Apples and pears: importance of the microstructure of fruit

Flanders Centre of Postharvest Technology (VCBT)
BIOSYST/MeBioS – Leuven University, Belgium

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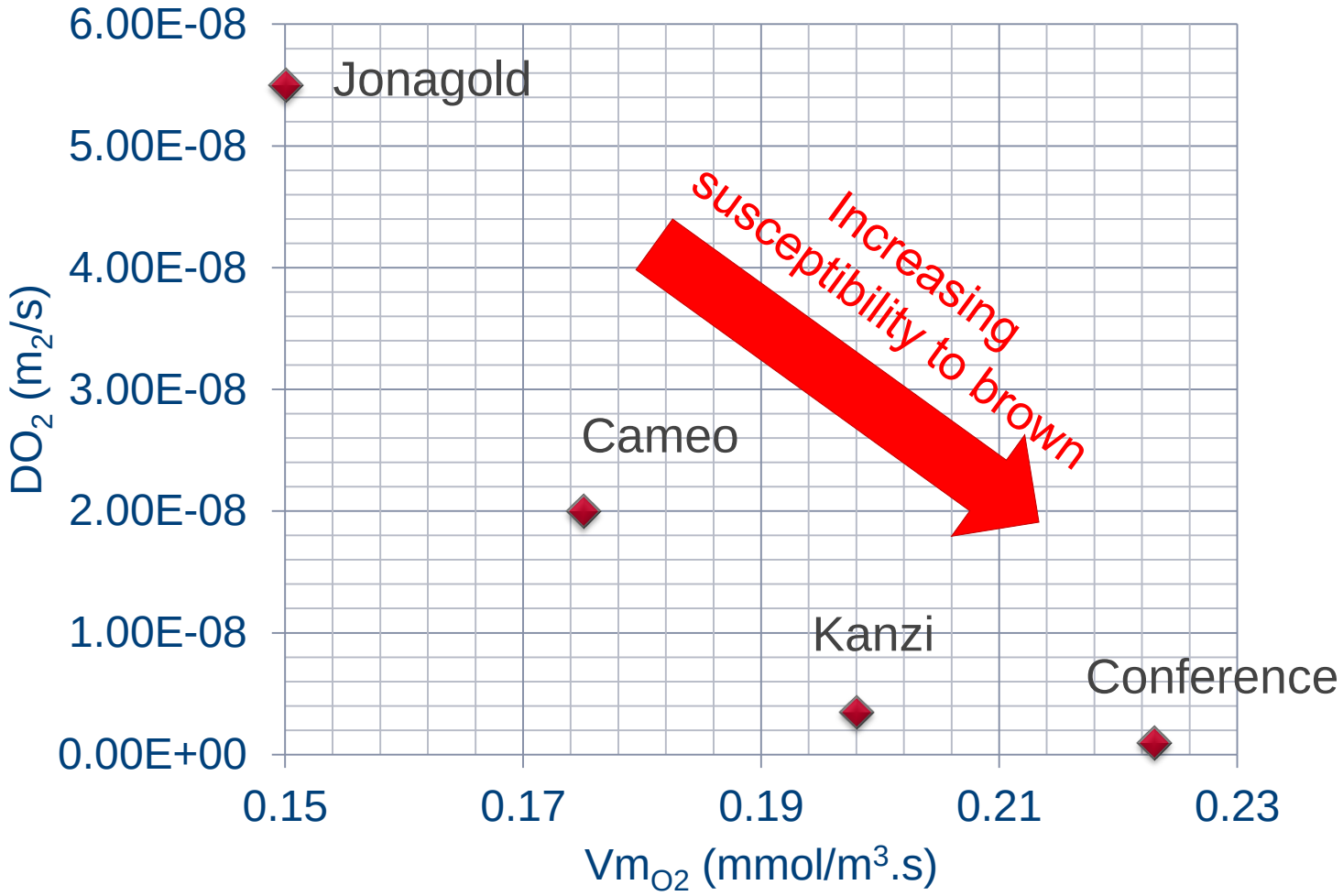
Biofluidics



Systems biology

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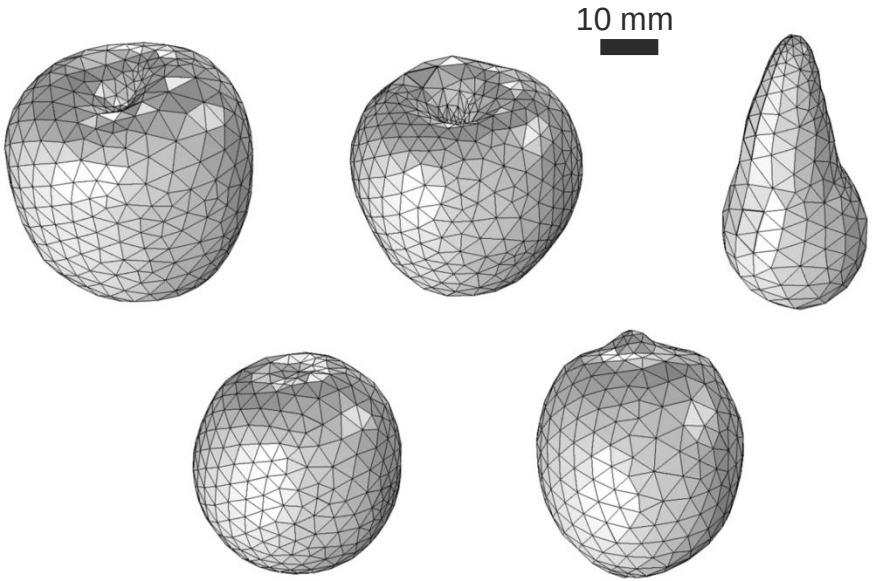
Continuum model for gas transport

- Variables: O_2, CO_2 and N_2
- Transport: diffusion + permeation
- Enzyme kinetics: Michaelis-Menten
- Geometry: based CT images



Rogge et al. (2015) J Food Eng

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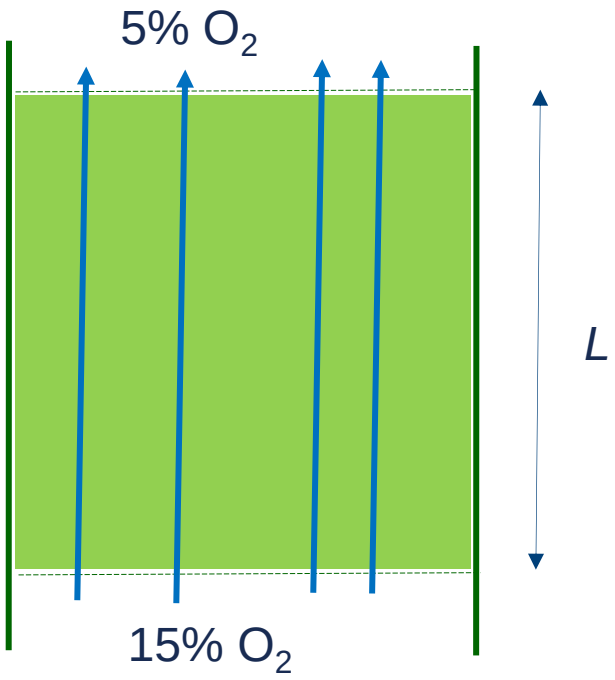

$$flux = D_{O_2} \frac{\Delta C_{O_2}}{L} \Rightarrow D_{O_2} = flux \frac{L}{\Delta C_{O_2}}$$

Brown, 1827; Fick,1855; Einstein,1905.
Ho et al. *Postharvest Biol Technol*, 41:113-120.

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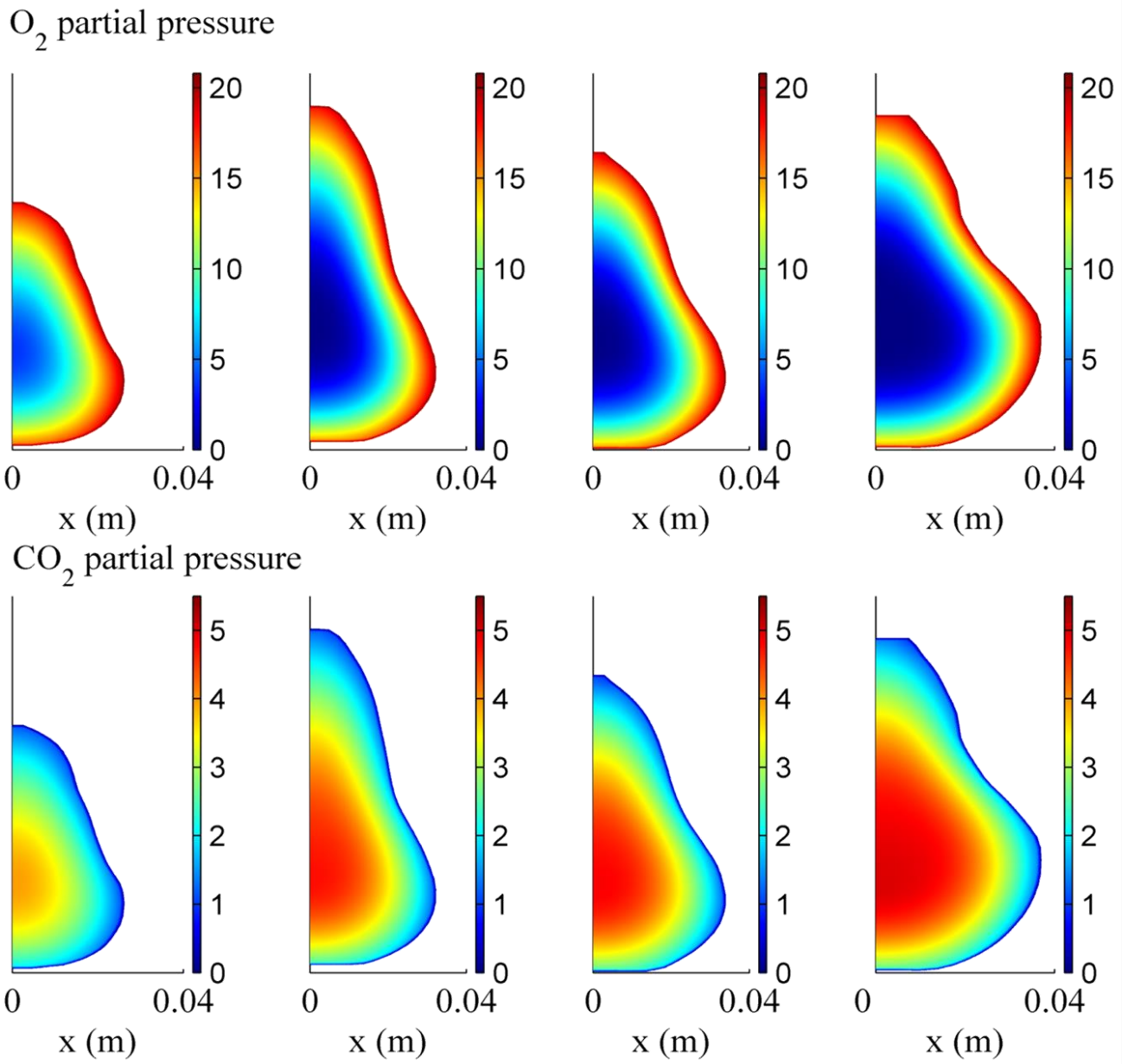

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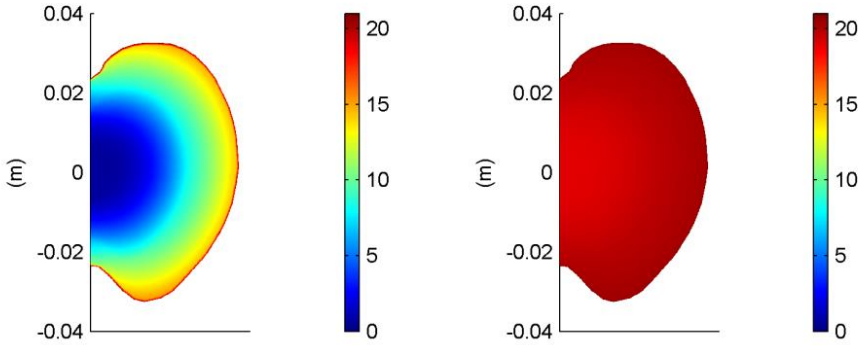
Ho et al. (2006) *J. Exp. Bot.*, 57 (15), 4215-4224; Ho et al. (2008) *PLoS Comp. Biol.*, 4 (3), art.nr. e1000023

Kanzi



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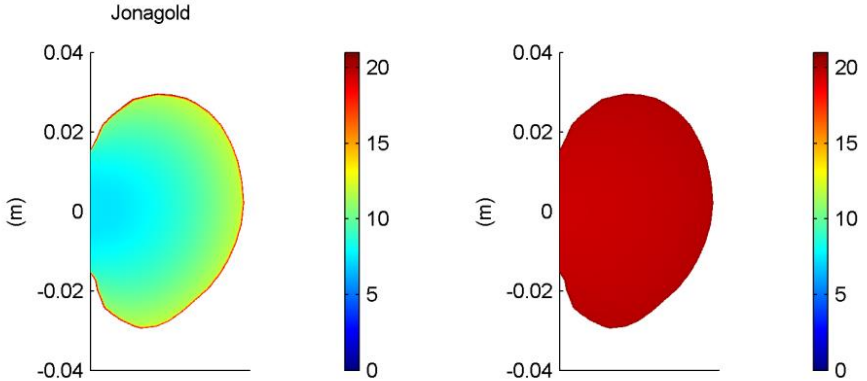

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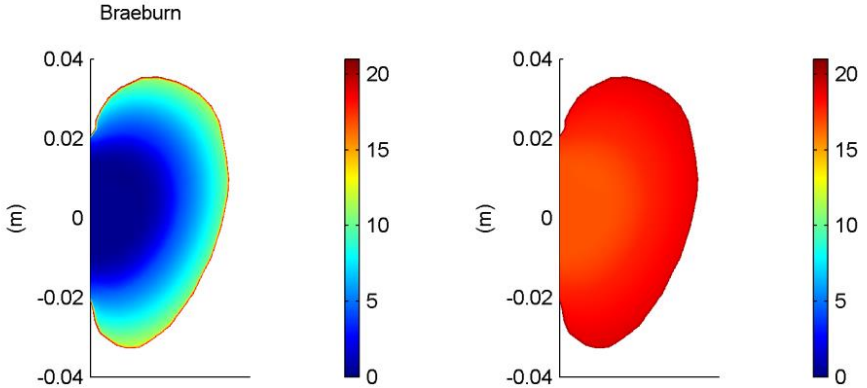

O_2 CO_2

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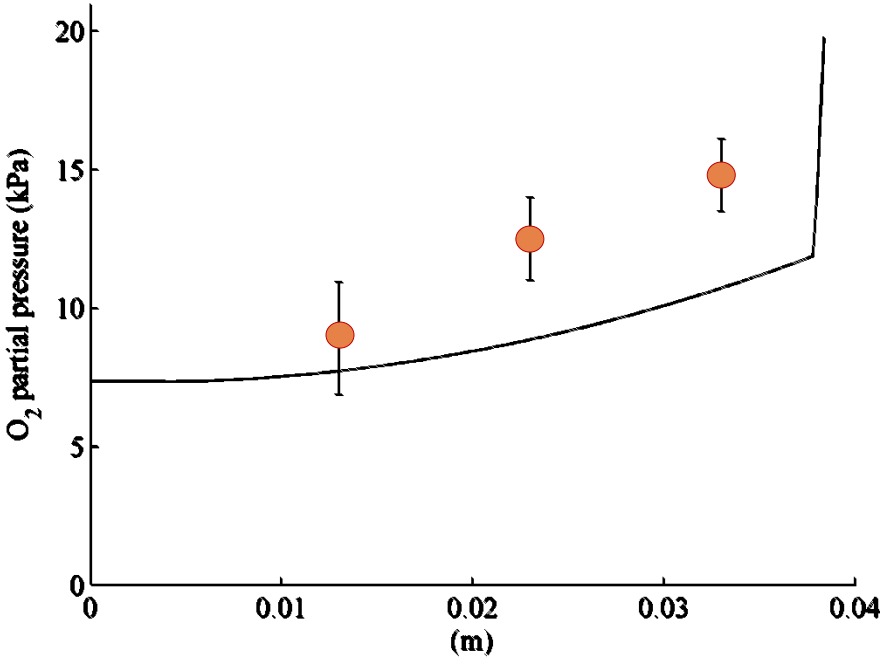
Ho et al. (2010) Journal of Experimental Botany, 61 (10), 2745-2755

Validation



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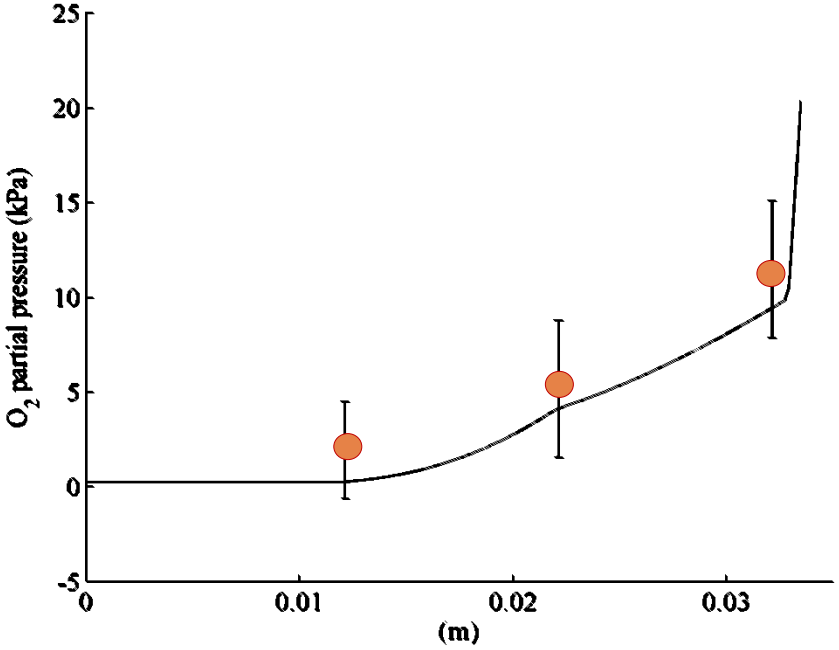

Braeburn

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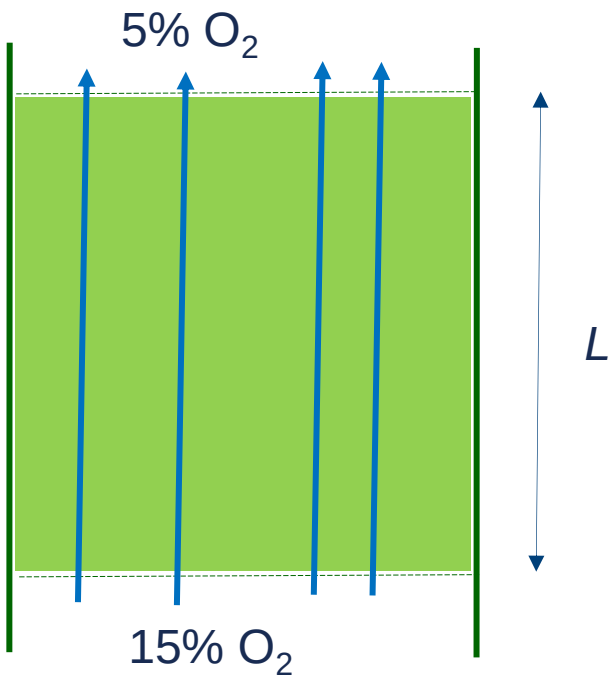
Ho et al. (2010) Journal of Experimental Botany, 61 (10), 2745-2755

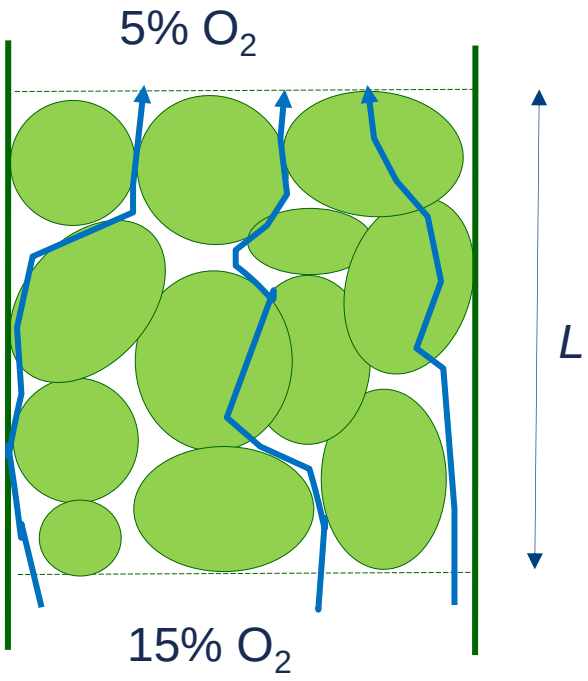
Limitations of continuum approach

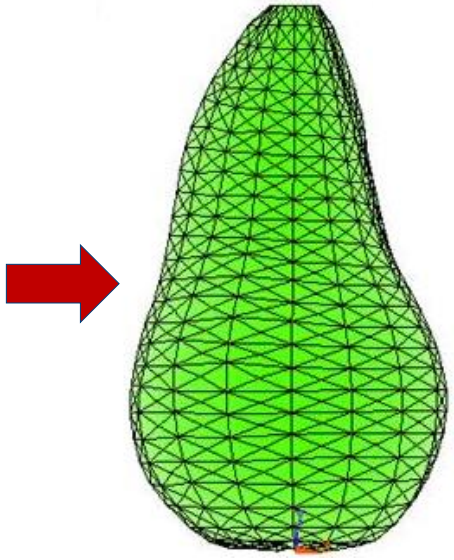
- Fit reasonable but not perfect
- *Apparent* model parameters
- Simulations do not provide direct information about gas related disorders

Multiscale model

Multiscale modelling

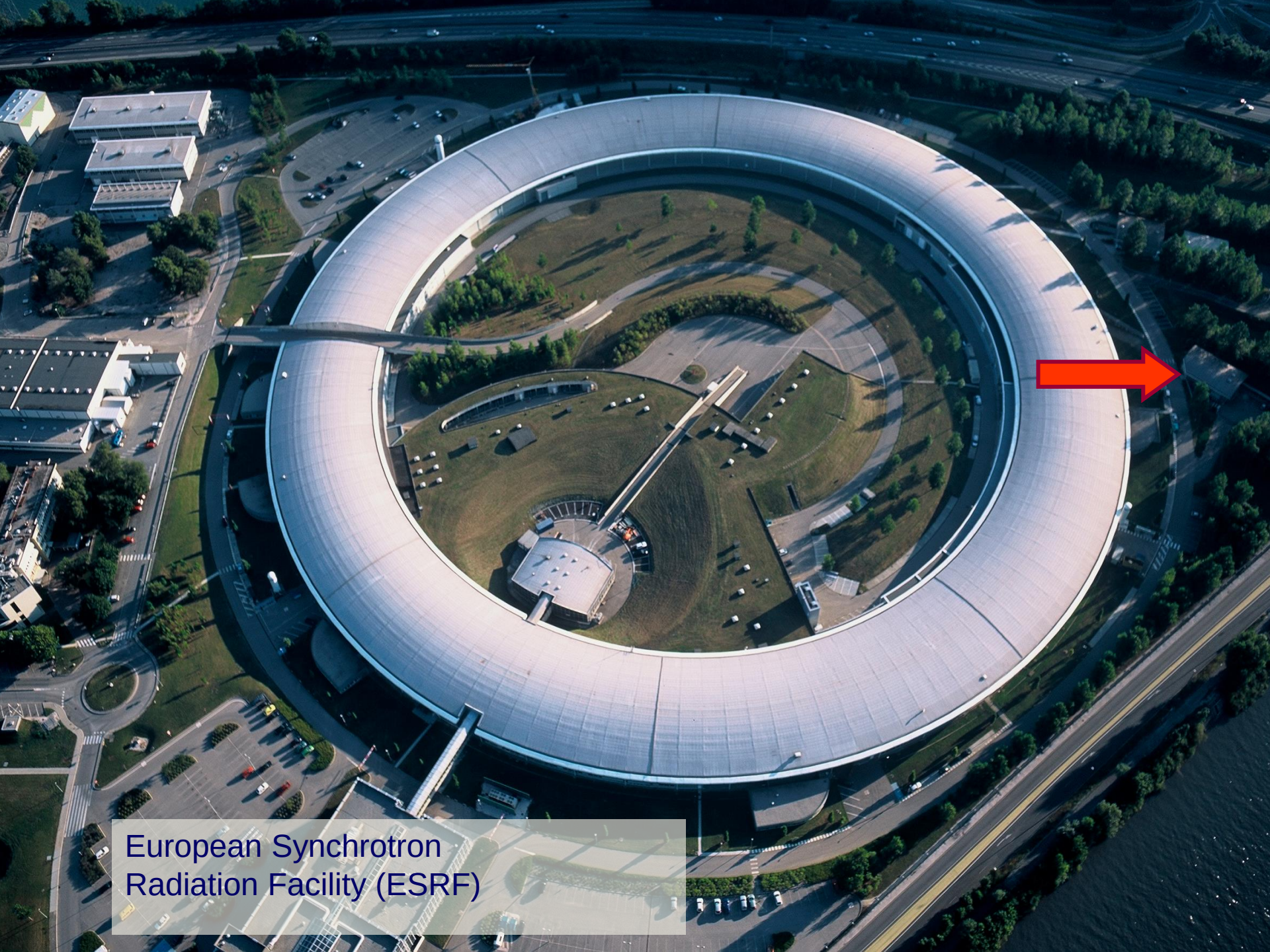






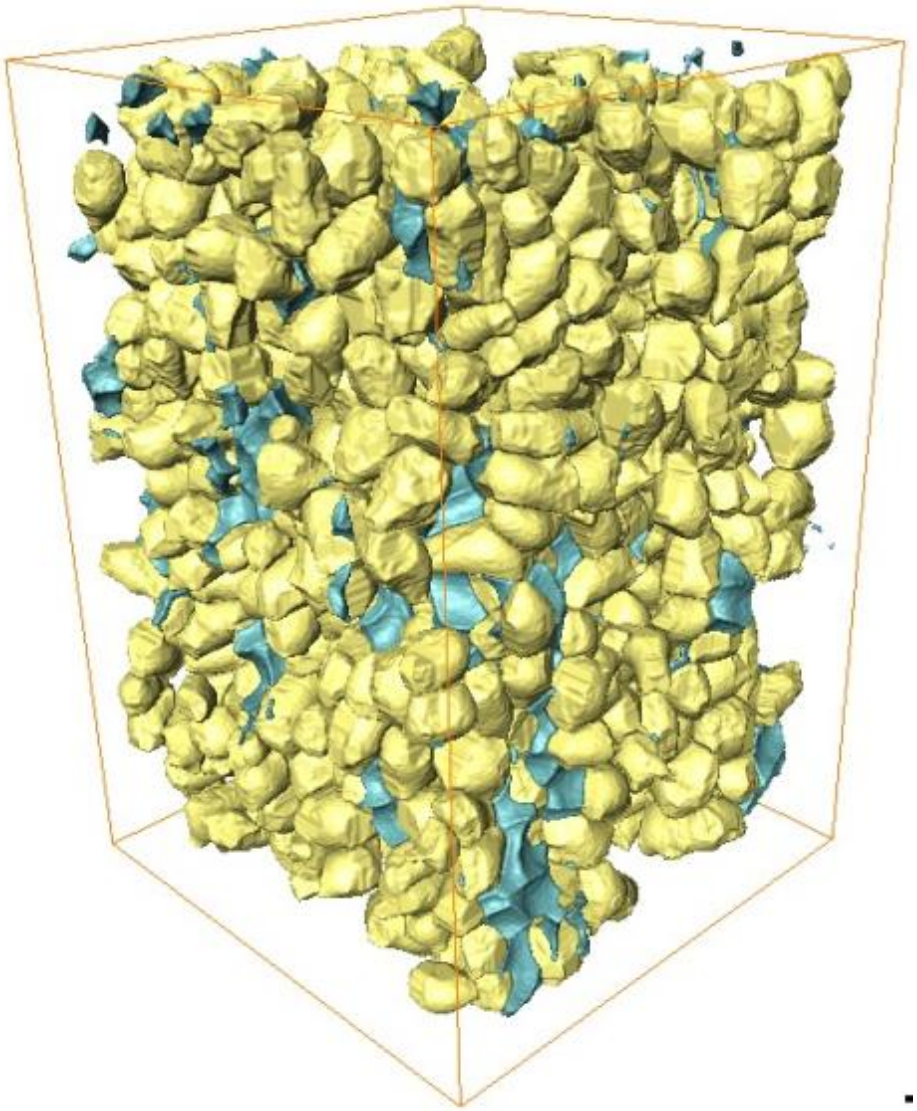
$$flux = D_{O_2} \frac{\Delta C_{O_2}}{L} \Rightarrow D_{O_2} = flux \frac{L}{\Delta C_{O_2}}$$

Ho et al. (2009) New Phytol., 182 (1), 163-174.



European Synchrotron
Radiation Facility (ESRF)

SKYSCAN
SkyScan Microcit



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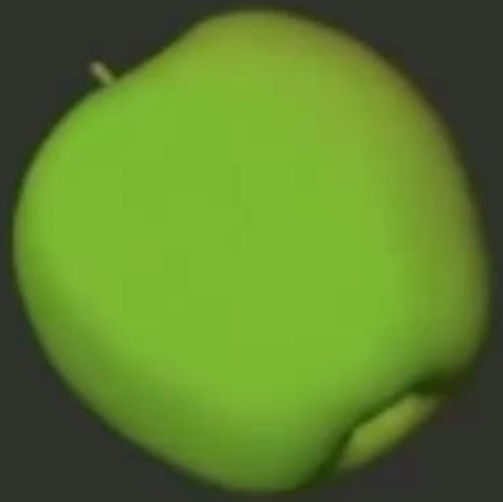
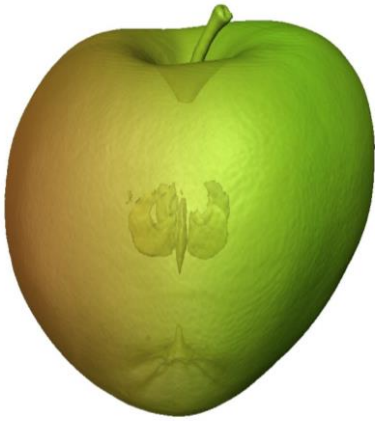
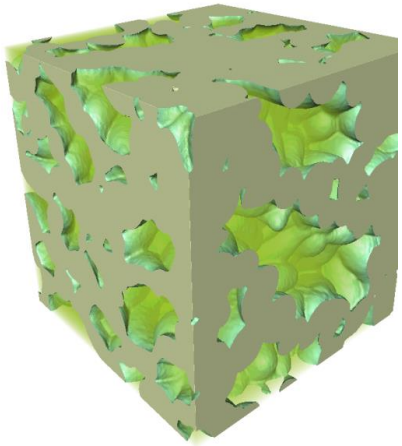
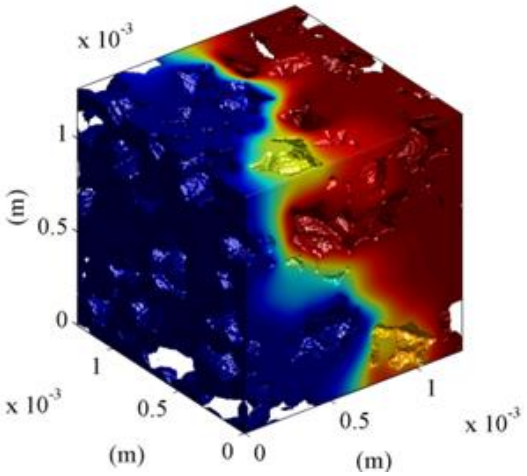
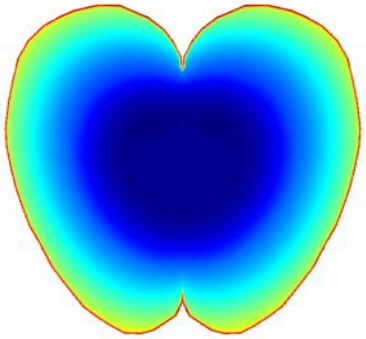
Verboven et al. (2008). Three-dimensional Plant Phys. 147 (2), 518-527.











Ho et al. (2008) PLoS Comp Biol 4 (3), art.nr. e1000023, -.
Ho et al. (2011) Plant Phys 155 (3), 1158-1168

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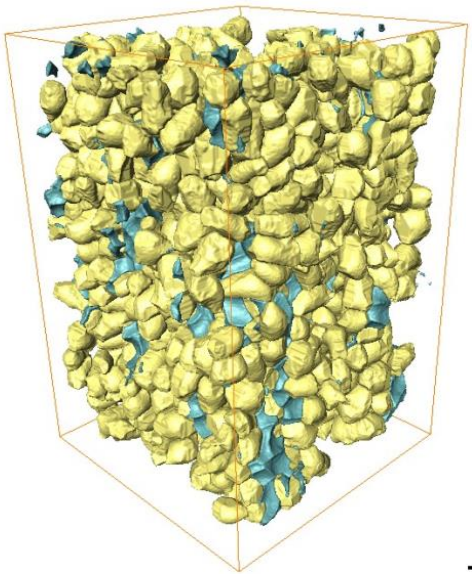
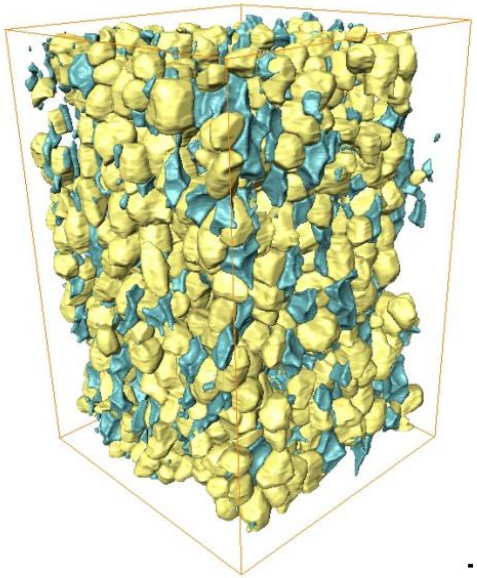
	Simulation	*Experiment*	*Reference*
Epidermis / hypodermis	8.5×10^{-10}—1.9×10^{-10}	1.9×10^{-10}—3.3×10^{-10}	Ho et al. (2006) Schotsmans et al. (2003)
Cortex parenchyma	3.6×10^{-10}—2.7×10^{-8}	2.8×10^{-10} —5.6×10^{-10}	Ho et al. (2006) Schotsmans et al. (2003)
Brachysklereids	1.48×10^{-10}		
Vascular tissue	3.45×10^{-8}		



Jonagold



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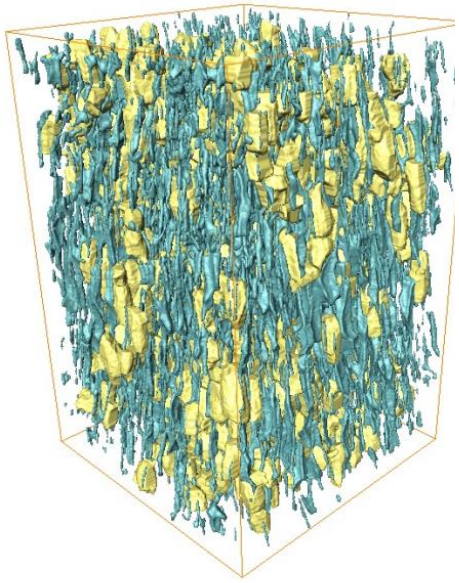

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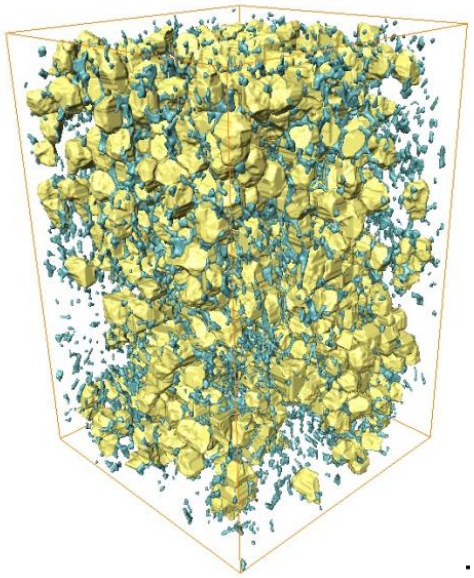

Conference

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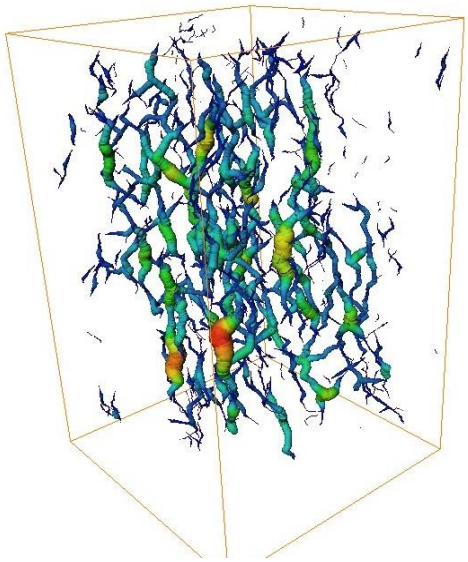

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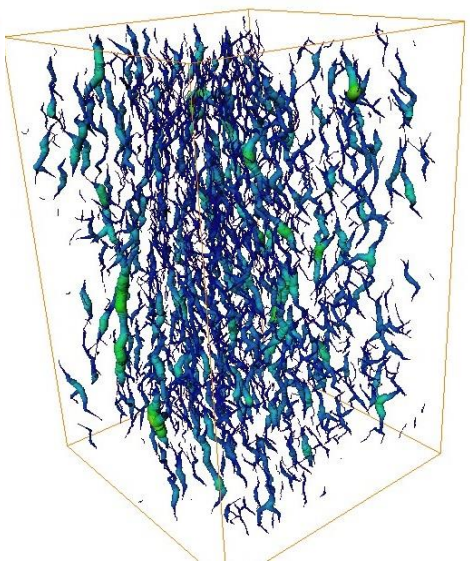

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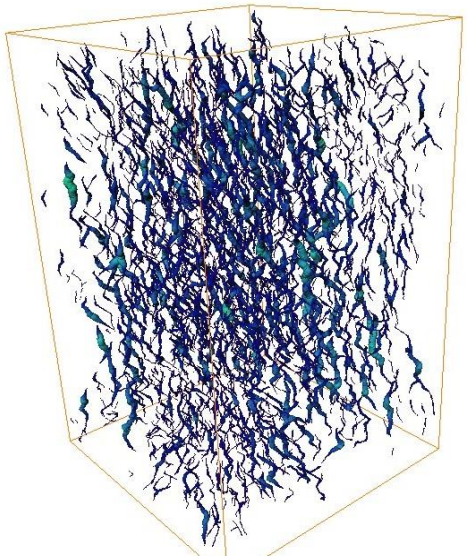

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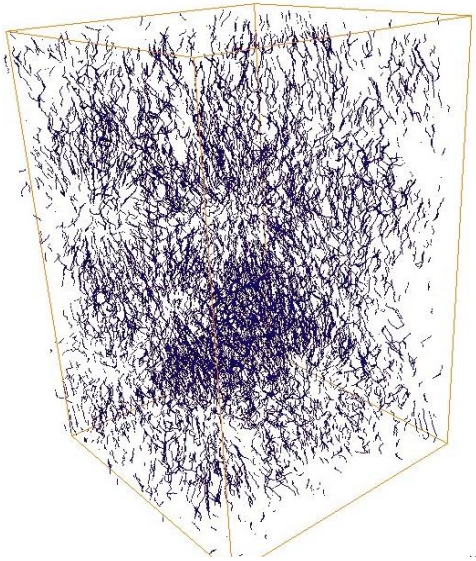

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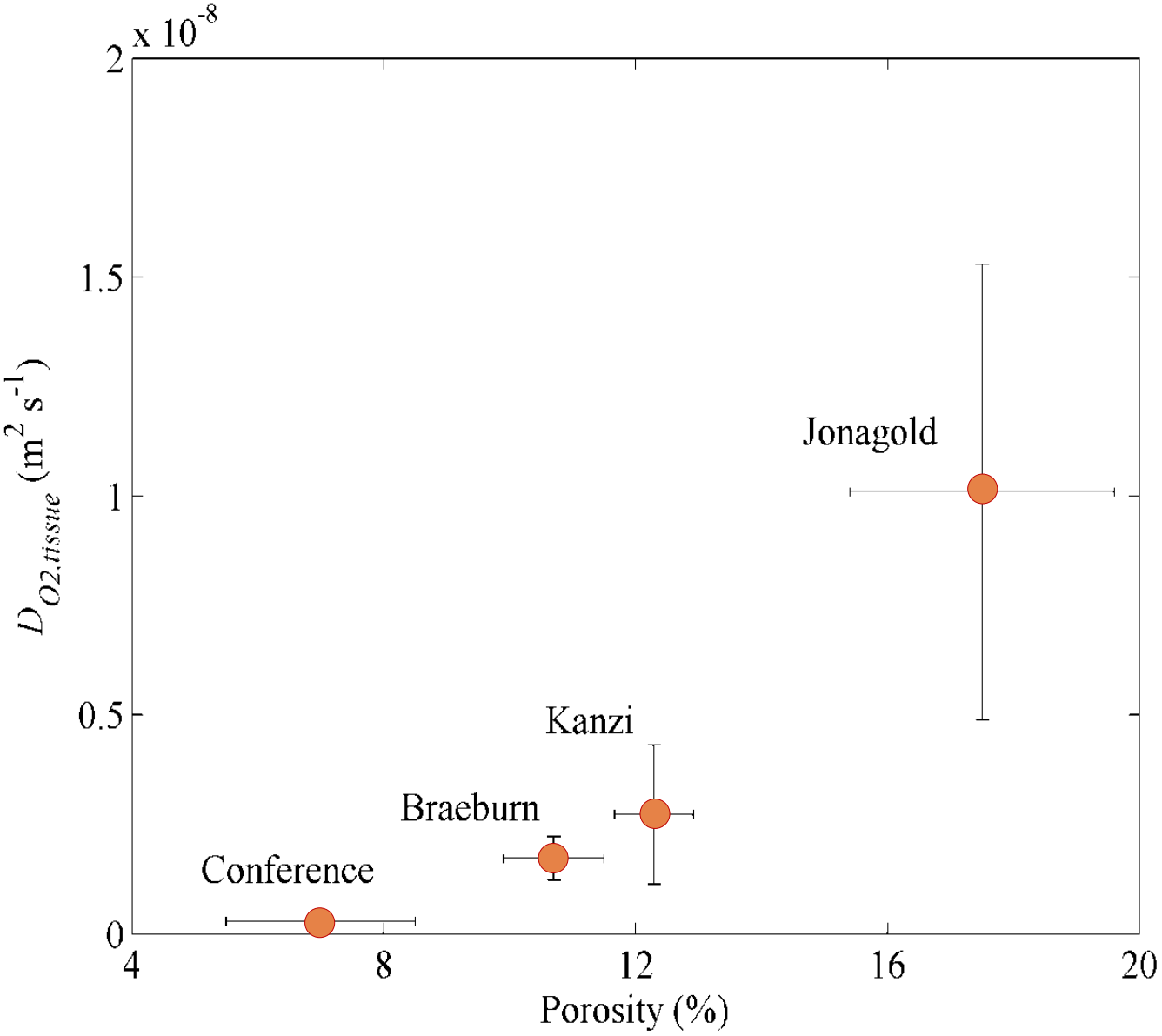
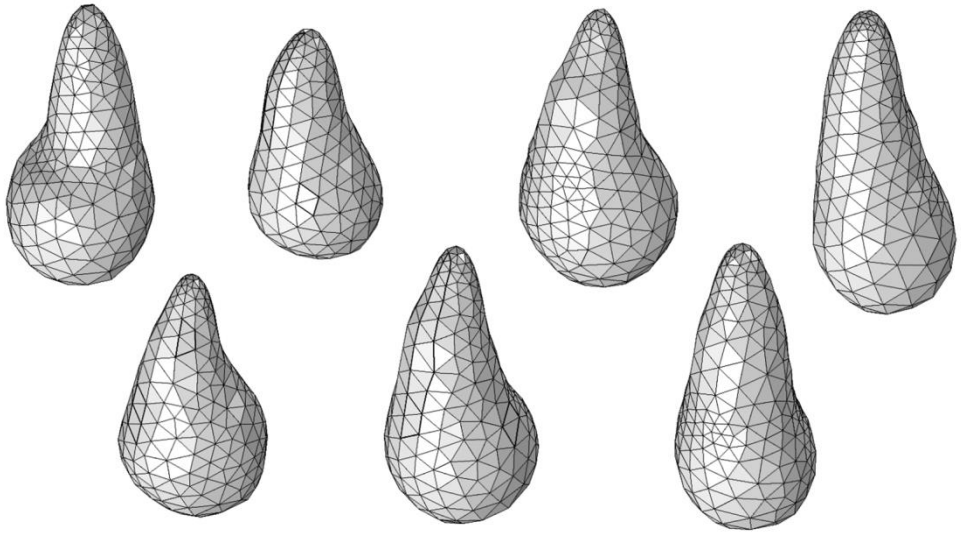
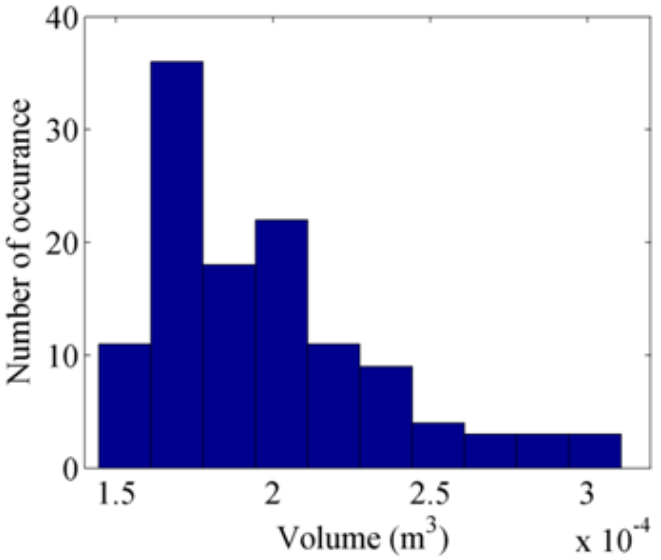


Ho et al. (2010) Journal of Experimental Botany, 61 (10), 2745-2755

Process design

- HortShape





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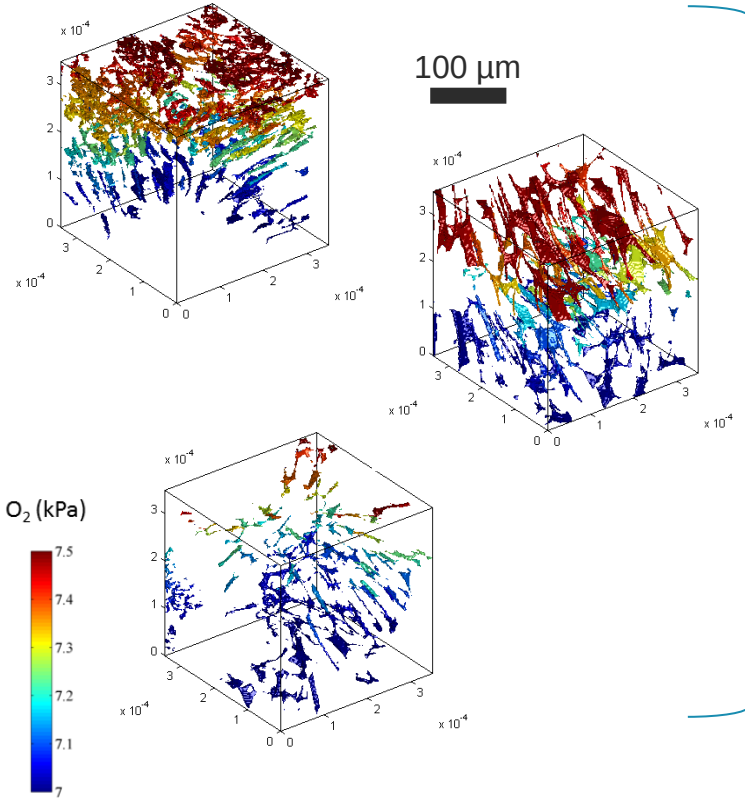
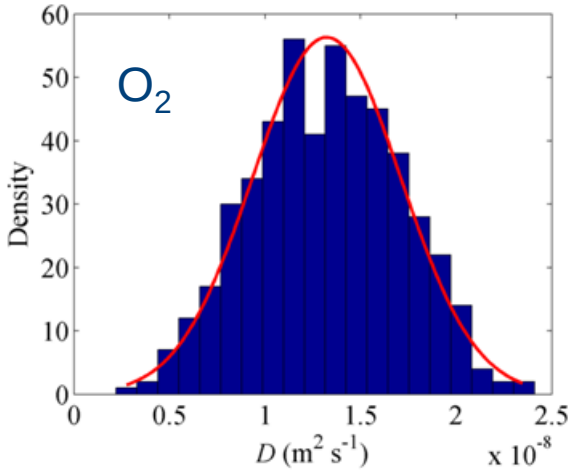
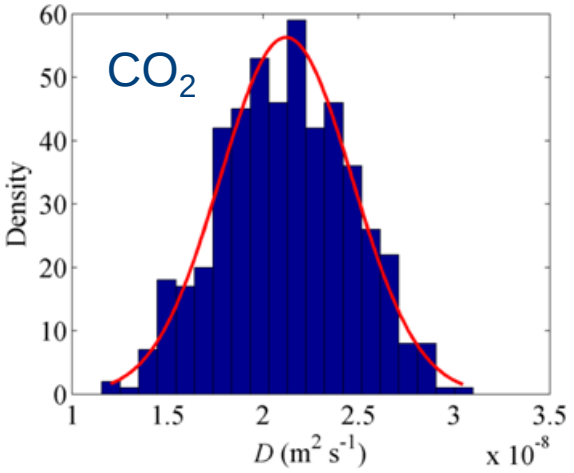
Process design

- Tissue diffusivity







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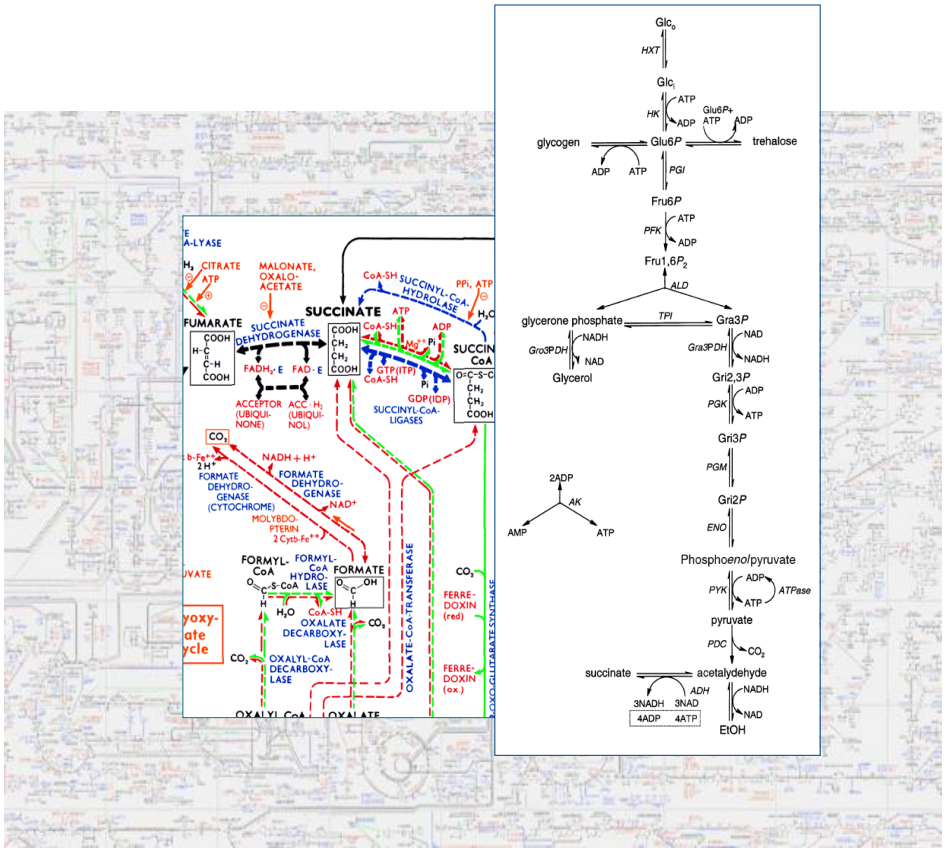
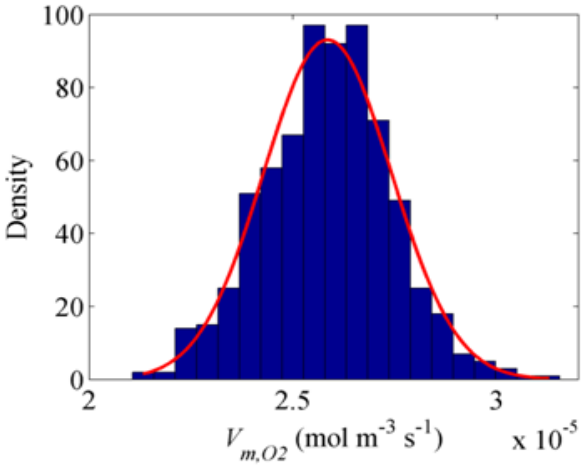
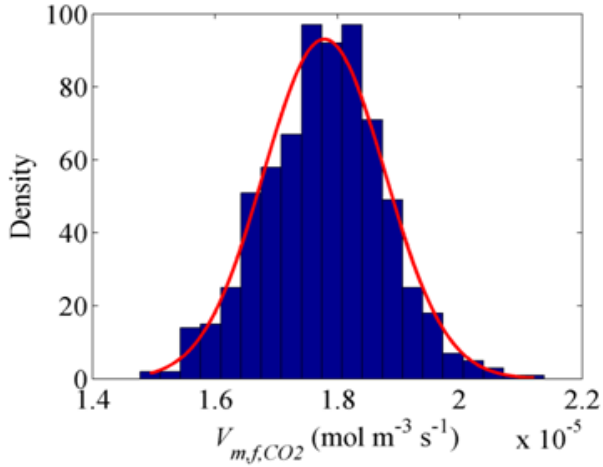
Ho et al. (2015) J Food Eng

Process design

- Tissue respiration







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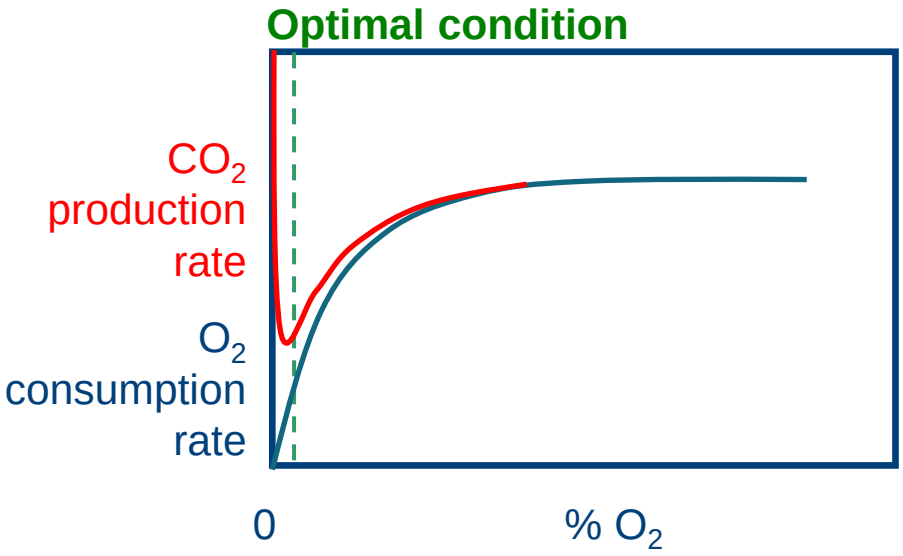
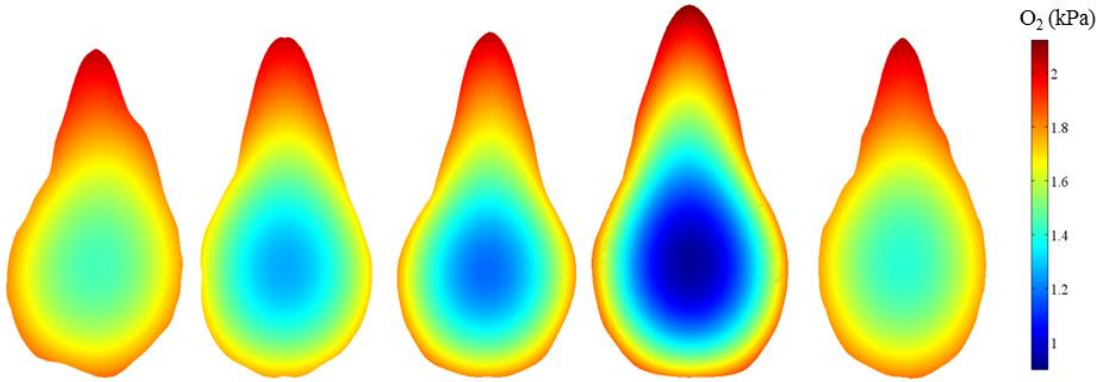
Hatoum et al. (2014) Postharvest Biol Technol

- Monte Carlo simulations





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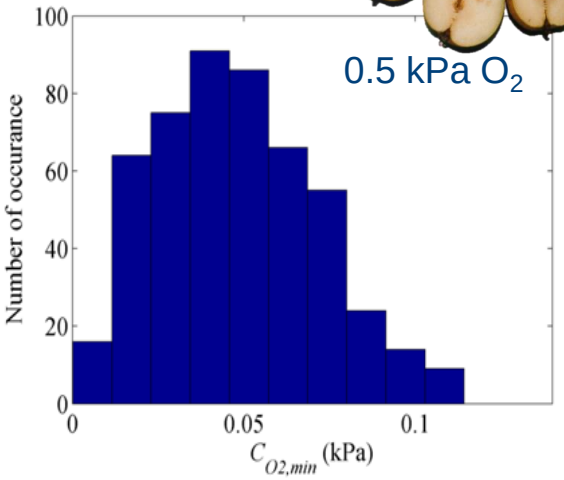
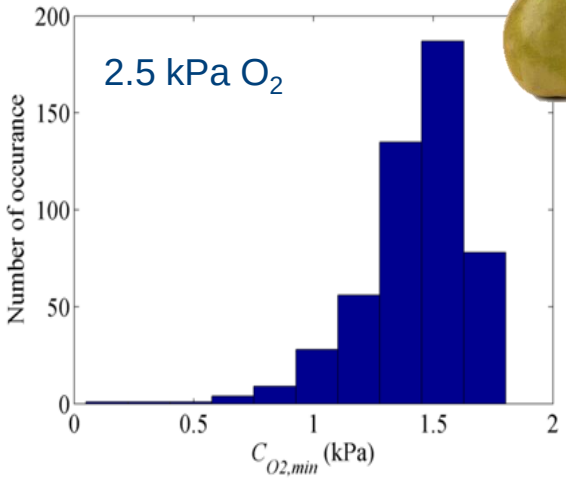
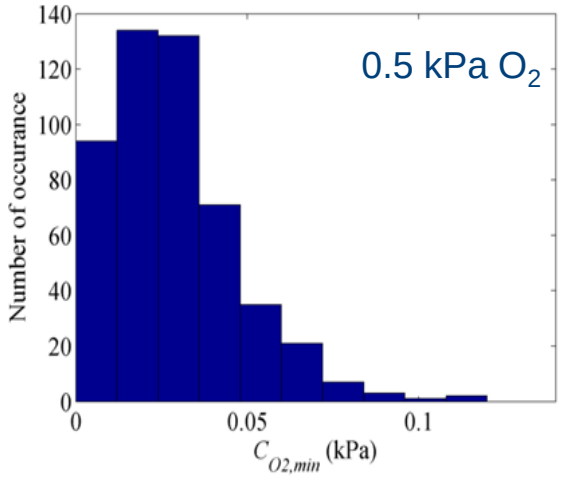
- Minimum oxygen concentration in fruit

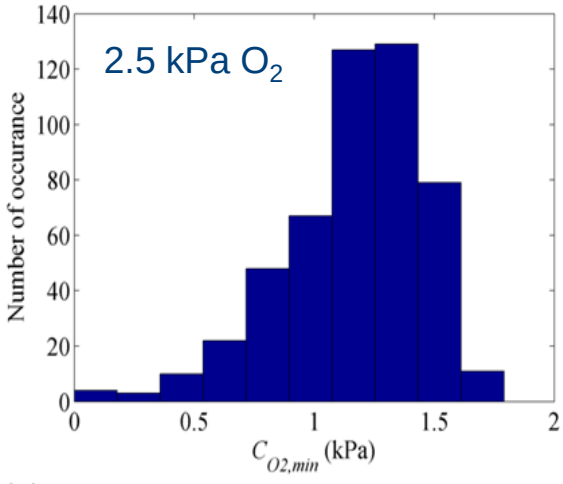
Optimal picking





Late picking





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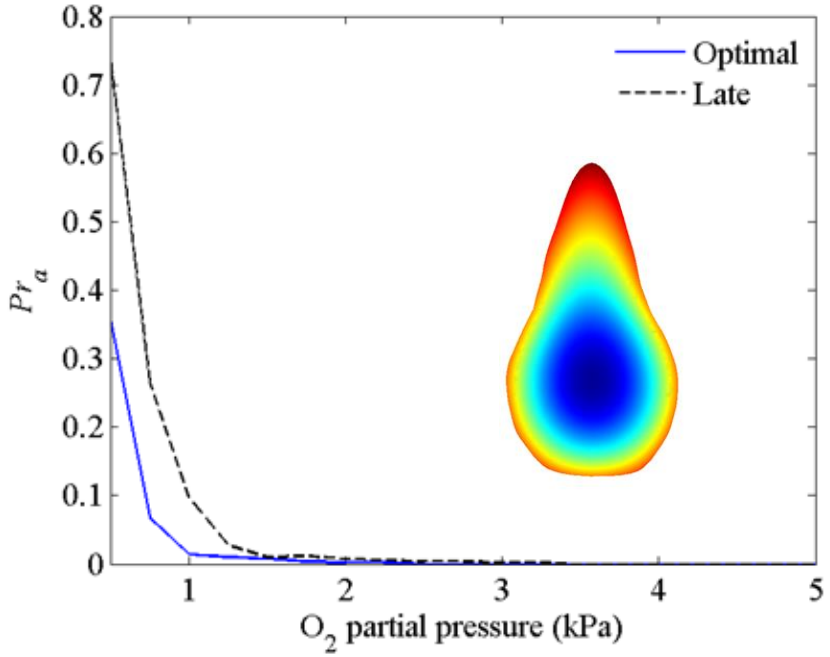
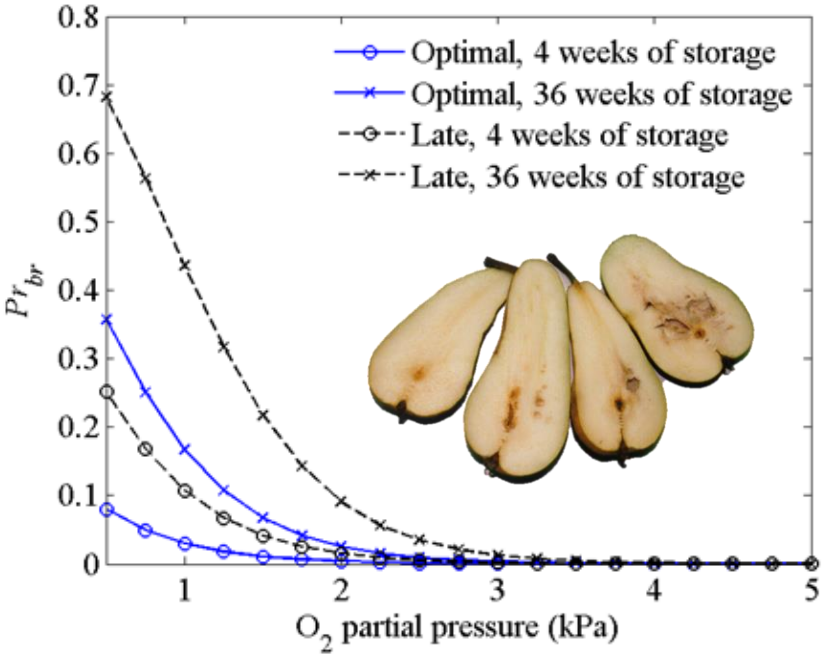
- Probability of fermentation agrees with probability of browning disorder





Verlinden et al. (2002) Biosystems Eng

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Conclusions

- Porous structure of fruit determines gas exchange
- A stochastic multiscale diffusion-reaction model
  - Predicts critical oxygen levels for development of disorders
  - Fruit size and maturity affect gas concentrations within the fruit the most
- Initiated novel storage techniques such as dynamic controlled atmosphere (RQ-DCA)

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