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A spatial dependent 3D model to predict the composition of the headspace of microperforated packages for respiring products

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INTRODUCTION

Modified Atmosphere packaging (MAP) is a widely applied technology for preserving the quality and safety of fresh and fresh-cut fruits and vegetables. It is based on achieving the most suitable gas composition for the product inside the package, and for certain high respiring products this is possible only by using microperforated packages. The application of mathematical models to predict the in-package gas composition is very useful for the optimal design of MAP, so different models have been evolving last years, incorporating new features to enhance precision in calculations. However, most models neglect the spatial dependence of the gas composition in the headspace and the convective flow through microperforations. Computational fluid dynamics (CFD) models applied to microperforated packages have enabled a more comprehensive understanding of gas exchange phenomena in these packages.

OBJECTIVES

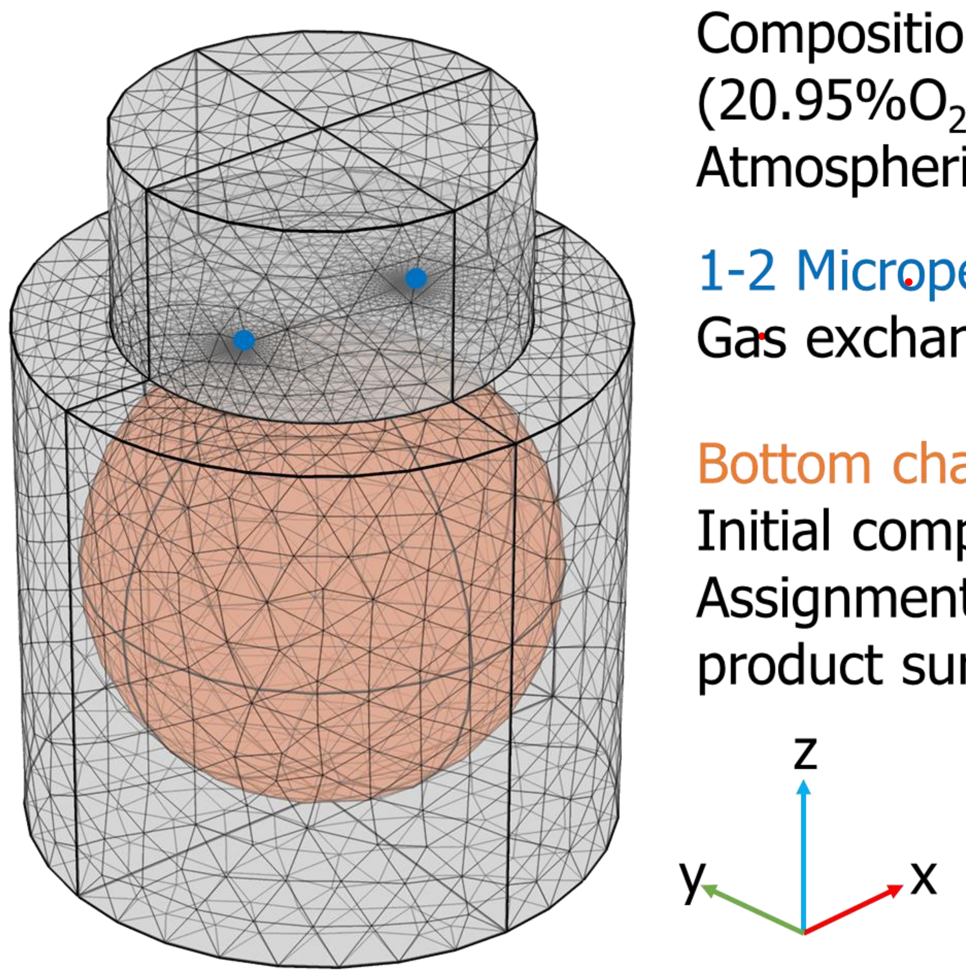
To develop and validate a spatial dependent 3D multiphysics model capable of adequately describing the gas composition in the headspace of microperforated packages during the storage of respiring products.

MATERIALS AND METHODS

- Model (based in that of Vega-Diez et al., 2024)
  - implemented in COMSOL Multiphysics® software
  - coupled transient convective and diffusive mass transfer and momentum transport through the microperforations
  - Maxwell Stefan and Navier-Stokes equations for compressible Newtonian flow
- Respiring products: fresh-cut peach (three cultivars: Andross, Calante and Catherine)
- Microperforated packages: 700mL of volume with two different microperforation sizes (90x50μm and 125x75μm).
- Respiration rate (González-Buesa et al., 2009):

$$R_{O_2} = m \cdot {O_2}^n$$
$$R_{CO_2} = q \cdot O_2 + s$$

Product	m (mL·kg^{-1}·h^{-1})	n	q (mL·kg^{-1}·h^{-1})	s (mL·kg^{-1}·h^{-1})	Weight (g)
Andross	2.559	0.318	0.038	3.753	185
Calante	1.192	0.632	0.216	2.230	250
Catherine	1.313	0.602	0.875	4.664	250

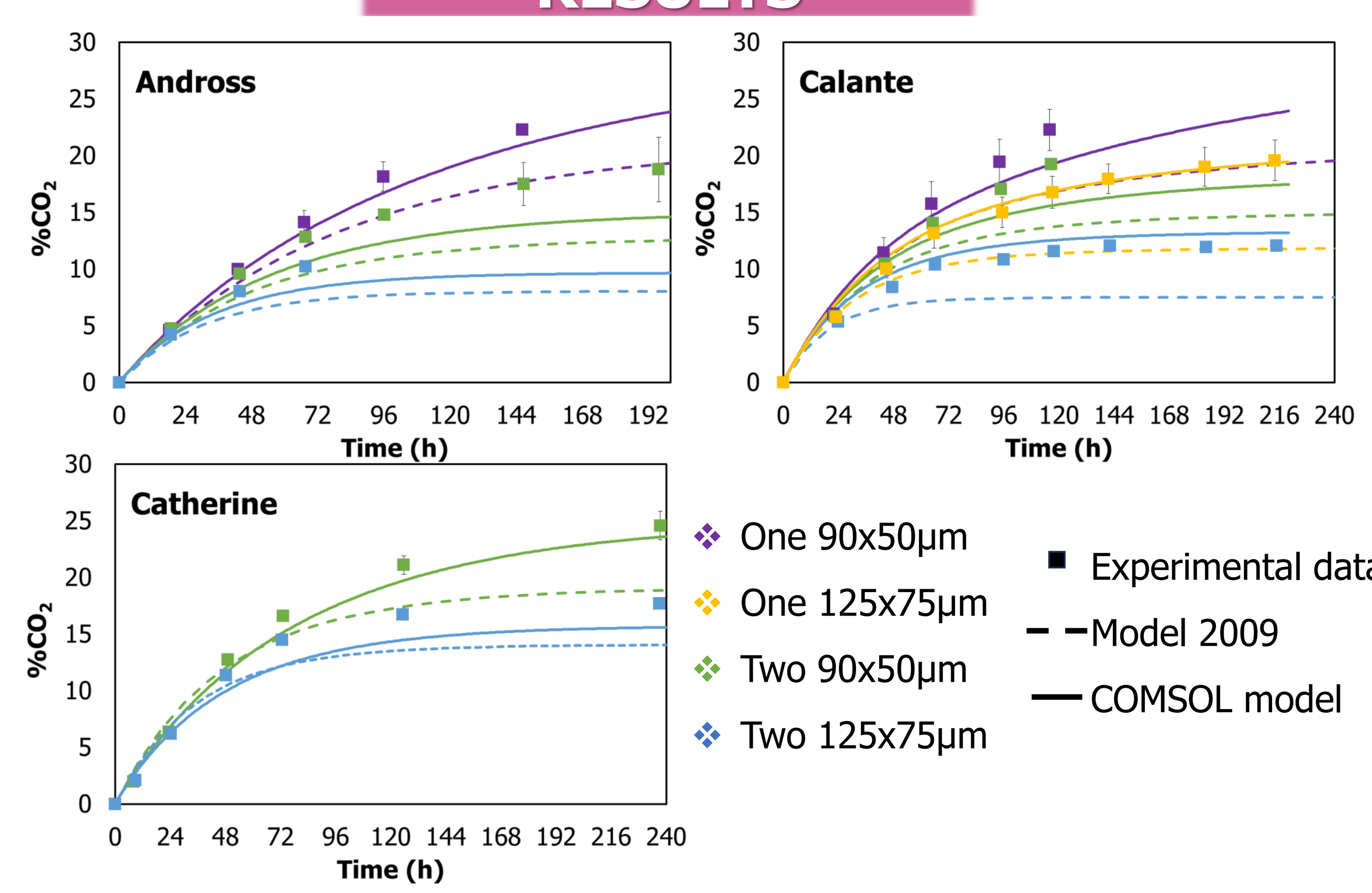


Upper chamber
Composition: Air
(20.95%O_2 0.005%CO_2)
Atmospheric pressure

1-2 Microperforations
Gas exchange occurs through them

Bottom chamber
Initial composition: Air
Assignment of respiration rate to product surface

RESULTS



- The previous model (González-Buesa et al., 2009) was not able to predict the CO_2 evolution inside the package for the three peach cultivars.
- The results obtained with this novel 3D model were able to adjust properly the CO_2 evolution.
- The small deviations between the model predictions and the experimental data may be attributed to the inadequate measurement of the perforation size, the respiration rate determination, among other factors.
- Both models were able to predict properly the O_2 evolution inside the packages for the 3 cultivars (data not shown).
- New research should be performed to check the potential and robustness of this model in other fresh and fresh-cut fruits and vegetables.

CONCLUSIONS

The 3D coupled mass and momentum transfer computational model has adequately predicted the gas exchange through microperforations, considering the spatial-time dependence of the gas composition, and evidences the relevance of considering the diffusive flow and the concentration gradients around the microperforations in order to accurately quantify the gas exchange through them.

REFERENCES

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