A phenomenological model of starchy materials expansion by extrusion

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Title:

A phenomenological model of starchy materials expansion by extrusion

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During extrusion of starchy products, the molten material is forced through a die so that the sudden pressure drop causes part of the water to vaporize, giving an expanded cellular structure. At die outlet, the material cools down, crosses glass transition T_g and becomes solid. No simple model is available to describe satisfactory dynamic, multiphysic and multiphase phenomena during expansion. Current models are too complex to be coupled with simple mechanistic model of co-rotating twin-screw extrusion process, in order to predict the foam cellular structure. Our objective is to elaborate a phenomenological model of expansion, simple enough to be coupled with Ludovic®, a simulation software of twin screw extrusion process. From experimental results that cover a wide range of thermomechanical conditions, a concept map of influence relationships between input and output variables is built. It takes into account the phenomena of bubbles nucleation, growth, coalescence, shrinkage and setting, in a viscoelastic medium. The input variables are the moisture content *MC,* melt temperature T_p, specific mechanical energy *SME*, shear viscosity η at the die exit, computed by Ludovic®, and the melt storage modulus $E'(T_p>T_g)$. The latter represents the elongational viscosity, and takes into account the influence of starch amylose content. The outputs of the model are the macrostructure (expansion indices and anisotropy factor), and cellular structure (fineness) of solid foams, determined by X-ray tomography. Then a general model is suggested: $VEI=\alpha(\eta/\eta_0)^n$ in which *VEI* is the volumetric expansion index. The model parameters, α and n depend on T_p, *MC*, *SME* and E'. The link between macroscopic anisotropy and fineness is also established, allowing the prediction of cellular structure. Finally, the model is validated using experimental data of wheat flour extrusion from literature.