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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:

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

model parameters

N - microbial load at time t; No – initial microbial load; Nres – Residual microbial load; t – time; k_{max} – maximum inactivation rate; L - shoulder

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

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

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

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(Nres/N0)), the dependence on pH and water activity can also be described by polynomials:

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

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_{max} and L on temperature were assumed to be polynomials:

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

$$\log(L) = G_{L_{T3}}\, T^3 + G_{L_{T2}}\, T^2 + G_{L_{T1}}\, T + G_{L_{T0}} \quad (6)$$

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

$$G_{k\,max_{Ti}} = G_{k\,max_{TipH2}}\, pH^2 + G_{k\,max_{TipH1}}\, pH + G_{k\,max_{TipH0}} \quad (7)$$

$$G_{L_{Ti}} = G_{L_{TipH2}}\, pH^2 + G_{L_{TipH1}}\, pH + G_{L_{TipH0}} \quad (8)$$

The tail (log(Nres/N0)) 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:

$$\log\left(\frac{N_{res}}{N_0}\right) = G_{Tail_{pH2}}\, pH^2 + G_{Tail_{pH1}}\, pH + G_{Tail_{pH0}} \quad (9)$$

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

$$G_{k\,max_{TipHj}} = G_{k\,max_{TipHjaw1}}\, a_w + G_{k\,max_{TipHjaw0}} \quad (10)$$

$$G_{L_{TipHj}} = G_{L_{TipHjaw1}}\, a_w + G_{L_{TipHjaw0}} \quad (11)$$

$$G_{Tail_{pHj}} = G_{Tail_{pHjaw1}}\, a_w + G_{Tail_{pHjaw0}} \quad (12)$$

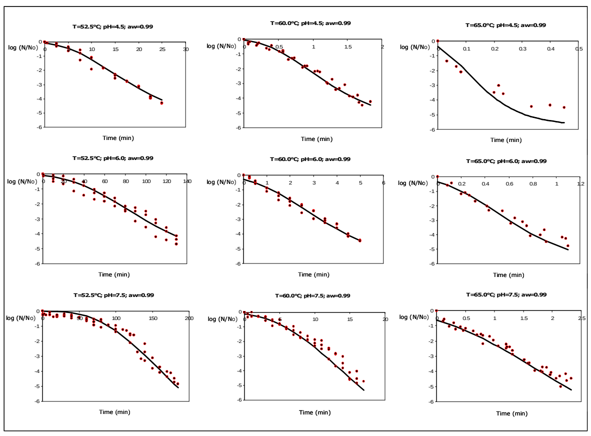
PREDICTIVE ABILITY OF THE INACTIVATION MODEL

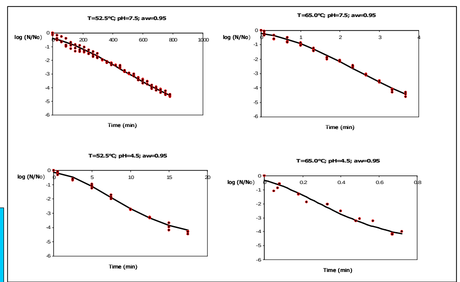
(expressed in terms of temperature, pH and water activity)

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. 2009c. Influence of pH, type of acid and recovery media on the thermal inactivation of *Listeria innocua*. International Journal of Food Microbiology (submitted).

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