MATHEMATICAL MODELS TO PREDICT THERMAL INACTIVATION KINETICS OF *Listeria innocua* 10528

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OBJECTIVES

Modelling inactivation kinetics of *Listeria innocua* 10528 in broth.

Study of the parameters temperature dependence.

INTRODUCTION

Food poisoning by pathogens directly affects human health and safety. Heat treatments are the most common and effective procedures for controlling the survival of microorganisms in food, and should be designed to provide an adequate safety margin against food-borne pathogens. The development of accurate and precise models, able to predict the behaviour of microorganisms populations, under specific environmental conditions, is of major importance to the food process industries for the development of new systems.

METHODOLOGY

➢**Two-steps regression procedure**

The Gompertz model was fitted to inactivation data, obtained separately at different temperatures

Equations 1 to 4 were used to describe the dependence of the kinetic parameters (k_{max}, L) on temperature

➢**One-step regression procedure**

Equations related with the temperature dependence of k_{max} and L were incorporated into the Gompertz, model and a global regression analysis was performed using all the isothermal data.

MATHEMATICAL MODELS

Square-root model (1)

$$\sqrt{k_{max}} = \sqrt{c}\,(T - d)$$

c, d constants

Arrhenius type equation (2)

$$k_{max} = k_{ref}\exp\left(-\frac{E_a}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right)$$

k_{ref} rate constant at T_{ref}

E_a activation energy

T_{ref} = 333 K

Gompertz modified model

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

Williams-Landel-Ferry model (3)

$$L = 10^{\left(\frac{a(T - T_{min})}{b + (T - T_{min})}\right)}$$

T_{min} = 310 K

a, b constants

Arrhenius type equation (4)

$$L = a\exp\left(b\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right)$$

T_{ref} = 333 K

Where:

N population size (CFU/unit volume)

N_o inicial population size = 1×10^7 CFU/unit volume

N_{res} residual population size = 100 CFU/unit volume

t processing time (s)

T temperatura (K)

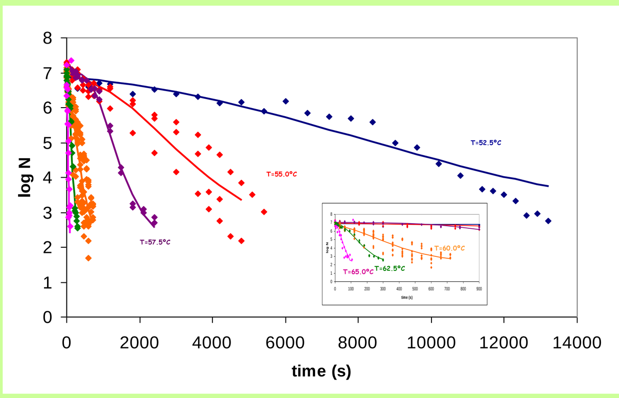
L lag time (s)

k_{max} reaction rate (s^{-1})

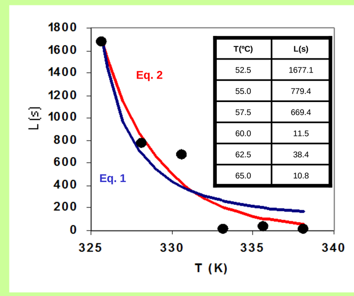
CASE STUDY

Inactivation data of *L. innocua* obtained in liquid medium at 52.5, 55, 57.5, 60, 62.5 and 65ºC (Miller *et al*. 2003)

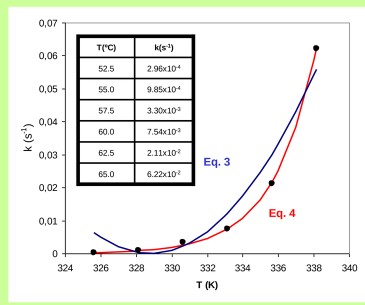
Gompertz



Two-step



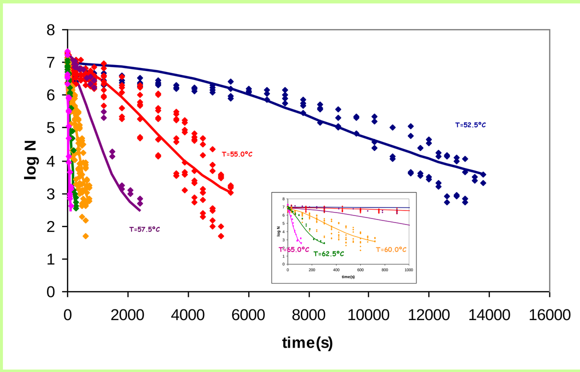
L= f(T)



k_{max}= f(T)

Equations 2 and 4 selected

One-step



Parameters estimation and relevant statistical data

Two-step regression procedure

k_{max}

Model	Parameters estimates				Regression analysis		
	k_{ref} or c (s^{-1}) or ($s^{-1}K^{-2}$)	E_a or d ($Jmol^{-1}$) or (K)	$SHW_{95\%}$ of k_{ref} or c	$SHW_{95\%}$ of E_a or d	R^2_{adj}	SSR/(n-p)	Randomness of residuals
Arrhenius	7.342×10^{-3}	3.998×10^{5}	20.21	9.940	0.9996	2.400×10^{-7}	✓
Square-Root	6.388×10^{-4}	3.288×10^{2}	138.6	1.654	0.9222	4.455×10^{-6}	✓

L

Model	Parameters estimates				Regression analysis		
	a (s)	b (K)	$SHW_{95\%}$ of a	$SHW_{95\%}$ of b	R^2_{adj}	SSR/(n-p)	Randomness of residuals
Arrhenius	2.192×10^{2}	3.007×10^{4}	195.2	104.6	0.9350	2.830×10^{4}	✓
WLF	1.593	-7.941	73.2	74.0	0.8815	5.163×10^{4}	✓

Statistica ® 6.0

One-step regression procedure

Model	Parameters estimates								Regression analysis		
	k_{max} (s^{-1})				L (s)						
	k_{ref}	Ea	$SHW_{95\%}$ of k_{ref}	$SHW_{95\%}$ of Ea	a	b	$SHW_{95\%}$ of a	$SHW_{95\%}$ of b	R^2_{adj}	SSR/(n-p)	Randomness
Arrhenius	7.616×10^{-3}	3.727×10^{5}	1.182×10^{-1}	5.999×10^{-2}	4.610×10^{1}	6.134×10^{4}	8.113×10^{-1}	2.139×10^{-1}	0.8616	0.3077	✓

$SHW_{95\%}$ standardised half width at 95% $= \frac{\text{half confidence interval at 95\%}}{\text{parameter estimate}}$

SSR sum of squares of residuals

n # experimental points

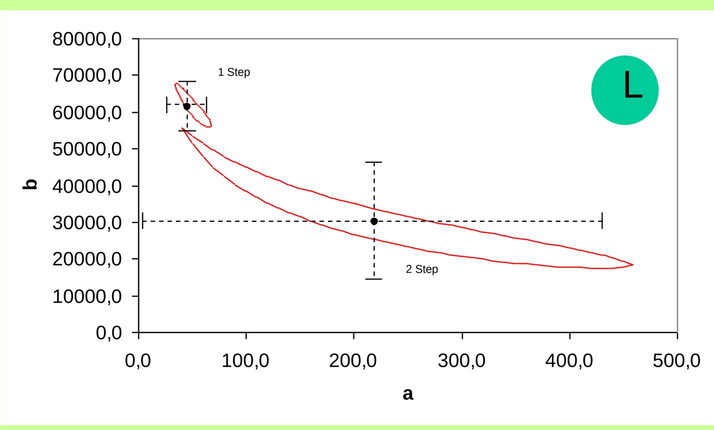
p # model parameters

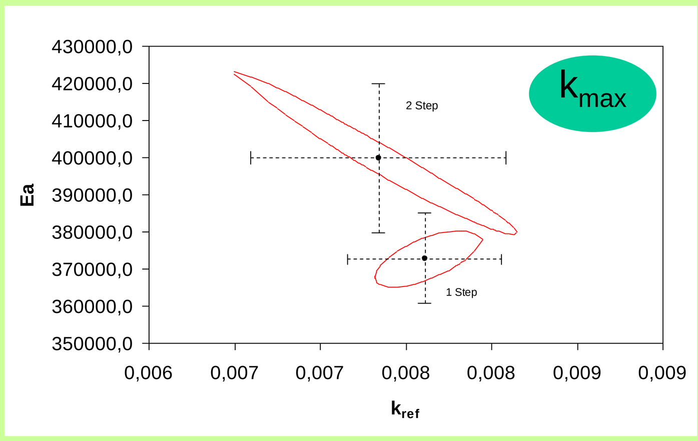
The criteria used, to conclude about the best models, were the quality of the residuals, the value of R^2_{adj} and the precision of the estimates (evaluated by SHW at 95%)

The **Arrhenius equation** describes better the dependence of $\mathbf{k_{max}}$ on temperature, as well as the dependence of L on temperature

These models were used in 1-step regression procedure

Joint confidence regions of the estimates at 90%





The dashed lines are the confidence intervals at 95%

CONCLUSIONS

➢The global fit improved parameters estimation, as expected ➡ narrow confidence intervals

➢Nevertheless, the two different regression procedures lead to different parameters estimates, as observed by the contours of the joint confidence regions

REFERENCES

Miller, F. A., Brandão, T. R. S., Teixeira, P. and Silva, C. L. M. (2003). Heat resistance of *Listeria innocua* in liquid medium as affected by the culture growth phase. Poster presented at: Biotec' 2003 (X Congresso Nacional de Biotecnologia), Lisboa - Algés, Portugal, 6-8 December

T(ºC)	**L(s)**
52.5	1677.1
55.0	779.4
57.5	669.4
60.0	11.5
62.5	38.4
65.0	10.8