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Modelling liquid food concentration processes for process flowsheeting simulation: application to milk evaporation

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An interesting way to design sustainable processes (which integrate simultaneously technical, economic and environmental constraints) entails a systematic approach combining process modelling, simulation, and process optimisation (Azapagic et al, 2011; Lam et al. 2011).

The chemical and petroleum industries are quite familiar with the simulation-optimisation approach and widely use process simulators (Aspen Plus, ProsimPlus, Pro/II, COCO, etc.) to compute mass and energy balances. Conversely efficient and reliable food-specific tools for process modelling and simulation are missing compared to those developed for the chemical process industries. This is mainly due to a lack of both food process and thermodynamic models that account for the complexity of food materials (Trystram, 2012).

Several attempts at modelling liquid food properties for process simulation have been achieved, either by the development of new unit operation mathematical models or assuming the additivity of the properties of food components. However none of the existing approaches satisfies the needs for food concentration processes simulation with process simulators (Madoumier et al., 2015).

The objective of this work is then to propose a new modelling strategy for food products in order to be able to use the potential of a chemical process software tool for the modelling and simulation of food processes. The concentration process of milk by evaporation is selected to illustrate the methodology, since it was identified as one of the most energy intensive operations in the dairy industry. Aspen Plus is selected as the chemical process simulator to be adapted to food process modelling.

The approach consists in defining the food product as a mixture of water and food-specific dry matter components (fat, proteins, carbohydrates, minerals, fibres), and integrating the properties of the food product (heat capacity, viscosity, etc.) as a function of process parameters (concentration and temperature in our case), in the process simulator. The food process is then modelled and simulated, and the results are compared with experimental data, so as to validate the food process model.

This approach was validated with three existing processes at different scales: a pilot evaporator, a semi-industrial pilot evaporator, and an industrial four-effect evaporator. The implementation of a new overall heat transfer coefficient model integrated in the simulator was necessary. The results obtained by simulation were satisfying compared to experimental data in the case of both the industrial and semi-industrial processes (2% error in required steam flow rate with the semi-industrial process).

Through the example of milk concentration, the approach proposed for the modelling of food properties and concentration process is intended to serve as a generic method for food products modelling in classical process simulators.

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