

Reducing energy use in food manufacturing by process flowsheeting: application to milk evaporation

Conference session Nb: 3 Green Food Factory

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The design and development of sustainable food processes constitute a major challenge in a context of transitions that encompass climate change, energy scarcity and energy price increase. A systemic approach combining process modelling, simulation, and optimization can be a sound way of coping with this issue (Azapagic et al, 2011; Lam et al. 2011). While the benefit of using computer-aided process engineering (CAPE) tools has long been recognized in the chemical and petroleum industries, their use is not yet systematic in the development of food processes. A major limitation of the development and use of CAPE tools in food processes is attributed to the complexity of food products and their intrinsic thermodynamic properties. Among the benefits to use a food process design software package, energy use minimization schemes that can be explored for further reduction in production costs will be highlighted in this paper.

This work is devoted to the development of a framework for the eco-design of food processes with an emphasis on dairy concentration processes. Specific attention is given to the concentration steps classically carried out prior to spray drying in the industry. The milk powder production is actually identified as one of the most energy intensive process and still some efforts need to be done to reduce the energy consumption of evaporators. The concentration step using evaporation first serves as a validation case of the methodology proposed.

For the methodology purpose, “pseudo-components” have been used to model milk by a mixture of water and four components (fat, proteins, carbohydrates, minerals) and correlations for physico-chemical properties of milk (heat capacity, boiling point elevation, density, thermal conductivity, viscosity and surface tension) have been embedded in Aspen software tool (Madoumier et al., 2015). The implementation of a new overall heat transfer coefficient model integrated in the simulator is necessary. This approach is validated with three existing processes at different scales: a pilot evaporator, a semi-industrial pilot evaporator, and an industrial four-effect evaporator.

Several scenarios are proposed to reduce energy consumption based on sensitivity analyses, i.e., on the number of effects in the evaporation train and then on a reverse engineering approach in order to design the evaporators with respect to product specifications.

This systemic approach paves the way for the development of an eco-design approach combining modelling, cost and environmental analysis and multi-objective optimization.

References

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Until April 15th 2016

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