Rheology and simulation for the processing of extruded breakfast cereals

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Many starch-based foods, such as texturized ingredients, breakfast cereals, snacks, crackers, pasta, noodles, and many others, are produced by twin-screw extrusion. Despite significant progress in process modelling, the design of extruded products at the industrial level is still based on a trial-and-error approach. The main challenge is to determine the viscous behaviour of melts under extrusion-like conditions that require specific rheometers[1]. The 1D global model of twin-screw extrusion Ludovic©[2] for the design of processing experiments has been restricted to simple formulations: maize and wheat starches and wheat flour[3,4]. Up to now, it has not been used to design food products. Hence, this work aims to test whether this model, implemented with an appropriate viscosity law, can be used as a computer-aided tool for predicting various properties of fibre-rich breakfast cereals extruded under various operating conditions.

Various food models were selected: blends of wheat flour and wheat bran (bran content ≤26 wt%). A large data set was built from literature data, including foods properties and extrusion variables (temperature T and specific mechanical energy SME)[5,6,7]. The foods characteristics were hydro-solubility of starch (WSI_{starch}), macrostructure described by radial expansion index (SEI) and cellular structure expressed as cell density per cm^3 (NC). Twin-screw extrusion processing was simulated using the 1D global extrusion model Ludovic© (Sciences Computers Consultants, France). The extruder operating charts representing predicted extrusion variables as function of operating parameters were drawn. From the correlations between predicted extrusion variables (T, SME, melt viscosity η_com) and product features (WSI_{starch}, SEI, NC) (Fig. 1a), a set of extrusion variables to obtain a product with desired properties can be targeted. Thereafter, the feasible region of operating conditions can be determined from extruder operating charts (Fig. 1b).

As a future prospect, extrusion simulation will be applied to design a wide range of extruded starch-protein blends from pulse crops. Beyond classical structural and functional properties, the prediction of textural and nutritional features will be tackled.

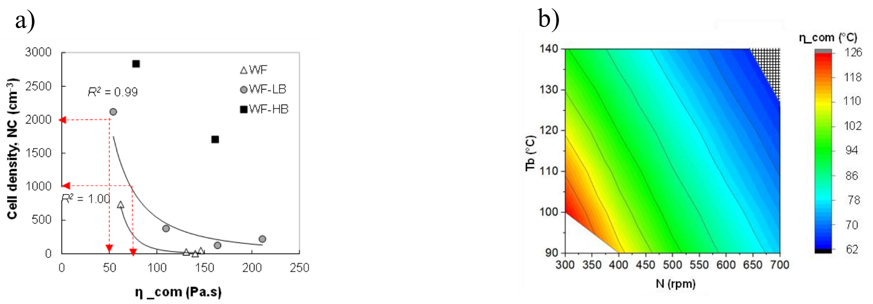

Figure 1: (a) Cellular structure variation as a function of melt viscosity. (b) Example of extruder operating chart: Variation of melt viscosity with last barrel temperature (Tb) and screw speed (N)

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