Modelling microbial spoilage as the bases to predict fish quality indexes

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Outline

Problem:
- Fish wastage and market prices highly depend on accurate and reliable predictions of product shelf-life and quality.

Current approach Established sensory methods used in the market to monitor fish quality
- QIM (Quality Index Method)
- SQM (EU grading criteria for white fish, Council Regulation(EC) No 2406/96, 1996)

Drawbacks
- QIM and SQM require the consultation of a panel of trained experts
- They refer exclusively to the current state of the fish without any prediction in the following days.

Objective:
- To develop a smart quality sensor to measure quality and to predict its progress through time.
- The sensor uses information of biochemical and microbial spoilage when fish arrives to the market to predict shelf life and quality in terms of the QIM and EU grading criteria.
- Besides, the sensor can account for the variability inside the batch if spoilage indexes are measured in more than one fish sample.

Previous studies: Quality in retail fresh Hake under temperature variations (García et. al 2015).

Case study:
- Quality in fresh cod (*Gadus mordua*) under commercial ice storage conditions.

SMART SENSOR DESIGN

Input

Spoilage indexes at t=0
- Psychrotrohic counts
- Total volatile base-nitrogen (TVB-N)

Model

Sensor engineering
- Dynamic non-linear **model selection**
- **Model calibration**
- **Model validation**

Output

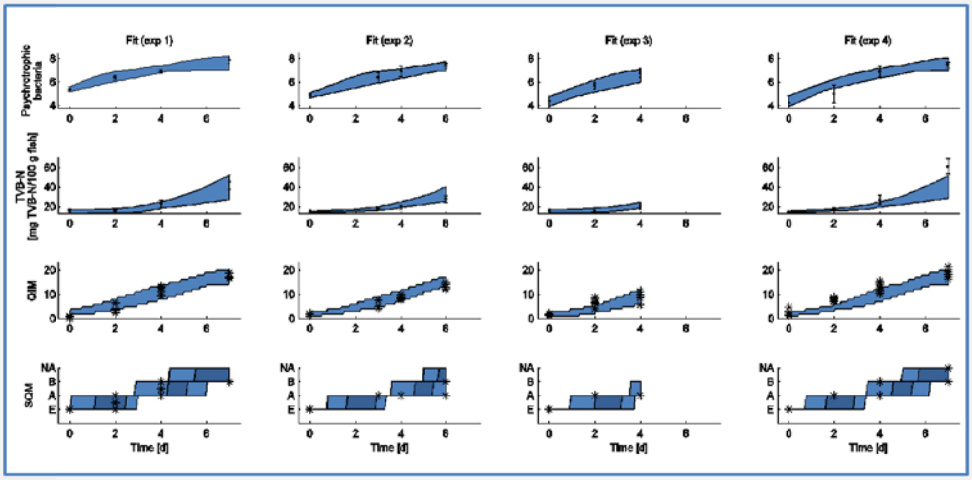
Quality indexes for t>0
- Quality index method (QIM)
- EU Standard Quality method (SQM)
- Shelf life

Methods

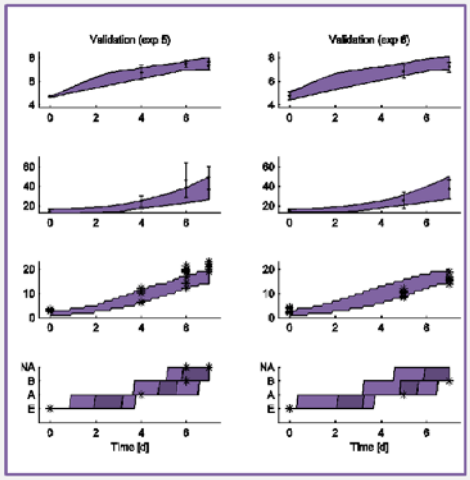
Experimental methods
- Fish handling and storage conditions.
  - 110 gutted fresh cod (*Gadus mordua*) 1.5-2kg/each
  - Purchased in 6 different days (6 experiments)
  - Ice and stored at 2-3 ºC
- Total volative base nitrogen
  - Method Lücke & Geigel (1935).
- Sensory analysis (QIM, SQM)
  - 6 trained assessors evaluated fish freshness
- Microbial analysis (QIM, SQM)
  - 25±1g of fish muscle was homogenized in 100 mL of peptone water for 30 s in a stomacher
  - Homogenates were ten-fold serially diluted in peptone Aliquots (0.1 mL) of adequate dilutions were spread on plate count agar and psychrotrophic bacteria was counted after incubation at 17 ºC for 3-5 days

Numerical methods using the toolbox AMIGO (Balsa-Canto & Banga, 2011).
- Parameter estimations and confidence
- State confidence (confidence for variables, green colored regions)
- Core predictions (confidence for predictions, violet colored regions)

Model calibration



Model validation



Model selection

- **Psychrotrophic counts** Baranyi growth model in log-scale (m=log(cfu/g))

$$\frac{dm(t)}{dt} = \mu(1 - 10^{m(t)-m^*})$$

- **TVB-N** Exponential growth dependent on psychrotrophic bacteria with dwell

$$\frac{dN(t)}{dt} = k\,a(t)\,m(t)$$

$$a(t) = \frac{a_0}{a_0 + (1-a_0)\exp(-k\,t)}$$

- **QIM** Perpectron model (Simplest ANN)

$$QIM = \text{nint}\left(23\frac{1}{1+\exp(-\alpha\, m - \beta\, N - \gamma)}\right)$$

- **SQM**. QIM-SQM correlation. E= extra, A=good, B=fair, NA=unfit

$$SQM = \begin{cases} \text{E}, & \text{if } QIM \in [1,3] \\ \text{E-A}, & \text{if } QIM \in (1,5] \\ \text{A}, & \text{if } QIM \in (5,10] \\ \text{A-B}, & \text{if } QIM \in (10,13] \\ \text{B}, & \text{if } QIM \in (13,14] \\ \text{B-NA}, & \text{if } QIM \in (14,21] \\ \text{NA}, & \text{if } QIM \in (21,23] \end{cases}$$

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Conclusions

- A smart sensor to predict fish quality and its variability with a limited number of measurements.
- It uses a nonlinear dynamic model describing the relationship between psychrotrophic counts and TVB-N content with the established sensory indexes.
- The smart sensor predicts quality of fresh Atlantic cod under usual market conditions,

Future work

The sensor will print a **QR code** for any fish batch with info about the fresh quality. Stakeholders and end-users will have the information by scanning the code.

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