Minimising energy use in milk heat treatment using a dynamic fouling predictive model

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Objective: Today, energy consumption reduction in food manufacturing is at the centre of scientific and industrial interest. The aim of this study is to identify processing conditions to reduce the energy consumption in conventional milk processing and cleaning-in-place, using a dynamic fouling predictive model. During the thermal treatment of milk, a fouling layer develops on the inner surface of the plate heat exchanger, which acts as a thermal insulator. As a result, heating energy needs to be supplied at an increasing rate to ensure sufficient pasteurisation. Additionally, the frequent application of the cleaning-in-place process to remove fouling demands considerable energy for heating the cleaning fluids.

Methods: A model that predicts the impact of fouling on energy use during milk processing and cleaning was developed following a mechanistic modelling approach. Literature kinetic models were used to predict fouling dynamics during milk processing and cleaning. To achieve realistic results for fouling prediction, a data-driven regression model for a key parameter of the fouling kinetic model was developed. This was accomplished using logged temperature and flowrate data from a pilot scale milk heat treatment processing line in which trials were performed under a range of processing conditions. The impact of fouling on energy use was evaluated by applying first principles of heat exchange.

Results: The model was able to predict the fouling layer growth and depletion during processing and cleaning respectively. The model was simulated under a range of effective processing and cleaning-in-place operating conditions to identify conditions that can minimise energy use. The results were visualised through energy heatmaps. Results demonstrated that a 50C decrease in heating and cleaning medium temperature and a 10-minute reduction in cleaning time can save up to 24% of the energy use for milk treatment.

Conclusion: Simulations showed processing and cleaning-in-place operating conditions that can best reduce energy use whilst still ensuring sufficient processing and cleaning. Minimising energy use in conventional milk processing can lead to substantial savings in dairy manufacturing. In addition, this model can contribute to reducing the carbon footprint of milk which is a highly consumed product that has a significant global environmental impact.