Microbial contamination affecting the atmosphere within modified atmosphere-packages of fresh-cut products

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Content

- What is MA-packaging?
- What happens inside a MA-package?
- Modelling the gas composition
- Extension of the model
- Simulation and discussion

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MA-packaging of fresh-cut vegetables (e.g. lettuce)

- Modified Atmosphere: Specific gas composition inside packages to
  - slow down the respiration
  - prevent oxidation of polyphenols (discoloration)
  - antimicrobial effect
- Commodities are packed in permeable films
- Not oxygen-free like for bakery products due to the risk of off-flavour formation (aerobic metabolism)
- Recommended gas composition for fresh-cut lettuce:

1…3 % oxygen, 5…10% carbon dioxide

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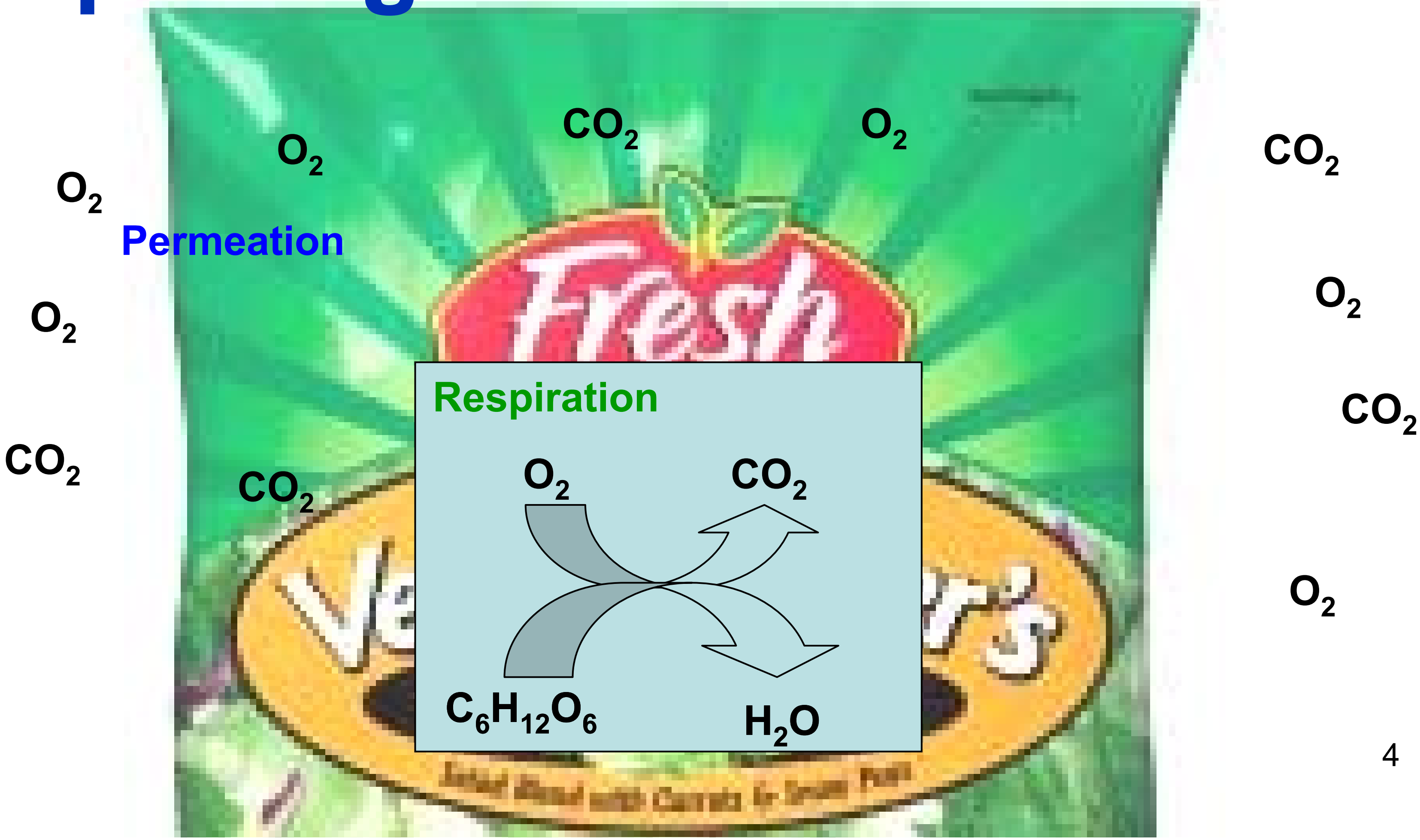
What happens inside a MA-package?



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MA packaging of respiring products

- gas composition is changed by the packed product
- change of gas composition is determined by
  - respiration of the product
  - film permeability

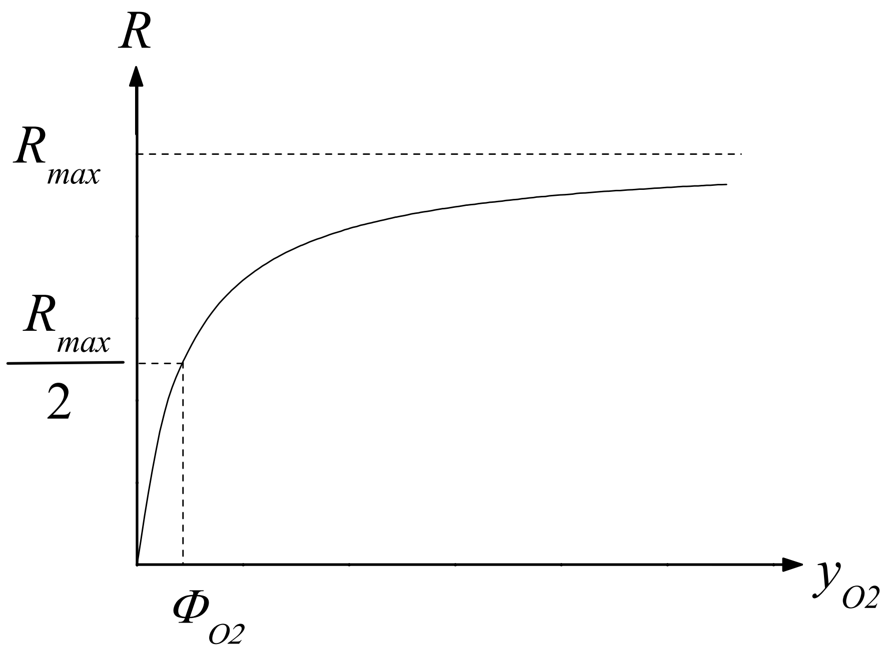
$$\frac{dV_{O2}}{dt} = \text{-Respiration} + \text{Permeation}$$

$$\frac{dV_{CO2}}{dt} = \text{Respiration} - \text{Permeation}$$

Modelling the Respiration of the plant tissue

- Michaelis-Menten type of equation is used to describe the substrate limitation

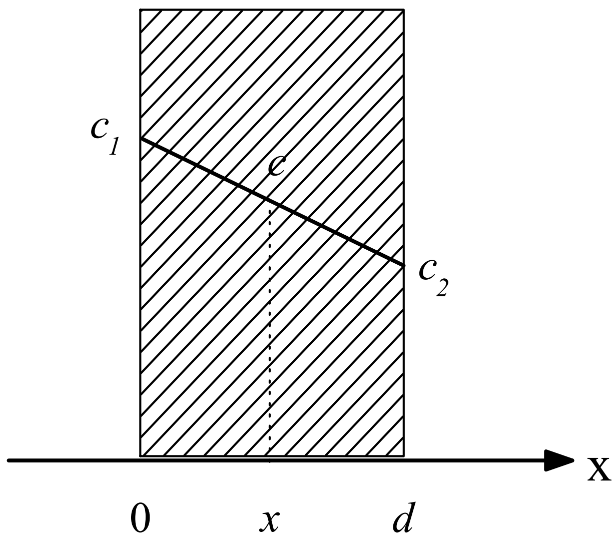
$$R_{PT} = R_{PT,\max} \cdot \frac{y_{O2}}{\phi_{O2} + y_{O2}}$$



Modelling the Diffusion

- Fick's first law $J = -D\frac{dc}{dx}$

$$\frac{dV}{dt} = \frac{A_{Film}}{d_{Film}} P_i (p_{outside} - p_{inside})$$

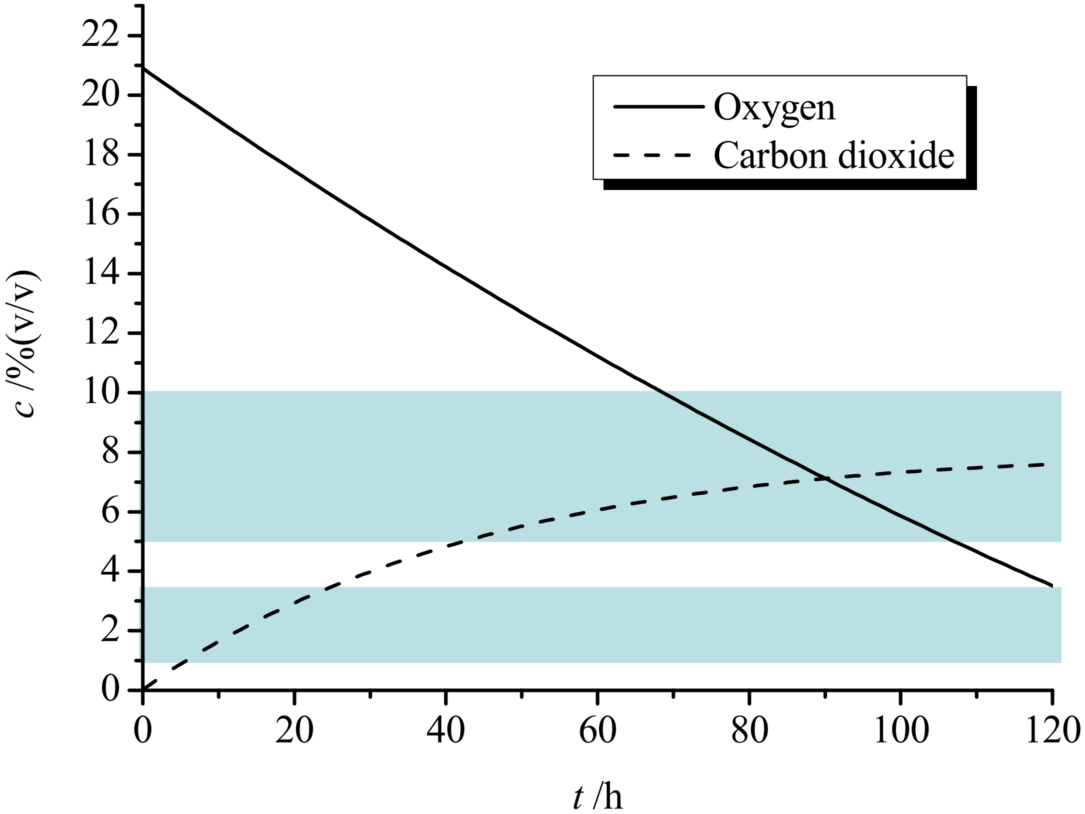


Simulation parameters

Value	Parameter
0,03 %	Carbon dioxide of ambient air
20,9 %	Oxygen of ambient air
101300 Pa	Standard pressure
1,3 L	Free packaging volume
200 g	Mass of lettuce
0,1 m^2	Film area
40 µm	Film thickness
0,017 $mL \cdot \mu m \cdot m^{-2} \cdot Pa^{-1} \cdot h^{-1}$	Oxygen permeability of oriented polypropylene
0,109 $mL \cdot \mu m \cdot m^{-2} \cdot Pa^{-1} \cdot h^{-1}$	Carbon dioxide permeability of oriented polypropylene
11,75 $mL \cdot kg^{-1} \cdot h^{-1}$	Maximum respiration rate of Iceberg lettuce
0,257 %	Halfmaximal oxygen concentration - respiration of Iceberg lettuce

Smyth et al. 1998

Results of the simulation



But…

…fresh-cut products are **not** sterile.

→ Possibility of the microorganisms affecting the gas atmosphere

Microbial contamination of fresh-cut lettuce

- Total aerobic count

  $10^4 \ldots 10^8$ cfu/g (*Pseudomonas spp.)*
- Lactic acid bacteria

  $10^1 \ldots 10^2$ cfu/g (*Lactobacillus spp.*)
- Yeasts

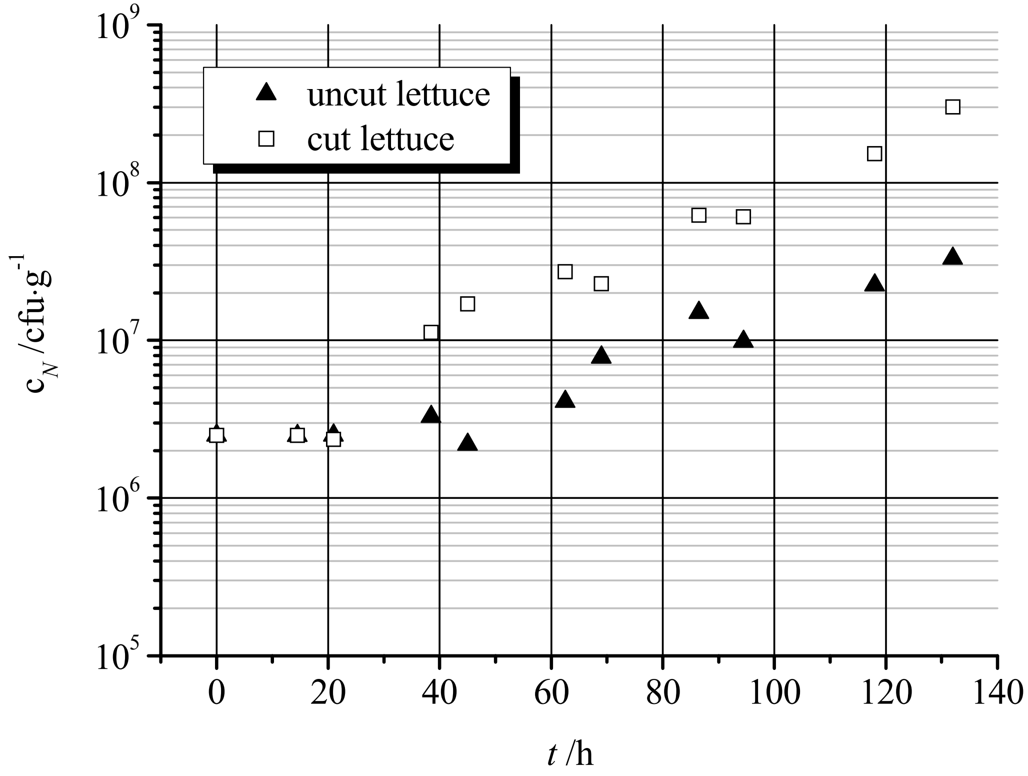
  $10^2 \ldots 10^4$ cfu/g (*Candida spp.*)

Model extension

- microbial respiration has to be covered separately due to growth of microorganisms
- growth models has to be combined with respiration
- respiration rate of *Pseudomonas fluorescens* was already determined

Growth experiments

Total aerobic count on lettuce at 7°C



Modelling the growth

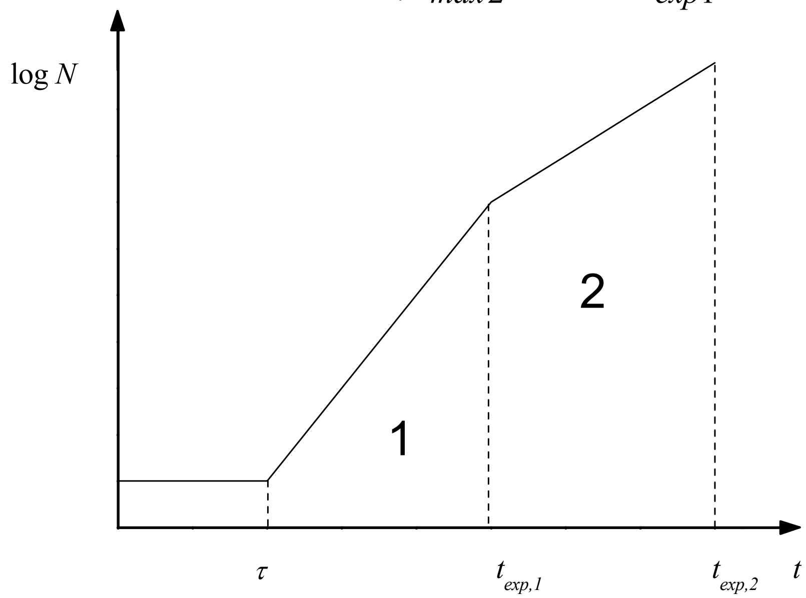
- one lag phase and two exponential growth phases

$$\frac{dc_N}{dt} = \mu(t) \cdot c_N \text{ with } \mu(t) = 0, \text{ for } 0 < t < \tau$$

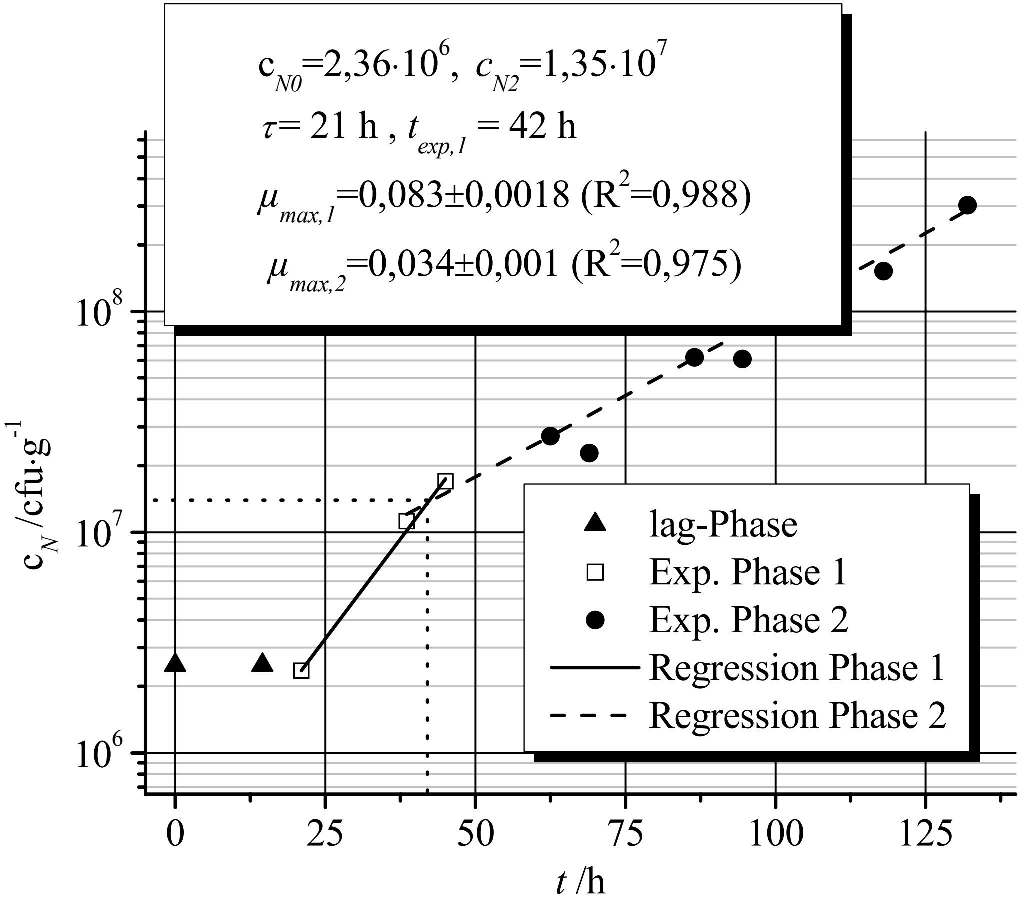
$$= \mu_{max1}, \quad \text{for } \tau < t < t_{exp1}$$

$$= \mu_{max2}, \quad \text{for } t_{exp1} < t < t_{exp2}$$

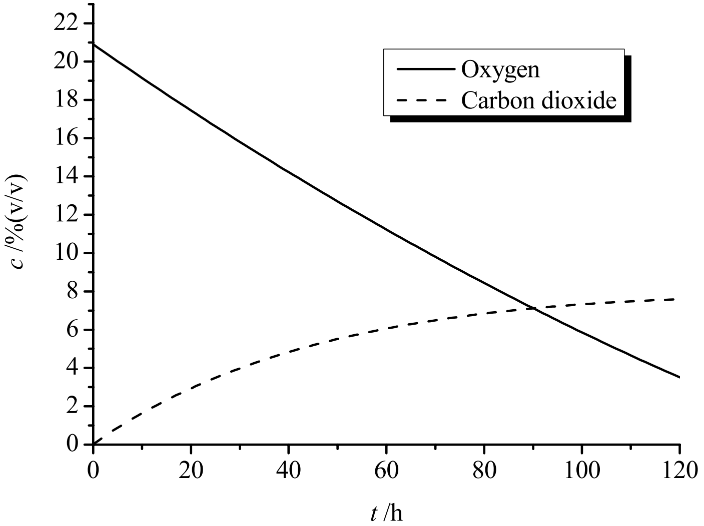
→ nonlinear regression

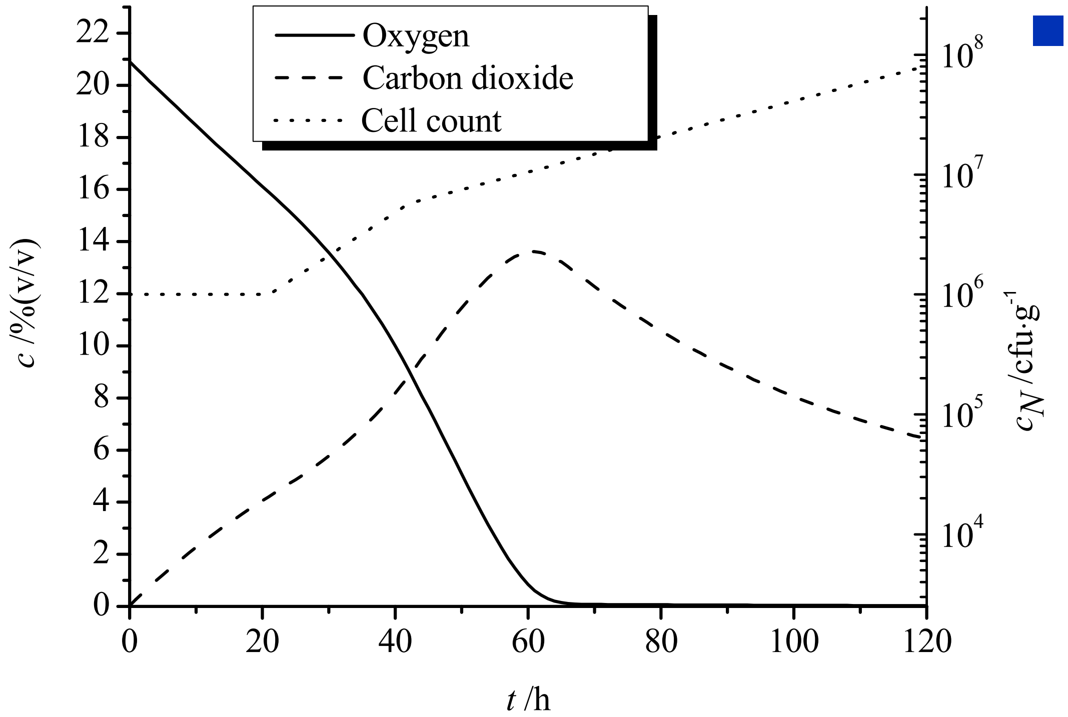


Fitting of the parameters



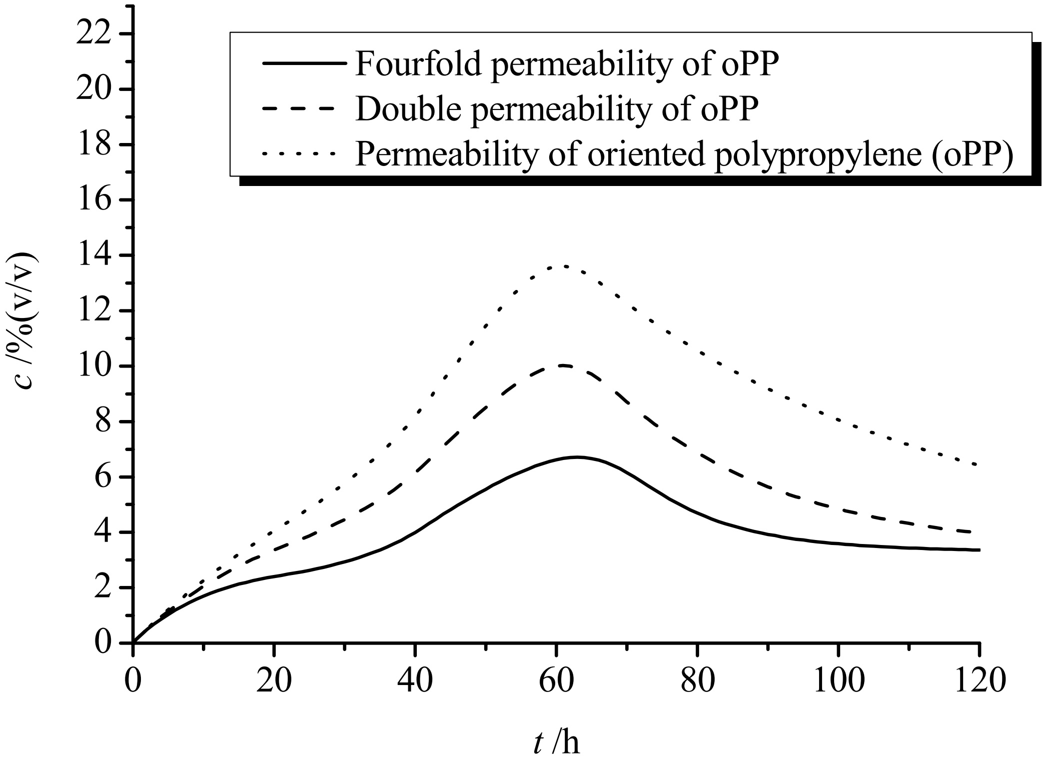
Simulation:
Original and extended model





Simulation: Different film permeabilities

- e.g. carbon dioxide



Change of permeability

… due to

- different film thickness
- perforations
- different film material

Conclusion

- Microbial respiration has to be taken into account when modelling the gas composition of MA-packages
- Changing the permeability can compensate the negative influence of the microorganisms
- Informations about the microbial status are helpful to select a proper packaging film

  → Quality improvement of MA-packed fresh-cut products