Modelling the evolution of liquid food products under continuous thermal treatment. Towards a predictive model for cream dessert structuration

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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 :

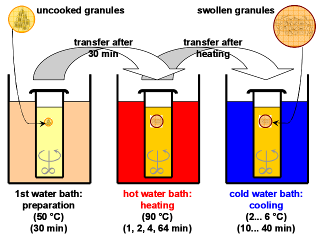
i) to study the product transformation under laboratory conditions, characterizing the product (its particle size distribution, its apparent viscosity) at selected transformation states;
ii) to represent the relevant phenomena occurring in heat exchangers through a physically-based numerical model which is able to account for the two-way coupling between fluid flow, heat transfer and product transformation; and
iii) 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 (ΔT < 1 C) cold water temperature;
under continuous agitation

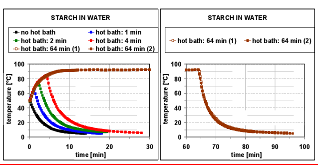


> thermal histories followed since the immersion into the hot water bath, ending when the sample approaches the cold water temperature

> good repeatability (ΔT < 3 C) at revisited temperatures

> essentially the same thermal histories for starch-in-water and starch-in-milk

EVOLUTION OF SAMPLE TEMPERATURE



3. Product mean volume diameter

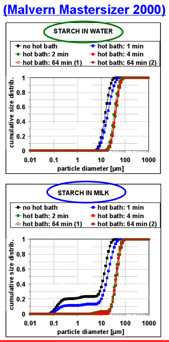
> a second-order kinetic equation is assumed to describe the evolution of the swelling degree:

$d(1 - S)/dt = -V * (1 - S)^2$, where $S = (D - Do)/(Dmax - Do)$

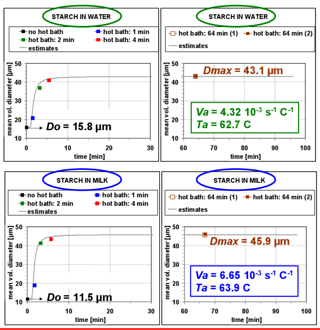
> kinetic rate constant V is assumed to increase linearly with the temperature above a threshold $T = Ta$:

$V = 0$ if $T < Ta$, otherwise $V = Va * (T - Ta)$

PARTICLE SIZE DISTR. (Malvern Mastersizer 2000)



EVOLUTION OF MEAN VOLUME DIAMETER



4. Apparent viscosity: Starch in water

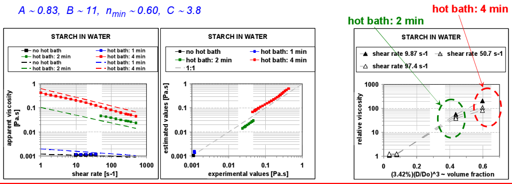
> measurements were conducted at 20 C after each thermal treatment over the 1...500 s^{-1} shear rate range with the help of a MCR 301 rheometer (Anton Paar, Austria) equipped with a coaxial-cylinder geometry

> 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 γ and of the "particle volume fraction" $\Phi = (3.42\%)(D/Do)^3$:

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

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

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



5. Numerical modeling: Starch in water

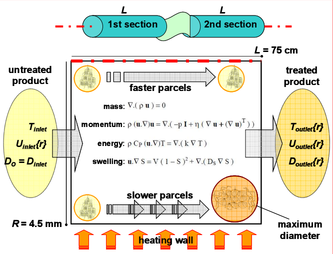
> deterministic model, coupling phenomena of fluid flow, heat transfer and transformation

> finite-element method, software COMSOL Multi-physics 4.4

> time-independent conditions

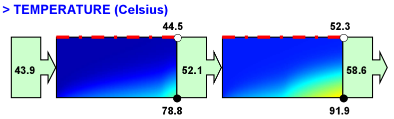
> representation of the two first heating sections of a HT220 pasteurization / sterilization unit (OMVE, The Netherlands)

> fluid flow and thermal boundary conditions from experiment:
15 L/h parabolic flow at inlet ($Re \sim 1100$);
43.9 C at inlet, 6520 W/m^2 at heating wall...

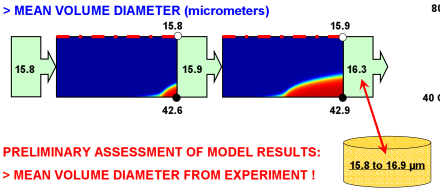


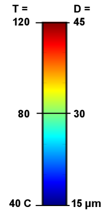
MODEL RESULTS:

> TEMPERATURE (Celsius)



> MEAN VOLUME DIAMETER (micrometers)





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:

a) 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;
b) 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
c) 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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Malvern Mastersizer 2000

Anton Paar MCR 301 rheometer

OMVE HT220 inline pasteurization and sterilization unit

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