



Sustainable technologies for reducing postharvest fruit losses and improving quality

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The Challenge

Postharvest losses are a major sustainability challenge

- A large proportion of fruit production is lost after harvest, not in the orchard
- These losses represent wasted natural resources, energy and labor
- Reducing postharvest losses is as important as increasing yield for sustainable horticulture





The Core Concept

Green technology for reducing postharvest losses and maintaining fruit quality

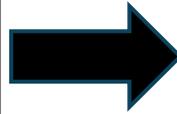
- ❖ Conventional postharvest technologies (eg., synthetic chemicals) have been effective at controlling postharvest decay and maintaining fruit quality
- ❖ These chemical treatments may cause chemical residue

There is an urgent need for alternative, sustainable green technologies to preserve fruit quality from harvest to the consumer

Many new innovative **green postharvest technologies** are being developed

Examples

- ❖ **Ozone (O₃)**
- ❖ **Ultraviolet radiation (UV-C)**
- ❖ edible coatings
- ❖ light emitting diode (LED)
- ❖ electrolyzed water
- ❖ plasma technology
- ❖ ultrasound



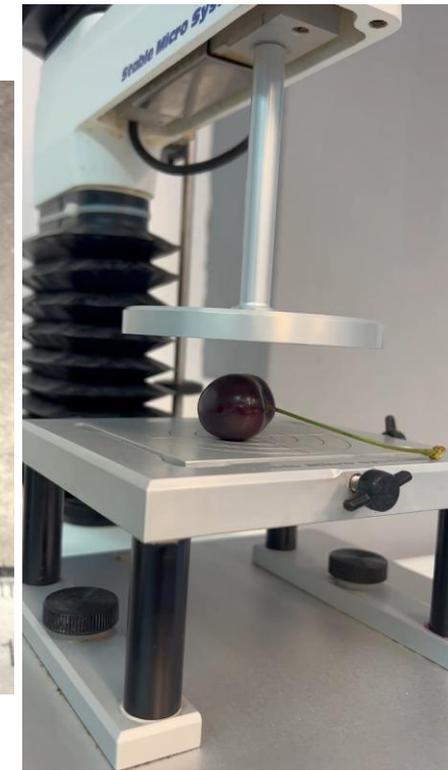
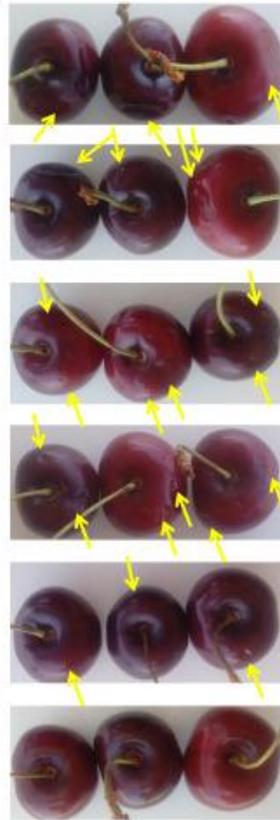
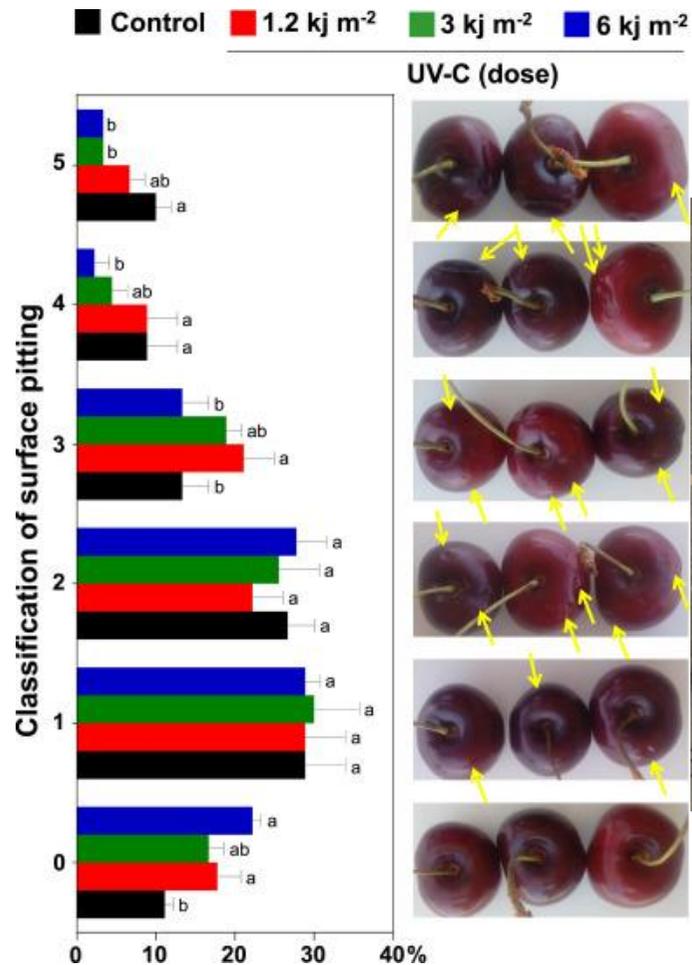
Aim

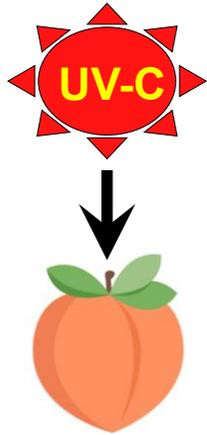
- reduce pathogenic microorganism
- **delay ripening**

Ozone acts mainly through the storage atmosphere while **UV-C** is applied as a physical light treatment



The physiological disorder 'pitting' was reduced by UV-C in sweet cherry fruit

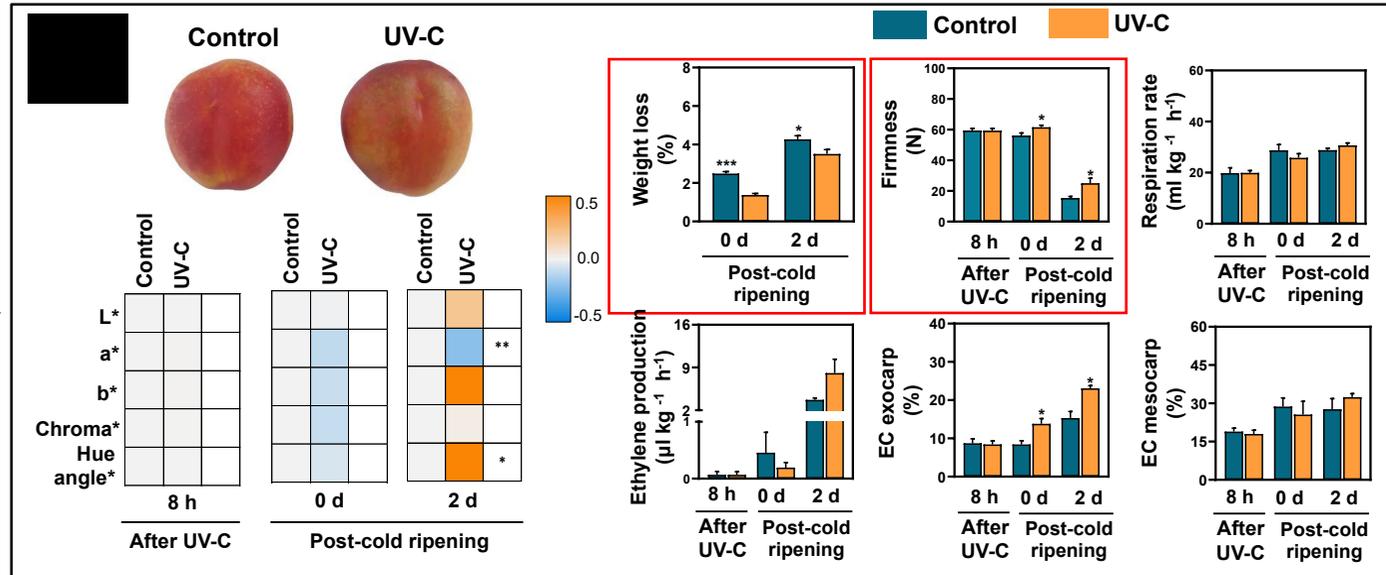


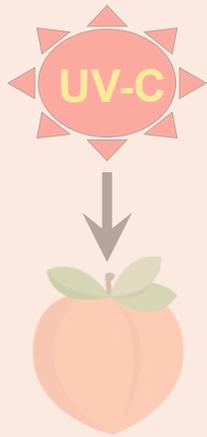


UV-C delayed peach ripening (softening and weight loss)

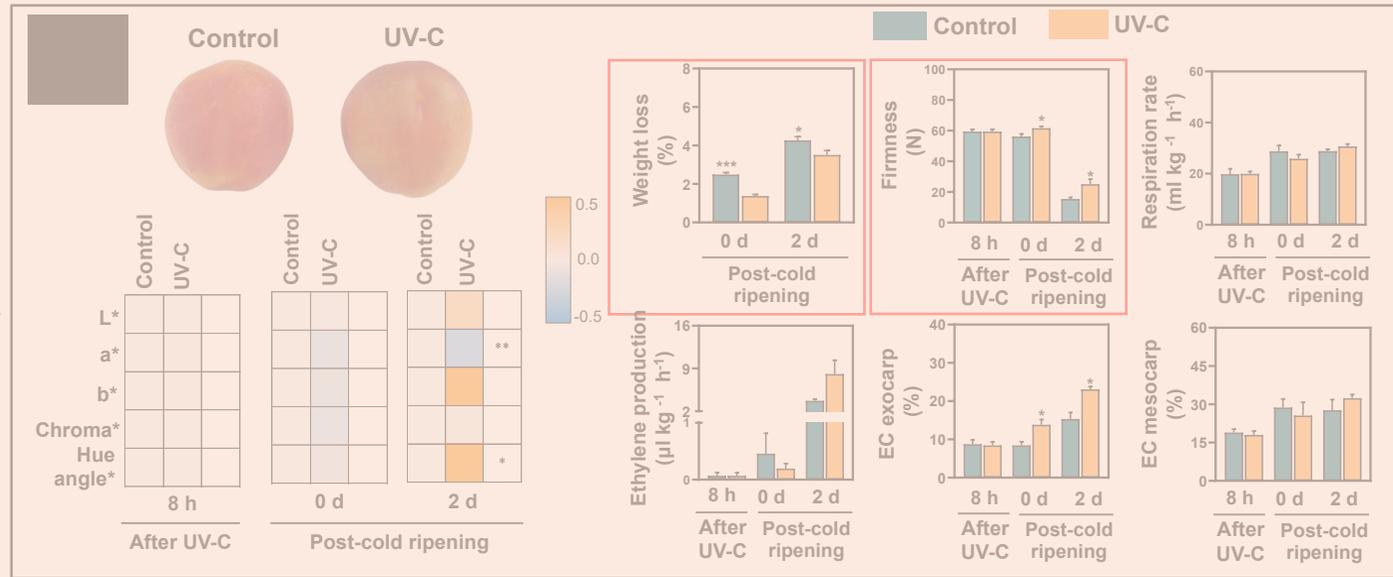
The ethylene response factor ERF1A regulates UV-C-induced delayed ripening in peach fruit

Elpida Nasiopoulou,¹ Michail Michailidis,¹ Christina Skodra,¹ Ioannis-Dimosthenis S. Adamakis,² Martina Samiotaki,³ Georgia Tanou,^{4,5} Christos Bazakos,^{5,6,7} Athanasios Dalakouras,⁸ Athanassios Molassiotis^{1,*}





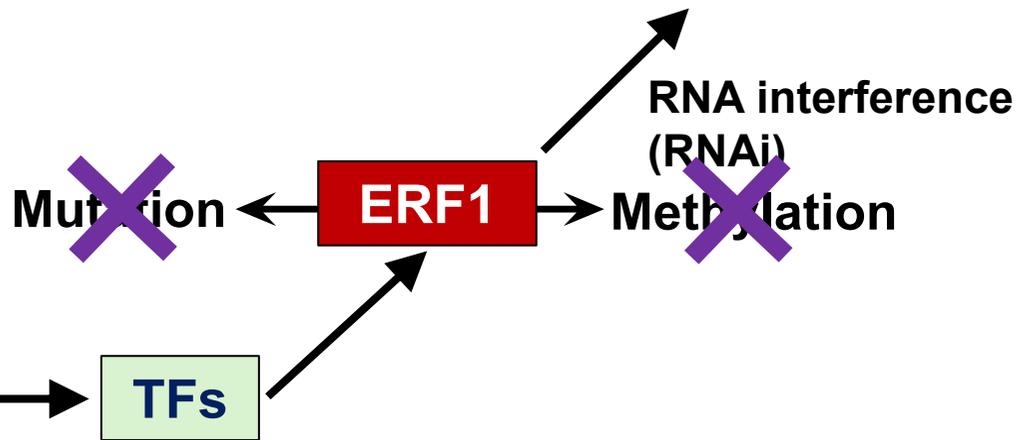
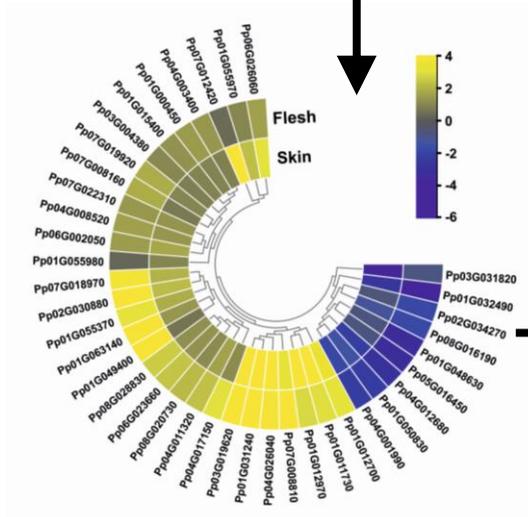
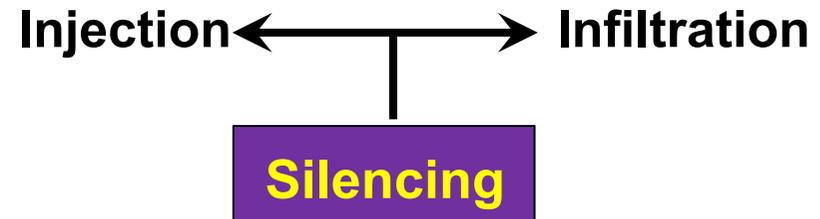
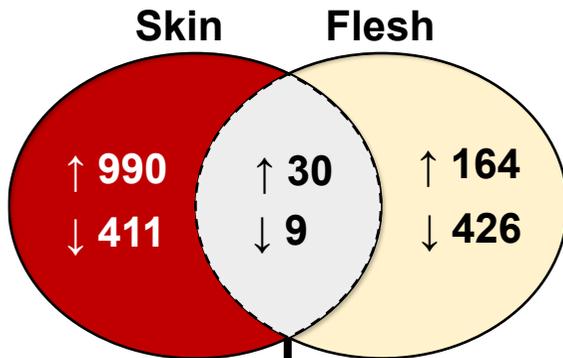
UV-C delayed peach ripening (softening and weight loss)



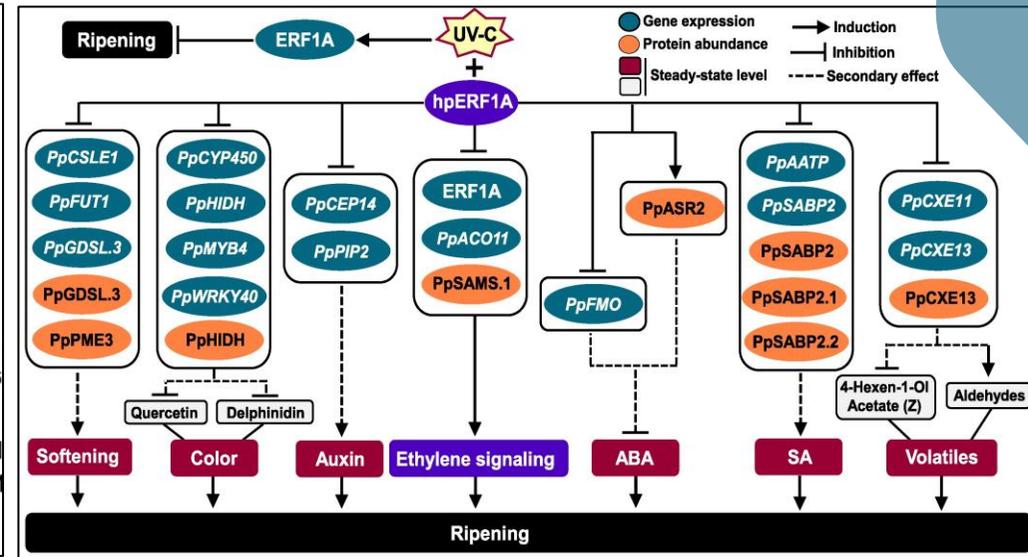
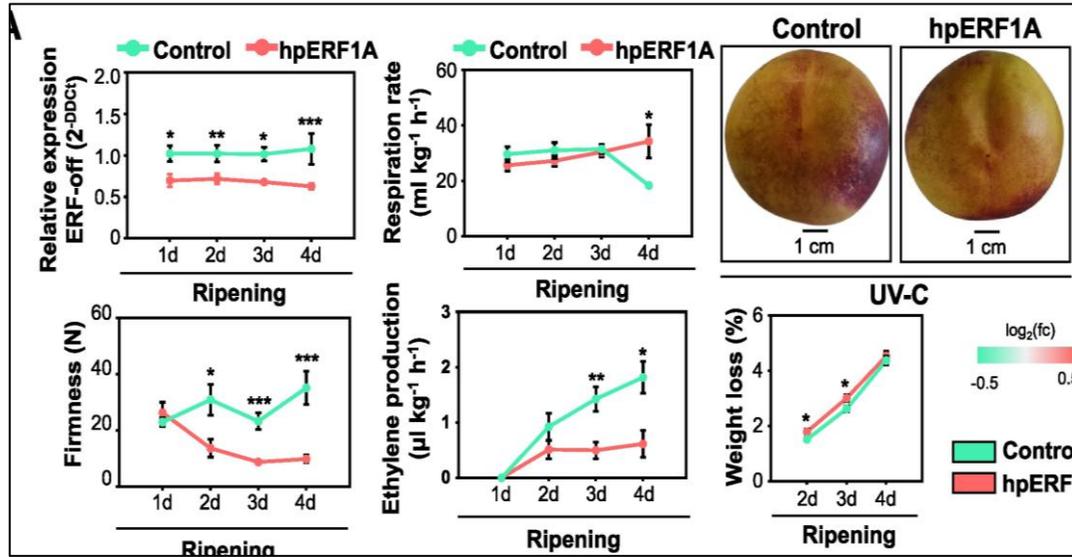
Mechanism of UV-C action?

RNA-seq analysis identified ERF1 as a key factor in UV-C signaling

UVC vs CONTROL



ERF1A silencing partially reversed UV-C ripening outcome



ERF1 is involved in UV-C ripening in peach fruit by regulating ethylene signaling

The impact of kiwifruit post harvest ripening



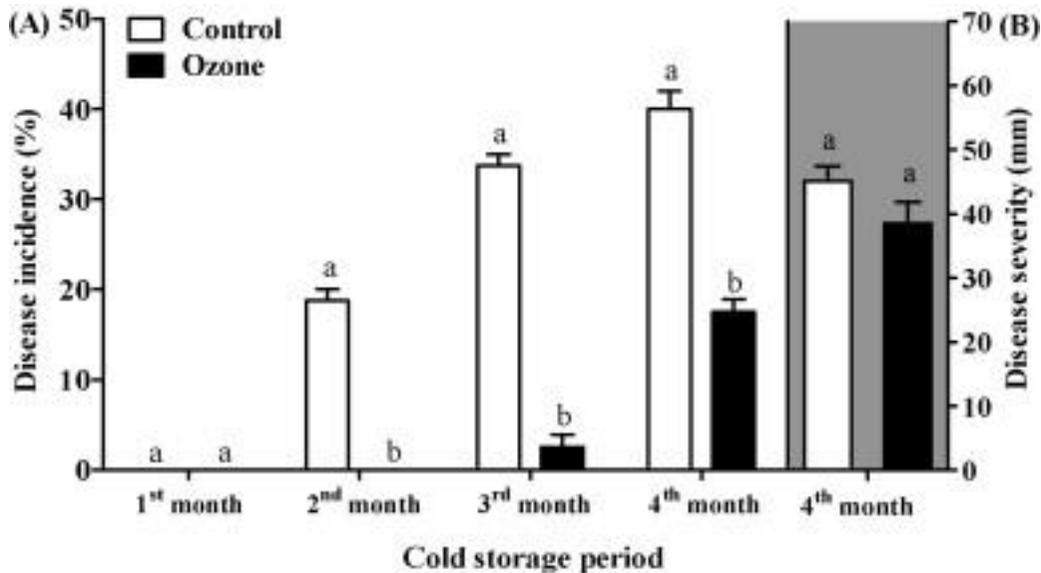
**Why
kiwifruit?**



Kiwifruit as a model for climacteric ripening

- ❖ The induction of postharvest kiwifruit ripening is stimulated by ethylene for some hours or alternatively by chilling exposure
- ❖ Kiwifruit can be successfully stored at 0 °C for 6 months in the absence of ethylene (very low ethylene level induce ripening)
- ❖ It does not produce endogenous ethylene at temperatures <10 °C (e.g. during cold storage), while it produces ethylene at room temperature (e.g. during ripening at 20 °C)

Ozone induces resistance of kiwifruit to stem-end rot caused by *Botrytis cinerea*



Disease incidence (%)

(A) and severity (decay depth, mm) (B) of stem-end rot caused on artificially infected kiwifruit during 4-month cold storage in a room with catalytic oxidation of ethylene (control) or catalytic oxidation of ethylene plus continuous supply of ozone

Key results

Ozone decreased incidence by 56%



Infected fruit formed sclerotia, while no sporulation of the pathogen occurred in ozone-treated kiwifruit



Control

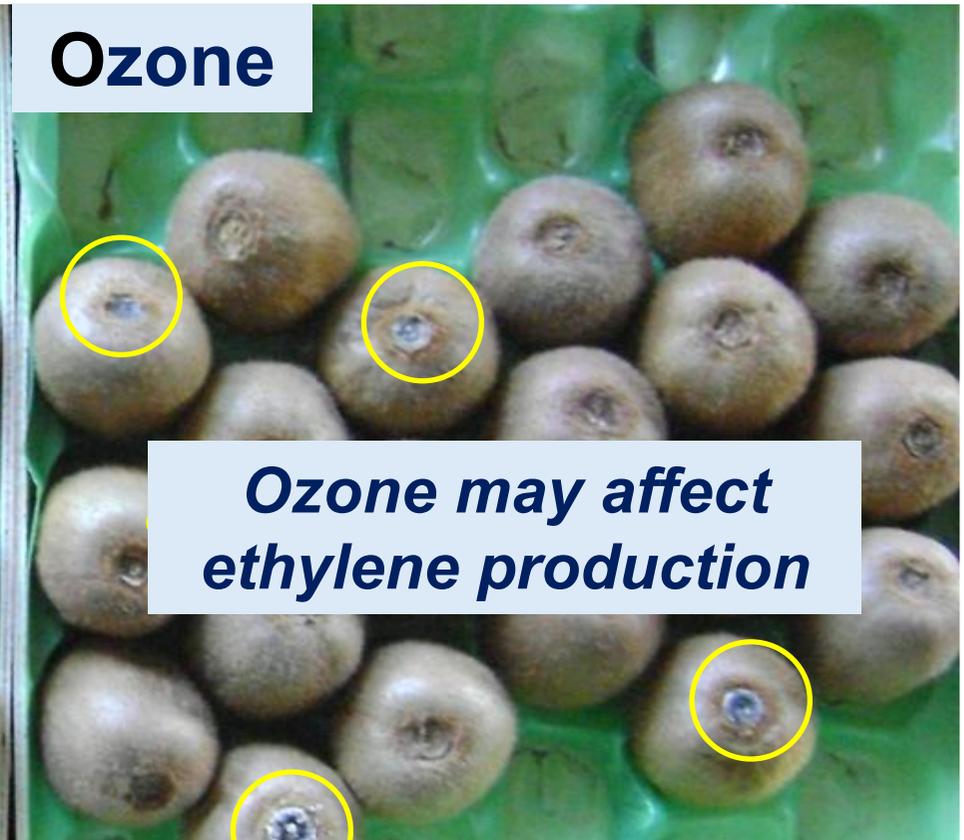
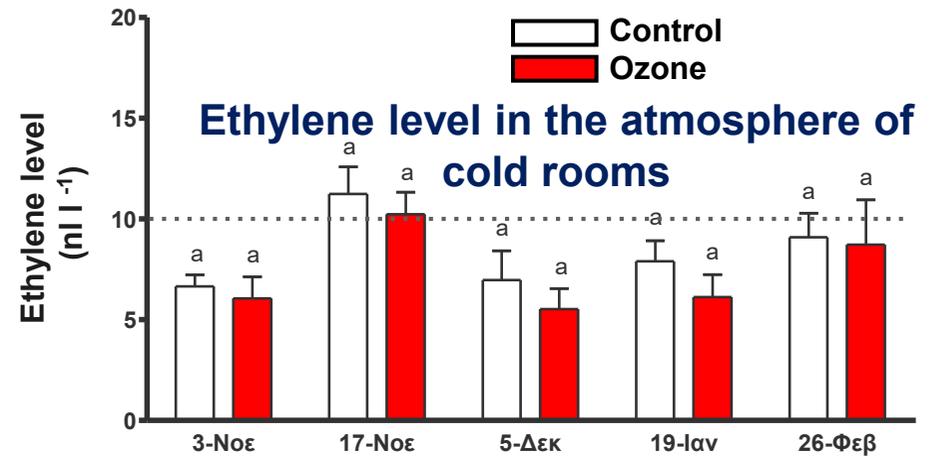
Catalytic oxidation of ethylene
(conventional cold storage)
(sporulation)



Ozone
(0.3 $\mu\text{L L}^{-1}$)

**Catalytic oxidation of ethylene plus
a continuous supply of ozone**
(sclerotia formation)

The application of gas ozone in a cold room depressed the ethylene level inside the room (to the same extent as catalytic oxidation)

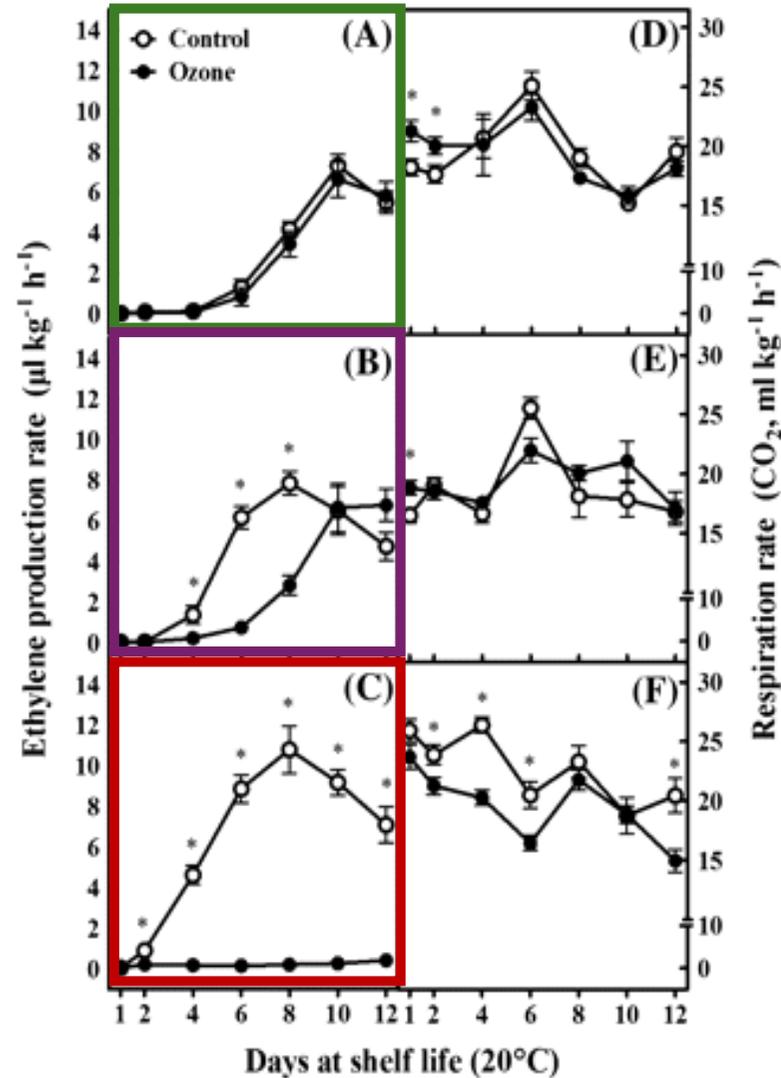


Ozone blocked ethylene production in kiwifruit

1 month cold storage

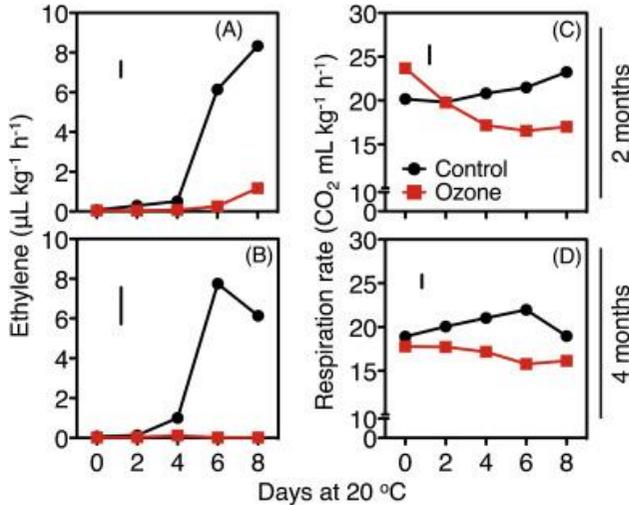
3 months cold storage

5 months cold storage

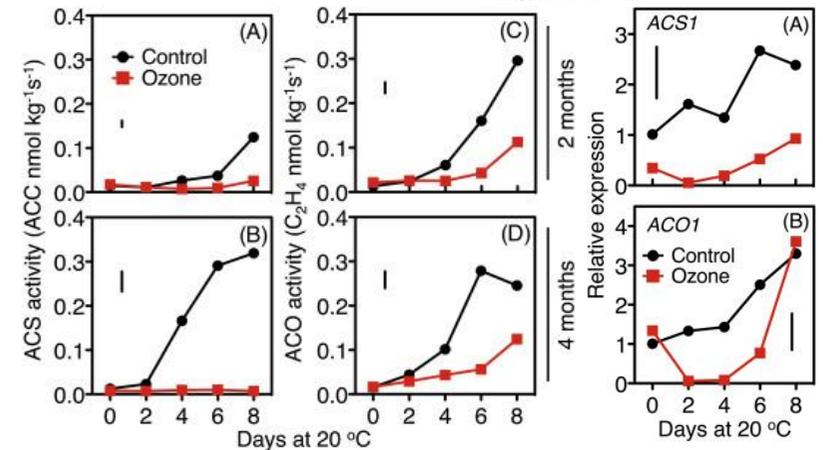
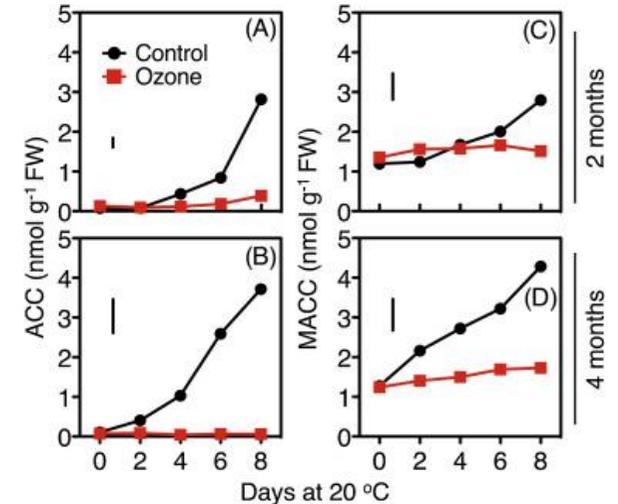
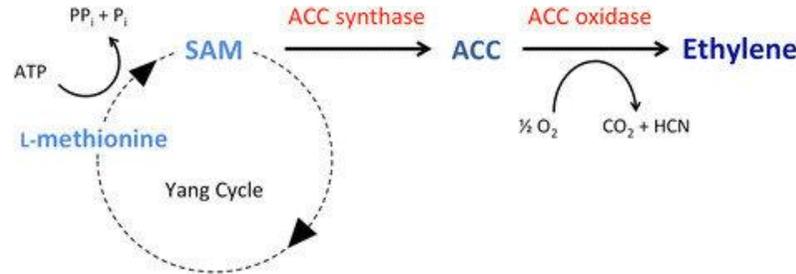


Ethylene production (A–C) and respiration rate (D–F) of kiwifruits ‘Hayward’ during shelf life (20 °C) for 1, 2, 4, 6, 8, 10, and 12 days after 1 (A,D), 3 (B,E), and 5 (C,F) months of cold storage (0 °C) in the absence (control) or presence of ozone

Ozone-induced kiwifruit ripening delay is mediated by ethylene biosynthesis inhibition

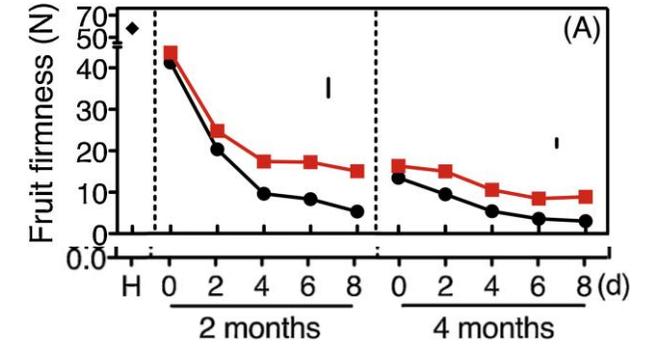
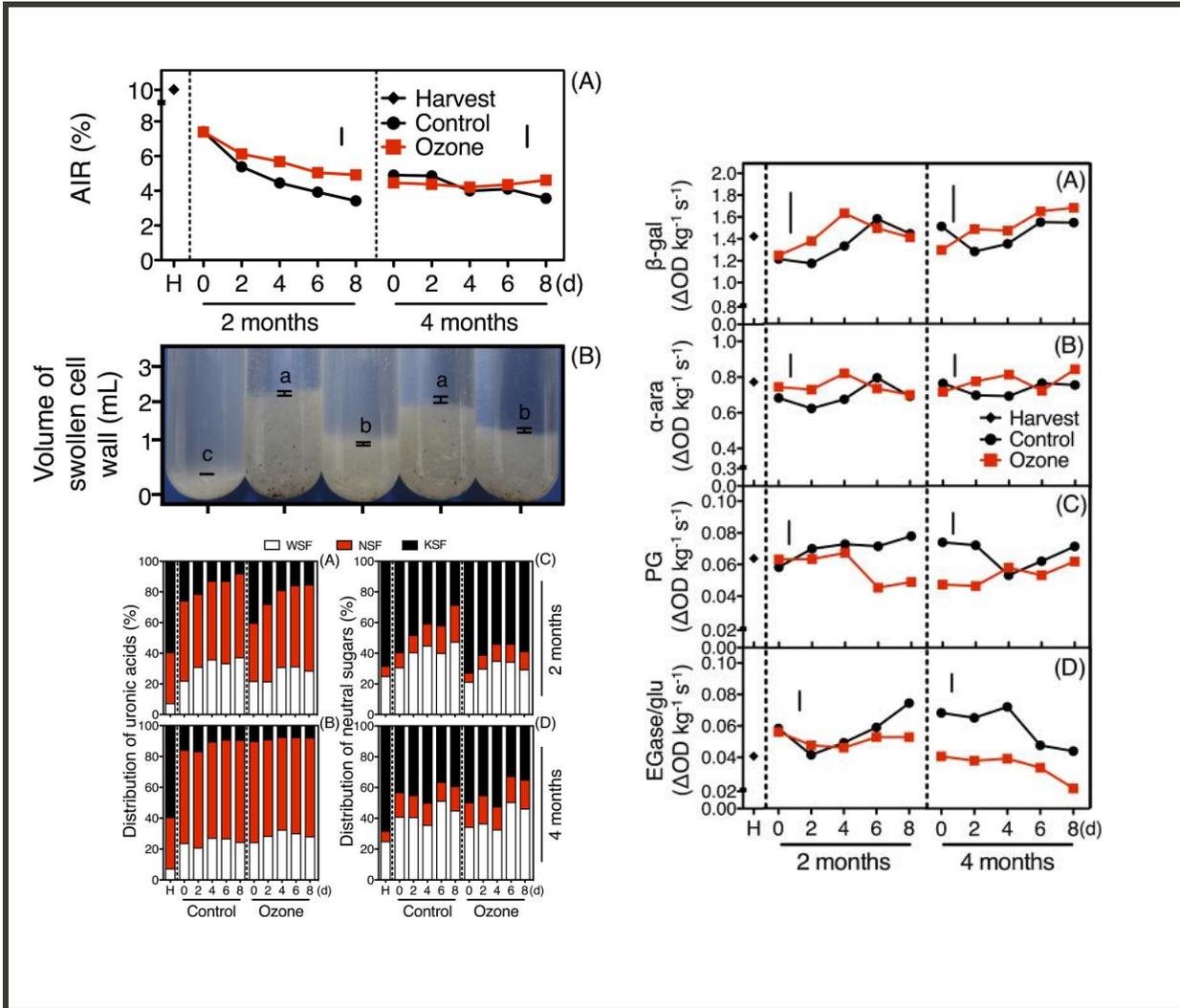


Ozone delays ripening and inhibit ethylene production and respiration rate



Ozone decreases ethylene biosynthesis by inhibiting *AdACS1* and *AdACO1* expression and activity

Ozone-induced kiwifruit ripening delay is mediated by cell wall disassembly



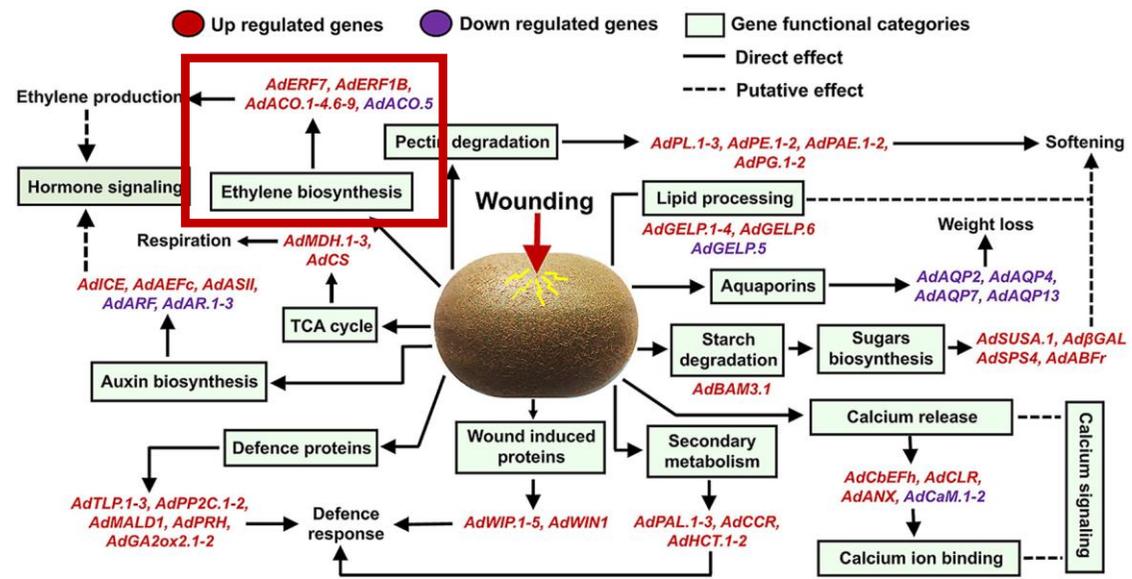
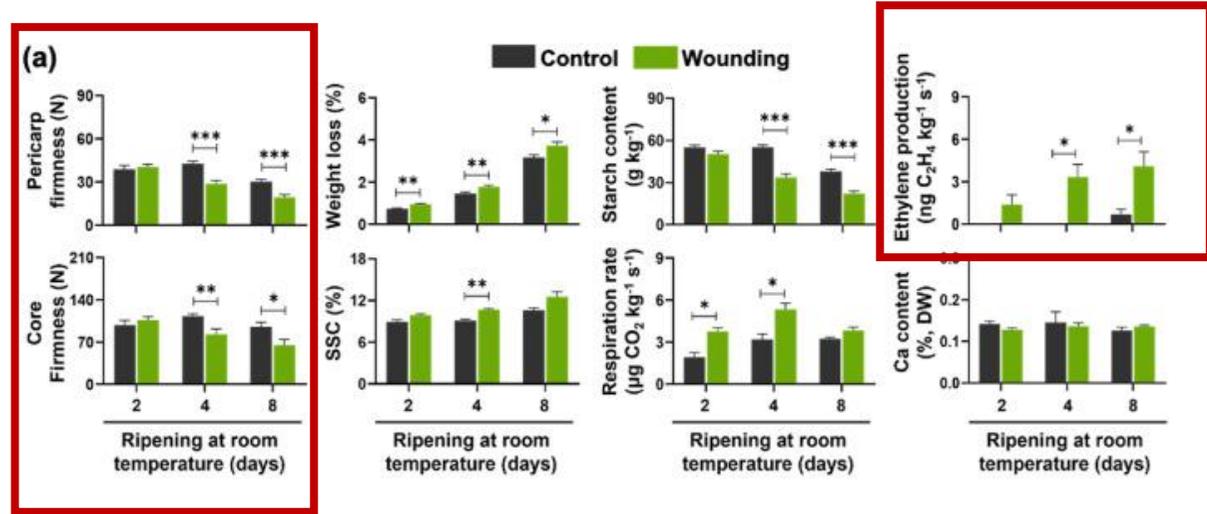
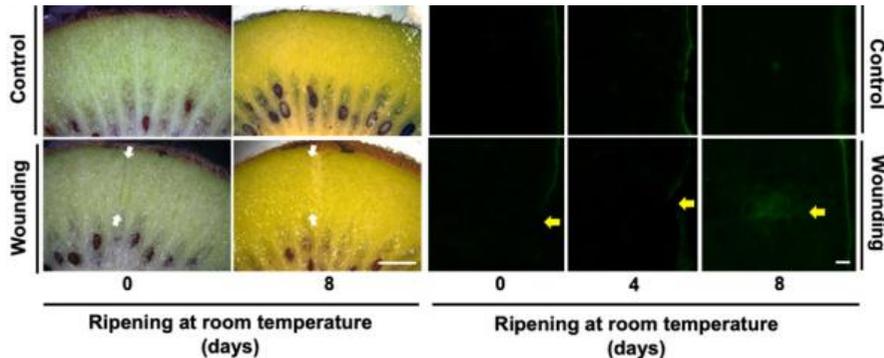
Anti-softening ozone effect

- reduced cell wall swelling
- pectin and neutral sugar solubilization
- inhibition of cell wall degrading enzymes activity

Wounding treatment-induced kiwifruit ripening

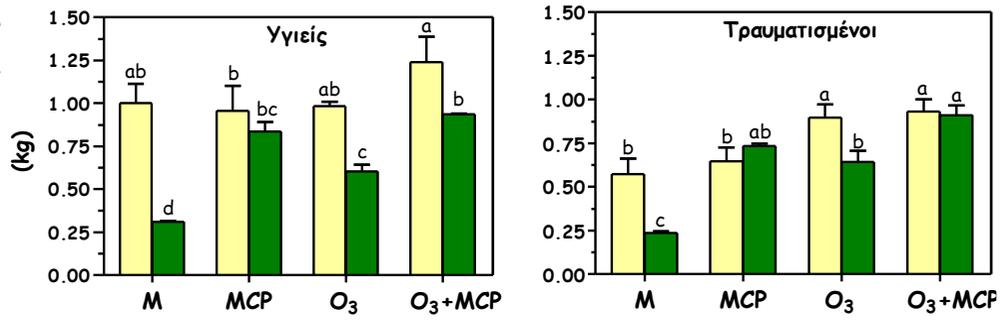


Artificial injury of 1 cm depth using a needle (wounding treatment)

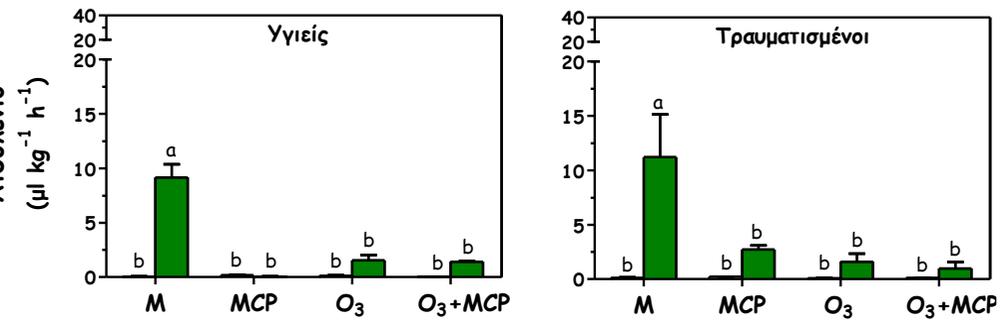


The ozone delayed kiwifruit ripening even following artificial wounding

ΣΥΝΕΚΤΙΚΟΤΗΤΑ ΣΑΡΚΑΣ (kg)



ΑΙΘΥΛΕΝΙΟ (μl kg⁻¹ h⁻¹)



Firmness and ethylene production in wounded kiwifruit in absence or in presence of ozone and 1-MCP



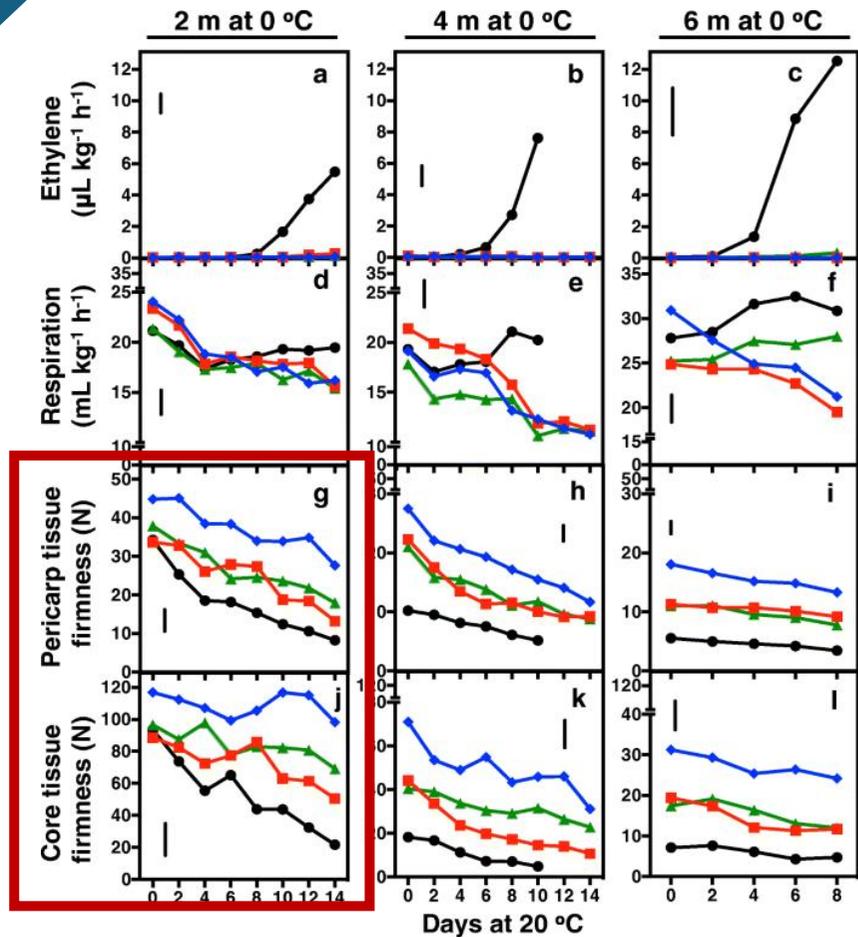
Artificial injury of 1 cm depth using a needle (wounding treatment)

→ **strong potential to protect fruit quality after mechanical damage**





**How does
ozone
interact with
other
ripening-
related
molecules?**

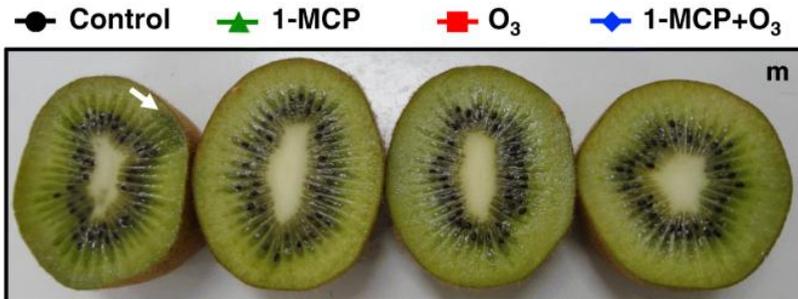


Kiwifruit ripening was inhibited by ozone and 1-MCP alone treatment

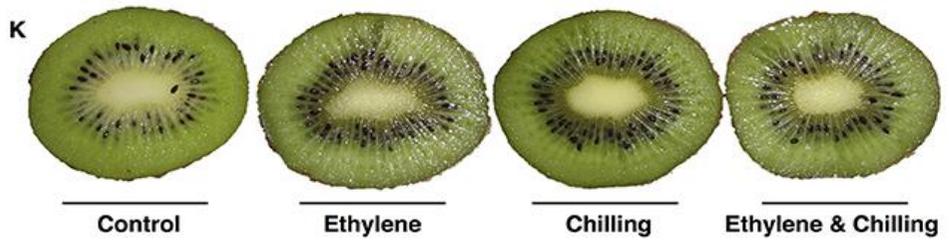
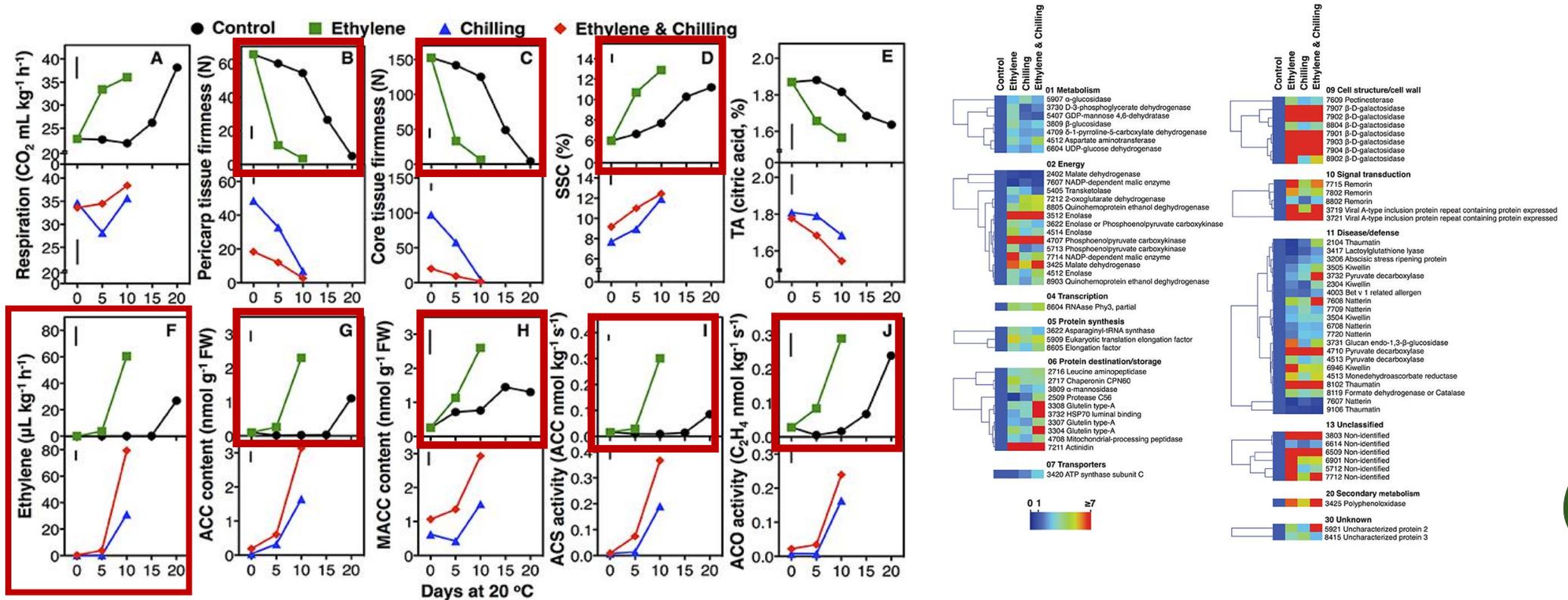
how these molecules interact?

Combined ozone and 1-MCP treatment strongly inhibits kiwifruit ripening

Synergistic effect between ozone and 1-MCP

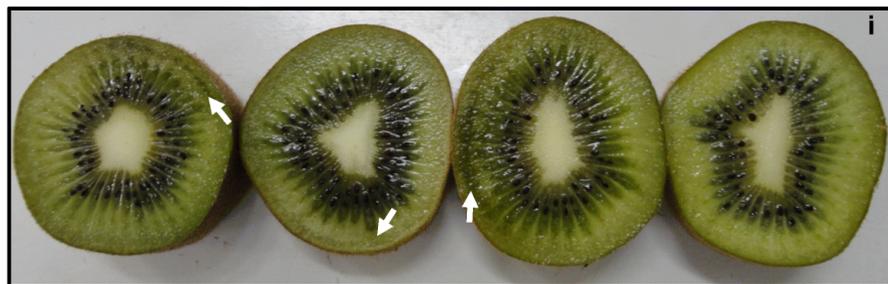
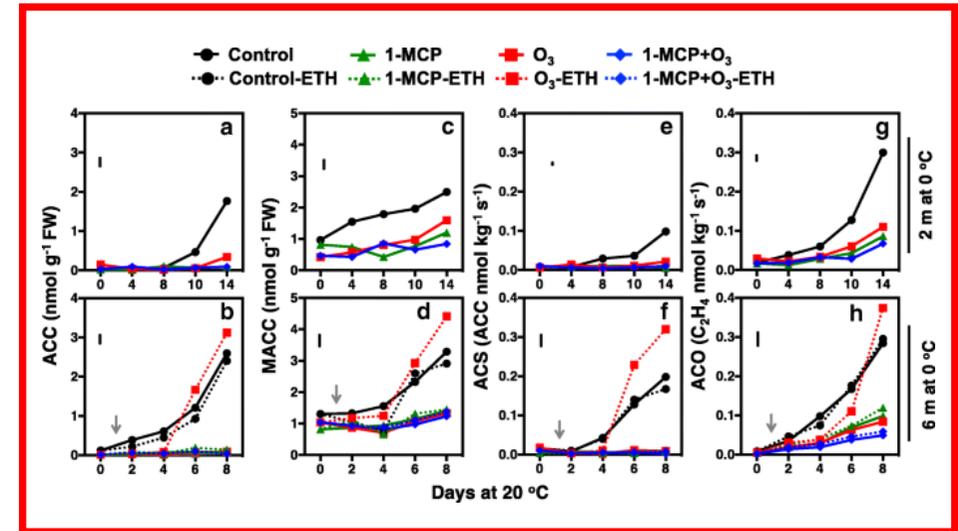
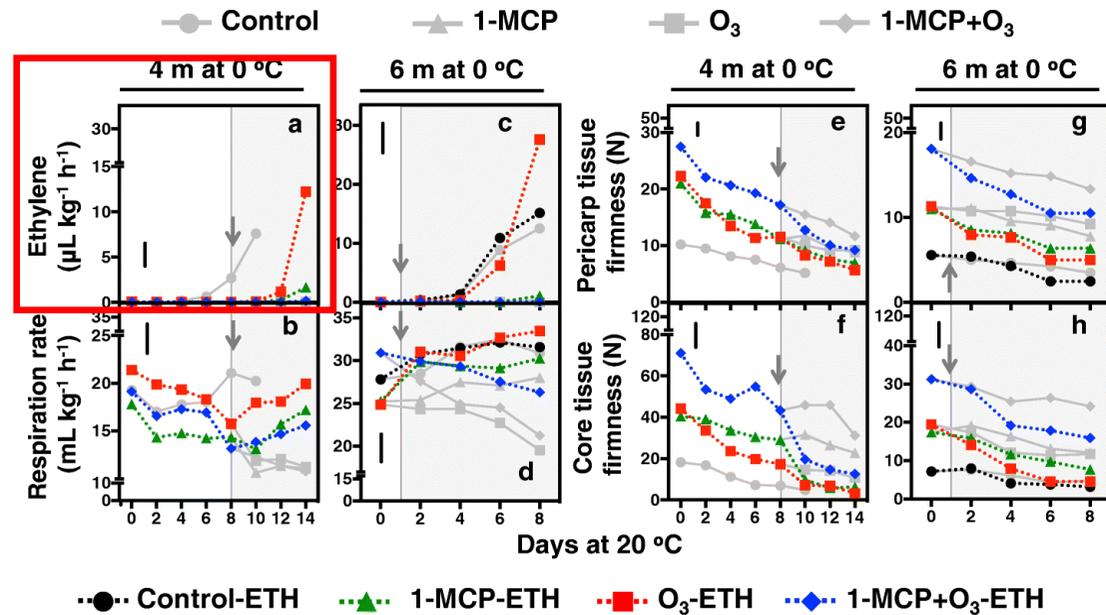


Exogenous ethylene directly induces kiwifruit ripening



Whether the inhibition of kiwifruit ripening by ozone and 1-MCP may reverse by exogenous ethylene?

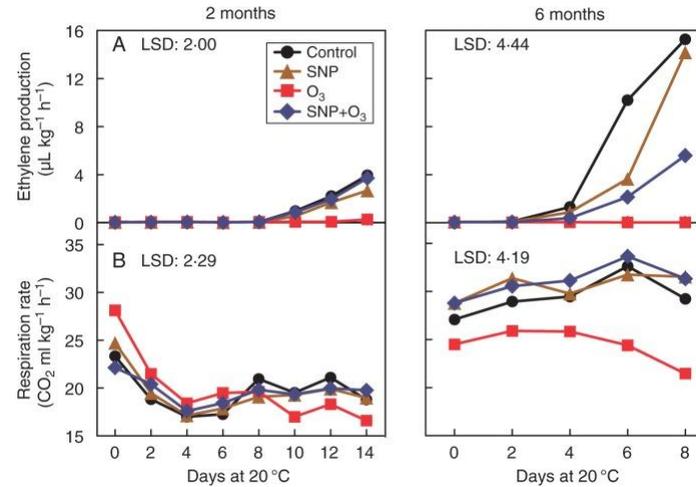
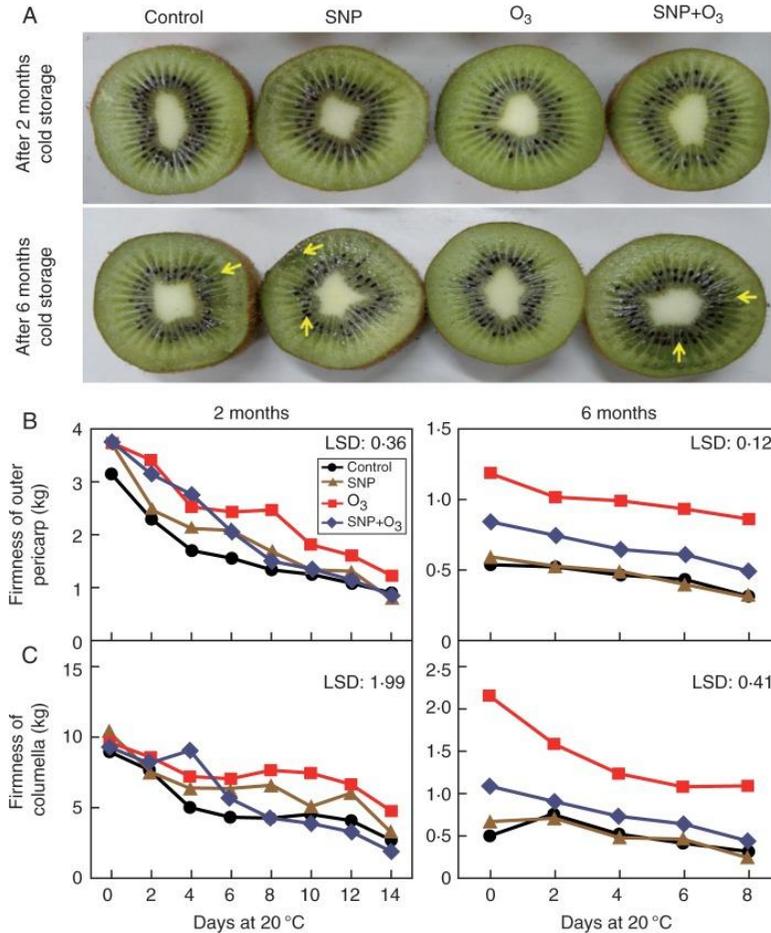
Ripening inhibition is reversible by exogenous ethylene in O_3 -treated, but not in 1-MCP + O_3 -treated, kiwifruit



Key finding

- ❖ O_3 -treated fruit exposed to exogenous ethylene produced endogenous ethylene
- ❖ Ethylene treatment did not induce endogenous ethylene production in MCP fruit

Ozone-induced ripening inhibition was partially reversed by nitric oxide



Key Results

- ❖ Ozone treatment delayed fruit softening and depressed the ethylene biosynthesis
- ❖ NO alone was relatively ineffective in regulating ripening, however, NO attenuated the O₃-induced ripening inhibition

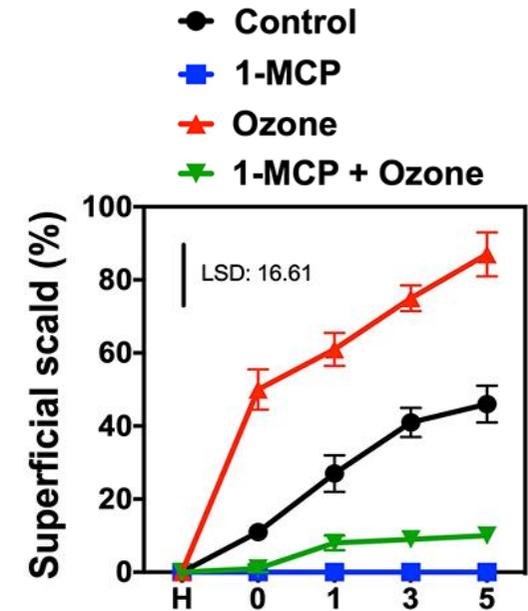
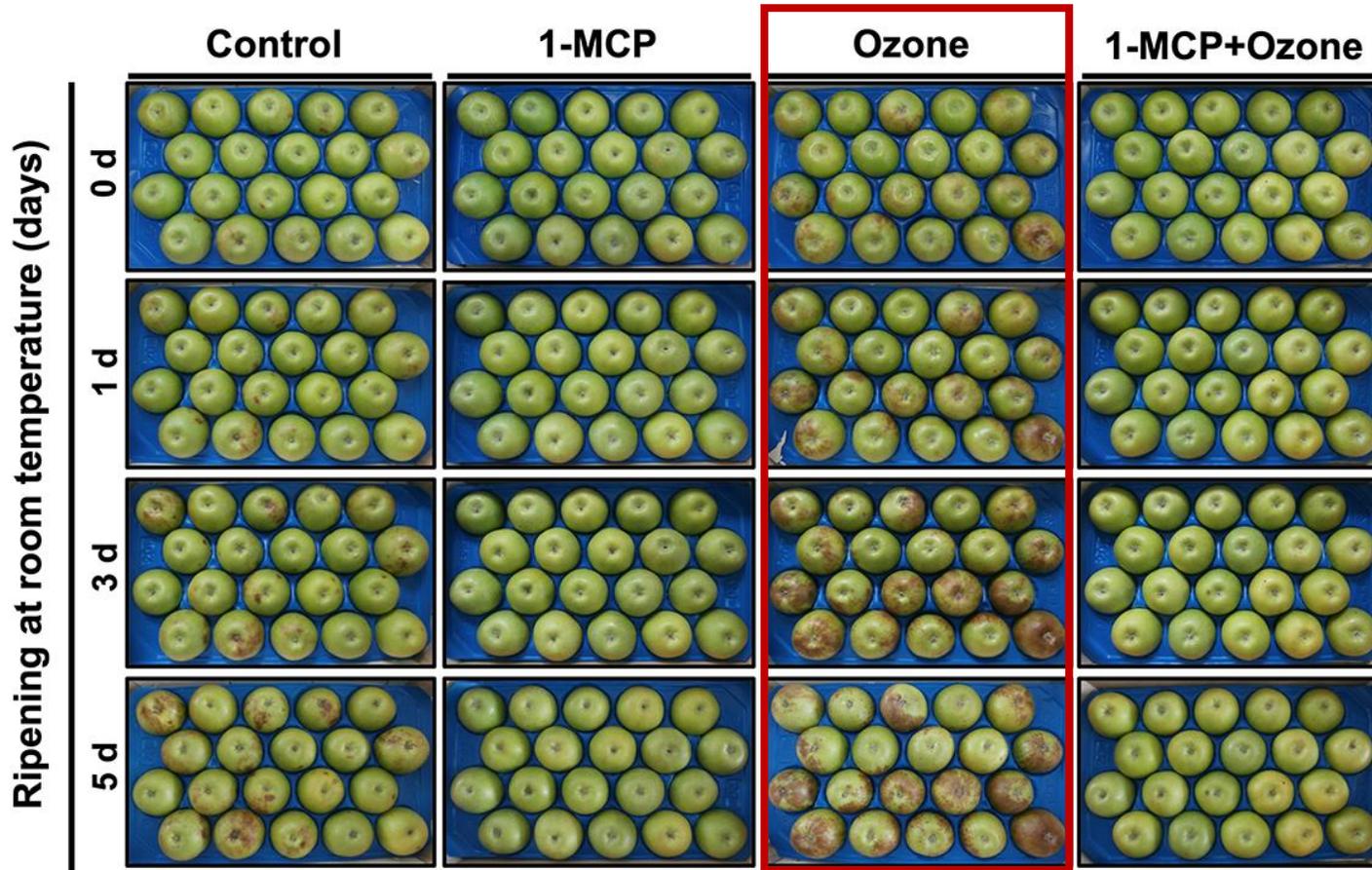
It remains elusive how NO can exert its ripening effect only in the presence of O₃



Is ozone also effective in other fruit species?

- The effectiveness of ozone is species-dependent

Ozone-induced scald symptoms in Granny Smith apple



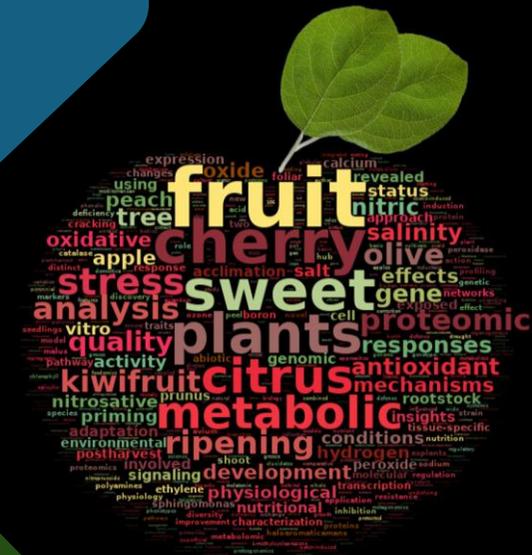
In apples, ozone exert detrimental effects; therefore, its application is highly species-dependent and requires careful management



Conclusions

- Postharvest losses can be reduced by using appropriate **green postharvest technologies**
- **Ozone and UV-C** can be applied to maintain postharvest fruit quality
- However, there are still many challenges that need to be overcome
 - a major challenge is understanding how the ozone and UV-C interact (**UV-C radiation produces ozone gas**)
- **Combined treatments** may be a focus of future research for the application

Acknowledgments



I would like to thank all the collaborators and funding sources of our research

**Thank you for
your attention!**

