

# PREDICTING COMBINED EFFECTS OF TEMPERATURE, pH AND WATER ACTIVITY ON MICROBIAL INACTIVATION

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## OBJECTIVE

Include in the inactivation model, temperature, pH and water activity effects using a black box polynomial model, aiming at accurate prediction of *Listeria innocua* inactivation

## INTRODUCTION

It is well known that temperature is the key factor controlling the microbial survival/inactivation. However, the interactive effects of further stressing environmental conditions influence microbial inactivation behaviour. Water activity and pH are examples of environmental factors that greatly affect bacterial thermal resistance. A number of mathematical models have been proposed for describing the effects of those factors on microbial kinetics. However, the effect of possible interactions is not commonly assessed.

## MATHEMATICAL CONSIDERATIONS

### The model

The microbial inactivation model assumed was a Gompertz-inspired model:

$$Y_{inact}(t) = \log\left(\frac{N}{N_0}\right) = \log\left(\frac{N_{res}}{N_0}\right) \exp\left[-\exp\left(\frac{k_{max} \exp(1)}{\log\left(\frac{N_{res}}{N_0}\right)}(L-t) + 1\right)\right] \quad (1)$$

*N* - microbial load at time *t*; *N*<sub>0</sub> - initial microbial load; *N*<sub>res</sub> - Residual microbial load; *t* - time; *k*<sub>max</sub> - maximum inactivation rate; *L* - shoulder

The log variations of *k*<sub>max</sub> and *L* on temperature, pH and water activity (*a*<sub>w</sub>) can be described by polynomials:

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

$$\log(L) = \sum_{i=0}^n \sum_{j=0}^n \sum_{k=0}^n G_{Lijk} a_w^k pH^j T^i \quad (3)$$

where, *n* is the order of the polynomial to be assumed and 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:

$$\log\left(\frac{N_{res}}{N_0}\right) = \sum_{i=0}^n \sum_{j=0}^n G_{Tailij} a_w^k pH^j \quad (4)$$

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

## MATERIALS AND METHODS

- Experimental 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 water activity of 0.95 and 0.99, were used for model assessment (Miller et al., 2009).
- Secondary models, that express the relations of kinetic parameters on environmental conditions, were purely empirical.
- Model parameters were estimated by non-linear regression analysis, using a flexible black box modelling approach.
- The log variations of *k*<sub>max</sub> and *L* on temperature were assumed to be polynomials:

$$\log(k_{max}) = G_{k_{max}T3} T^3 + G_{k_{max}T2} T^2 + G_{k_{max}T1} T + G_{k_{max}T0} \quad (5)$$

$$\log(L) = G_{LT3} T^3 + G_{LT2} T^2 + G_{LT1} T + G_{LT0} \quad (6)$$

The pH and water activity effects were then included in those models. This relation was also assumed to be polynomial:

$$G_{k_{max}Tj} = G_{k_{max}TjPH2} pH^2 + G_{k_{max}TjPH1} pH + G_{k_{max}TjPH0} \quad (7)$$

$$G_{LTj} = G_{LTjPH2} pH^2 + G_{LTjPH1} pH + G_{LTjPH0} \quad (8)$$

The tail ( $\log(N_{res}/N_0)$ ) was assumed to be independent on temperature, but dependent on pH and water activity.

The variation of tail parameters on pH was also assumed to be secondary-order polynomial:

$$\log\left(\frac{N_{res}}{N_0}\right) = G_{TailpH2} pH^2 + G_{TailpH1} pH + G_{TailpH0} \quad (9)$$

The variations of polynomial parameters on water activity were assumed to be first-order polynomials:

$$G_{k_{max}TjPHj} = G_{k_{max}TjPHjaw1} a_w + G_{k_{max}TjPHjaw0} \quad (10)$$

$$G_{LTjPHj} = G_{LTjPHjaw1} a_w + G_{LTjPHjaw0} \quad (11)$$

$$G_{TailpHj} = G_{TailpHjaw1} a_w + G_{TailpHjaw0} \quad (12)$$

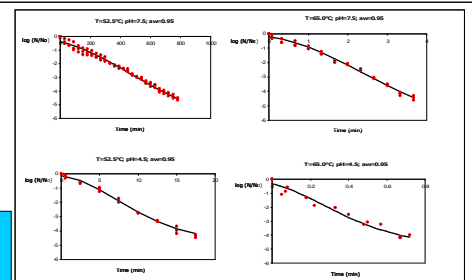
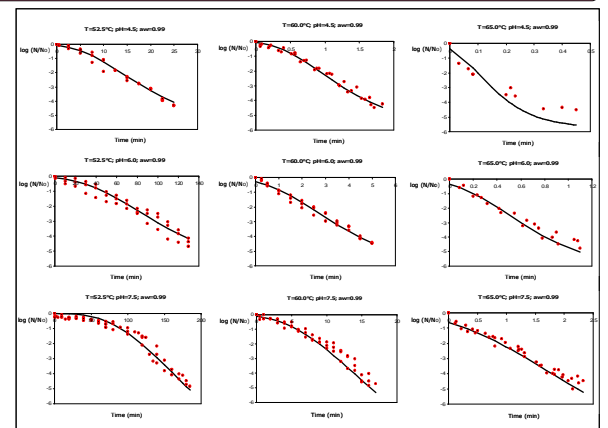
## PREDICTIVE ABILITY OF THE INACTIVATION MODEL

(expressed in terms of temperature, pH and water activity)

To predict the inactivation behaviour, a combined model including the main and combined effects of environmental factors (merging eqs.2, 3 and 4 into the Gompertz-inspired model) was used.

Assuming given parameters, simulated values of microbial load were calculated and are presented in Figure:

Inactivation model predictions (continuous black line) of experimental inactivation data of *Listeria innocua* (black dots)



## CONCLUSIONS

The model predicts successfully the inactivation kinetics (accurate predictions were observed).

This is certainly a contribution to design more efficient thermal inactivation processes with controlled influence of the stressing environmental factors.

## REFERENCES

Miller, F.A., Ramos, B.F., Gil, M.M., Brandão, T.R.S., Teixeira, P. and Silva, C.L.M. 2009. Influence of pH, type of acid and recovery media on the thermal inactivation of *Listeria innocua*. International Journal of Food Microbiology (submitted).

