Post Harvest Cold Chain Optimization of Little Fruits

Simone Marai[1], Enrico Ferrari[1], Raffaele Civelli[1]
1. Università degli Studi di Milano, DiSAA, Via Celoria, 2, 20133, Milano, Italy.

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. The Icepack is a polystyrene box with a plastic hermetic bag filled of iced water placed on the bottom. The heat flux from the outside is absorbed by the fusion of the ice (phase change) keeping the temperature inside the Icepack almost constant, to 0°C, for a long period of time.

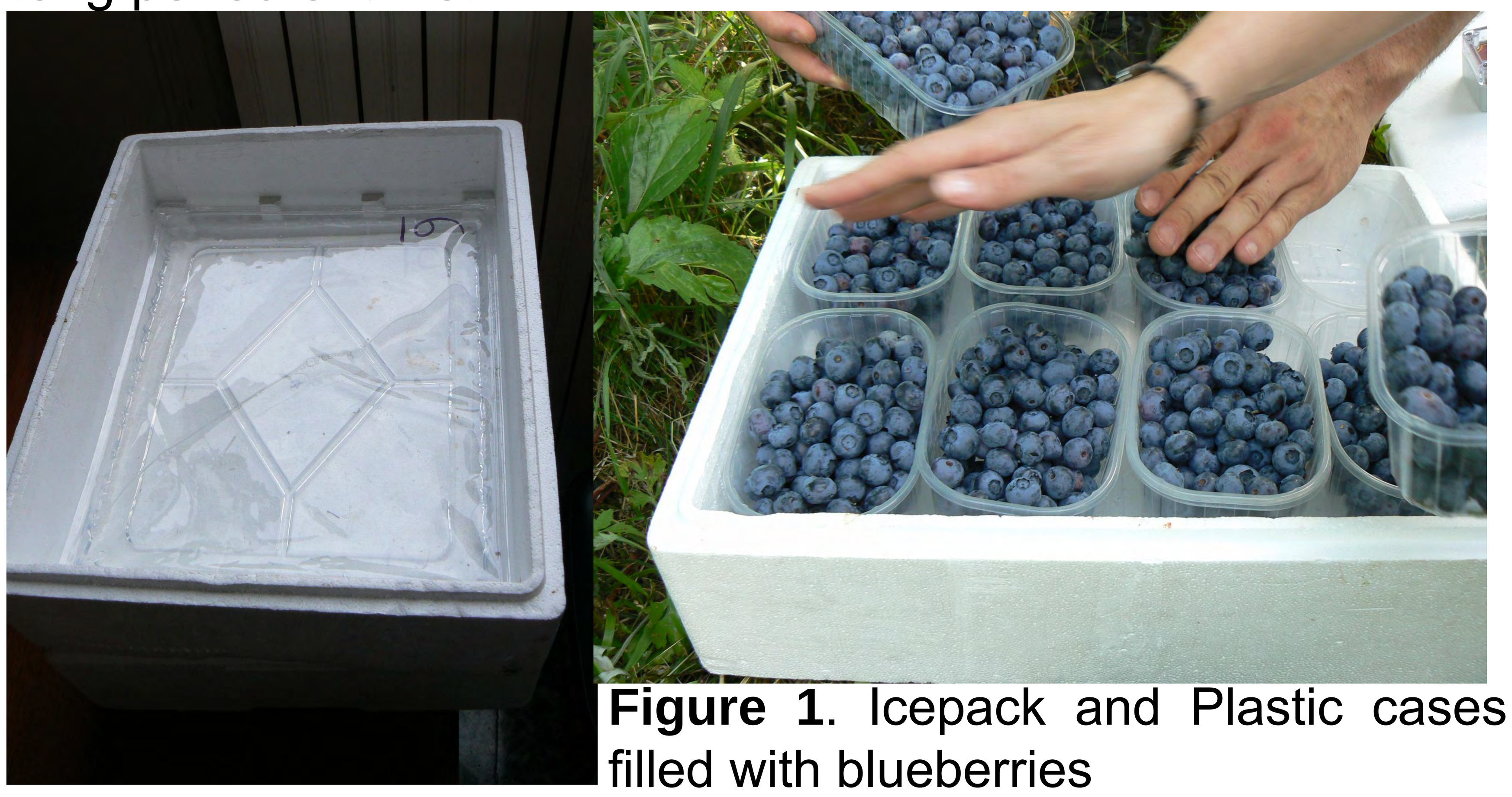


Figure 1. Icepack and Plastic cases filled with blueberries

Finite Element Modeling of Icepack

Energy conservation equation and boundary condition

$$\rho \cdot C_p \frac{\partial T}{\partial t} = \nabla(k \nabla T) \qquad -\vec{n} \cdot \left(k \vec{\nabla} T\right) = h \cdot (T_{ext} - T)$$

where ρ=density, C_p=specific heat, k=thermal conductivity of different materials, h is the convective heat transfer coefficient and T_{ext} the external temperature

Modified specific heat equation

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

where lda is the latent heat of fusion, the subscript w is water, *H(T)* is a step function from 0 to 1 and *G(T)* is a gaussian pulse centered in fusion temperature of ice.

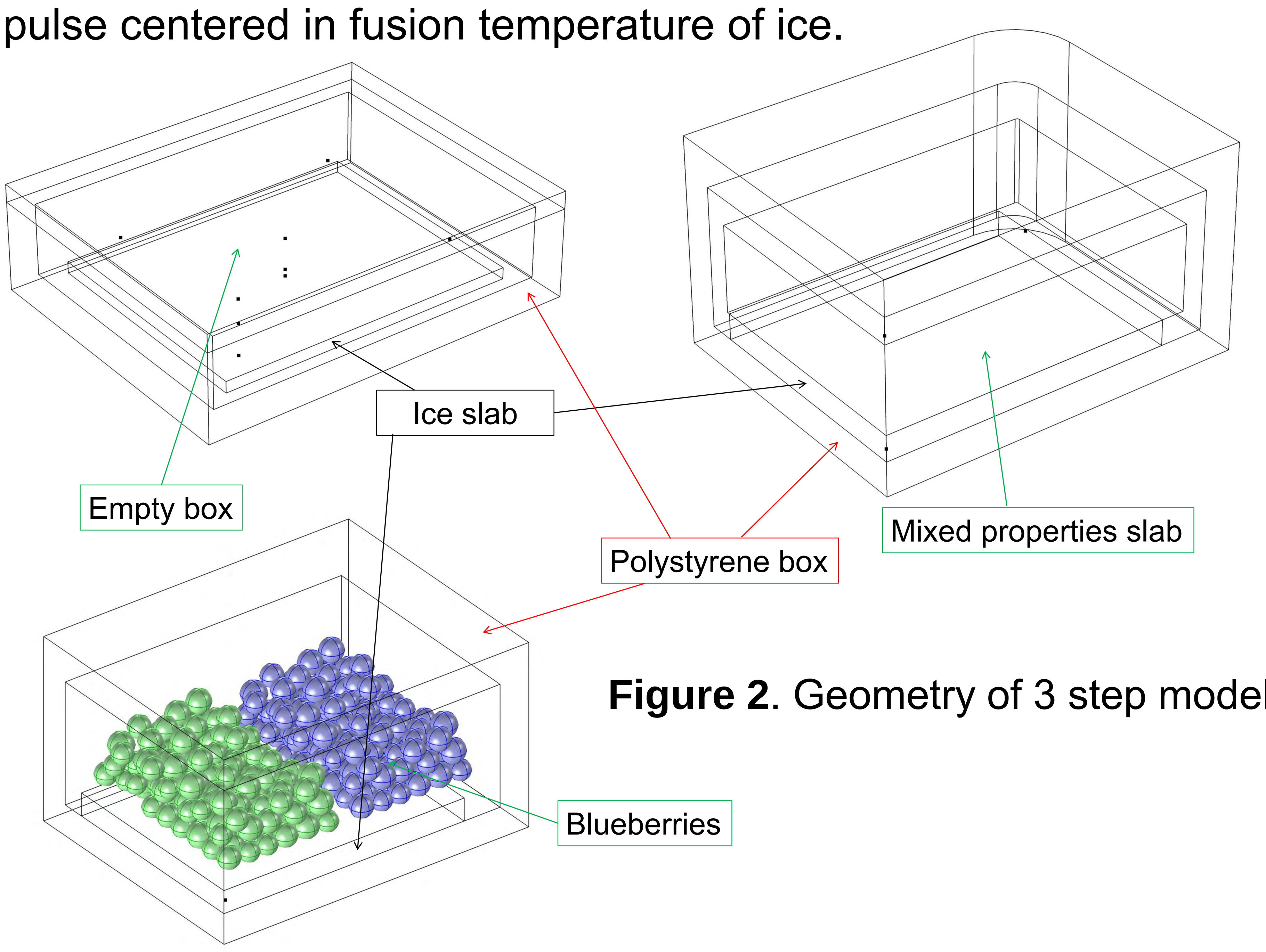


Figure 2. Geometry of 3 step model

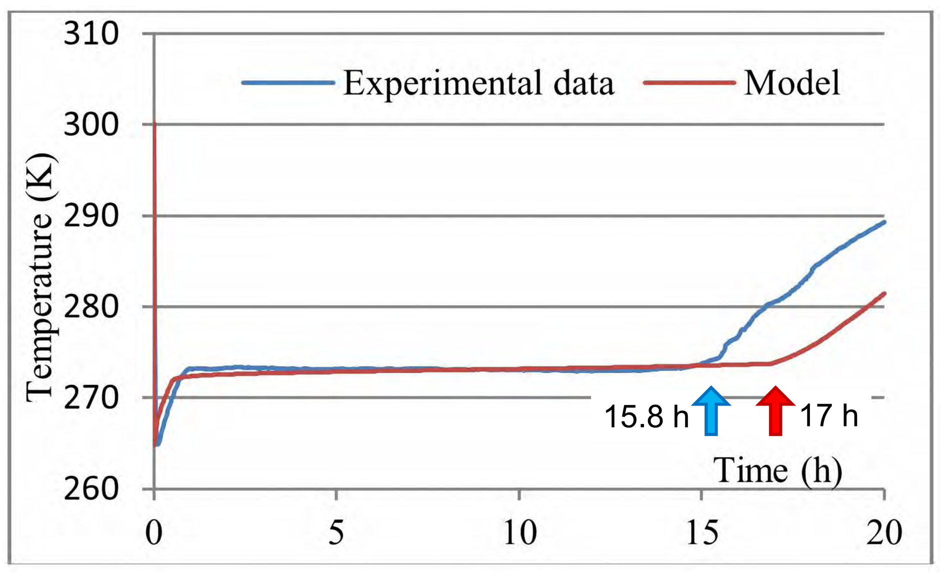
A original script in MatLab has been applied to generate a random filling of spherical fruits in a 3-D rectangular box with a Gaussian distribution diameter experimentally determined.

	blueberries	air	polystyrene	ice	water
ρ - Density (kg/m³)	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

Table 1. characteristic of materials

Results

Empty icepack, focused on melting time of ice slab

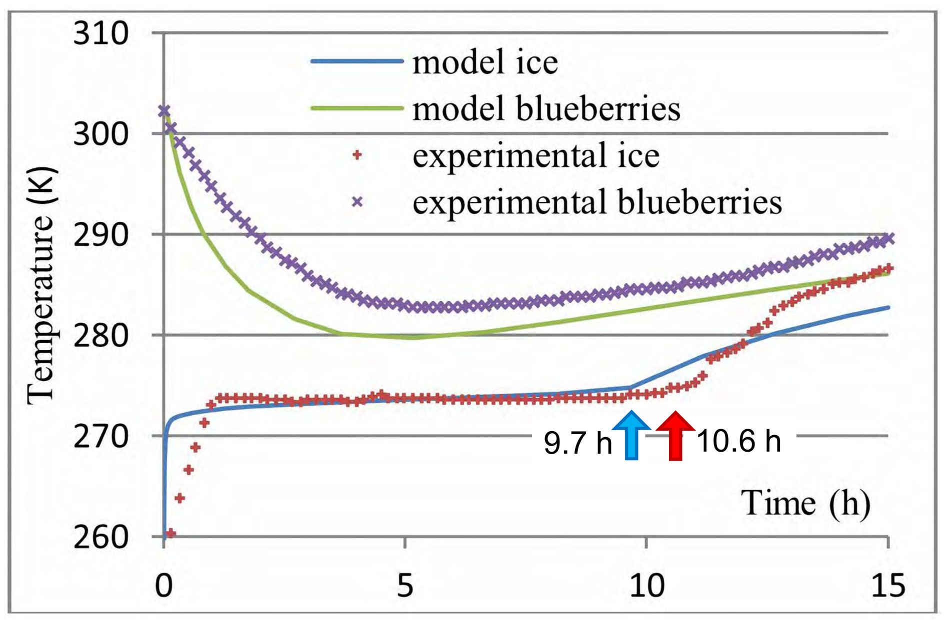


Relative percentage error:

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

Figure 3. Empty model: temperature of ice slab

Mixed properties slab model was focused on melting time of ice slab and on temperature distribution inside blueberries mass



Relative percentage error of melting time:

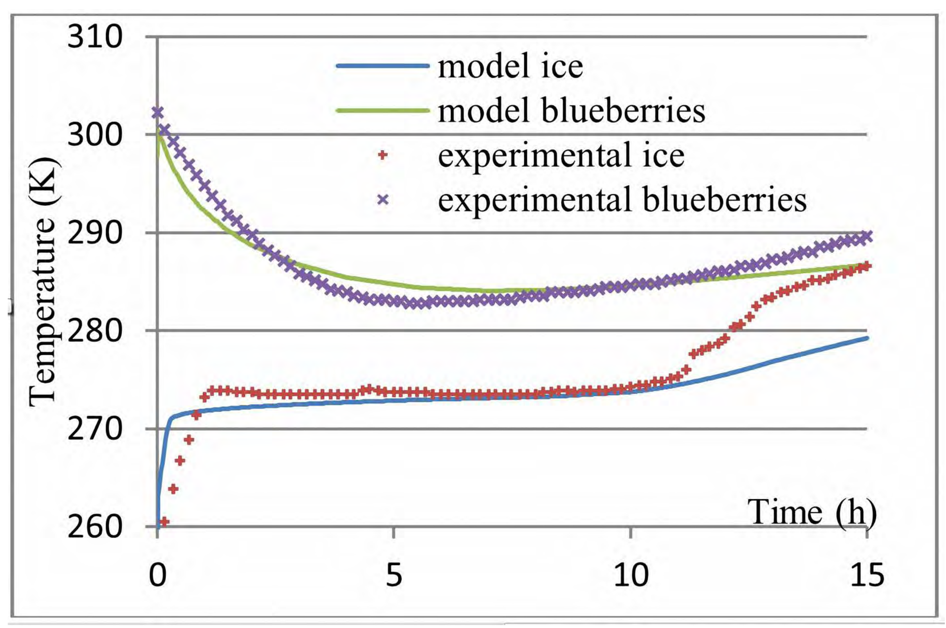
$$e = \frac{\left|t_{exp} - t_{mod}\right| \cdot 100}{t_{exp}} = 8.5\%$$

Mean relative error of blueberries temperature

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

Figure 4. slab model: temperature profile of ice and blueberries

The model with simulated blueberries was focused on melting time of the ice slab and on temperature distribution inside blueberries mass, trying to improve slab model results



Relative percentage error of melting time:

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

Mean relative error of blueberries temperature

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

Figure 5. Simulated fruits model: temperature profile of ice and blueberries

Conclusions

Finite element models were developed to investigate temperature profile and cooling of blueberries. Model prediction agree with experimental data.

Future improvements will deal with optimized geometry to improve melting time using stackability of the box and reducing the weight of the packaging cutting the height of the ice slab

COMSOL CONFERENCE EUROPE 2012