Design of Carvacrol-Based Active Packaging for Extending Fresh Fish Shelf-life

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Motivation

- Design of active packaging

![Diagram showing packaging with Carvacrol and Listeria](image)
Motivation

• Design of active packaging

Objectives

– to extend shelf-life:

Use by Food Safety

Best Before Quality
Motivation

• Design of active packaging

- to extend shelf-life:
  - Carvacrol (antimicrobial substance)
  - Listeria (pathogen)

- Smart labels (smart sensor) ➔ update of shelf life

Objectives

Use by Food Safety

Best Before Quality

Shelf life date

Abusive temperature

Time
Motivation

- Design of active packaging

To extend shelf-life:

- Smart labels (smart sensor) ➔ update of shelf life

OBJECTIVES

- Use by Food Safety
- Best Before Quality

Modelling

- Predictive microbiology
- Biochemical dynamics
- Mass transfer (diffusion) and optimization
maximize
\[ t_f, L_i, C_{i,0} \]
subject to
Use-by date \( t_f \)
Safety requirements,
Design constraints.
Fish Safety Requirements ➔ Predictive microbiology

- **Listeria concentration at final time ≤ 2 logs**
  - Assumed exponential growth
    \[
    \frac{d \log_{10} L_m}{dt} = \mu^* \gamma_T \gamma_C
    \]
  - Velocity depends on the temperature following (Rosso et al 1995)
    \[
    \gamma_T = \frac{(T - T_-)(T - T_-)^2}{(T_+ - T_-)[(T_+ - T_-)(T - T_+) - (T_+ - T_-)(T_+ + T_- - 2T)]}
    \]
  - Inhibition by carvacrol using the square root model (Dalgaard, 1995)
    \[
    \gamma_C = \begin{cases} 
      \left(1 - \frac{C_f}{MIC}\right)^2, & C_f < MIC \\
      0, & C_f \geq MIC 
    \end{cases}
    \]
Design Constraints ➔ Packaging modelling

Packaging constraints

- Concentration of carvacrol in the food at all times $C_f(t) \leq 0.03$ kg/m$^3$.
- Thickness of each layer: $12 \times 10^{-6}$ μm $\leq L_i \leq 70 \times 10^{-6}$ μm.
- Total thickness of the active packaging $35 \times 10^{-6}$ μm $\leq L \leq 70 \times 10^{-6}$ μm.
- Initial concentration of carvacrol in each layer $C_{i,0} \leq 80$ kg/m$^3$.

➔ Partial differential equations (PDEs) modelling the spatial distribution of carvacrol on package and food matrix
Active packaging design to extend use-by date

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<th>Layer configuration</th>
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Best Before Quality

\[
\begin{align*}
\text{maximize} & \quad t_f,L_i,C_{i,0} \\
\text{subject to} & \quad \text{Best-before date } (t_f) \\
& \quad \text{Quality requirements,} \\
& \quad \text{Safety requirements,} \\
& \quad \text{Design constraints.}
\end{align*}
\]
Fish Quality Requirements

- **k-quality index**

\[
K_i(\%) = \frac{[\text{Ino}] + [\text{Hx}]}{[\text{IMP}] + [\text{Ino}] + [\text{Hx}]} \times 100
\]

- To develop a mathematical model describing early quality losses in hake including:
  - Enzymatic degradation model
  - Bacterial growth model
  - Mass diffusion through the food matrix (leaching)

A mathematical model to predict early quality attributes in hake during storage at low temperature

C. Vilas, A.A. Alonso, J.R. Herrera, M. Bernaldez, M.R. Garcia
Active packaging to extend use-by and best-before date

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Active packaging to extend use-by and best-before date.
Effect of transport/storage temperature on shelf-life

(a) Temperature vs. Time

(b) % Value vs. Time
Smart label/sensor ➔ Consumers industry 4.0
Conclusions

• Tool to optimally design active packaging to extend shelf combining predictive microbiology and diffusion models of active packaging

• Study the effect of transport/storage on shelf life date using active packaging

• Details about software and general methodology:
  – Vilas, Mauricio-Iglesias, García «Model-based design of smart active packaging systems with antimicrobial activity»

submitted to Food Packaging and Shelf Life
Acknowledgments

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http://resistance.iim.csic.es/

CoPro project, No 723575 (H2020)

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