Experimental and numerical study of heat and mass transfer during contact heating of potato slices

T. Viné, D. Flick, Emmanuel Bernuau, B. Broyart

EXPERIMENTAL AND NUMERICAL STUDY OF HEAT AND MASS TRANSFER DURING CONTACT HEATING OF POTATO SLICES

VINE Thibaut, FLICK Denis, BERNUAU Emmanuel, BROYART Bertrand

UMR Ingénierie Procédés Aliments, AgroParisTech, INRA, Université Paris-Saclay, 91300, Massy, France

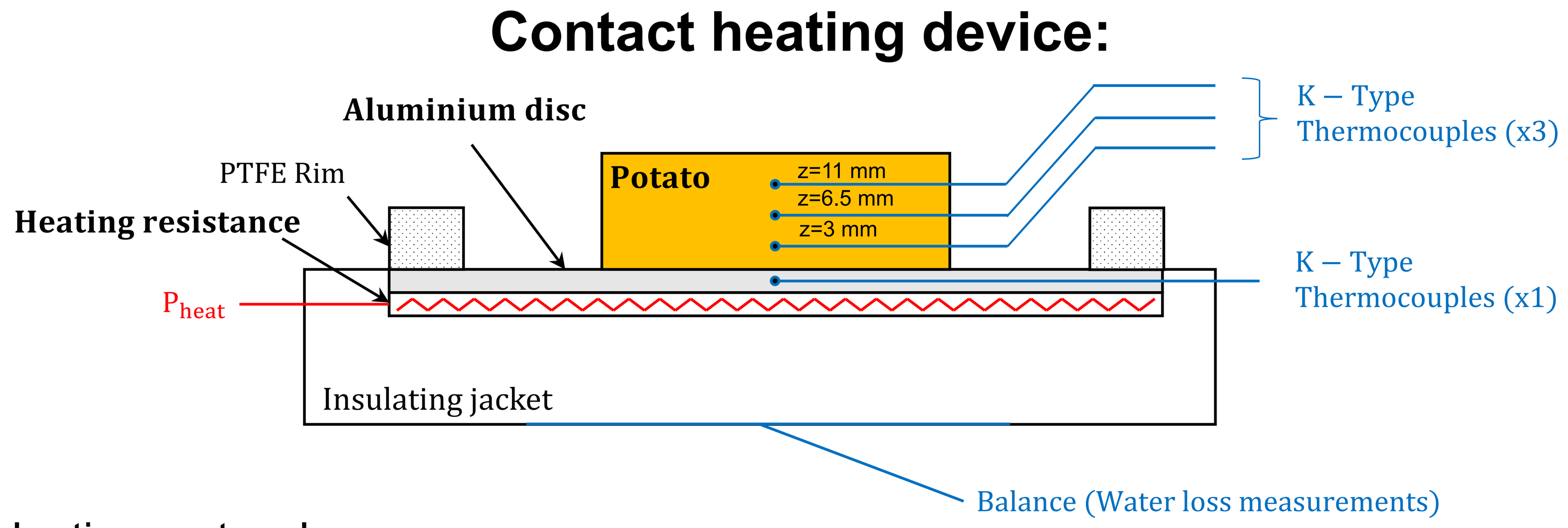
Introduction:

Studies concerning the contact heating of food products remain relatively rare in the literature despite the importance of this mode of heat transfer in many industrial and domestic operations such as grilling or pan-frying. This lack of knowledge makes it very difficult to determine rational strategies in order to improve the sensory and nutritional qualities of food products heated by contact.

To deal with this situation, experimental data (water loss, temperature at different positions inside the product) were recorded during contact heating of potato slices performed on a laboratory heating device specially designed for this study. Based on the interpretation of these data, a 2D mathematical model was developed and used to better understand heat and mass transfer phenomena occuring at the contact interface during heating.

Experiments

Contact heating device:



Heating protocol:

- Pre-heating until the aluminium disc temperature reaches 180°C.
- Product laying and heating at constant heating power, P_{heat}.

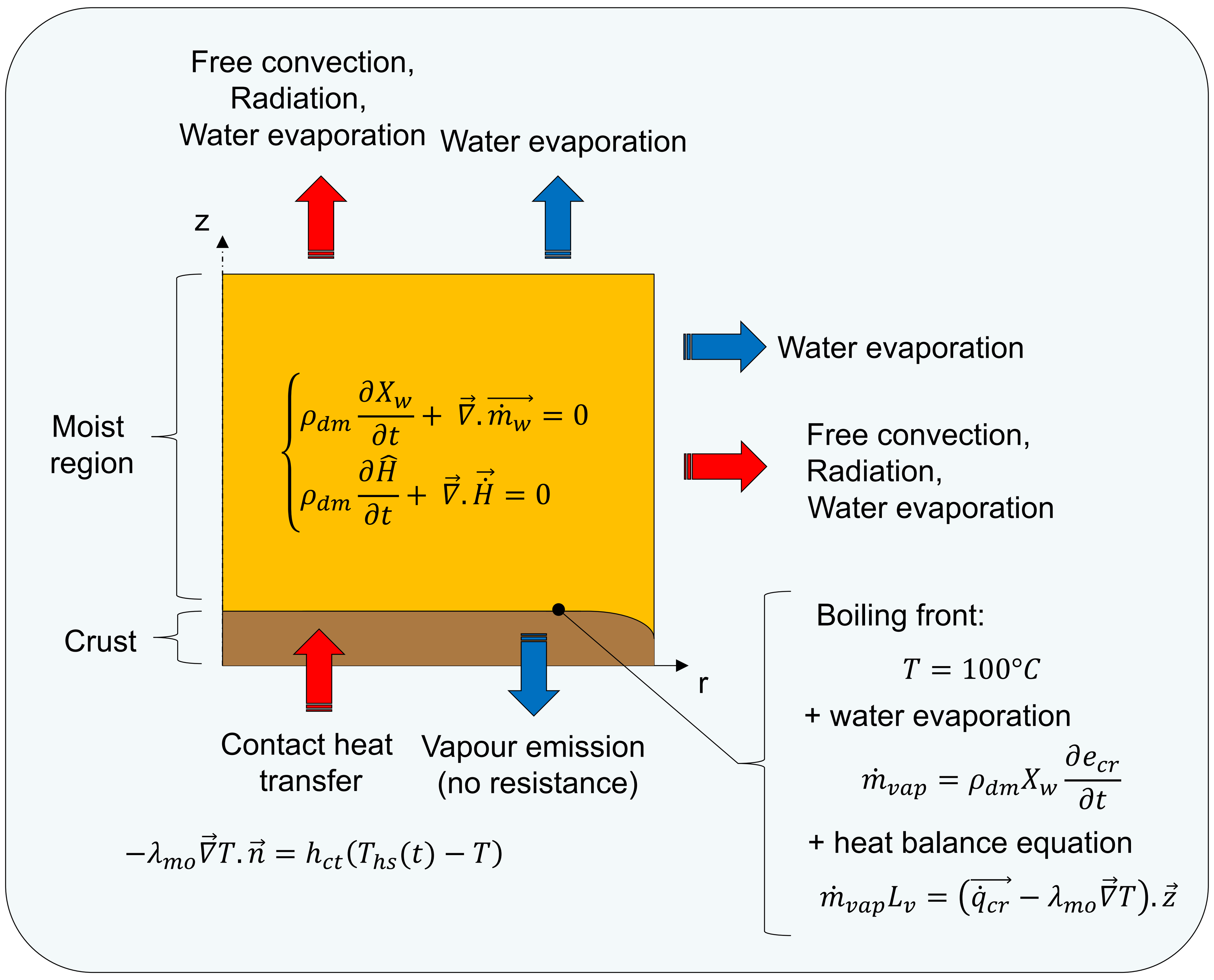
Six operating conditions were tested in order to study the influence of:

- The heating power, P_{heat} (3.2 kW.m^{-2}, 6.4 kW.m^{-2} and 9.6 kW.m^{-2}).
- The presence or not of an oil layer below the product.

Model of heat and mass transfer

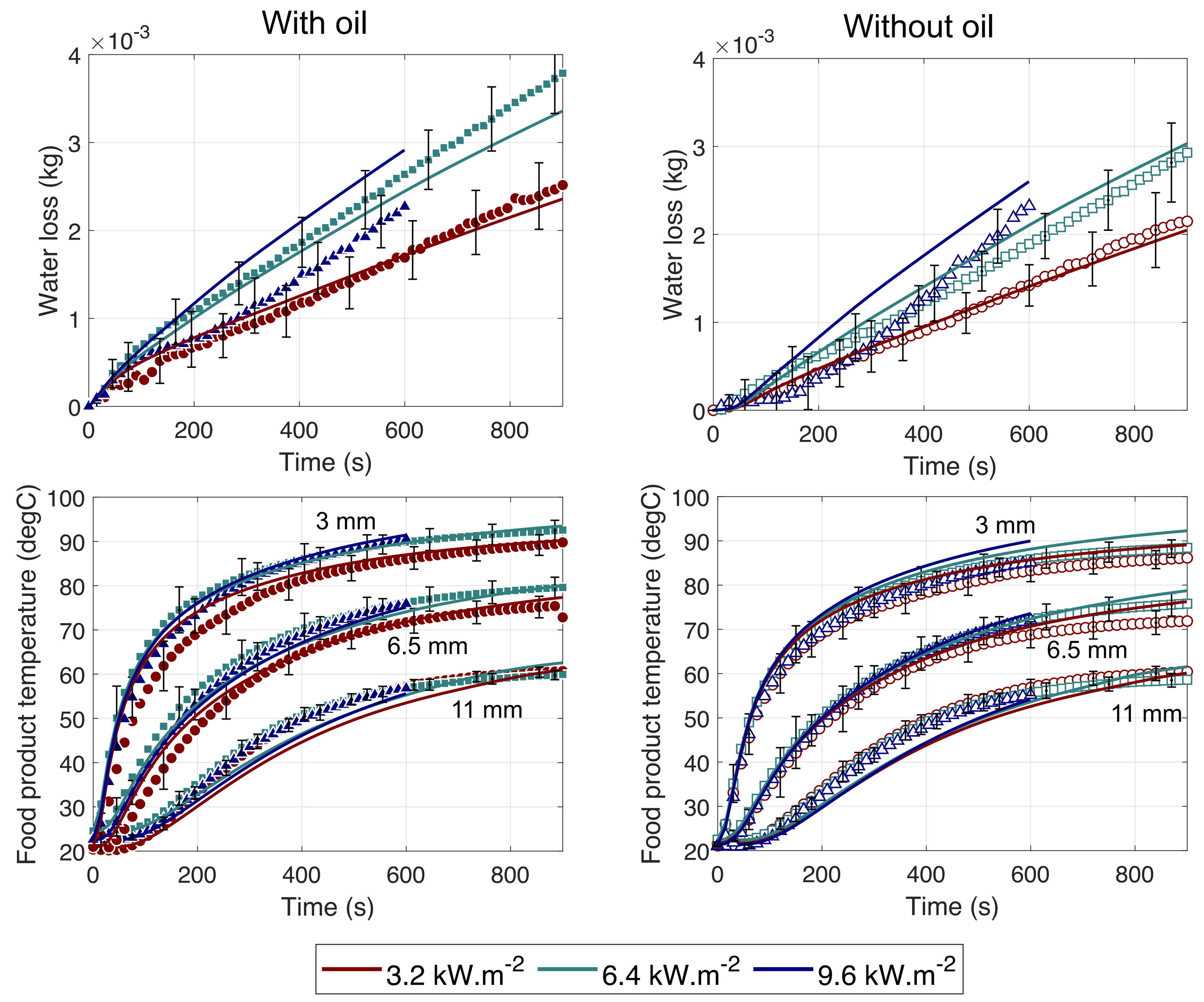
Given the high temperature of the aluminium disc, the formation and moving of a boiling front at the bottom surface of the product is assumed. This boiling front divides the product in two regions: the moist region and the dry region (crust). Other assumptions are:

- In the moist region, heat and mass transfer are 2D axisymetric. Heat transfer is due to thermal conduction and water transfer is due to water diffusion.
- In the crust, heat and mass transfer are supposed to be z-directional. There is no resistance to vapour transfer and heat transfer is considered to occur in quasi-steady state.

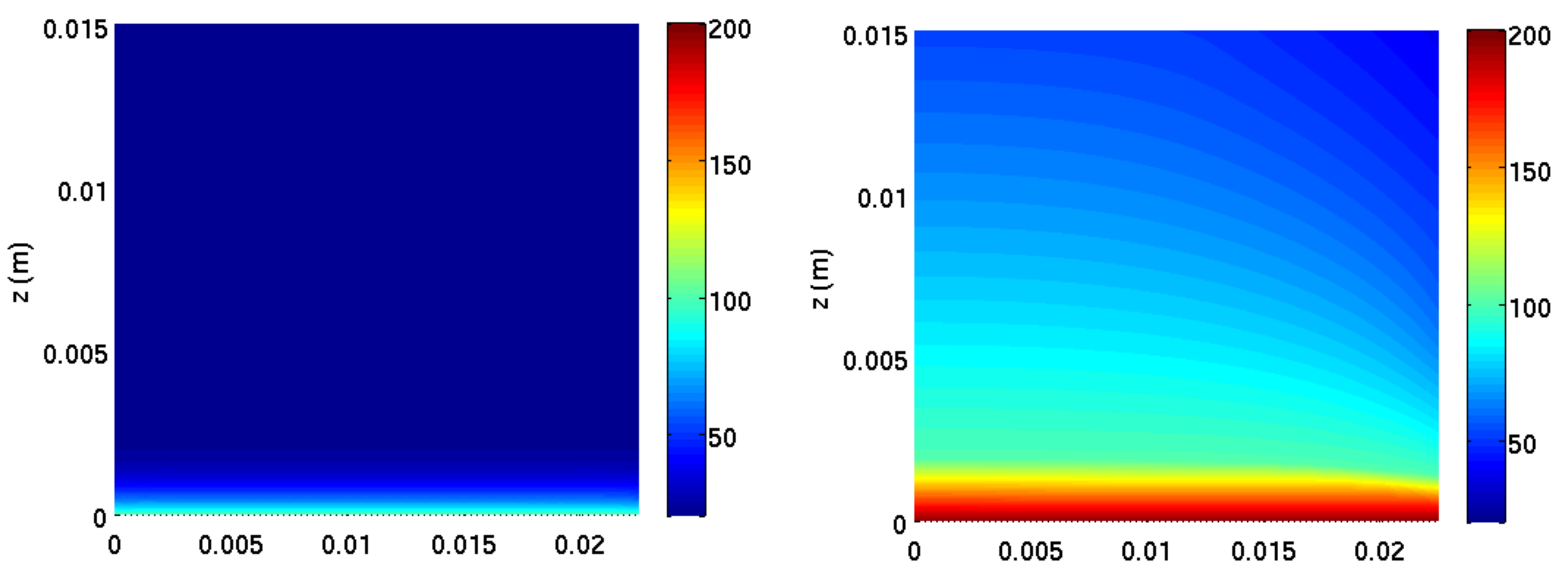


Results and discussion

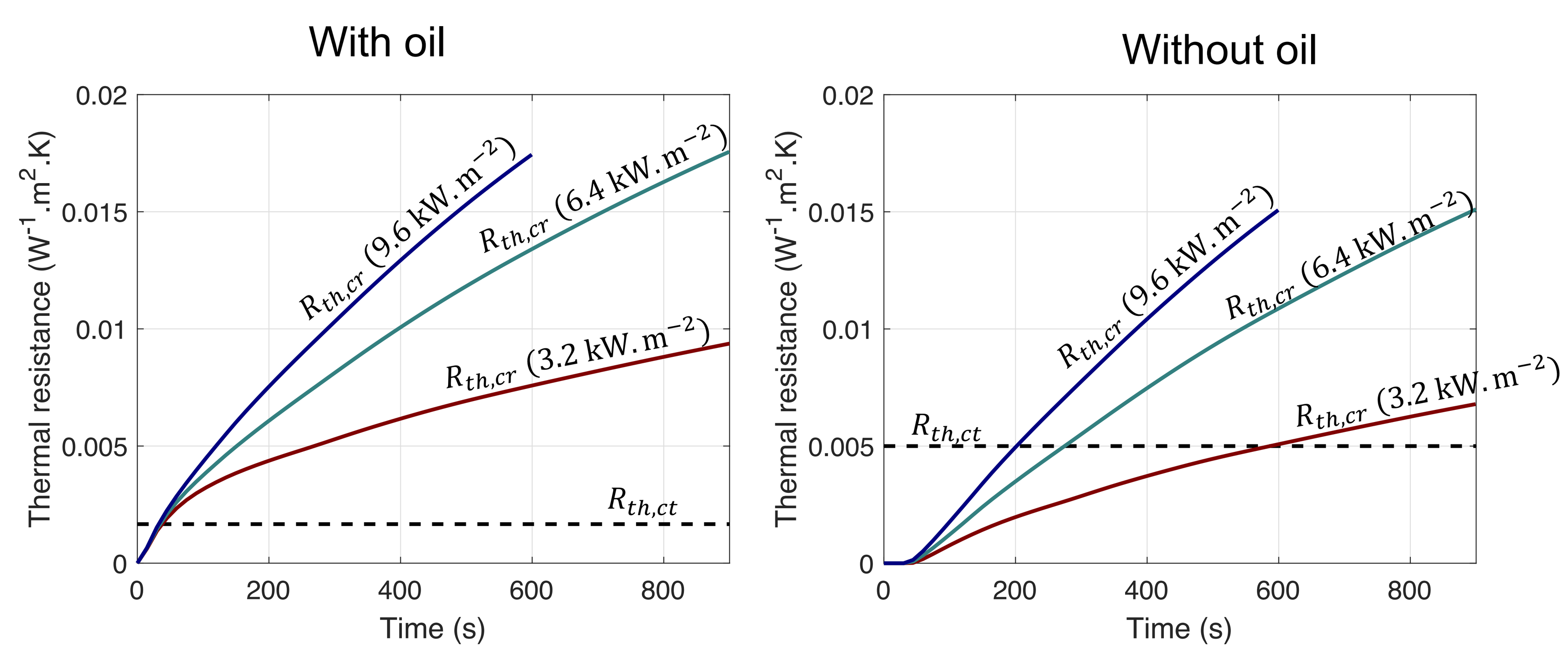
Experiments vs Simulation:



Temperature field calculated by the model (COMSOL 5.2):



Thermal contact resistance vs thermal crust resistance:



- With oil, the thermal contact resistance ($R_{th,ct}$) is negligeable compared to the one induced by the crust ($R_{th,cr}$). Contact heat transfer influences the overall heating of the product only at the early beginning of heating.
- Without oil, the thermal contact resistance ($R_{th,ct}$) is of the same order of magnitude as the thermal resistance of the crust ($R_{th,cr}$) .

Conclusion

The model was validated by showing good agreements between measured and calculated values of product temperature and water loss. Simulation results show that the overall heating of the product is limited by (i) the boiling front (ii) the developement of the insulating crust. Experimental characterization of the structure of the crust (porosity, permeability) is planned to improve model accuracy.

Contact

Thibaut VINE
UMR Ingénierie Procédés Aliments / AgroParisTech
1 Avenue des Olympiades, F-91744, Massy
thibaut.vine@agroparistech.fr

4th I.C. FABE
Crete Island (Greece)
30/05/2019 – 02/06/2019