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MODELING THE EVOLUTION OF LIQUID FOOD PRODUCTS UNDER CONTINUOUS THERMAL TREATMENT

TOWARDS A PREDICTIVE MODEL FOR CREAM DESSERT STRUCTURATION

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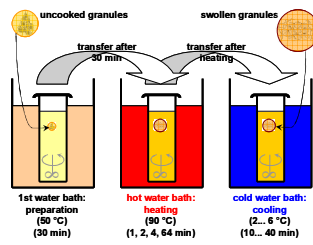
1. Aims and objectives

Understanding of the mechanisms which drive the transformation of liquid food products under thermal continuous treatment is essential to the manufacture of high-quality products, like cream desserts, in a reproducible manner. In this contribution we focus the attention on a relatively simple product transformation (granule swelling in starch suspensions) in order to demonstrate the feasibility of :

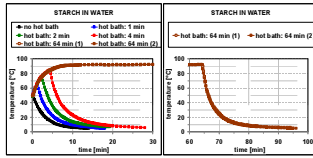
- to study the product transformation under laboratory conditions, characterizing the product (its particle size distribution, its apparent viscosity) at selected transformation states;
- to represent the relevant phenomena occurring in heat exchangers through a physically-based numerical model which is able to account for the two-way coupling between fluid flow, heat transfer and product transformation; and
- to compare model predictions with measurements obtained with a tubular heat exchanger.

2. Thermal treatment in laboratory

- liquid food product: 3.42 % w/w starch in water (0.1 M NaCl) or in milk; stabilized & cross-linked waxy maize starch provided by Cargill (France); < 1 % amylose
- preparation: rehydration of starch powder in water or in milk during 30 minutes at 50 °C
- thermal treatment:
 - hot water bath during a prescribed time;
 - cold water bath during the time required for approaching ($\Delta T < 1$ °C) cold water temperature;
 - under continuous agitation



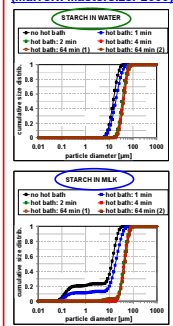
EVOLUTION OF SAMPLE TEMPERATURE



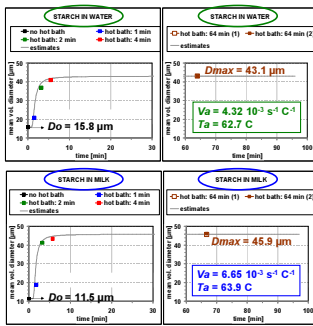
3. Product mean volume diameter

- a second-order kinetic equation is assumed to describe the evolution of the swelling degree: $d(1-S)/dt = -V \times (1-S)^2$, where $S = (D - D_0) / (D_{max} - D_0)$
- kinetic rate constant V is assumed to increase linearly with the temperature above a threshold $T = T_a$: $V = 0$ if $T < T_a$, otherwise $V = Va \times (T - T_a)$

PARTICLE SIZE DISTR. (Malvern Mastersizer 2000)



EVOLUTION OF MEAN VOLUME DIAMETER



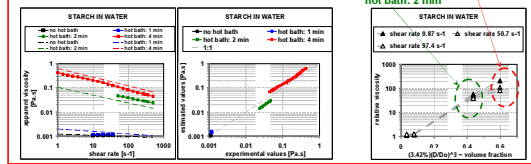
4. Apparent viscosity: Starch in water

- measurements were conducted at 20 °C after thermal treatment over the $1 \cdot 500 \text{ s}^{-1}$ shear rate range with the help of a MCR 301 rheometer (Anton Paar, Austria) equipped with a coaxial-cylinder geometry
- in the numerical model, the apparent viscosity is represented by multiplying the dynamic viscosity of the water (which depends on the temperature T) and the relative viscosity; the latter is expressed as a function of the shear rate $\dot{\gamma}$ and of the "particle volume fraction" $\phi = (3.42\%)(D/D_0)^3$:

$$\eta = \eta_{water}(T) (A \exp(B \phi) \dot{\gamma}^{n-1})$$

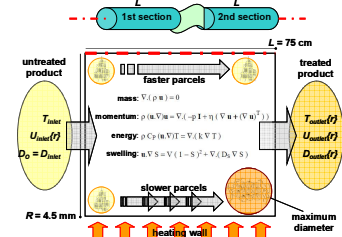
$$n = n_{min} + (1 - n_{min}) \exp(-C \phi)$$

$$A = 0.83, B = 11, n_{min} = 0.60, C = 3.8$$

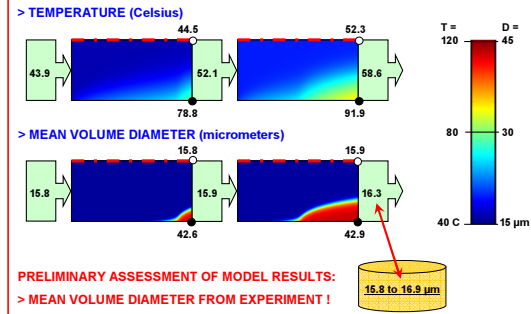


5. Numerical modeling: Starch in water

- deterministic model, coupling phenomena of fluid flow, heat transfer and transformation
- finite-element method, software COMSOL Multi-physics 4.4
- time-independent conditions
- representation of the two first heating sections of a HIT20 pasteurization/sterilization unit (OMVE, The Netherlands)
- fluid flow and thermal boundary conditions from experiment:
 - 15 L/h parabolic flow at inlet ($Re \approx 1100$);
 - 43.9 °C at inlet, 6520 W/m² at heating wall...



MODEL RESULTS:



PRELIMINARY ASSESSMENT OF MODEL RESULTS:

- MEAN VOLUME DIAMETER FROM EXPERIMENT! (15.8 to 16.9 μm)

6. Forthcoming work

- Next efforts on this subject include:
- the implementation of the remaining sections of the heat exchanger, allowing the global picture of the liquid food product transformation as represented in the numerical model;
 - the replacement of starch-in-water by starch-in-milk in the numerical model, increasing the complexity of the liquid food product which is taken into account; and
 - the application of the same experimental protocol to the following liquid food product of interest, namely starch-in-milk with addition of carrageenan.
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