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EasyTemper: from Heat Transfer Modelling in Liquid Chocolate to a Simple Method to Temper Chocolate

Puratos Group - Yves Kegelaers

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Tempering chocolate

Tempering chocolate

Select the right polymorphic form of cocoa butter

Tempering chocolate

Seeding of chocolate with right crystals

Seeds serve as model of crystallisation

Chocolate or Cocoa butter

Chocolate cooled to 31°C

Alternative tempering of chocolate

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Adding Cocoa butter

to more viscous chocolate

Chocolate not cooled before

⇨ cooling by melting of CB

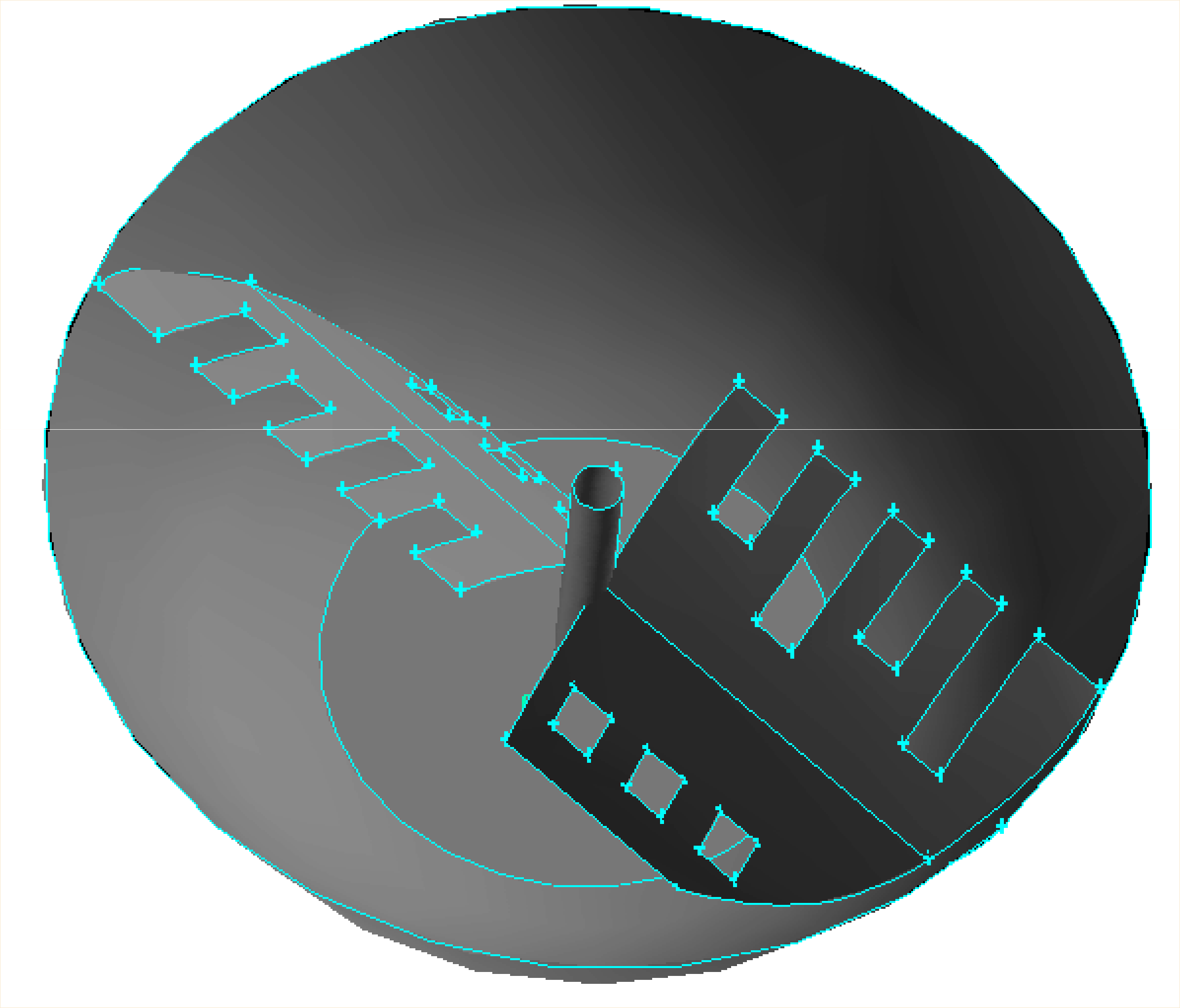
⇨ some crystals remain as seeds

Initial temperature Important !

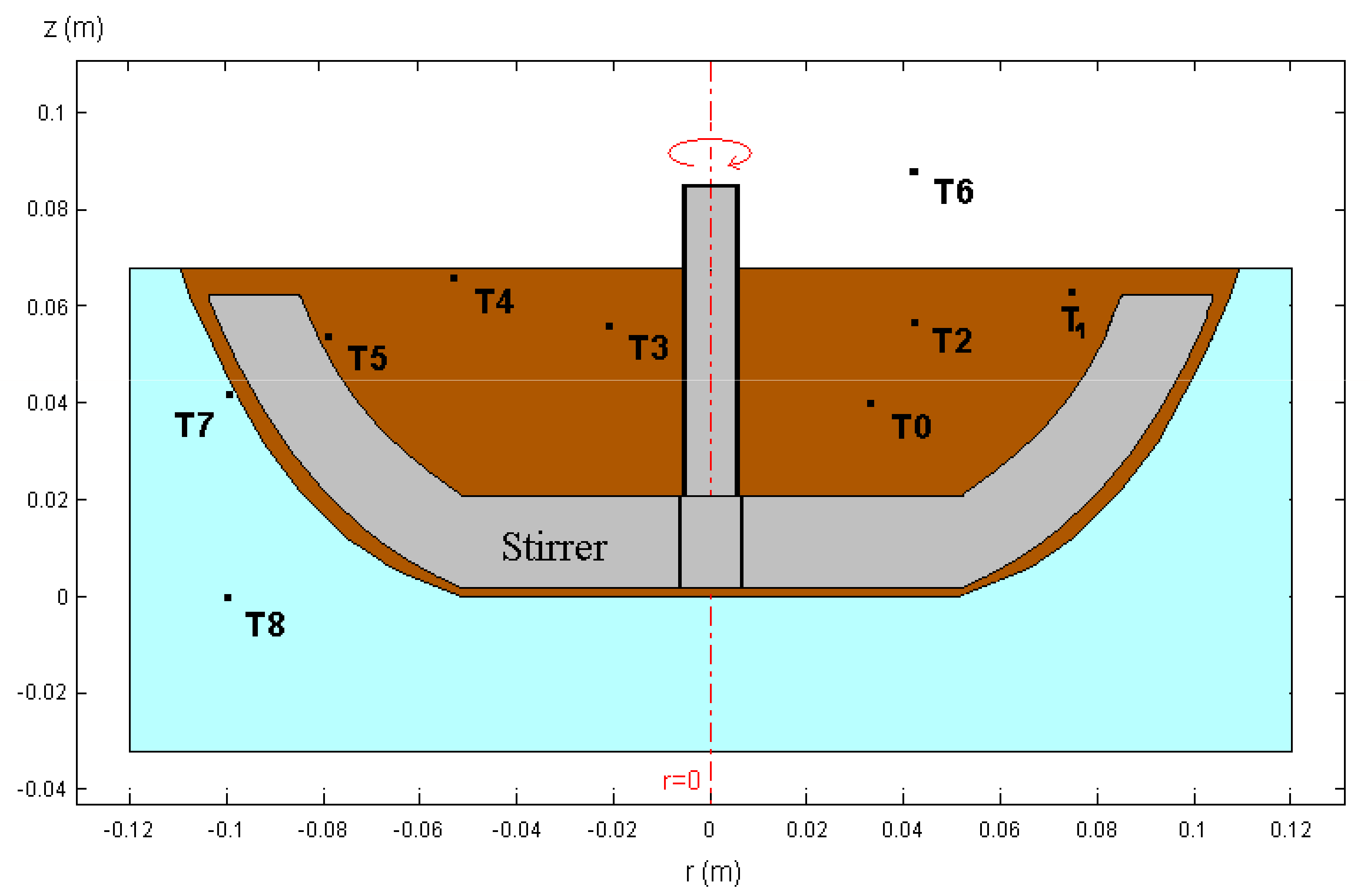
- Experimental datas
- Constructing a model
- Validation of the model

⇨ What about the tempering of my chocolate ?

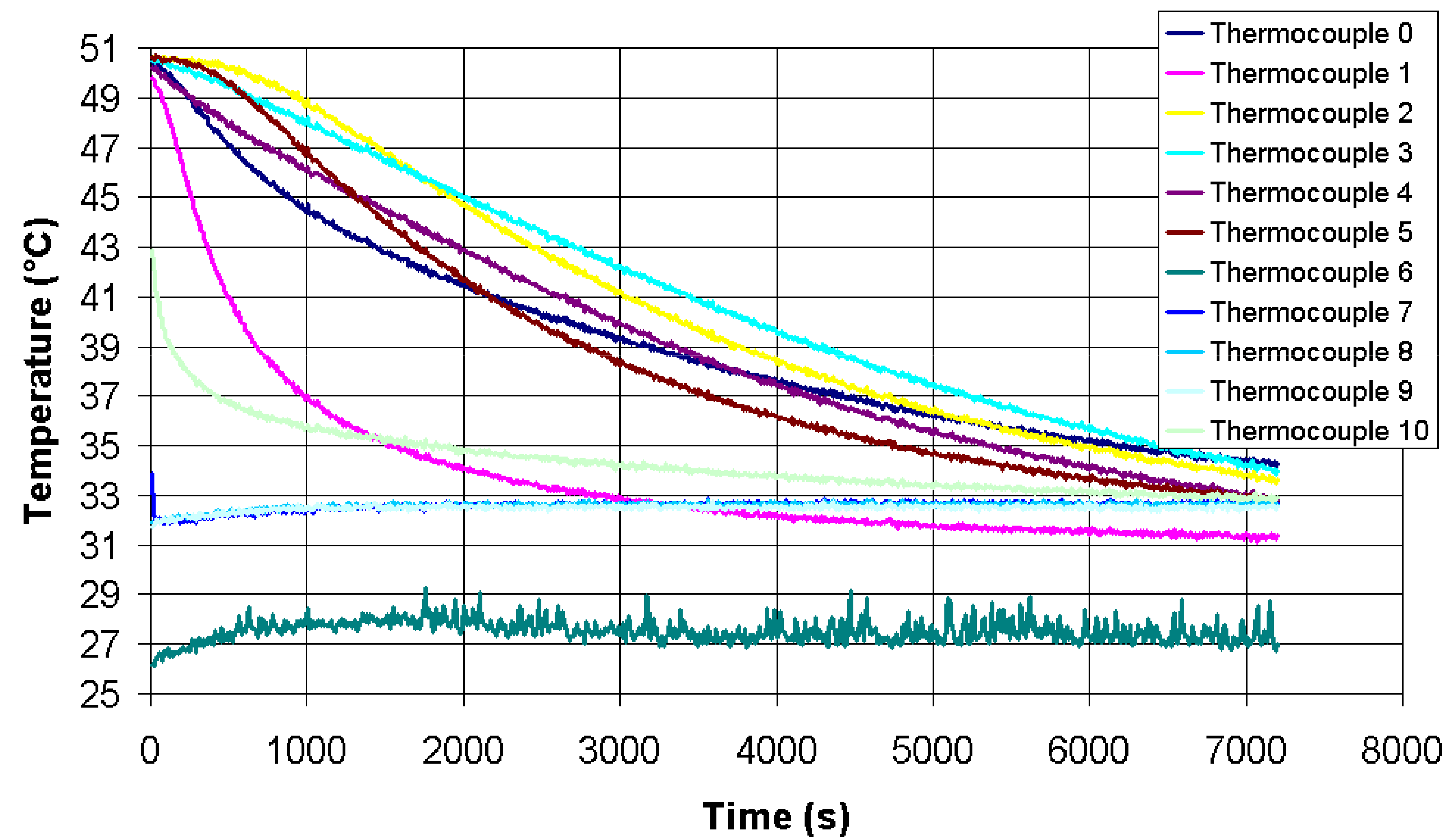
Collecting experimental datas



Collecting experimental datas



Collecting experimental datas



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Constructing the model

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Energy balance

$$\rho C_p \frac{\partial T}{\partial t} = \lambda \Delta T - \rho C_p U \nabla T + Q$$

Internal energy variation

Variations due to conduction

Variations due to convection

Heat sinks

Constructing the model

Energy balance simplified

$$\rho C_p \frac{\partial T}{\partial t} = \lambda_{eff} \Delta T + Q$$

Internal energy variation

Variations due to conduction & convection

Heat sinks

Constructing the model

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Sink term - shrinking core model

- Spherical shape
- Variation of C following variation of R
- Equilibration of mass
- Equilibration of heat
- Kinetics of fusion in function of size

$$Q = L\frac{dc}{dt}$$

variation of amount of CB

enthalpy of fusion

Constructing the model

$$\rho C_p \frac{\partial T}{\partial t} = \lambda_{eff} \Delta T + Q$$

- ⇨ type of chocolate
  mass of chocolate
- ⇨ mass of cocoa butter seeds
- ⇨ nature of medium (air or water)
  material of bowl
- ⇨ unknown: T_{ci} = temperature to add cocoa butter

EasyTemper Model

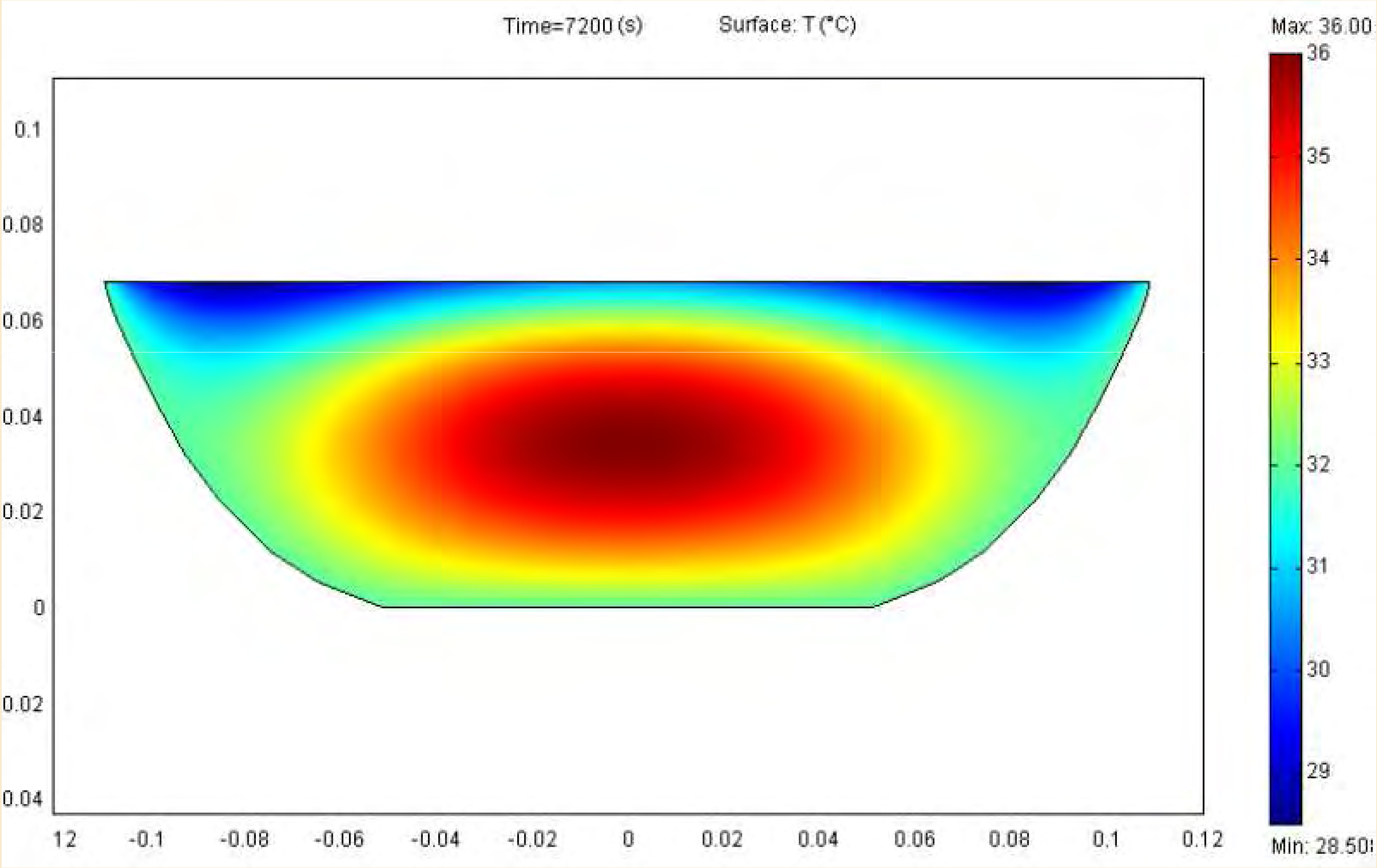
Complete model

$$\begin{cases} \rho C_p \dfrac{\partial T}{\partial t} = \lambda_{eff} \Delta T - \dfrac{3 c_i \lambda}{R_i^2 \rho_s} \left(\dfrac{(f+1)}{f} (T - T_V) \right) \sqrt[3]{\dfrac{c}{c_i}} \\ \dfrac{dc}{dt} = - \dfrac{3 c_i \lambda}{R_i^2 L \rho_s} \left(\dfrac{(f+1)}{f} (T_\infty - T_V) \right) \sqrt[3]{\dfrac{c}{c_i}} \end{cases}$$

EasyTemper Model

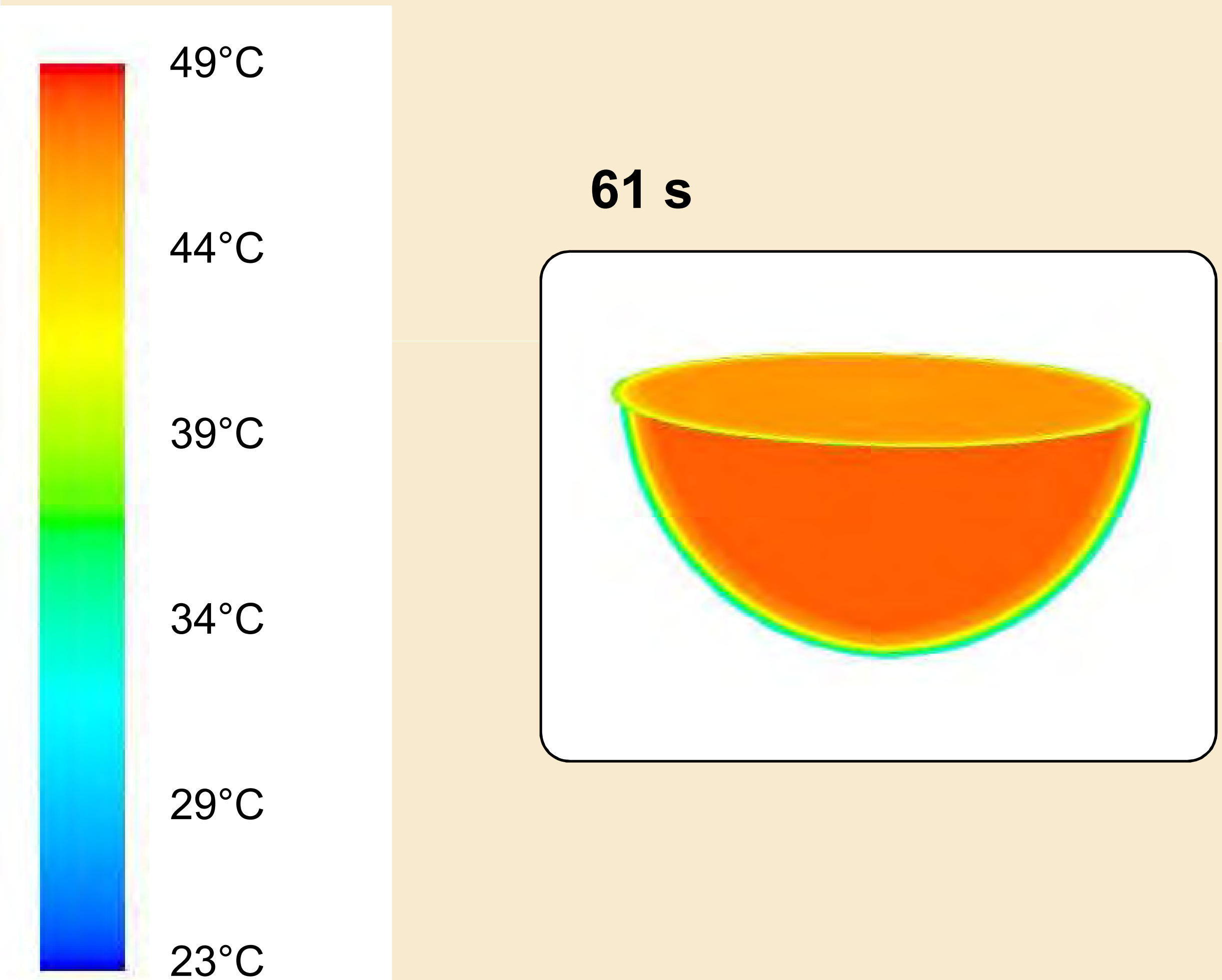
Model solved with computer

Validation of model



Validation of model

- Temperature evolution



Validation of model

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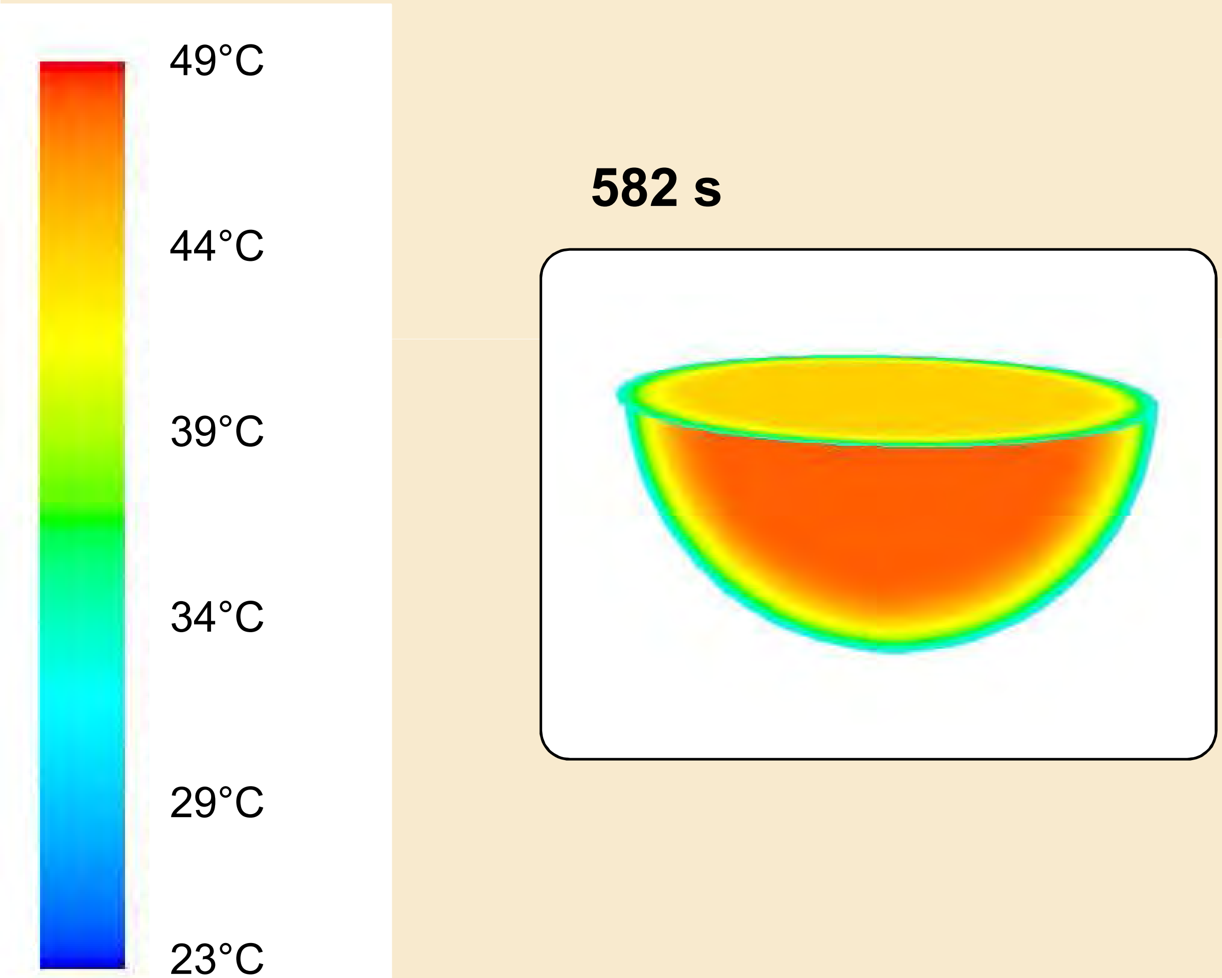

Validation of model

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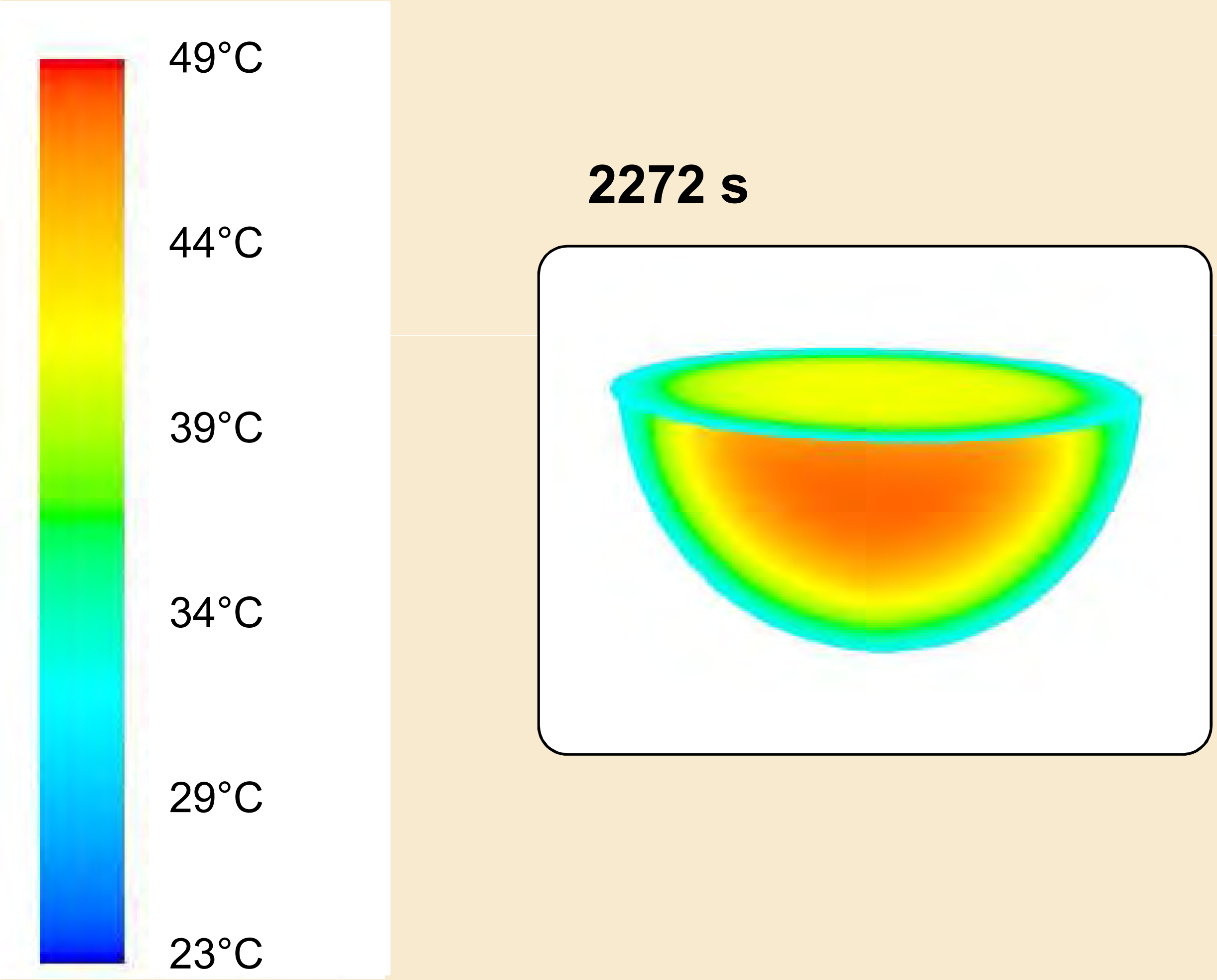
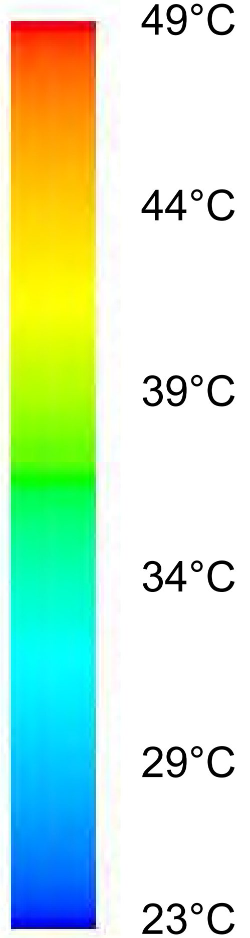
- Temperature evolution



Validation of model

- Temperature evolution



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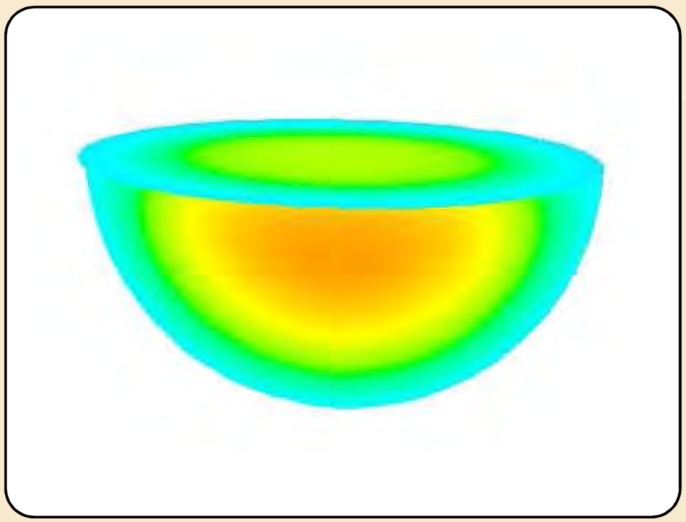
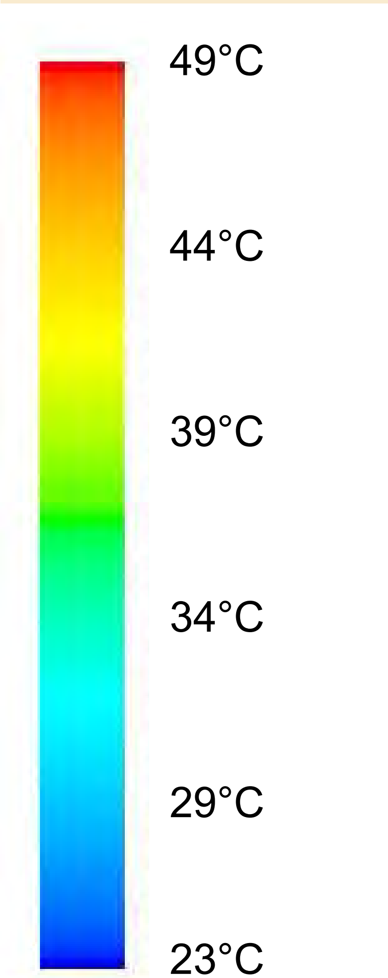


Validation of model

- Temperature evolution



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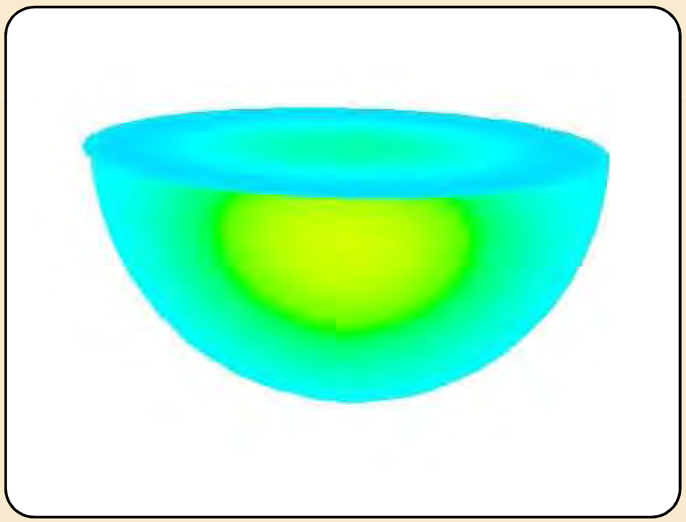

Results of model: exp vs. model

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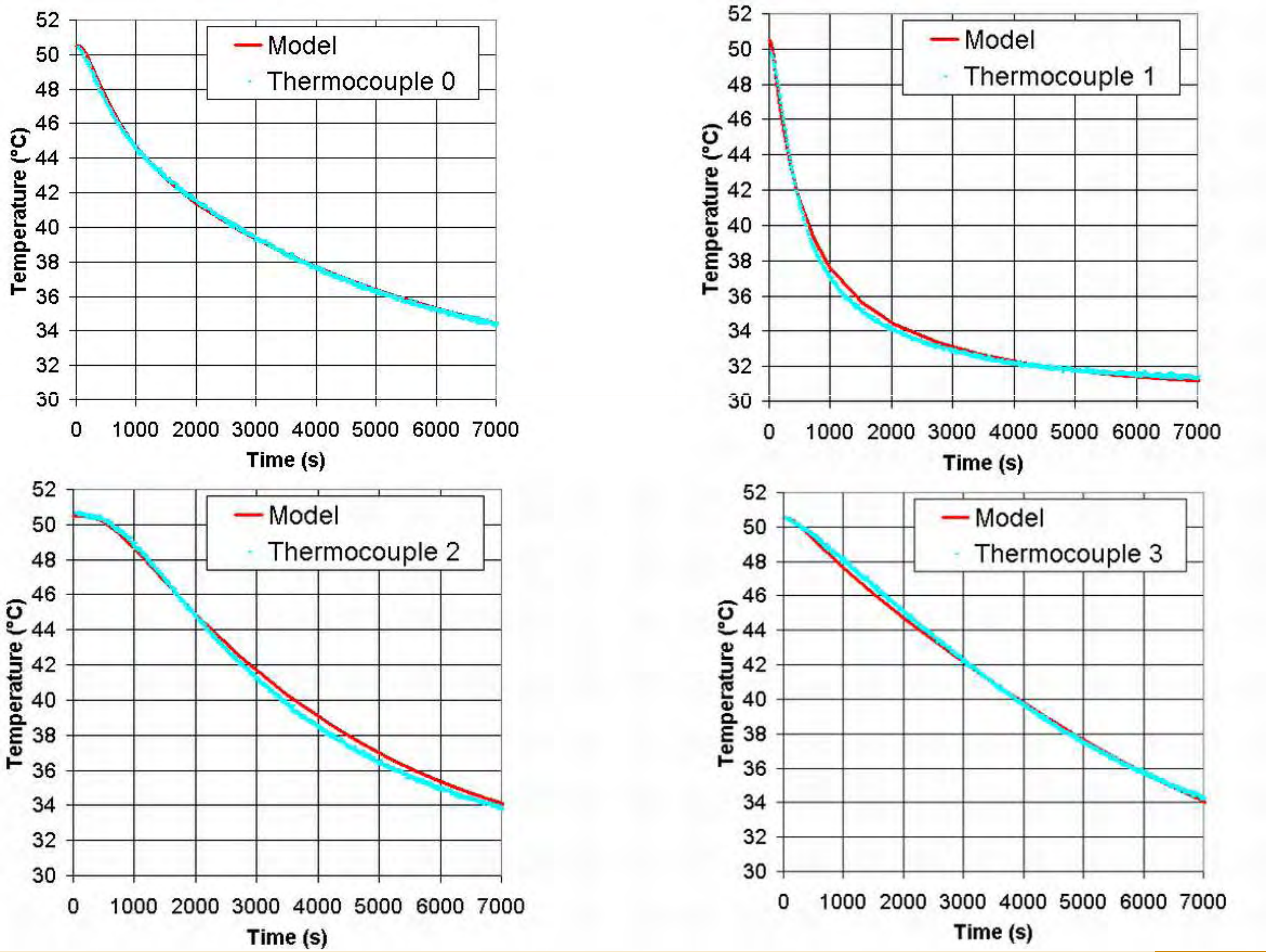
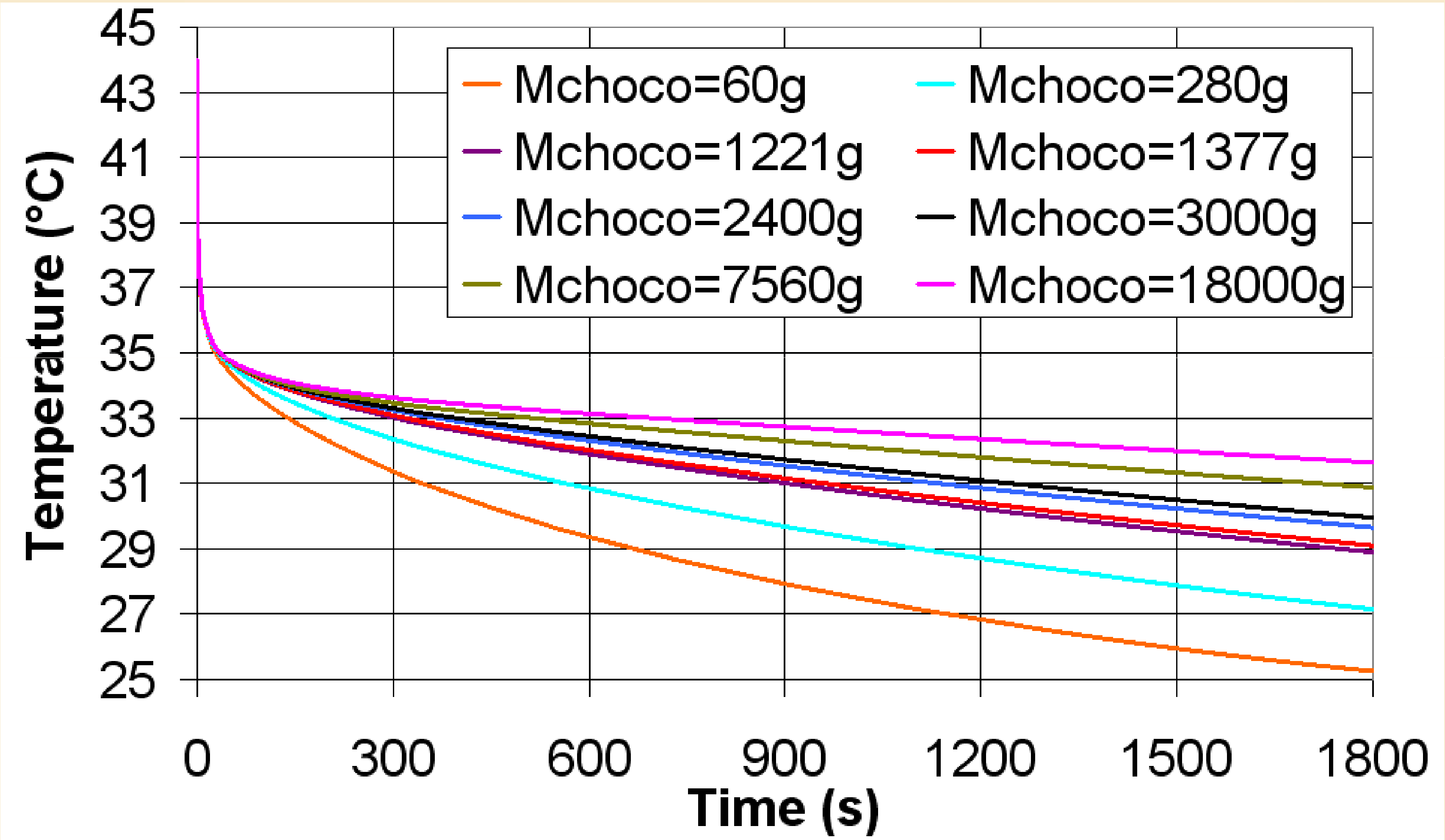
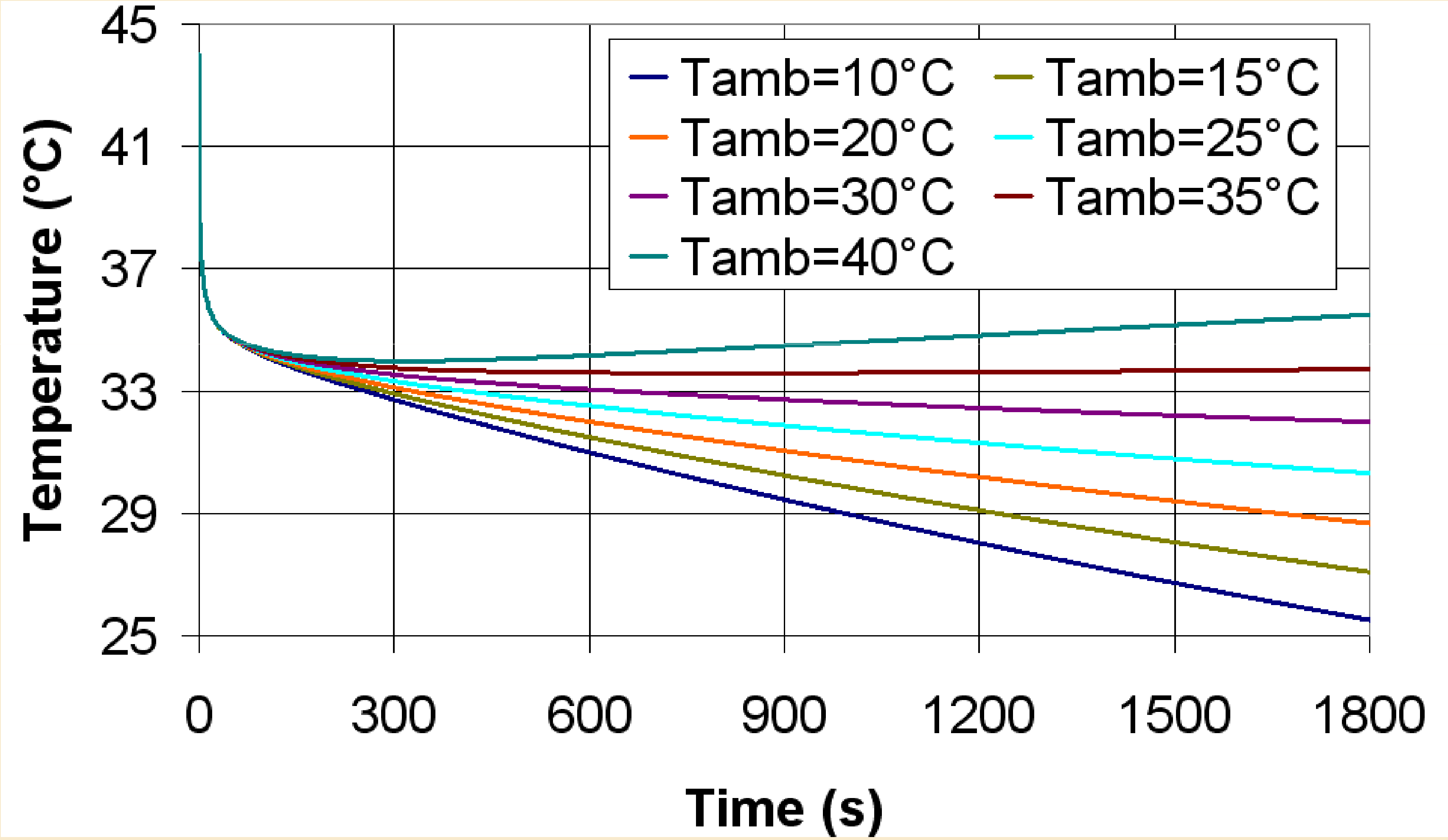


Results of model: mass of chocolate



Results of model: room temperature



Results of model: initial temperatures

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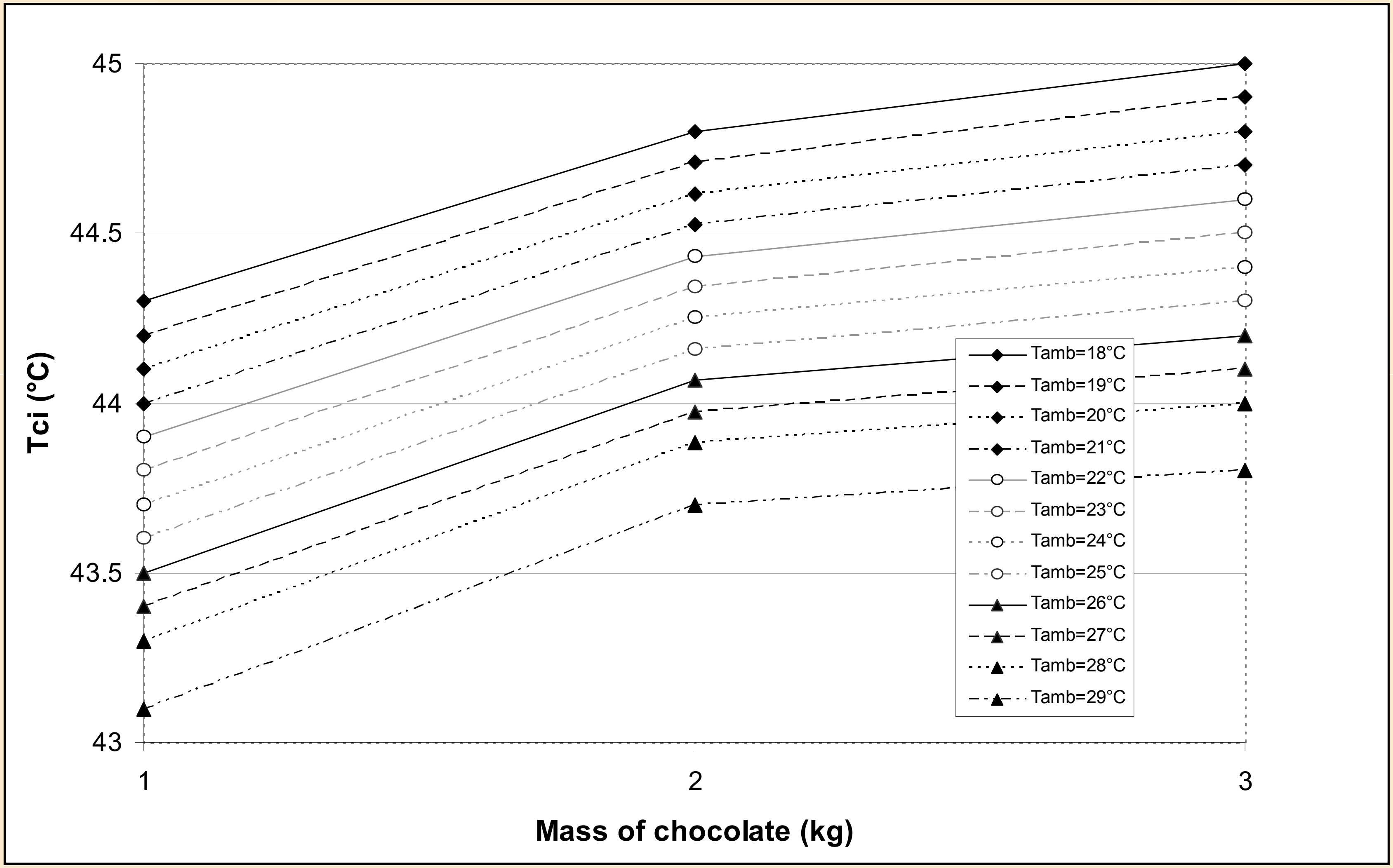
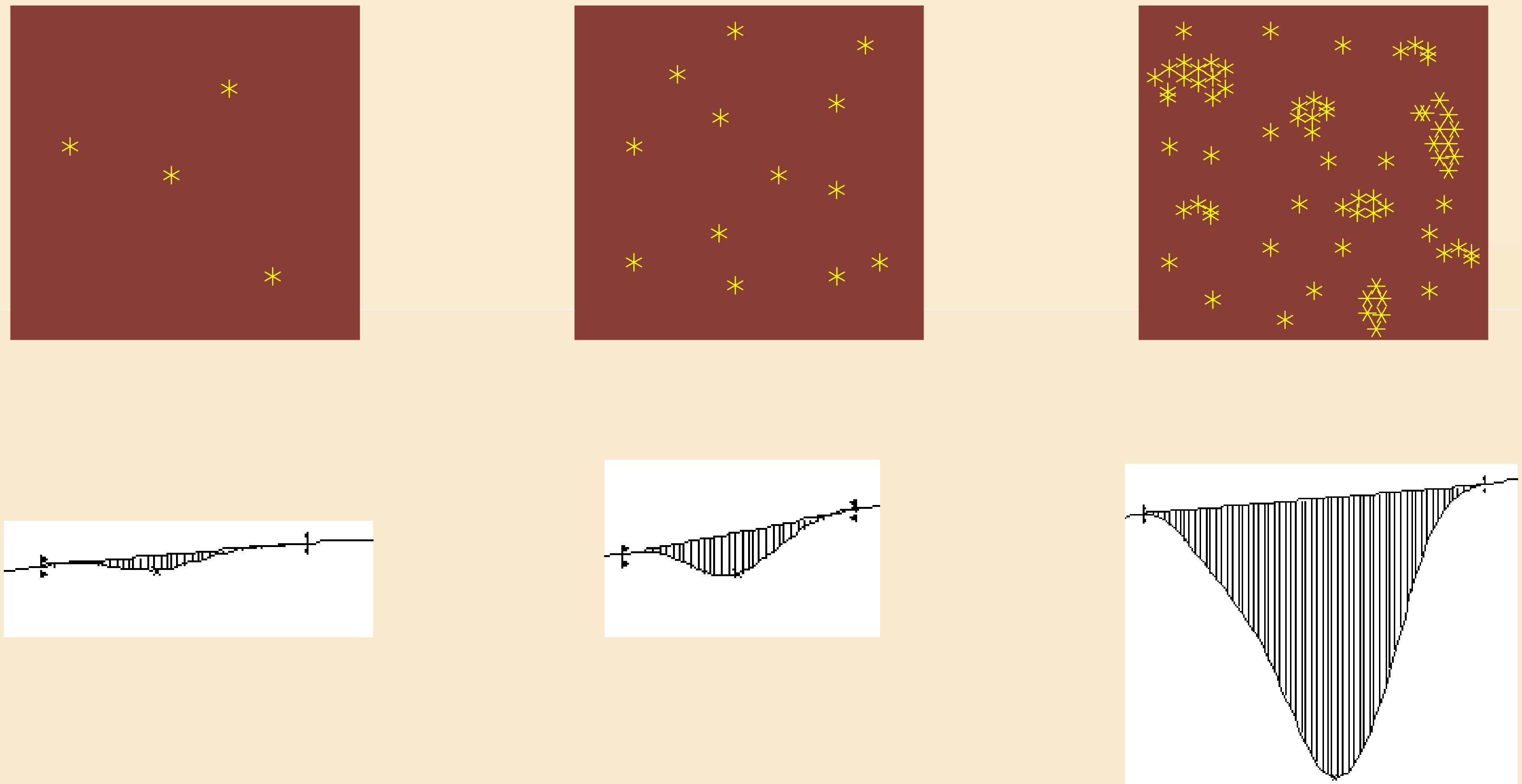


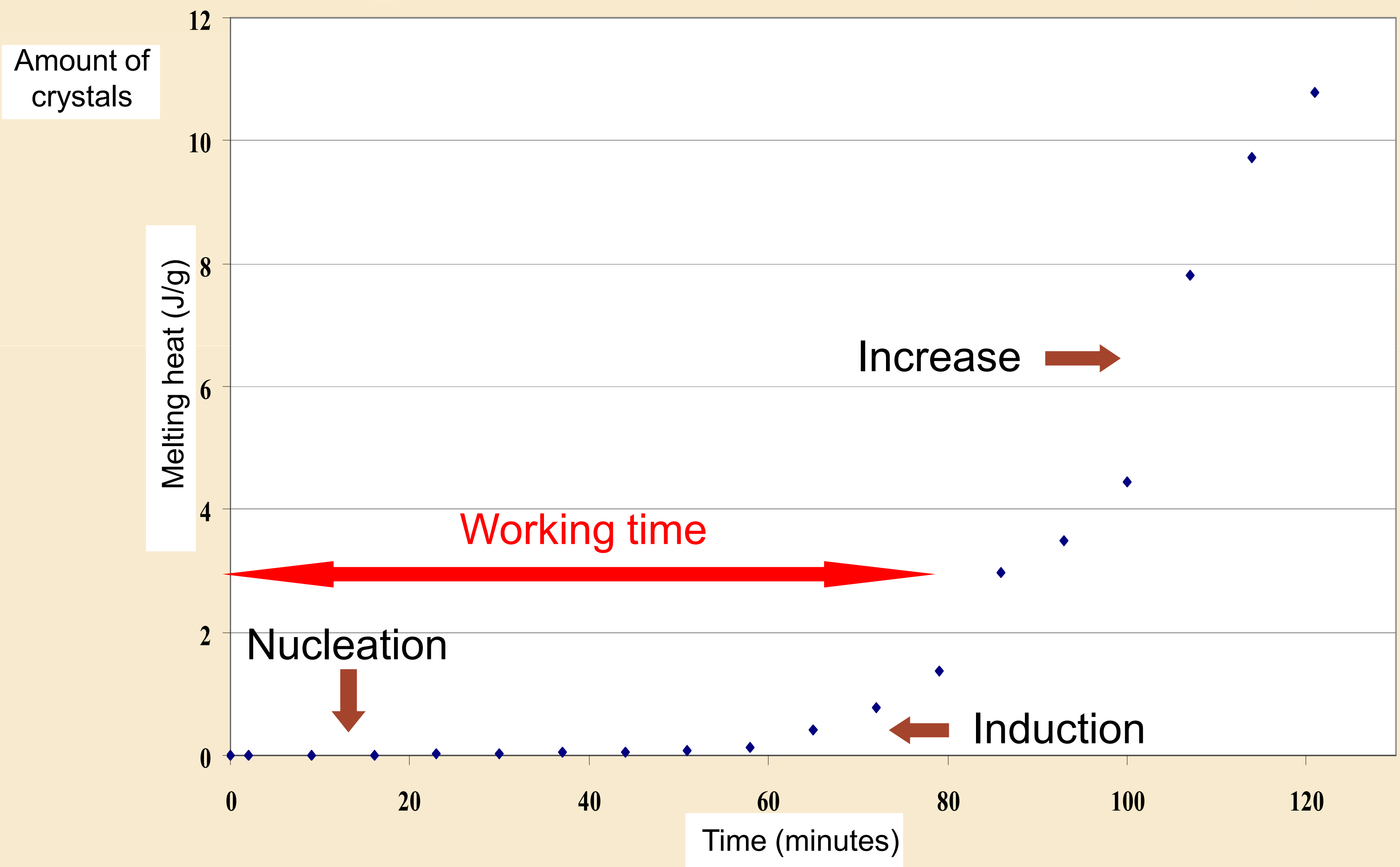
Validation of model

- Model describing temperature in chocolate
  - temperature to add cocoa butter pellets
  - obtain tempered chocolate
- Practical validation of the model
  - test of tempering of chocolate
  - follow crystallisation of chocolate
  - crystal amount in chocolate

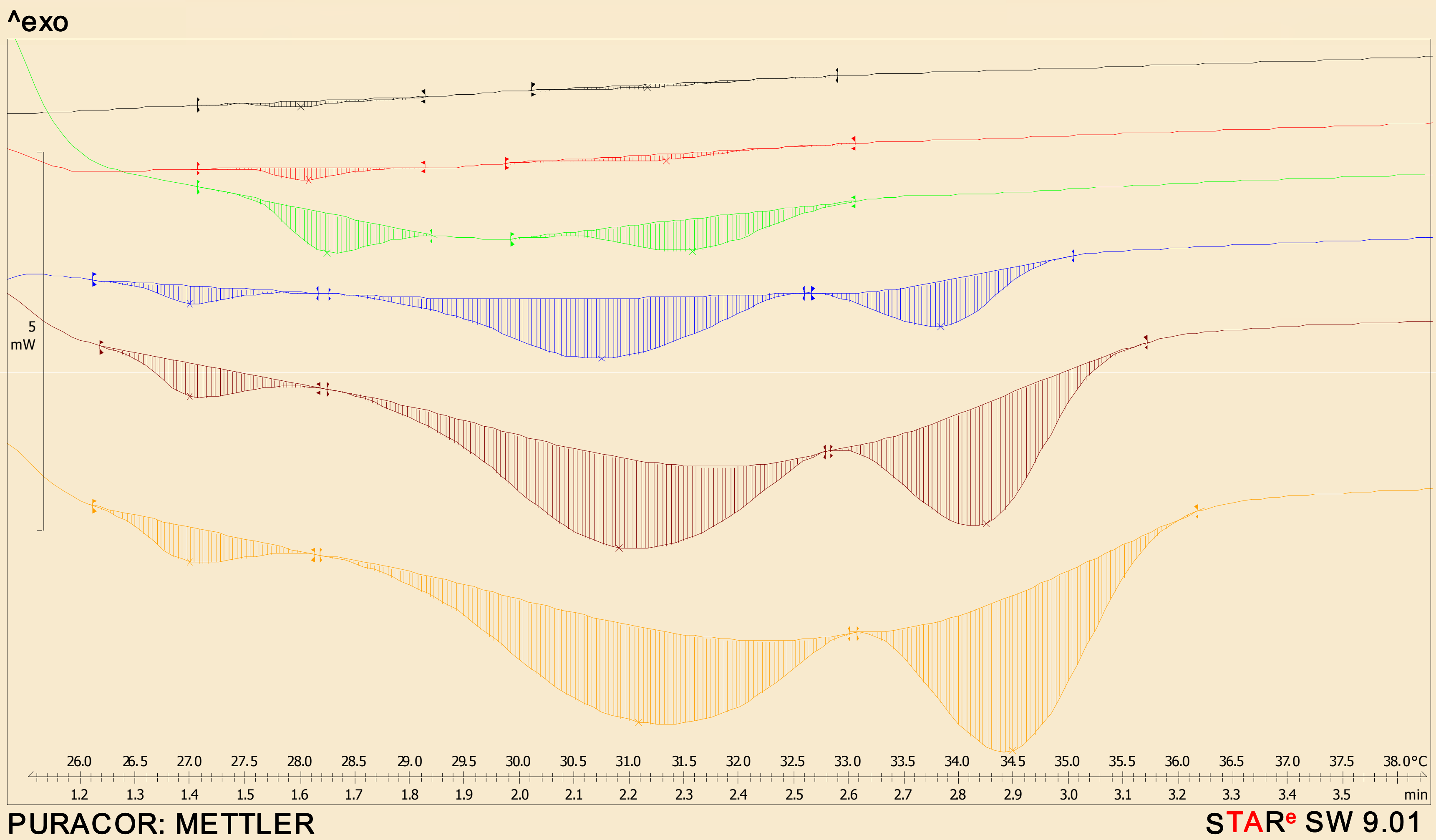
Practical validation of model



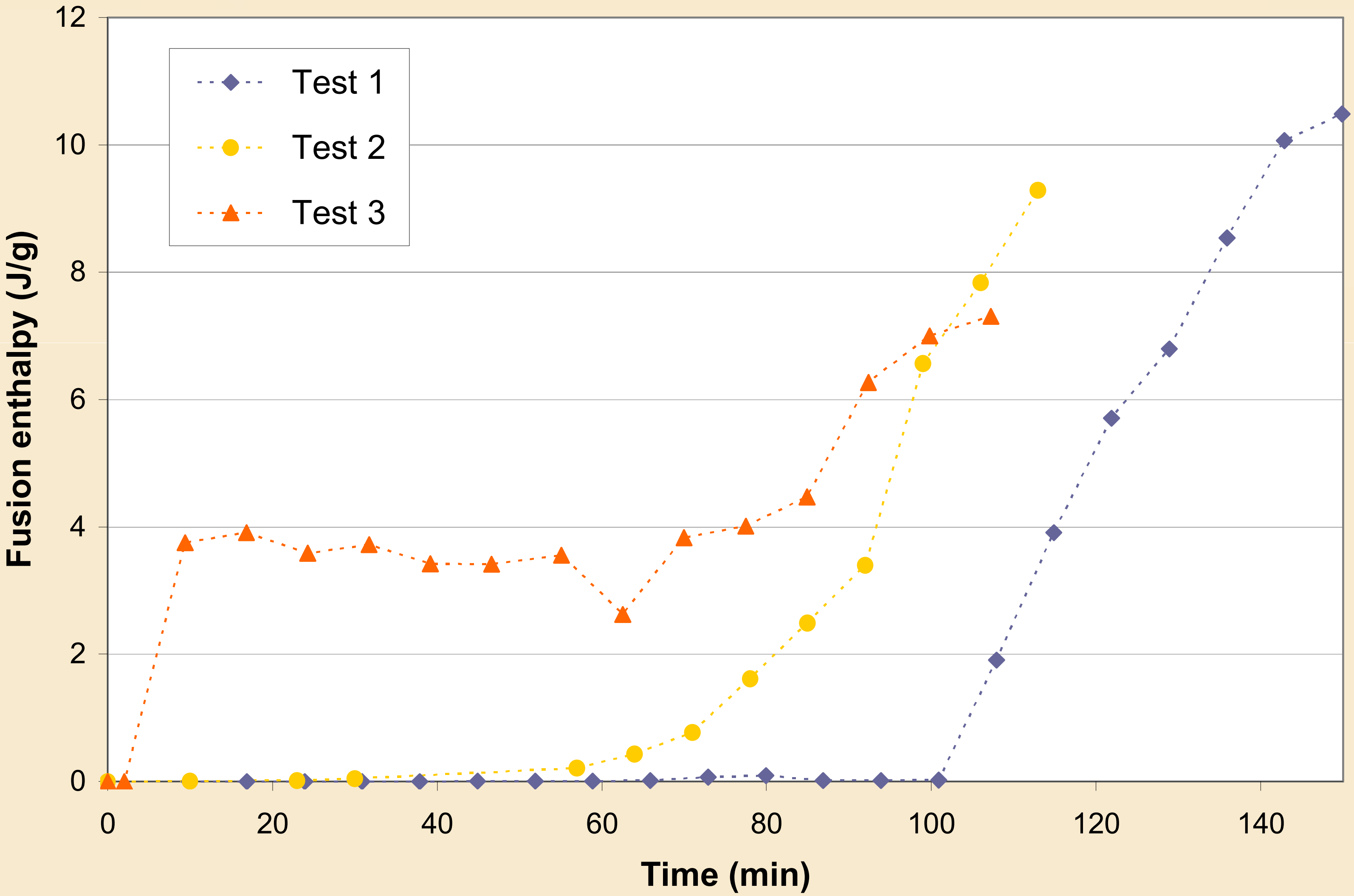
Practical validation of model



Practical validation of model



Practical validation of model



Conclusion

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- New easy way to temper chocolate
- Full model for temperature evolution in chocolate
- Predict temperature of cocoa butter addition
- Depending on conditions
- New product to introduce tempering at home

Acknowledgments

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