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

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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

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 data
• Constructing a model
• Validation of the model

What about the tempering of my chocolate?
Collecting experimental datas
Collecting experimental data
Collecting experimental data
Energy balance

\[ \rho C_p \frac{\partial T}{\partial t} = \lambda \Delta T - \rho C_p UN \nabla T + Q \]

- Internal energy variation
- Variations due to conduction
- Heat sinks
- Variations due to convection
Constructing the model

Energy balance simplified

\[ \rho C_p \frac{\partial T}{\partial t} = \lambda_{\text{eff}} \Delta T + Q \]

- Internal energy variation
- Variations due to conduction & convection
- Heat sinks
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
Complete model

\[
\begin{aligned}
\rho C_p \frac{\partial T}{\partial t} &= \lambda_{\text{eff}} \Delta T - \frac{3 c_i \lambda}{R_i^2 \rho_s} \left( \frac{(f + 1)}{f} (T - T_V) \right) \frac{3}{c_i} \\
\frac{dc}{dt} &= -\frac{3 c_i \lambda}{R_i^2 L \rho_s} \left( \frac{(f + 1)}{f} (T_\infty - T_V) \right) \frac{3}{c_i}
\end{aligned}
\]
EasyTemper Model

Model solved with computer
Validation of model
Validation of model

- Temperature evolution

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time (61 s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
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<td>34</td>
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<td>39</td>
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<tr>
<td>44</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td></td>
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</tbody>
</table>
Validation of model

- Temperature evolution

![Temperature distribution chart with temperatures ranging from 23°C to 49°C and 582 seconds indicated.](image)
Validation of model

- Temperature evolution

![Temperature evolution diagram](image)

- 49°C
- 44°C
- 39°C
- 34°C
- 29°C
- 23°C

**2272 s**
Validation of model

- Temperature evolution

4277 s
Validation of model

• Temperature evolution

49°C
44°C
39°C
34°C
29°C
23°C

9297 s
Results of model: exp vs. model
Results of model: mass of chocolate
Results of model: room temperature
Results of model: initial temperatures

![Graph showing the relationship between Tci (°C) and Mass of chocolate (kg) at different Tamb temperatures (18°C to 29°C).]
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

- Amount of crystals
- Melting heat (J/g)
- Time (minutes)

Increase
Working time
Nucleation
Induction
Practical validation of model
Practical validation of model

![Graph showing fusion enthalpy (J/g) over time (min) for Test 1, Test 2, and Test 3.]

- Test 1
- Test 2
- Test 3

Fusion enthalpy (J/g) vs. Time (min)
Conclusion

- 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
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