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Combined effects of temperature, pH and water activity on predictive ability of microbial kinetic inactivation model

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Abstract

It is well known that temperature is the key factor controlling the microbial survival/inactivation. However, the interactive effects of further stressing environmental conditions may influence microbial behaviour. The objective of this work was to include, in the inactivation model, temperature, pH and a_w effects using a black box polynomial model, aiming at accurate prediction. Data of *Listeria innocua* obtained within the temperature range of 52.5 and 65.0 °C, pH of 4.5, 6.0 and 7.5, and a_w of 0.95 and 0.99 were used for model assessment. The relations of such parameters with temperature, a_w and pH were assumed to be polynomials.

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Keywords: Maximum inactivation rate; shoulder parameter; tail; temperature, pH and water activity effects; polynomial functions.

1. Introduction

Temperature is the key factor controlling the survival/inactivation of bacteria. Nevertheless, other adverse factors such as low pH values and reduced water activity influence the microbial response. The study of main and combined effects of temperature, water activity, and pH on kinetic parameters is important for a complete process assessment and control. Several authors studied the influence of those effects per si on microbial behaviour. However, significant interactions between environmental factors are not commonly assessed. Besides the considerable attempt in modelling kinetic parameters as function of environmental influences, the predictive ability of the inactivation

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behaviour is scarcely assessed (and often compromised). One can ask "what is the sense of using so diverse secondary models (such as Arrhenius, Peleg, Ratkowsky type models) if deplorable predictions of microbial survival are observed when those models are merged?"

Polynomial models still receive considerable attention in describing such relations. The flexible behaviour, making possible the purely empirical but underlying relation between microbial kinetic parameters and environmental influences, makes polynomial modelling approaches a promising field, for an accurate prediction of the microbial survival.

The objective of this work was to include, in the inactivation model, temperature, pH and water activity effects using a black box polynomial model, aiming at accurate prediction. The relations of maximum inactivation rate (k_{max}) and shoulder (L) on environmental factors were purely empirical. The log variations of k_{max} and L on temperature were assumed to be polynomials. The pH and water activity effects were then included in those models. Tail [$\log(N_{res}/N_0)$] was assumed to be independent of temperature, but dependent on pH and water activity (this relation was also assumed to be polynomial). The predictive ability of the inactivation model, expressed in terms of all environmental factors, was assessed.

2. The models

Gompertz inspired model can be used to describe sigmoidal microbial inactivation, under isothermal conditions:

$$y_{inact}(t) = \log\left(\frac{N}{N_0}\right) = \log\left(\frac{N_{res}}{N_0}\right)\exp\left(-\exp\left(-\frac{k_{max}\,e}{\log\left(\frac{N_{res}}{N_0}\right)}(L-t)+1\right)\right) \tag{1}$$

herein, y_{inact} represents the microbial cell density: logarithm of the microbial load (N) at a certain process time (t), normalized to the initial content (N_0); L is the time parameter (or shoulder) and k_{max} the maximum inactivation rate; N_{res} is the residual microbial load.

The log variations of k_{max} and L on temperature, pH and water activity (a_w) can be described by polynomials:

$$\log(k_{max}) = \sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} G_{k_{max\,ijk}}\; a_w^{\,k}\; pH^j\; T^i \tag{2}$$

$$\log(L) = \sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} G_{L_{ijk}}\; a_w^{\,k}\; pH^j\; T^i \tag{3}$$

where n is the order of the polynomial to be assumed and G are polynomials coefficients (i=1,…, n; j=1,…, n; k=1,…, n).

Regarding the tail parameter ($\log(N_{res}/N_0)$), the dependence on pH and water activity can also be described by polynomials:

$$\log\left(\frac{N_{res}}{N_0}\right) = \sum_{i=0}^{n}\sum_{j=0}^{n} G_{Tail_{ij}}\; a_w^{\,k}\; pH^j \tag{4}$$

where n is the order of the polynomial to be assumed and G are polynomials coefficients (i=1,…, n; j=1,…, n).