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ActInPak

Moisture Absorption Kinetics of Active Absorbing Pads

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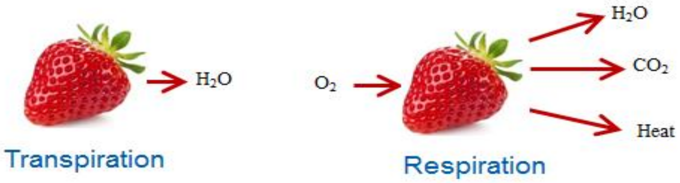
ATB
Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)

Overview

- Introduction
- Kinetics of active absorbing pads
- Performance evaluation pads with strawberries
- Highlight of topics that are currently being worked on at ATB

Fresh produce: alive products 

- Remain metabolically active
- Highly perishable commodities
- Continue to lose water due to transpiration and indirectly due respiration (heat generation)



Effects of water loss in fresh produce

- Defects in the external appearance:

- wilting

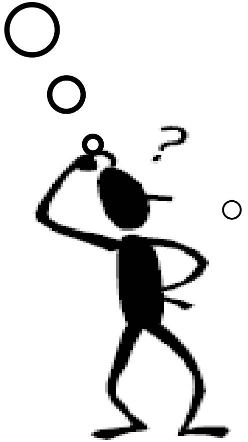
- shriveling

- texture softening

- Economic loss:

- direct reduction in saleable mass

How to reduce water loss of fresh produce?



Modified atmosphere packaging (MAP) helps to reduce water loss…

Packing a living product: Challenges

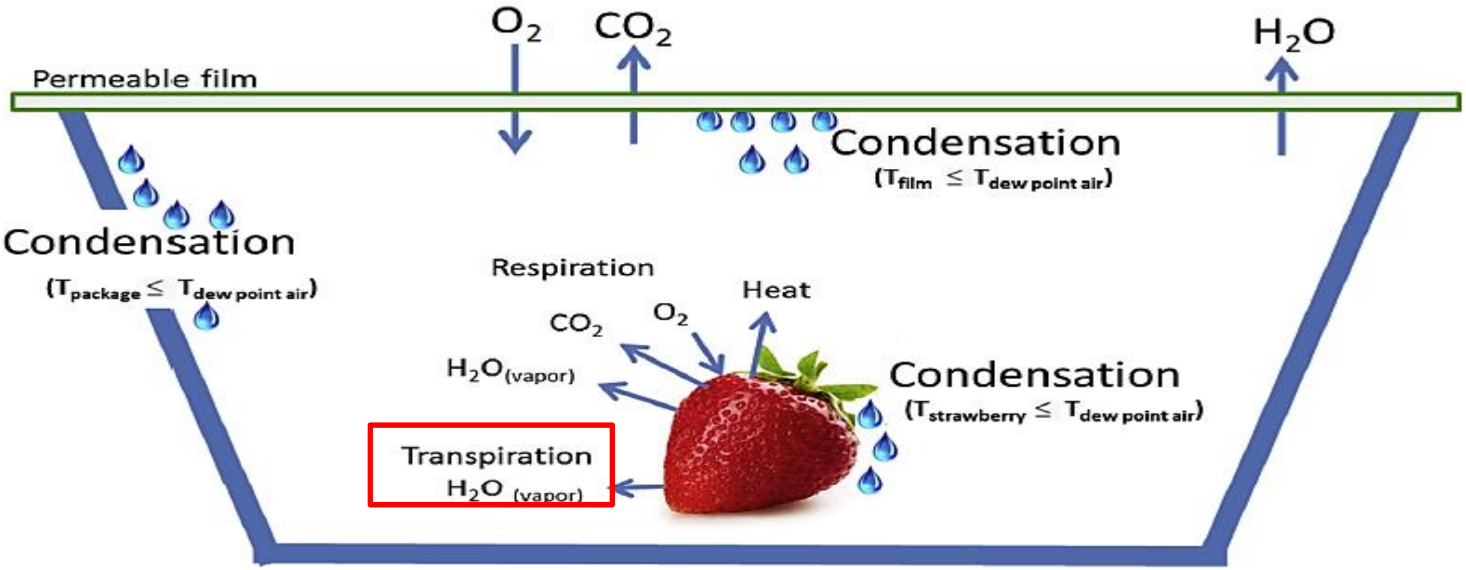


Figure 1 Moisture condensation dynamics.

Causes of water in packaged fresh produce:

- **Transpiration (directly) and respiration (indirectly)**
- **Temperature fluctuation throughout the supply chain**
- **Low permeability to water vapor of the packaging material**

Source: Bovi and Mahajan (2017). Regulation of humidity in fresh produce packaging. In: Reference Module in Food Science, Elsevier, 1-6.

Problem: Condensation

- Bad appearance

- Leads to accelerate microbial decay:

    - growth of fungal and bacterial pathogens

Existing MAP concept needs further optimization to a MAHP

Modified Atmosphere and Humidity Packaging (MAHP)

- Integrates humididy control measures and/or strategies to control condensation

- Challenge: Finding a balance

High humidity

Conditions favourable for microbial growth

Low humidity

Leads to water loss and shrinkage

Strategies to reduce condensation…

Past	Present		Future
Macro-perforations	**Highly permeable films**	**Water contact absorber**	**Water non-contact absorber**

Macro-perforations (Past)

- Big holes
- Reduce condensation
- **But no MAP**

Highly permeable films (Present)

- Suitable for MAP applications (e.g. Xtend and Natureflex)
- **But excessive mass loss**

Xtend®

NatureFlex

Water contact absorber (Present)

- Remove excess liquid (e.g. meat)
- **But only absorbs water in direct contact**

Water non-contact absorber (Future)

- Attracts and holds water molecules (e.g. humidity regulating trays and FruitPads)
- **Absorbs water vapor in the headspace**

Objective

- Kinetics of moisture absorption of active absorbing pads
  ->Temperature: 4, 12, 20 °C
  -> RH: 76, 86, 96, 100 %RH

- Performance evaluation of the active absorbing pads with strawberry

Active absorbing pads: FruitPads

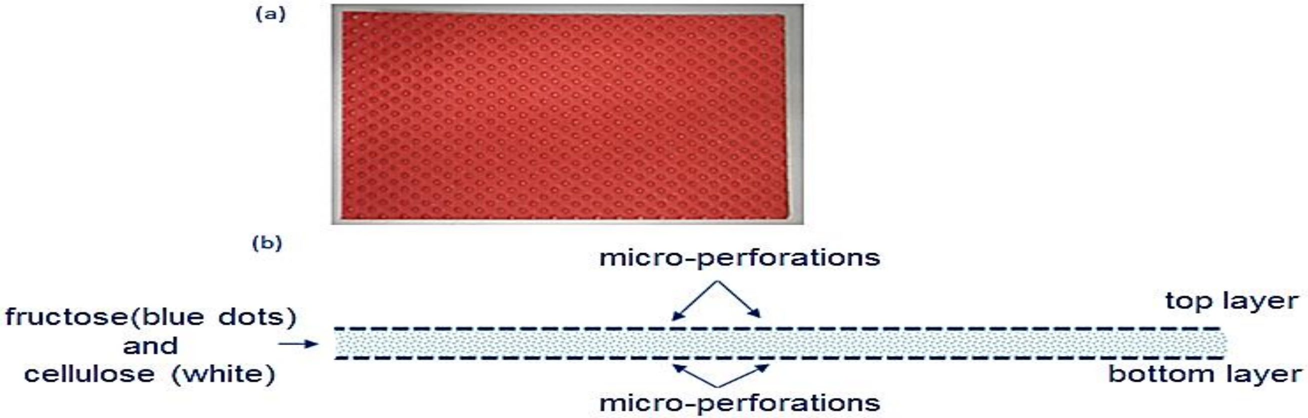


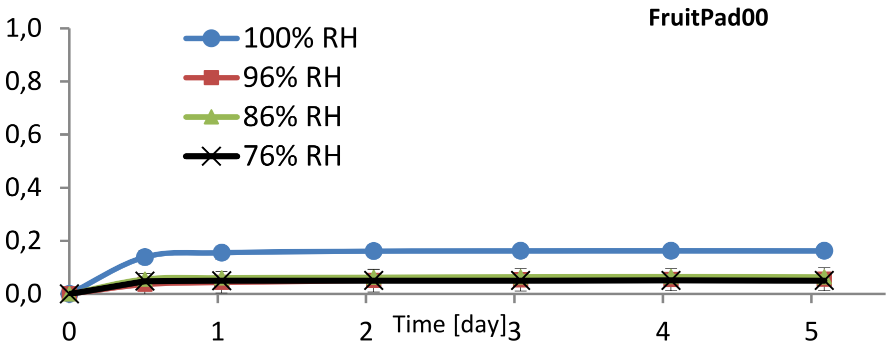
Fig. Fruitpad from McAirlaid's Vliesstoffe GmbH. (a) Fruitpad (b) Schematic lateral view representation of the Fruitpad.

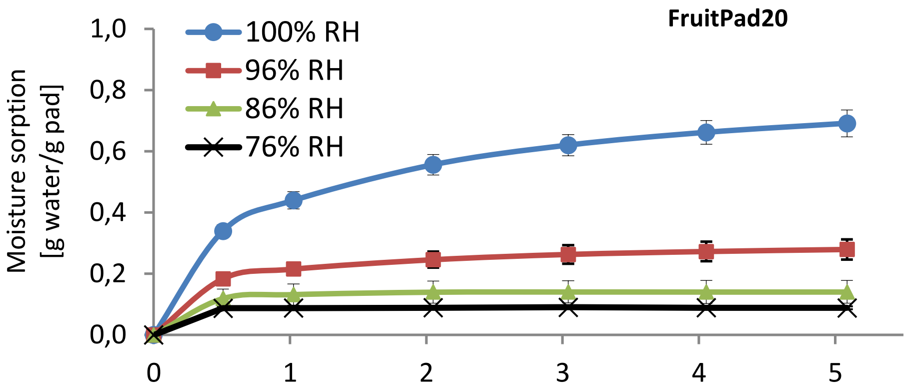
- 3 kinds of FruitPads: 0 wt.-% concentration of fructose (**FruitPad00**)
  20 wt.-% concentration of fructose (**FruitPad20**)
  30 wt.-% concentration of fructose (**FruitPad 30**)

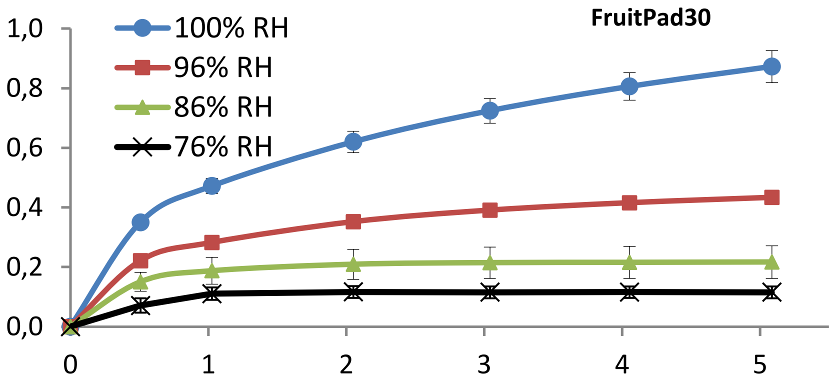
Source: Bovi et al., (2018). Moisture absorption kinetics of FruitPad for packaging of fresh strawberry. Journal of Food Engineering, 223, 248-254.

Characterization

Results: Kinetics at 12°C



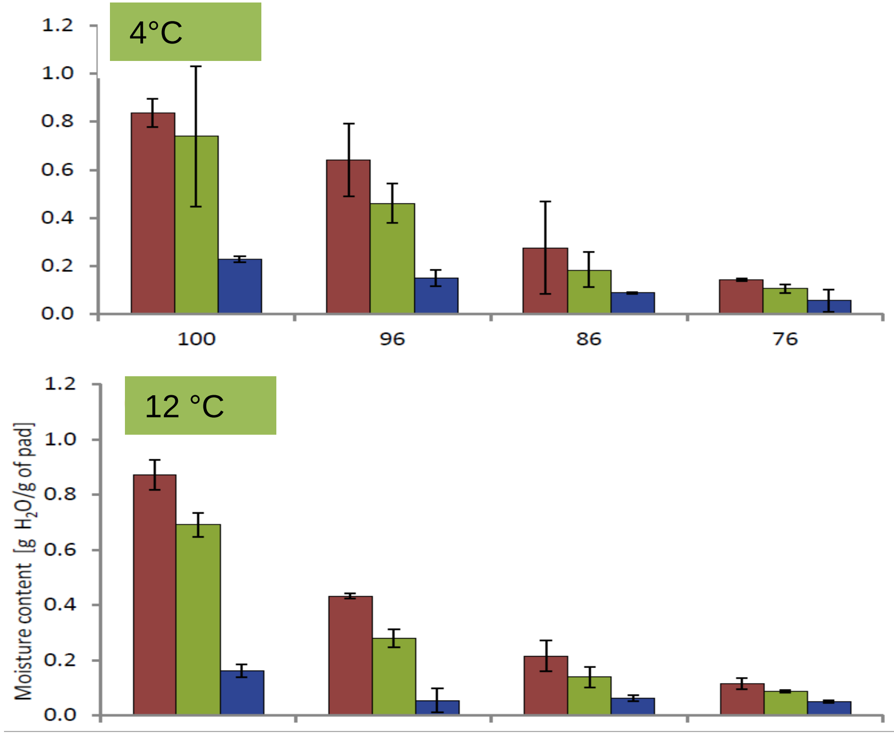


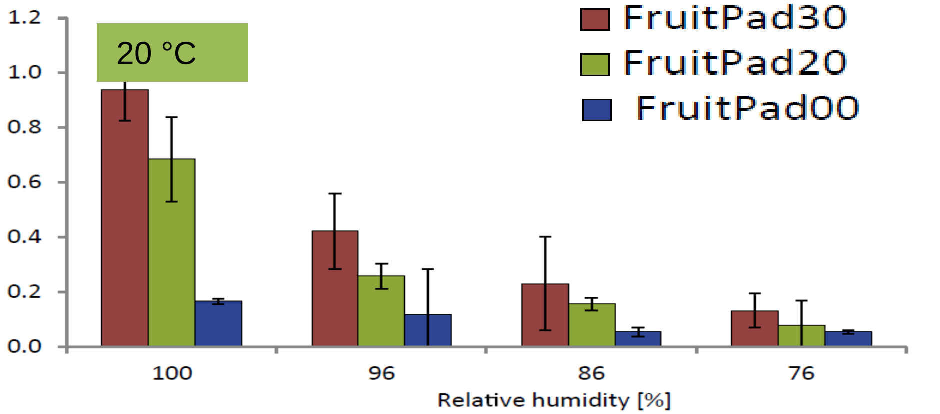


- Moisture uptake was faster in day 1 and slower from day 2.
- ↑RH ↑moisture sorption capacity

Source: Bovi et al., (2018). Moisture absorption kinetics of FruitPad for packaging of fresh strawberry. Journal of Food Engineering, 223, 248-254.

Results: Effect of fructose and RH on moisture absorption





- ↑fructose ↑moisture sorption capacity
- Fructose and RH has a significant effect on moisture absorption ($p<0.5$)

Source: Bovi et al., (2018). Moisture absorption kinetics of FruitPad for packaging of fresh strawberry. Journal of Food Engineering, 223, 248-254.

Results: Model development

Primary model:

$$M_t = \left(\frac{W_t - W_i}{W_i}\right)$$

$$M_t = M_0 + (M_\infty - M_0)\; x \left[1 - e^{\left(\frac{-t}{\beta 1}\right)}\right]$$

Weibull model:

- M_∞ is the moisture holding capacity at equilibrium
- β^1 is the kinetic parameter that defines the rate of moisture uptake process: time needed to accomplish approximately 63% of the moisture uptake process.

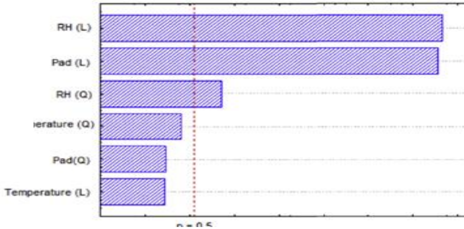


Table 1
Estimated parameters of the primary model for FruitPad containing different concentrations of fructose (0%: FruitPad00, 20%: FruitPad20, and 30%: FruitPad30).

Absorbing pad	M_∞				β_1			
	RH: 76%	86%	96%	100%	76%	86%	96%	100%
FruitPad00	0.0499	0.0575	0.0886	0.1572	0.0010	0.0100	0.3447	0.0010
FruitPad20	0.0886	0.1398	0.2656	0.5515	0.0020	0.2741	0.5002	0.0020
FruitPad30	0.1073	0.1898	0.4118	0.6410	0.0030	0.0100	0.8172	0.0003

M_∞ is the equilibrium moisture and β_1 is a primary model constant. All parameters shown are at 12 °C.

Secondary model:

$$M_\infty = A\; x\; e^{(B\; x\; a_w)}$$

Flory-Huggins model:

- aw is the water activity (RH/100)
- A and B are model constants

$$M_t = M_0 + \left(A\; x\; e^{(B\; x\; a_w)} - M_0\right) x \left[1 - e^{\left(\frac{-t}{\beta 2}\right)}\right]$$

Table 2
Estimated parameters of the secondary model for FruitPad containing different concentration of fructose (0%: FruitPad00, 20%: FruitPad20, and 30%: FruitPad30).

Absorbing pad	Estimated coefficients			R^2 (%)
	A	B	β_2	
FruitPad00	0.00074	0.05445	0.28333	92.56
FruitPad20	0.00005	0.09371	0.77688	92.99
FruitPad30	0.00031	0.07817	1.09146	96.09

A, B, and β_2 are secondary model constants and R^2 is a coefficient of determination.

Source: Bovi et al., (2018). Moisture absorption kinetics of FruitPad for packaging of fresh strawberry. Journal of Food Engineering, 223, 248-254.

Experiments with strawberry

Results: Package performance evaluation

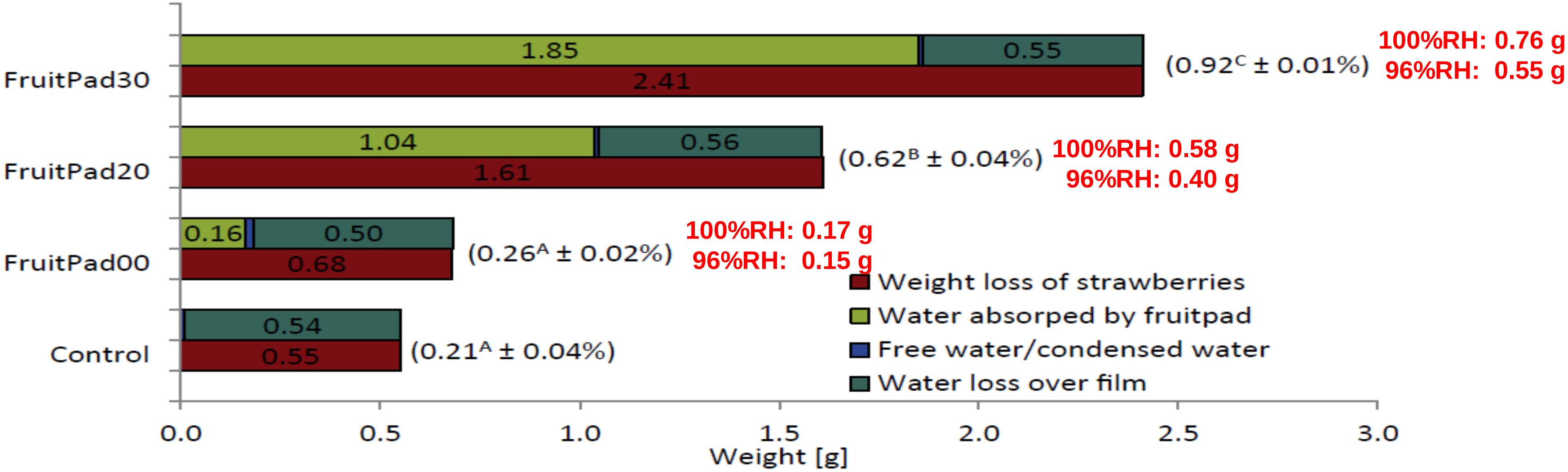


Fig. 5. In-package moisture dynamics of strawberries packaged with FruitPad containing different fructose concentration (0: FruitPad00, 20: FruitPad20, and 30%: FruitPad30) stored at 12 °C for 5 days. The values in bracket represent the percentage mean values (mean value ± standard derivation, $n = 2$) for total strawberry weight loss. Different upper case superscript is significantly different based on Tukey test at $p < 0.05$.

This shows that when there is an `extra` source of water (strawberry) the <u>fructose</u> present in the pad absorbs water directly from the fruit.

Conclusions

- The water uptake was higher in pads with higher fructose concentration.
- The use of water absorbing pads have a good potential in absorbing water vapor in the package headspace.
- FruitPads are efficient, however, at an expense of higher mass loss.
- Need to find a correcting factor based on the amount of fructose present in the pads

Research Topics at ATB

Indian Council of Agricultural Research Scholarship:
Photocatalytic and photochemical oxidation of ethylene for potential application in fruit storage

Ethylene removal

RemOpack project (CORNET):
Removing of specific undesirable odours with the development of new food packaging materials.

Volatile compounds

Humidity regulation

Science without Borders Brazil:
Development of an integrative mathematical modelling tool for water vapor and condensation dynamics in fresh produce packaging.

Packaging Systems

Respiration sensor

German Academic Exchange Service(DAAD):
Development of modular intelligent system for controlled-environment storage of fresh produce.

Low-cost cooling

iPosTech project (BLE):
Adsorption-based cooling systems for improved storage of mango in sub-saharan African countries

Modelling aspects

FreshPack project (BLE)
Mathematical modelling of fresh produce packaging, storage and supply chain

Goal:

1. **Maintain quality and improve shelf life of fruit and vegetables**
2. **Optimize packaging and storage along supply chain**

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