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NEW TERM FOR EFFECT OF TEMPERATURE ON pH_{min}-VALUES IN CARDINAL PARAMETER GROWTH MODELS FOR LISTERIA MONOCYTOGENES

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Cardinal parameter models for growth and growth boundary of L. monocytogenes (CPM-Lm) are popular, extensively validated and widely used for various foods in the assessment and management of risk. Interestingly, available CPM-Lm includes very different pH_{min}-values from 4.3 to 5.0. This can be due to differences in the mathematical terms used to estimate pH_{min}-values and to strain variability as often suggested. However, the experimental conditions used to estimate pH_{min}-values remain little studied although the minimal pH-values supporting growth is known to depend on other environmental conditions including temperature. Therefore, the objective was to study the influence of temperature on pH_{min}-values of L. monocytogenes as used in CPM-Lm.

The combined effect of temperature and pH on maximum specific growth rate (\(\mu_{\text{max}}\)) for eight different L. monocytogenes strains were determined experimentally by using Bioscreen C or collected from the literature (287 \(\mu_{\text{max}}\)-values). 16 pH-values from 4.4 to 6.8 and eight temperatures from 5°C to 37°C were studied. At each temperature the pH_{\text{min}}-value was estimated by fitting a simple pH_{\text{min}}-model (AEM, 63, 2355-2360, 1997). pH_{\text{min}}-values decreased from 5.0 at 5°C to 4.3 at 20°C and then increased to 4.7 at 37°C. These changes in pH_{\text{min}}-values has major influence on predictions from CPM-Lm, particularly for products with low pH values of less than about 5 and a new pH_{\text{min}}-model to describe the influence of temperature on pH_{\text{min}}-values in CPM-Lm was developed as shown below.

\[0^\circ C \leq T < T_{\text{ref}} \quad pH_{\text{min}}^T = pH_{\text{min}}^0 - T \left( \frac{pH_{\text{min}}^0 - pH_{\text{min}}^R}{T_{\text{ref}}} \right)\]

\[T_{\text{ref}} < T < 37^\circ C \quad pH_{\text{min}}^T = pH_{\text{min}}^R + (T - T_{\text{ref}}) \left( \frac{pH_{\text{min}}_{37^\circ C} - pH_{\text{min}}^R}{37 - T_{\text{ref}}} \right)\]

where \(T\) is the storage temperature (°C); \(pH_{\text{min}}^T\) the fitted \(pH_{\text{min}}\)-value at \(T\)°C; \(T_{\text{ref}}\) the estimated reference temperature (°C); \(pH_{\text{min}}^0\) and \(pH_{\text{min}}^R\) the fitted \(pH_{\text{min}}\)-values at 0°C and \(T_{\text{ref}}\) (°C), respectively.

The fixed \(pH_{\text{min}}\)-value from an existing CPM-Lm including 12 environmental parameters (IJFM, 141, 137-150, 2010) was substituted by the new \(pH_{\text{min}}\)-model and the model performance has been evaluated for 33 growth/no growth responses of L. monocytogenes in a well characterized food with pH below 5.

Average bias and accuracy factor values were 1.16 and 1.27 for 30 growth curves at constant temperatures. The new \(pH_{\text{min}}\)-model can estimate the \(pH_{\text{min}}\)-value for L. monocytogenes based on temperature storage conditions and this markedly extend the limit of applicability of the existing CPM-Lm from pH 5.6 to pH 4.4.