Application of a validated predictive model to prevent growth of *Listeria monocytogenes* in readyto-eat foods – importance for product development and risk management

8th May 2010, ISOPOL XVII, Porto, Portugal

Ole Mejlholm and Paw Dalgaard



DTU

DTU Food National Food Institute

- Growth and growth boundary model for L. monocytogenes (Mejlholm and Dalgaard, 2009)
 - Temperature
 - pH
 - NaCl/water activity
 - Smoke components (phenol)
 - Nitrite
 - CO₂
 - Acetic acid
 - Benzoic acid
 - Citric acid
 - Diacetate
 - Lactic acid
 - Sorbic acid
 - Interactions between all these parameters

| $\mu_{\max} = \mu_{ref} \cdot \left[\frac{(T - T_{\min})}{T_{ref} - T_{\min}} \right]^2 \cdot \frac{(a_w - a_{w\min})}{(a_{wopt} - a_{w\min})} \cdot \left[1 - 10^{(pH_{\min} - pH)} \right] \cdot \left(1 - \frac{[LAC_U]}{[MIC_{Ulactic acid}]} \right) \cdot \frac{(P_{\max} - P)}{P_{\max}}$ |
|---|
| $ \cdot \left[\frac{(NIT_{\max} - NIT)}{NIT_{\max}}\right]^{2} \cdot \frac{(CO_{2\max} - CO_{2equilibrium})}{CO_{2\max}} \cdot \left(1 - \sqrt{\frac{[DAC_{U}]}{[MIC_{U}diacetate}]}\right) \cdot \left(1 - \sqrt{\frac{[AAC_{U}]}{[MIC_{U}acetic acid}]}\right)$ |
| $ \cdot \left(1 - \frac{[BAC_U]}{[MIC_{U \ benzoic \ acid}]}\right) \cdot \left(1 - \frac{[CAC_U]}{[MIC_{U \ cliric \ acid}]}\right) \cdot \left(1 - \frac{[SAC_U]}{[MIC_{U \ sorbic \ acid}]}\right) \cdot \xi $ |

12 parameters



• Developed and validated for lightly preserved seafood



 Incorporated in the Seafood Spoilage and Safety Predictor (SSSP) program version 3.1 (<u>http://sssp.dtuaqua.dk/</u>)







Product characteristics and storage conditions

- Temperature: 5 °C
- NaCl in the water phase: 3 %
- pH: 6.0
- Smoke components: **10 ppm phenol**
- CO₂: 25 % in the package at equilibrium
- Lactic acid in the water phase: 8000 ppm

| 🔀 Listeria monocytogenes growth model | | | | | | | | |
|---|----------------------|---|---------------------|------------------|-------------|--|--|--|
| ! 🖂 🔚 🕱 📀 🔷 🔈 | | | | ۰F | | | | |
| Product characteristics Broduct | 1 Product 2 | - Organic acids in water phase of product | | | | | | |
| I monocytogenes initial cell level (cfu/g) | 1 Product 2 | organic acids in water priase or product | Product 1 Product 2 | | | | | |
| Tanaanka (C) 5 | 0 50 | Acetic acid (ppm) | | | | | | |
| NaClin water alters % | 0 30 | Benzoic acid (ppm) | | | | | | |
| NaLl in water phase % | | Citric acid (ppm) | | | | | | |
| pH 0 | 0 8.0 | Diacetate (ppm) | 0 🖬 0 | | | | | |
| Smoke components - phenol(ppm) | 0 10 | Lactic acid (nom) | 8000 | | | | | |
| % CO2 in headspace gas at equilibrium | 5 🔠 25 | Cashia anid (ana) | | | | | | |
| Nitrite, mg/kg | 0 0 | Sorbic acid (ppm) | | | | | | |
| Storage period (d) 3 | 0 | Apply | Clear | | | | | |
| Include lag time for L. monocytogenes | | | | | | | | |
| Constant temperature Series of constant temperatures | Temperature profiles | rom logger data | | | | | | |
| Growth rate, lag time and growth boundary parameter (| osi) | Time for 100-fold increase (c | 0 | | | | | |
| µmax (1/h) lag time (d | 0 Psi (Ψ) | L. monocytogenes (d) | | | | | | |
| Product 1 0.0085 | 0 0.5313 | 22.04 | | | | | | |
| Product 2 0.0003 | 0 0.01 | 22.04 | | | | | | |
| Predicted growth of L. monocytogenes | | | | | | | | |
| | E 🗸 🗡 | | | | | | | |
| 8.18 | | | | | | | | |
| Pci | $(u_{1}) =$ | ± 0 59 | | | | | | |
| 7.36 | (ψ) - | | | | | | | |
| | | | | | | | | |
| 6.65 | | | | | | | | |
| | 1 | | | | | | | |
| 5.7.3 | | | | | | | | |
| C 491 | | | | | | | | |
| 8 | 1 | | | | | | | |
| ي ق 4.09 | | | | | | | | |
| | | | | | | | | |
| 3.27 | + | | | + | | | | |
| | | | | | | | | |
| 2.45 | + | | | + | | | | |
| | 1 | | | | | | | |
| 1.64 | + | | | | | | | |
| | | | | | | | | |
| 0.62 | | | | | | | | |
| 0.00 | 1 | | | | | | | |
| 0.00 2.73 6 | .45 8 | 18 10.91 1 | 3.64 10.36 1 | 9.09 21.82 24.55 | 27.27 30.00 | | | |
| Storage period (days) | | | | | | | | |
| Product 1 - L. monocytogenes Product 2 - L. monocytogenes | | | | | | | | |
| Time (d): I Lm (Log cfu/g) - product 1: Lm (Log cfu/g) - product 2: | | | | | | | | |

Cold-smoked salmon





DTU

 Ξ



Developed and validated for lightly preserved seafood



- Incorporated in the Seafood Spoilage and Safety Predictor (SSSP) program version 3.1 (<u>http://sssp.dtuaqua.dk/</u>)
- Recently the performance of the model has been evaluated for more than 1000 sets of data from different types of ready-to-eat food¹



• Largest validation study conducted for *Listeria* models

¹Accepted for publication in International Journal of Food Microbiology



| | Number of growth responses for L. monocytogenes | | | | | |
|----------|---|--------|-----------|--|--|--|
| Products | Total | Growth | No-growth | | | |
| Meat | 702 | 442 | 260 | | | |
| Seafood | 193 | 160 | 33 | | | |
| Poultry | 64 | 50 | 14 | | | |
| Dairy | 55 | 55 | 0 | | | |
| | 1014 | 707 | 307 | | | |

Collected from 37 independent sources (published and unpublished data)

- More than 20 different types of products
- More than 100 different isolates of *L. monocytogenes*



Evaluation of *Listeria* model – growth rate







 89 % of the evaluated growth/no-growth responses were correctly predicted (908 out of 1014) – the remaining 106 products were:



DTU

Evaluation of Listeria model





Evaluation of Listeria model









- A psi-value of 2.0 can be used as a conservative measure of the "safe boundary"
- Takes variability of product characteristics and storage conditions into account

| Product | Temp. (° C) | NaCl (%) | pН | Phenol (ppm) | CO ₂ (%) | Acetic acid (ppm) | Lactic acid (ppm) | psi-value |
|---------|----------------|-------------|-----|-----------------|------------------------|----------------------|----------------------|-----------|
| А | 5 | 3.0 | 6.0 | 10 | 25 | 0 | 8000 | 0.59 |
| В | 5 | 3.0 | 5.9 | 10 | 25 | 3000 | 15000 | 2.0 |

Application of *Listeria* model









Application of *Listeria* model









Conclusions



- Most extensive and best validated model available for *L. monocytogenes*
- Successfully validated for meat, seafood, poultry and dairy products → thus, product specific models are not necessarily needed
- Predicts both growth rates and the growth boundary more accurately than other available models for *L. monocytogenes*
- Can be used for e.g. product development and risk management of readyto-eat foods
- A conservative measure of the "safety boundary" for ready-to-eat foods is suggested based on data from more than 1000 products
- Takes variability of product characteristics and storage conditions into account – simple and practical alternative to stochastic models (not yet available with a sufficient number of environmental parameters)