Modified Atmosphere and Humidity Packaging of Fresh Produce

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10 Round Table 2016
Food Preservation and Sustainability at Home
Future Opportunities for Consumers to Reduce Food Waste

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About Leibniz-Institut für Agrartechnik Potsdam-Bornim (ATB)

- Non-university research institution, member of Leibniz Association
- Close collaboration with universities, agriculture / horticulture industry

- Total budget 17 Mio Euro (2013)
  - Core funding by Federal Government and State (50 % each)
  - Third-party funding of approx. 35 %

- > 250 staff members, interdisciplinary research teams, young researchers (50 PhD candidates)

- Excellent scientific infrastructure
  (labs, pilot plants, 50 ha experimental orchard)

- Our research is organised in 4 programs

www.atb-potsdam.de
Limitations of fresh produce (fruit and vegetables)

- After harvest, fruit & vegetables continues to live
- Changes in physiological processes after harvest
  - Respiration and transpiration
  - Produce depends on its own water and organic substrates
- Growth of spoilage microorganisms
- Natural senescence

(Caleb et al., 2013; Mahajan et al., 2014)
What is the best packaging film for a given product? e.g. grapes
Packaging industry practises: “Pack & Pray”

- Most of the packages had minimal atmosphere modification
- Not harmful, but also not beneficial, from quality/safety point of view

(Mahajan et al., 2011)
Modified Atmosphere Packaging Design

First principle mathematical equation:

\[
RR = \frac{\alpha \times y_{O_2}}{\phi + y_{O_2} \times \left(1 + \frac{y_{CO_2}}{\gamma}\right)}
\]

\[
RR = R_{\text{ref}} \times e^{-\frac{E_a}{R_e} \left(\frac{1}{T} - \frac{1}{T_{\text{ref}}}\right)}
\]

\[
P_{O_2} = P_{O_2}^* \exp\left[-\frac{E_{O_2}}{R \times T}\right]
\]

\[
P_{O_2} = \left[P_{O_2} + \pi \frac{R_H^2 \times 16.4 \times 10^{-6}}{(e + R_H)} \times N_H\right]
\]

I wish there would be a software to solve all these steps...

Integrate the models:

Optimum MAP Conditions
- O₂, CO₂, Temp

Respiration Rate
- Fruit & Veg, whole & fresh-cut

Product Volume
- Product Mass & Density

Packaging Films
- Permeability, Microperforations

Package Geometry
- Pouch, Tray, Flow-wrap

Integrate the models...
Systematic study to compile database in ready-to-use format

**Database**

- **Storage**
  - \(\text{Optimal atmosphere (O}_2, \text{CO}_2)\)
  - \(\text{Storage temperature}\)

- **Product**
  - \(\text{Respiration rate}\)
  - \(\text{Product density}\)

- **Package**
  - \(\text{O}_2, \text{CO}_2\) permeability
  - \(\text{Diffusion through micro-perforations}\)
  - \(\text{Package geometry and size}\)

- Mathematical algorithm to select the film, size & number of micro-perforations
- Mass balance equations to simulate package atmosphere
- Monte Carlo simulations to evaluate impact of product/package variability

*(Mahajan et al., 2007)*
Modified Atmosphere Packaging Design

- Strawberry, 180 grams
- Tray + Lidding film, heat sealed
- NVS Film, 30 μ thickness
- Two micro-perforations (0.25 mm φ)

(Sousa & Mahajan, 2013)
Optimum perforations for Rucola packaging

Time (d)

O2 (%)

Not optimised holes

Optimised holes

No holes
Perforations in the packaging film

- Low risk of anaerobic conditions (very low O₂)
- Reduce moisture condensation, less spoilage

**High RH**
Conditions favourable for microbial growth

**Low RH**
Leads to water loss and shrinkage
Water vapour saturation is commonly observed in the packaged fresh produce, and therefore, decay.

Plastic materials: Low permeability for water vapor results in condensation inside package.

Micro-perforated packaging films: Not complete elimination of condensation, not possible to use MAHP-technology.
Humidity Regulating Trays

ReguPack Project

Developed by...

Fraunhofer Institute of Process Engineering & Packaging
Freising, Germany
Humidity-Regulating Trays

Inner layer: water vapor permeable

Active layer: hygroscopic NaCl

Outer layer: high barrier

• 2 kinds of H-R trays: 0 wt-% concentration of NaCl (T-0)
  12 wt-% concentration of NaCl (T-12)

• 1.5 g of NaCl in T-12 tray

• Size: 129 x 129 x 75 mm

(Rux et al., 2016)
Humidity-Regulating Trays

- Water vapor absorption even without salt in the inner layer
- Water vapor absorption greatly enhanced by salt (2 times)

At 13°C and 100% RH

![Humidity-Regulating Trays](image)

Moisture sorption (g) vs. Storage time (d)

- T-0
- T-12

R² = 0.99

(Rux et al., 2016)
Humidity-Regulating Trays

- Performance evaluation: strawberries and tomatoes
- Storage in cooling room at 13 °C and 60 % RH for 7 days
- Measure the product quality at end of storage time

![Strawberry and tomato diagrams with lidding film and weight labels]
Humidity-Regulating Trays: Packaging performance

RH (%) vs. Storage time (d)

- T-0
- T-12
- Control

(Rux et al., 2016)
Humidity-Regulating Trays: Packaging performance

- Control-PP tray
- 0% NaCl tray
- 12% NaCl tray
- Control macro-perforated tray

Comparison:
- Higher water loss by H-R tray compared to control-PP tray
- Lower water loss in H-R tray compared to perforated film (Rux et al., 2016)

Legend:
- Weight loss of produce, g
- Moister absorption by tray, g
- Moisture loss over film, g

Graphical Representation:
- Bar charts showing weight, moisture absorption, and moisture loss over film for different tray conditions.
Humidity-Regulating Trays: Packaging performance

Less condensation on the lidding film on H-R tray
Humidity-Regulating Trays: Packaging performance

Control (macro-perforated)  T-0  T-12

Richer color of tomatoes after storage, still too high RH
**Sustainable Packaging Technology**

**Paper Tray**
- Novel fibre-based tray
- Thermo-formable packaging material
- High barrier properties, compostable
- Antimicrobial functionalities
- Recyclability and compostability after usage

[Actipoly, CORNET project](www.cornet-actipoly.eu)

**Bio-film**
- Cellulose from trees (wood pulp)
- Fully compostable (home, industrial, marine)
- High water vapour transmission rate
- Suitable for modified humidity packaging
Bio-film for packaging of tomato

![Graph showing the comparison of relative humidity over time for different film types: Polypropylene film, Bio-film (NatureFlex), and Polypropylene film + holes. The graph illustrates the effectiveness of each film in maintaining a desired humidity level for tomato packaging.](image)
Conclusions:

- Integrative approach helps to design optimal packaging for fresh produce
- Integration of salt into polymer matrix provides a novel approach for regulating in-package humidity
- Biodegradable films hold potential for controlling humidity inside fresh produce packaging
Thank you for your attention...

Acknowledgements: