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POST HARVEST COLD CHAIN OPTIMIZATION OF LITTLE FRUITS

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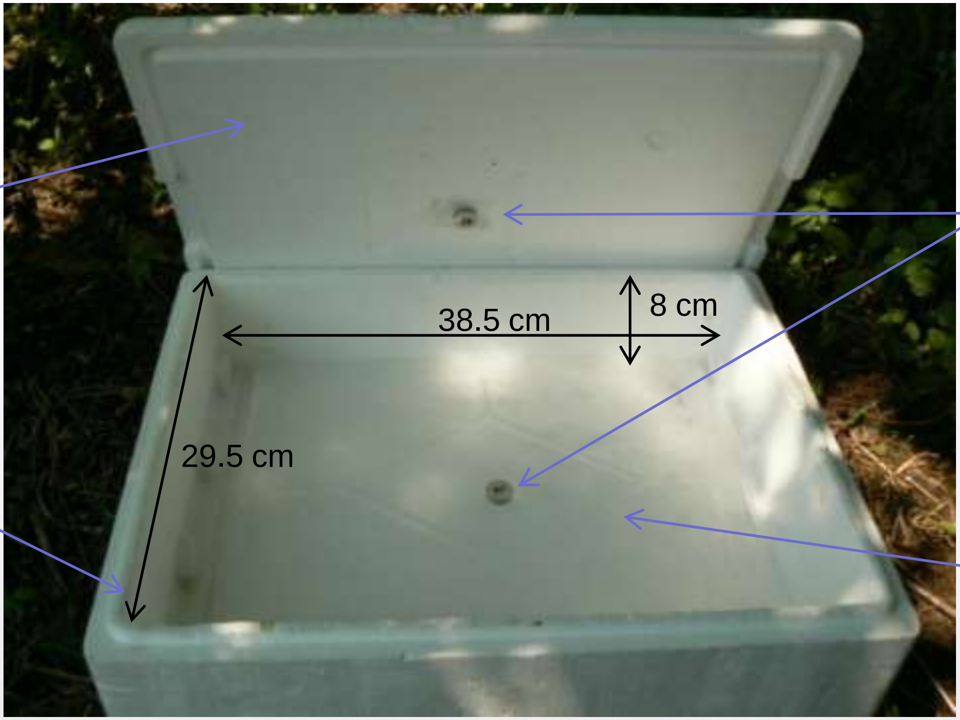
INTRODUCTION

Blueberry needs to be refrigerated as soon as possible after the harvest, to preserve nutritional and organoleptic properties and extend its shelf life

The refrigeration can start immediately with a passive refrigerator system, called Icepack.

PASSIVE REFRIGERATOR SYSTEM

Passive refrigerator system uses the changing phase of a material to keep temperature close to the melting temperature. Icepack is a polystyrene box with a hermetic plastic bag filled with water.

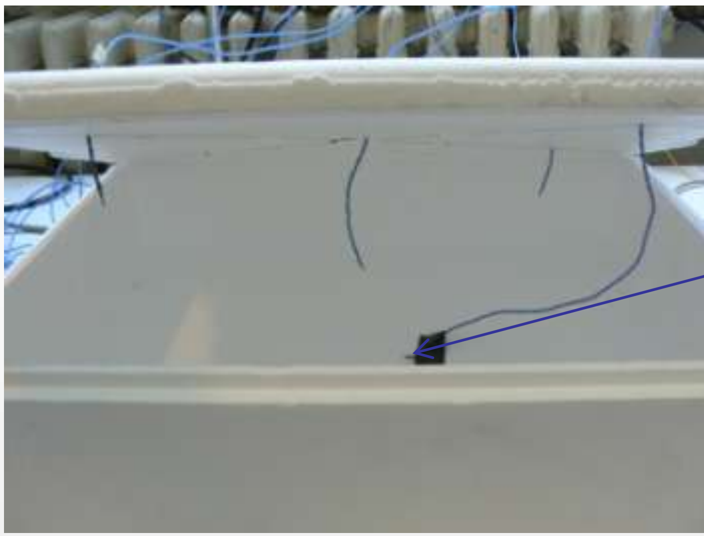


Iced water keeps temperature near to 273.15K

EXPERIMENTAL METHOD

Two different kind of experiment:

- empty Icepack in laboratory
- Icepack filled with blueberries on field



TARGET: melting time of ice slab and temperature distribution inside the Icepack

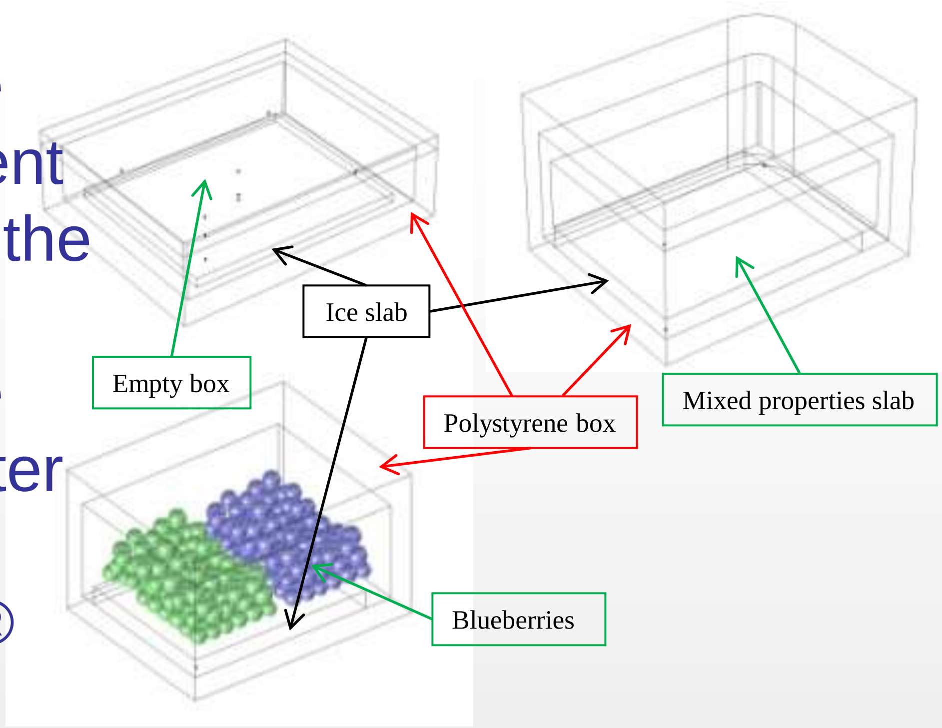
MODELS

A multy-step study was performed:

•a 3-D heat transfer model on the empty box;

•a 3-D heat transfer model on the box containing a slab with apparent thermal properties obtained from the air and the fruit;

•a 3-D heat transfer model on the box filled with randomized diameter spheres, simulating the fruits, created with an original MatLab® script and imported in COMSOL Multiphysics®



MATLAB® SCRIPT

The original script consist in a randomized Gaussian distribution diameter of the fruits (sphere) experimentally determined.

Each fruit have to touch three points of the geometry to be in equilibrium.

The sphere that must be positioning will be placed in the point with less absolute potential energy.

No overlapping between spheres is allowed.

The loop ends when all the spheres have been positioned.

GOVERNING EQUATIONS

Conduction equation

$$\rho \cdot C_p \frac{\partial T}{\partial t} = \nabla\left(k \nabla T\right)$$

Boundaries condition

$$-\vec{n} \cdot \left(k \vec{\nabla} T\right) = h \cdot (T_{ext} - T)$$

Modified specific heat

$$C_p = C_{p_{ice}} + H(T) \cdot (C_{p_w} - C_{p_{ice}}) + G(T) \cdot lda$$

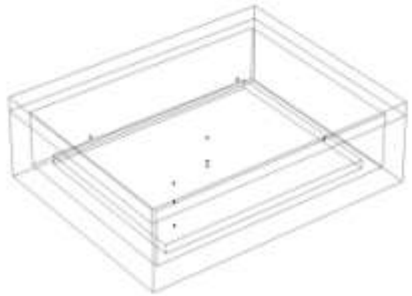
THERMO-PHYSICS PROPERTIES AND INITIAL VALUES

	blueberries	air	polystyrene	ice	water
ρ - Density (kg/m^3)	990	1.248	25	917	1000
C_p - Specific heat (J/kg K)	3786	1013	1200	2260	4186
k - Thermal conductivity (W/m K)	0.539	0.024	0.033	2.208	0.6

Parameters	Value	Parameters	Value
Blueberries initial temperature	302.25 K	h - Convective heat transfer coefficient	8 $W/m^2 K$
Polystyrene initial temperature	295.15 K	T_{ext} - Ambient temperature	300.15 K
Air initial temperature	297.15 K	Ice fusion temperature	273.15 K
Ice initial temperature	253.15 K	Percentage of blueberries in mixed slab	75 %
lda - Latent heat of fusion	333 kJ/kg		

MESH AND SOLUTION TIME

	Empty Icapack	Slab Icepack	Simulated fruits Icepack
Mesh refinement	NORMAL	NORMAL	NORMAL
Number of elements	34568	14398 (a quarter)	87271 (a quarter)
Solution time	About 2 hours	About 5 hours	About 12 hours

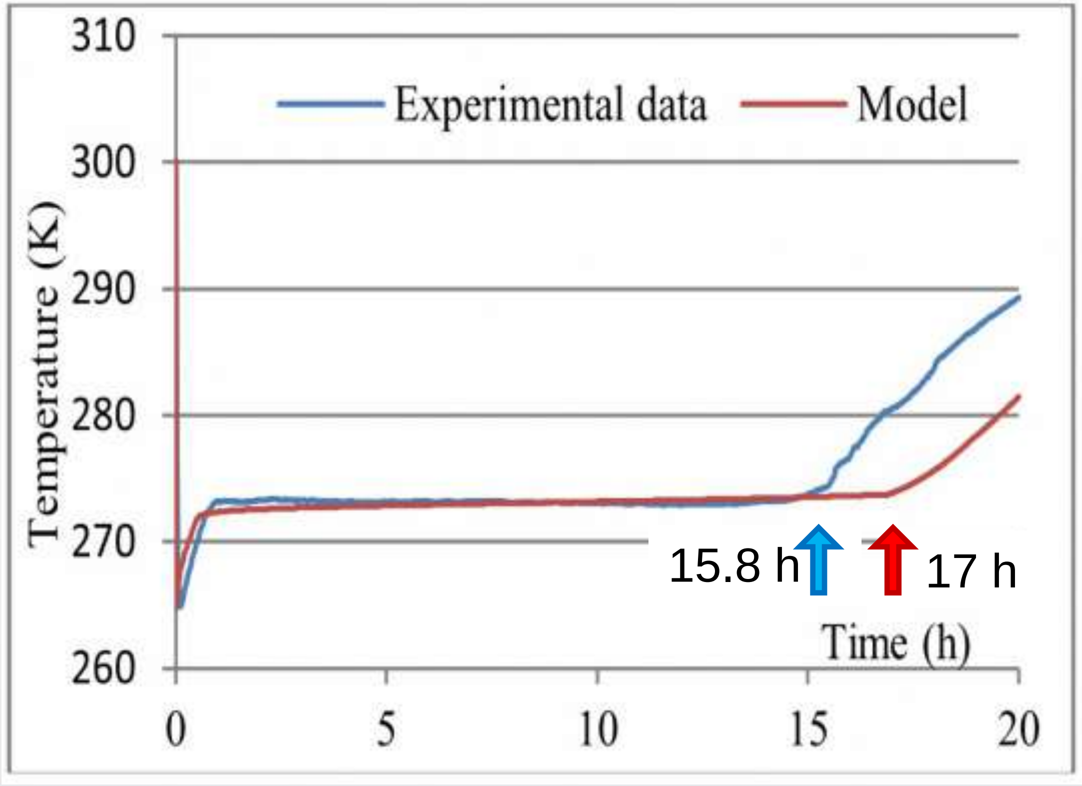


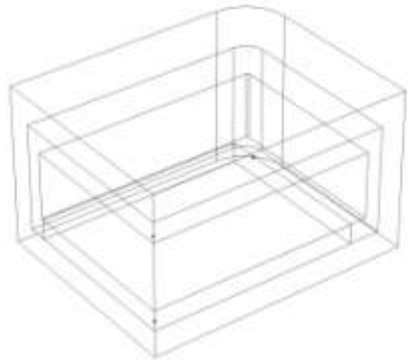
RESULTS (1)

Model 1: empty Icepack

Melting time error

$$e = \frac{\left| t_{\exp} - t_{\mathrm{mod}} \right| \cdot 100}{t_{\exp}} = 7.6\%$$





RESULTS (2)

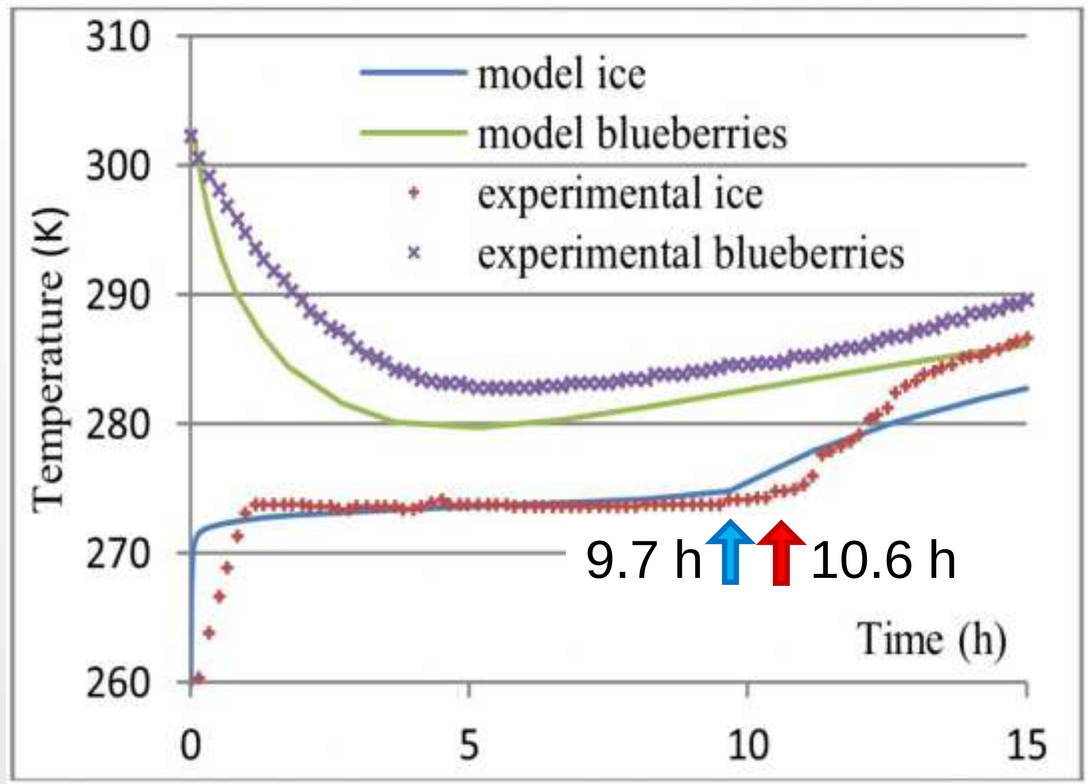
Model 2: slab Icepack

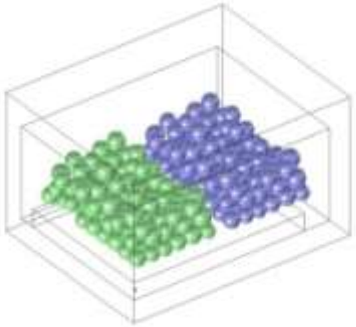
Melting time error

$$e = \frac{\left| t_{\exp} - t_{\mathrm{mod}} \right| \cdot 100}{t_{\exp}} = 8.5\%$$

Mean relative error of blueberries temperature

$$em(\%) = \frac{100}{n} \sum_{i=1}^{n} \left(\frac{\left| T_{\exp} - T_{\mathrm{mod}} \right|}{T_{\exp}} \right)_i = 1.06\%$$





RESULTS (3)

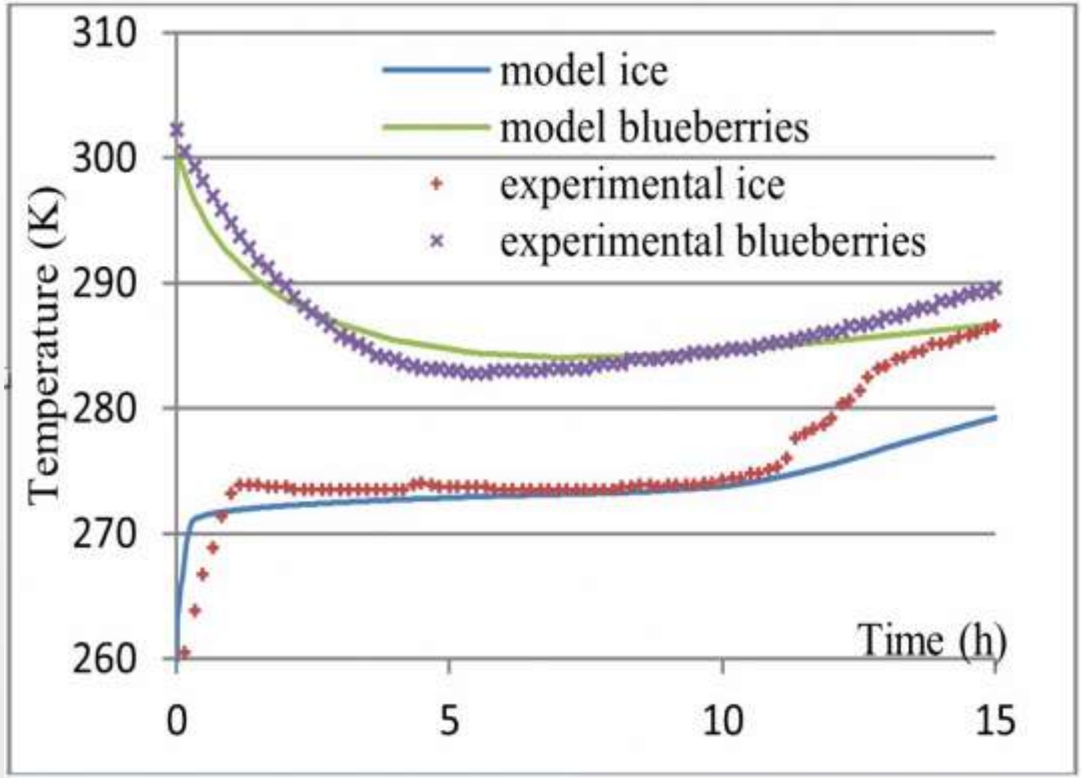
Model 3: simulated fruit Icepack

Melting time error

$$e = \frac{\left| t_{\exp} - t_{\mathrm{mod}} \right| \cdot 100}{t_{\exp}} \cong 0\%$$

Mean relative error of blueberries temperature

$$em(\%) = \frac{100}{n} \sum_{i=1}^{n} \left(\frac{\left| T_{\exp} - T_{\mathrm{mod}} \right|}{T_{\exp}} \right)_i = 0.43\%$$



CONCLUSION

Future improvement of this models is under way, which will deal with the optimization of the Icepack:

•TRIP TIME:

The trip time after the harvest is smaller than 10.6 hours

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reduce the weight of the packaging reducing the ice slab dimensions.

CONCLUSION

Future improvement of this models is under way, which will deal with the optimization of the Icepack:

•STACKABILITY:

Stackability of Icepack

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Less exposed surface to ambient

⇩

Extension of melting time of ice

⇩

Reduce again the dimension of the ice slab and packaging weight

CONCLUSION

Future improvement of this models is under way, which will deal with the optimization of the Icepack:

•Melting temperature:
Use others materials then water

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Change the melting temperature and latent heat of fusion

THAT’S ALL FOLKS

Thank you!