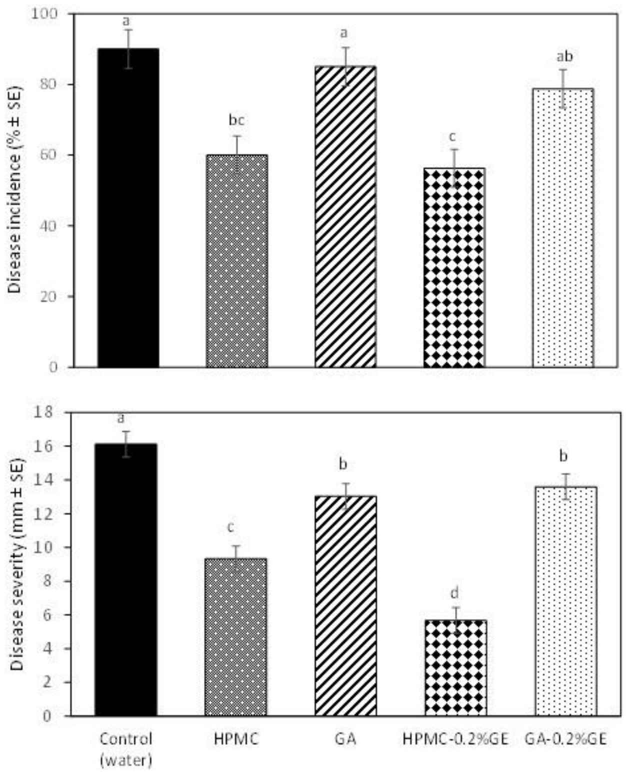
Coatings satisfactorily **reduced weight loss, maintained the quality, and improved fruit gloss** of long-term cold-stored oranges



✓ Overall, **eugenol-enriched pectin coatings** performed best in terms of postharvest quality preservation and decay control, showing potential as a safe, bio-based alternative to conventional waxes containing synthetic fungicides for the management of citrus postharvest green mold and sour rot

Main results in plums

Monillinia fructicola –
5 weeks at 1 ºC



During cold storage, the HPMC-0.2% geraniol (GE) coating was the most effective to reduce **brown rot** incidence (30% disease reduction) and severity (60% reduction) compared to control samples after 5 weeks of storage at 1ºC

HPMC-based coatings maintained **better fruit color and firmness** and significantly **reduced weight loss and chilling injury symptoms** manifested as flesh bleeding, even after a simulated storage period of 3 days at 7 °C after 8 weeks of cold storage at 1 °C and before shelf life at 20 °C, which is within the so-called 'killing temperature zone' in terms of plum physiological disorders.

✓ Overall, the **HPMC coating containing 0.2% GE** showed the greatest potential for commercial use as it controlled brown rot incidence and severity and reduced weight and firmness loss in plums with no negative effects on the physicochemical and sensory quality of treated fruits

Main results in pomegranates

Natural fungal decay caused by latent (crown decay) and wound (wound decay) pathogens in 'Mollar de Elche' pomegranates during cold storage and shelf-life period

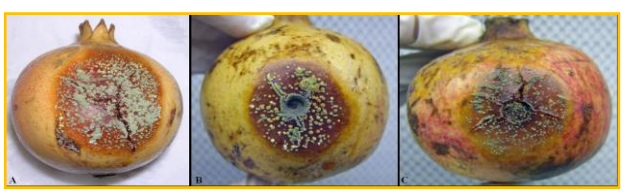
Storage Time	Treatment[a]	Storage period[d]: External decay – % Incidence	Storage period[d]: External decay – Severity Index (0-4)[b]	Storage period[d]: Internal decay – % Incidence	Storage period[d]: Internal decay – Severity Index (0-3)[c]
8 weeks at 5°C + 1 week at 20°C	CONTROL	4.17 ± 2.08 a	0.67 ± 0.33 a	0.00 ± 0.00 a	0.00 ± 0.00 a
	HPMC-CW-SB	2.08 ± 2.08 a	0.67 ± 0.67 a	2.08 ± 2.08 a	0.67 ± 0.67 a
	HPMC-BW-SB	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
	HPMC-CW-SB + MAP	4.17 ± 4.17 a	1.00 ± 0.50 a	0.00 ± 0.00 a	0.00 ± 0.00 a
	HPMC-BW-SB + MAP	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
	Uncoated + MAP	6.25 ± 3.60 a	0.83 ± 0.44 a	4.17 ± 2.08 a	0.00 ± 0.00 a
	FLUDIOXONIL	4.17 ± 2.08 a	1.33 ± 0.88 a	4.17 ± 2.08 a	1.00 ± 0.58 a
15 weeks at 5°C + 1 week at 20°C	CONTROL	35.42 ± 5.51 a	1.41 ± 0.21 a	22.92 ± 7.51 a	1.78 ± 0.20 a
	HPMC-CW-SB	20.83 ± 9.08 ab	1.17 ± 0.17 a	10.42 ± 4.17 a	1.17 ± 0.17 a
	HPMC-BW-SB	16.67 ± 2.08 abc	1.39 ± 0.06 a	8.33 ± 4.17 a	1.00 ± 0.58 a
	HPMC-CW-SB + MAP	2.08 ± 2.08 d	1.00 ± 0.58 a	2.08 ± 2.08 a	0.33 ± 0.33 a
	HPMC-BW-SB + MAP	18.75 ± 6.25 abc	1.17 ± 0.08 a	14.58 ± 7.51 a	1.06 ± 0.53 a
	Uncoated + MAP	8.33 ± 2.08 bcd	1.33 ± 0.33 a	2.08 ± 2.08 a	0.67 ± 0.67 a
	FLUDIOXONIL	6.25 ± 3.61 cd	1.17 ± 0.60 a	6.25 ± 0.00 a	2.00 ± 0.58 a

[a]CONTROL: uncoated; HPMC: hydroxypropyl methylcellulose; BW: beeswax; CW: carnauba wax; SB: sodium benzoate.

[b]External decay severity index: 0 = no decay; 1 = decay lesion < 1 cm2; 2 = 1 cm2 < decay lesion < 25% of rind surface; 3 = decay lesion on 26-50% of rind surface; and 4 = decay lesion > 50% of rind surface.

[c]Internal decay severity index: 0 = none; 1 = slight; 2 = moderate; and 3 = severe.

For each type of decay and storage time, means in columns with different letters are significantly different by Fisher's protected LSD test ($P < 0.05$) applied after an ANOVA. Data is presented as means ± standard error (SE).



The combination a **HPMC-BW-SB coating + modified atmosphere packaging (MAP)** was the most promising treatment as it **reduced weight loss and decay**, without negatively affecting the fruit physicochemical and sensory quality during long term cold storage and shelf-life of 'Mollar de Elche' pomegranate

Scaling up of selected coatings

Lab scale

Pilot plant scale

Commercial scale

Packinghouse application of selected coatings

Nectarines
Plums
Pomegranates
Citrus

foods

Article

Natural Pectin-Based Edible Composite Coatings with Antifungal Properties to Control Green Mold and Reduce Losses of 'Valencia' Oranges

María Victoria Alvarez [1,2], Lluís Palou [2,*], Verònica Taberner [2], Asunción Fernández-Catalán [2], Maricruz Argente-Sanchis [2], Eleni Pitta [2,3] and María Bernardita Pérez-Gago [2]

foods

Article

Hydroxypropyl Methylcellulose and Gum Arabic Composite Edible Coatings Amended with Geraniol to Control Postharvest Brown Rot and Maintain Quality of Cold-Stored Plums

Zahra Sadat Asgarian [1,2], Lluís Palou [2], Ricardo Felipe Lima de Souza [2], Paloma G. Quintanilla [2,3], Verònica Taberner [2], Rouhollah Karimi [1,4] and María Bernardita Pérez-Gago [2,*]

coatings

Article

Postharvest Application of Novel Bio-Based Antifungal Composite Edible Coatings to Reduce Sour Rot and Quality Losses of 'Valencia' Oranges

María Victoria Alvarez [1,2], María Bernardita Pérez-Gago [2], Verònica Taberner [2], Laura Settier-Ramírez [2], Victoria Martínez-Blay [2] and Lluís Palou [2,*]

coatings

Article

Antifungal Hydroxypropyl Methylcellulose (HPMC)-Lipid Composite Edible Coatings and Modified Atmosphere Packaging (MAP) to Reduce Postharvest Decay and Improve Storability of 'Mollar De Elche' Pomegranates

Bruno Di Millo [1,2], Victoria Martínez-Blay [1], María B. Pérez-Gago [1], Maricruz Argente-Sanchis [1], Amparo Grimal [1], Elena Baraldi [2] and Lluís Palou [1,*]

coatings

Article

Postharvest Application of Potato Starch Edible Coatings with Sodium Benzoate to Reduce Sour Rot and Preserve Mandarin Fruit Quality

Lourdes Soto-Muñoz [1,2], María B. Pérez-Gago [1], Victoria Martínez-Blay [1] and Lluís Palou [1,*]

foods

Article

Postharvest Treatments with Sulfur-Containing Food Additives to Control Major Fungal Pathogens of Stone Fruits

Victoria Martínez-Blay, Verònica Taberner, María B. Pérez-Gago and Lluís Palou *

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VI International Symposium Postharvest Pathology Limassol 2022

ICPP 2023 ONE HEALTH for all plants, crops and trees LYON 20-25 August, France

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5 Orals
9 Posters

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Plant Food Waste Valorisation – Opportunities and Challenges
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PRIMA · STOP MED WASTE · Cyprus University of Technology
Workshop
"Advances and applied research along the supply chain to reduce postharvest losses"
Agenda
1 June 2022 – Day 1

PRIMA · MESRS · STOP MED WASTE
Meeting
INNOVATIVE SUSTAINABLE STRATEGIES TO CONTROL POSTHARVEST DECAY OF FRESH FRUIT AND VEGETABLES AND REDUCE FRUIT LOSS AND WASTE
Thursday, 15 June 2023
Espace de l'innovation (amphithéâtre), INRAT, TUNIS

PRIMA · Meeting · STOP MED WASTE
INNOVATIVE SUSTAINABLE TECHNOLOGIES TO EXTEND THE SHELF-LIFE OF PERISHABLE MEDITERRANEAN FRESH FRUIT, VEGETABLES AND AROMATIC PLANTS AND TO REDUCE WASTE
Tuesday 11 July 2023
14:30-17:00 (GMT+1) Fondazione AGRION, Manta (CN), Italy

5 Workshops organized by StopMedWaste Partners

Innovative Sustainable technologies TO extend the shelf-life of Perishable MEDiterranean fresh fruit, vegetables and aromatic plants and to reduce WASTE (STOPMEDWASTE)
PRIMA IN THE MEDITERRANEAN AREA · MIUR · STOP MED WASTE
LA FILIERA PRODUTTIVA DEL MELOGRANO:
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PRIMA · Meeting · STOP MED WASTE
INNOVATIVE SUSTAINABLE TECHNOLOGIES TO EXTEND THE SHELF-LIFE OF PERISHABLE MEDITERRANEAN FRESH FRUIT, VEGETABLES AND AROMATIC PLANTS AND TO REDUCE WASTE
Friday 5 May 2023
10:30-12:00 (GMT+2) Sala Mimosa, MacFrut, Rimini
14.30-17.00 Apofruit, Cesena

Workshops to the Spanish sector

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Curso técnico de especialización

Factores pre y poscosecha para la conservación de la granada

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Estación Experimental Agraria de Elche
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Del 07/03/2023 al 07/03/2023

programa

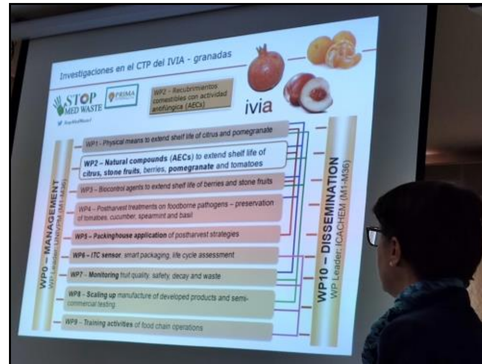
martes 07/03/23

16:00 a 19:00 **Epidemiología y control de las podredumbres de poscosecha de la granada.**

Dr. LLUÍS PALOU. Centre de Tecnologia Postcollita (CTP), IVIA.

16:00 a 19:00 **Fisiología y tecnología poscosecha de la granada.**

Dra. MARÍA B. PÉREZ-GAGO. Centre de Tecnologia Postcollita (CTP), IVIA.



II Jornada Poscosecha de Cítricos

14 de septiembre de 2023 – Valencia –

Inscripciones abiertas

Evento presencial y online

Organizan: ivia instituto valenciano de investigaciones agrarias; Poscosecha

II JORNADA POSCOSECHA DE CÍTRICOS

La Comunidad Valenciana es la primera zona productora y exportadora de cítricos en España. En este contexto, resulta fundamental extender la vida comercial de estos productos en condiciones óptimas de calidad así como reducir las pérdidas en las diferentes fases de la cadena de manipulación, transporte y distribución, y ampliar la época de comercialización de cada variedad. Por ello, podemos afirmar que la poscosecha, culminación de los esfuerzos realizados durante el cultivo, es una etapa clave en la cadena de valor de la citricultura valenciana.

Por ello, el Instituto Valenciano de Investigaciones Agrarias (IVIA) y Poscosecha.com organizan la **II Jornada Poscosecha de Cítricos** que tendrá lugar el jueves **14 de septiembre**, de 15:30 a 19:00 h, en el **Salón de actos del IVIA**. El objetivo de la Jornada es que sea un punto de encuentro anual entre la comercialización, la industria, la distribución y la investigación y un foro de discusión entre los principales actores de la cadena de valor. Para ello se realizará un análisis comercial y técnico de la campaña anterior y se presentarán las previsiones y novedades comerciales en poscosecha para la próxima campaña citrícola.

Además, como partner de investigación español, el **Centro de Tecnología Poscosecha (CTP) del IVIA presentará el proyecto europeo StopMedWaste**, financiado dentro del programa PRIMA, cuyo objetivo principal es la preservación de frutos cítricos y productos hortofrutícolas mediterráneos frescos con estrategias de poscosecha innovadoras que garanticen la seguridad del consumidor y la reducción del desperdicio alimentario y de la aplicación de pesticidas químicos sintéticos.

STOP MED WASTE — PRIMA

EVENTO PRESENCIAL Y ONLINE

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