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Thermal inactivation kinetics of *Salmonella enterica* and *Listeria monocytogenes* are practically similar

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Objectives

The variability of thermal inactivation kinetics can be estimated in a meta-model based on literature data (Van Asselt & Zwietering, 2006). Differences in product and processing conditions, however, are known to cause large variability. The right adjustments result in a balance between food safety and other quality variables. The hypothesis of this study was that there is little or no difference in kinetics between the unrelated species *Salmonella enterica* (SE, Gram⁻) and *Listeria monocytogenes* (LM, Gram⁺). The practical objective was to develop a model that includes the full uncertainty of variables that are not under control (e.g. the strain) while adjusting for the effects of experimental conditions and product variables that are either absent in practice or possible to control.

Methods

The linear relation between logD (log_{10} minutes to 10-fold inactivation) and temperature was evaluated in a single regression model as well as multiple regression models (Van Lieverloo *et al.*, 2013a, 2013b), taking into account variables affecting the heat resistance reported in 72 publications from 1968 to 2012 resulting in 1321 data sets (liquids): 521 SE (26 serovars), 810 LM (51 strains). Water activity and other data missing from publications were estimated from other papers. Interactions of genus (SE vs. LM) with the other variables were tested among a large number of other interaction terms.

Results

Single regression analysis of logD vs. temperature) showed high variability for SE, severe non-constant variance and large differences between SE (R^2 = 0.003) and LM (R^2 = 0.72) (***Figure 1A***). The bare SE model is useless (z_{temp} = 160 °C) and using the bare LM model (z_{temp} = 6.7 °C) under all circumstances would lead to overestimation of heating required due to the large residual variance (standard error = 0.471).

Multiple regression analysis (combined and for SE and LM individually) showed considerable effects of composition (pH, water activity, as well as sugar) (***Table 1***). These model adjustments greatly increase the variance explained (R^2 = 0,79) and therefore reduce temperatures or holding times required for food safety, e.g. during pasteurisation of milk (***Figure 1B***).
The regression analyses in this study were limited to the variables having the largest influence on variance, although including other variables is known to further limit variance (Van Lieverloo, 2013a, 2013b).

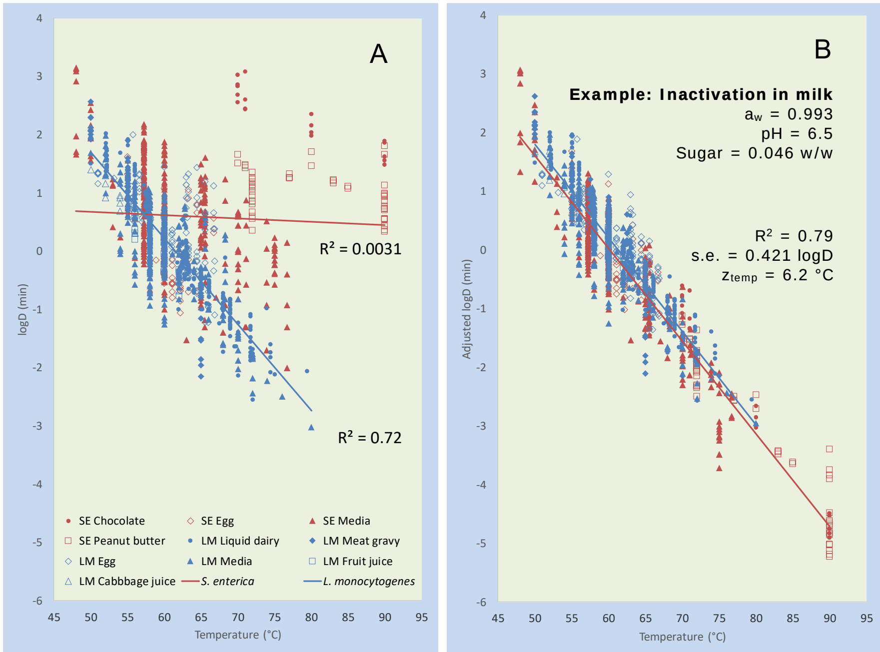

Figure 1 Regression models of logD vs. temperature. A: Single regression (varying conditions). B: Partial regression of logD vs. temperature simulated for milk where logD is adjusted for effects of other conditions by multiple regression analysis (see Table 1).

Table 1 Variables and their coefficients of the multiple regression models (all p < 0.001)

Parameter	Regression coefficients per model		
	Both (s.e.)	***LM***	***SE***
R^2 (adjusted)	0.79	0.83	0.73
Standard error (log D)	0.421	0.371	0.458
Constant (logD)	10,9 (2,49)	18,0	10,5
Heating conditions			
Temperature (°C)	-0,161 (0,0346)	-0,157	-0,158
z_{Temp}	6,23	6,38	5,90
Heating menstruum			
Water activity (a_w)	-33,3 (7,11)	-9,48	-33,6
Water activity $(a_w)^2$	31,5 (4,77)		32,3
pH	0,120 (0,0119)	0,145	0,155
Sugar fraction (w/w)	1,16 (0,0749)		1,50
Interaction terms			
Temp.a_w	0,561 (0,103)		0,561
Temp.a_w^2	-0,564 (0,0705)		-0,577

Similarity between LM and SE
The coefficients of temperature and pH of the three models are practically similar (***Table 1***), although on average SE is less resistant (-0.3 logD). The effects of a_w and sugar are different due to a limitation of investigated experimental conditions for LM.

Discussion

Over four decades of world wide research results in an unbalanced data set that warrants causion during analysis, formally just enabling the formulation of hypothesis. The analysis confirms known effects of a_w and pH. This study however also suggests that thermal inactivation kinetics of the unrelated LM and SE are similar.

References

The 72 data papers (1968-2012) are not listed.
Van Asselt & Zwietering (2006) Int. J. Food Microbiol. 107: 73 – 82.
Van Lieverloo *et al.* (2013a) Food Control 29: 394 – 400 (on *Listeria monocytogenes*).
Van Lieverloo *et al.* (2013b) Int. Conf. Predictive Modeling in Foods 8, Paris (on *Salmonella*).

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Conclusions and impact

- *Salmonella* and *Listeria monocytogenes* have practically similar heat resistances.
- Z-factors for temperature, a_w, pH and sugar (including variance) support optimal heating designs, reducing energy costs and improving nutritional value and taste.
- Validation remains necessary for specific applications.

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