

Phage attack of lactic acid bacteria: a dynamic predictive model

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Milk acidification is a key step in the cheese-making process. In the industry, bacteriophages can attack lactic acid bacteria (LAB), which are responsible for the conversion of lactose to lactic acid. In consequence, acidification can be reduced or even stopped, leading to a halt in the production and thus severe economic losses for cheese-makers. The goal of this study is to develop a dynamic mechanistic model to predict the dynamics of phage attack.

To build the model, acidification curves, i.e. pH measurements versus time, were generated for 96 different couples of initial LAB concentrations and phage titers.

A dynamic mechanistic model was then constructed and consisted of 6 ordinary differential equations for the state variables: lactose and lactic acid concentration, susceptible, infected, and dead LAB concentration, and phage titer. The model parameters were estimated by minimizing the squared discrepancies between observed data, on the one hand, and their expected values on the other. The model and its optimization were implemented using python.

The acidification data showed that normal acidification takes place when the LAB concentration is high and phage titer is low. When the LAB concentration decreases, the acidification is delayed. With high phage titers, acidification can be delayed, prematurely stopped or not take place at all.

The model was able to predict satisfactorily most of the cases. Parameters were estimated with a reasonable confidence interval. The model simulates time evolution of phage and bacteria concentrations which are not measured routinely.

The model succeeded in predicting most of the phenomena taking place in the experiment. Important parameters and behaviors were deduced from simple and low-cost acidification measurements. The model can be expanded to include different phages and bacteria species, and blends of both to mimic a typical cheese-making environment. The model can be used to raise awareness amongst cheese-makers on the importance of cleaning to avoid economic losses.