499d Modeling and Design of a Mini Food Extruder with High Viscous Heat Generation

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The design of a mini extruder with high viscous heat generation is important in some special cases where weight is critical, such as long duration Advanced Life Support (ALS) system missions beyond low Earth orbit, and for biotechnological innovations demanding a very low capacity food processor compatible with the costly and/or limited supply of experimental seeds.

In commercial size extruders, viscous dissipation energy usually cannot generate enough heat for cooking, and external heat must be applied. Temperature rise from viscous heat generation is even lower for extruders with small sizes because the viscous heat generation is reduced. Attempts to design small scale extruders in which food products are cooked only by viscous heat are missing in the literature.

The objectives of this study were: (i) To develop a computational model for scaling down existing commercial extruders into extruders on a pilot plant scale while maintaining the same product quality; (ii) To characterize material properties of soy dough to be processed in the mini extruder in order to develop a properties database to be used for scaling down; and (iii) To instrument a commercial size extruder to measure pressure, temperature, and other system variables to validate the scaling down process.

A finite element model was developed to simulate fluid flow and heat transfer in a single-screw extruder, and FEMLAB was used to perform the simulation. Experiments were conducted in commercial extruders on a pilot plant scale. Soy dough, which exhibits shear thinning behavior, was used in the simulation and experiment. Rheological properties of soy dough were found to be a function of temperature, moisture, and oil content. It was found that the model-predicted flow rate and temperature rise were close to the experimental values. This indicates the developed model can be used to design extruders on a small scale. Product quality was influenced primarily by the temperature and average shear rate experienced by the product during the extrusion processing. Therefore, the challenge in the design of the mini extruder was to find appropriate dimensions which can generate the same histories of temperature and average shear rate as those in commercial size extruders to meet the same product quality requirements. During processing in the mini extruder, product was cooked only through viscous heat. For this purpose, special structural components, which are called ‘steam locks', were also designed and mounted on the screw root to reduce the flow rate, and thus increase the residence time and temperature rise in the equipment.