Modelling the preservative effect of modified atmosphere packaging on fresh fish quality and shelf life

Tsironi T.[1,*], Semenoglou I., Tsevdou M.[1], Ntzimani A.[1], Geropanagioti E.[2], Marountas A.[2], Dermesonlouoglou E.[1], Taoukis P.[1]

[1]School of Chemical Engineering, National Technical University of Athens, Greece (taoukis@chemeng.ntua.gr)
[2]Selonda Aquaculture S.A., Mandra, Attica, Greece (maroudas.a@gr.selonda.com)

Introduction

The limited and variable shelf life of chilled fish, mainly due to bacterial activity, is a major problem for their quality assurance and commercial viability. Modified atmosphere packaging (MAP) can effectively alter and delay the spoilage process and extend the shelf life of fresh fish (Tsironi & Taoukis, 2018). CO_2 inhibits the development of the respiratory organisms like *Pseudomonas* spp. and *Shewanella putrefaciens*. However, a disadvantage of ordinary MAP is its demand for high gas to product volume ratio (*g:p*). Despite the increasing importance of MAP technology in fish industry and the several studies evaluating the effect of MAP on fish products, a limited number of predictive models for quality deterioration and shelf life have been proposed, including the combined effect of temperature and gas concentration in the packaging environment (Dalgaard 1995; Koutsoumanis *et al.,* 2000; Tsironi *et al.*, 2008). The objective of the study was to mathematically model the preservative effect of MAP and define optimal packaging conditions for farmed, gutted European sea bass.

Materials & Methods

Whole and gutted European sea bass (*Dicentrarchus labrax*) packed under modified atmospheres (40-60%CO_2/40%N_2/20-0%O_2) were provided by Selonda S.A. Alternative packaging types were tested, i.e. 1-3 specimens/package, corresponding to different ratios *g:p* in the package headspace. Samples were stored at controlled isothermal conditions in the refrigerated range (0-10°C) in high-precision (±0.2°C) low-temperature incubators for shelf life evaluation.

1 or 2 or 3 x

40-60%CO_2/40%N_2/20-0%O_2

0°C
2.5°C
5°C
10°C

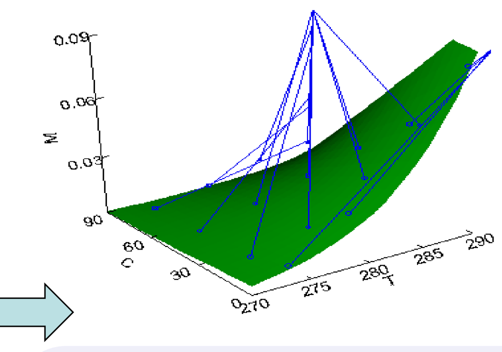
Microbial growth
Total viable count, *Pseudomonas* spp., Lactic acid bacteria
Enterobacteriaceae spp.
H_2S-producing bacteria

Headspace composition
pH
Sensory scoring

Mathematical modelling
<u>*Primary modelling*</u>
Baranyi growth model DMfit software (IFR, UK)

<u>*Secondary modelling*</u>
Arrhenius model

<u>*Non-linear regression*</u>
SYSTAT 10.2® Software



User friendly software

Shelf life= f(T, %CO_2, g:p)

Results

<u>*Shelf life evaluation of MAP sea bass*</u>

CO_2 concentration in the package headspace decreased during the initial hours of storage (up to final CO_2 level of 20%), due to CO_2 dissolution in the fish flesh, especially at the lower gas to product volume ratios. Afterwards, %CO_2 level increased, due to metabolic activity of spoilage bacteria, reaching highest levels at the end of storage period. O_2 concentration showed a descending trend, while at the end of shelf life O_2 concentration exhibited zero levels, which was related to increased microbial population of total viable counts.

Microbial growth was modelled using the Baranyi growth model (Baranyi & Roberts, 1995). Decrease of sensory scoring with storage time was adequately described by zero-order equations. The temperature and %CO_2 dependence of the rates of quality deterioration was adequately described using an Arrhenius type equation (Eq. 1, Koutsoumanis et al., 2000) in the temperature range 0-10°C for each g:p ratio.

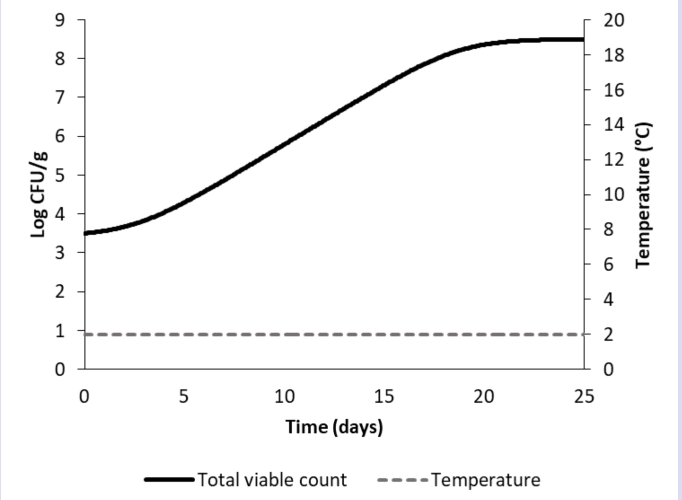
$$k = \left(k_{ref}\frac{CO_{2max} - CO_2}{CO_{2max}}\right) exp\left[\frac{E_a}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right] \quad \text{(Eq. 1)}$$

where CO_2 is the percentage of carbon dioxide, k_{ref}, is the specific growth rate at T_{ref} (4°C, in the absence of carbon dioxide), $CO_{2,max}$ is the nominal maximum CO_2 concentration for microbial growth, T is the temperature in K, E_a is the activation energy of the microbial growth rates (E_a=64-110 kJ/mol, depending on microorganism), R is the universal gas constant.

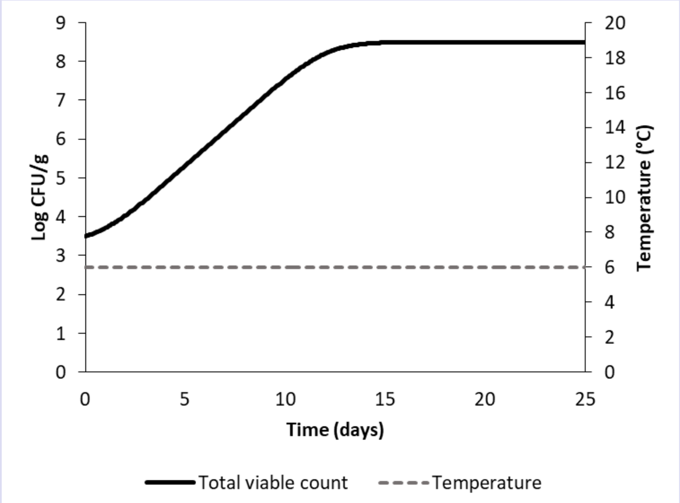
Shelf life determination of MAP fish was based on the correlation of microbial load and the sensory scoring of the samples. At all studied conditions, the time of sensory rejection (scoring 5 for overall impression) coincided with an average total viable count of 10^7 cfu/g.

<u>*Shelf life prediction*</u>

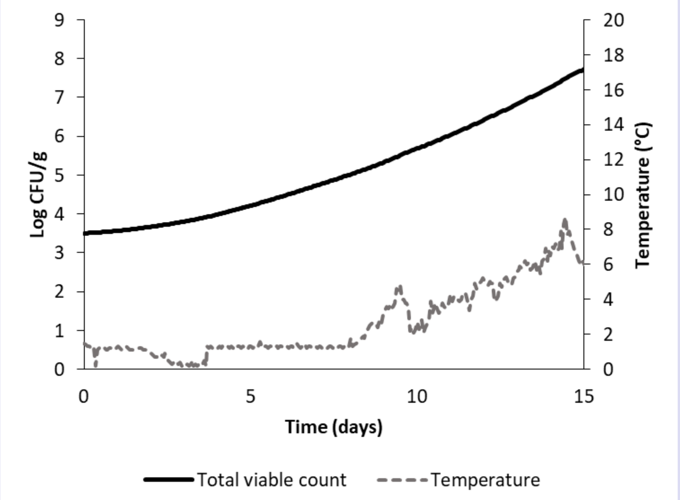
The developed mathematical models were incorporated into user friendly software based on worksheets that allow the prediction of microbial growth and shelf life of gutted European sea bass packed in MA and stored under different time-temperature conditions.



Scenario 1:
MAP gutted sea bass stored at isothermal conditions (T=2°C), 40% CO_2, 1 fish per package ($SI_{pred,2}$=15 d)



Scenario 2:
MAP gutted sea bass stored at isothermal conditions (T=6°C), 40% CO_2, 1 fish per package ($SI_{pred,2}$=9 d)



Scenario 3:
MAP gutted sea bass stored at dynamic conditions (real cold chain, T_{eff}=2.6°C), 40% CO_2, 1 fish per package ($SI_{pred,3}$=14 d)

Conclusions

It is apparent that the selection of optimal MAP parameters (i.e. initial headspace gas composition and gas to product volume ratio) is a complex issue and is a very important step in the design of MAP systems for fish products. Selection depends on the effect on microbial growth, desired product quality and shelf life, as well as the appearance of a package. Since shelf life extension of MAP fish requires in pack CO_2 concentration maintenance, the application of active packaging technologies would ensure this. CO_2 emitters, which produce CO_2 in contact with water from liquid leaking from the fish flesh may enable reduced gas to product volume ratios in MAP fish and further increase shelf life. The combined use of the developed shelf life models with an indicator with function of CO_2 detection in the package headspace and a Time Temperature Indicator (TTI) would provide useful information on the probability of the quality deterioration of packed fish, allowing better management and optimization of the cold chain from manufacture to consumption (Tsironi *et al.*, 2011).

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