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Predictions of microbial thermal inactivation in solid foods: isothermal and non-isothermal conditions

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Abstract

This work focuses on the use of the Gompertz-inspired model to predict the thermal inactivation behaviour of microorganisms obtained in solid food products, validated for isothermal and non-isothermal conditions. Experiments were carried out in parsley, artificially inoculated with *Listeria innocua*. For the isothermal conditions tested, the predictive ability of the model was confined. The higher the temperature, the higher deviations observed (i.e. the model underestimates the inactivation behaviour). However, for the non-isothermal condition tested, the model predicted the microbial response accurately.

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Keywords: Microbial inactivation; solid foods; isothermal and non-isothermal; experimental validation; Gompertz-inspired model.

1. Introduction

The selection of an appropriate mathematical model, as well as the identification and quantification of the relevant factors that affect microorganism inactivation, are two difficult tasks in predictive modelling. The majority of bacterial data relating heat treatments to thermal death kinetics are usually obtained in medium. The broths are inoculated with known concentrations of the target organism and placed in a controlled thermostatic environment. Samples are removed at given times and viable microbial cells are enumerated. A model that describes the kinetic behaviour is then selected and kinetic parameters are estimated on the basis of regression analysis procedures.

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However, when the microorganism is on a solid food surface, its kinetic response may be considerable different. Assumption that broth-data-based models are conservative, because of the ideal conditions, might not be valid. For inactivation, it is widely known that bacterial pathogens tend to be more resistant to heat in real food products than in broth-based media [1].

To assess the predictive ability of a model in pathogen inactivation is an important topic, since dangerous underestimations should be avoided. Mathematical models developed from data obtained in broth should be validated in "real" food systems, where there is wider influencing factors rather than the stressing conditions such as temperature, pH or water activity. The main objective of this work was to assess the use of Gompertz-inspired model expressed in terms of relevant factors (temperature, pH and water activity), developed on the basis of experiments carried out in broth, in predictions of *Listeria innocua* inactivation in parsley surface. Both isothermal and time-varying temperature conditions were considered.

2. Model description

2.1. Isothermal conditions

A Gompertz-inspired model that included the temperature, pH and water activity effects on shoulder, maximum inactivation rate and tail parameters (merging eqs. 2, 3 and 4 into the Gompertz-inspired model expressed by eq. 1) was used [1]:

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

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.

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

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

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).

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

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

The values of the parameters (coefficients of the polynomial equation) used in the simulation were the ones previously estimated considering inactivation experimental data of *L. innocua* obtained at different conditions in broth[2].