25th iapri
HUT Hunan University of Technology Zhuzhou, China 2026

Project in collaboration with
3 research partners
& 18 companies

Challenges in Leak Detection and Seal Integrity in Emerging Packaging Materials

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Packaging compliant with

PPWR

Packaging & Packaging Waste Regulation

Reduce Packaging Waste

Recyclable monolayers & bioplastics

But also...

Product Protection Maintained

and

Sustainable Process

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Sustain-ability

Shelf Life

Leak & Seal Integrity

Product Safety

Sustainable Process

Product Protection Maintained

Destructive

Standard

Non-Destructive

Desirable

A survey conducted in 2023 showed that **81%** of the surveyed companies require **more knowledge about leak and seal integrity**

Main objective **LEAK**:

Knowledge development and transfer to **facilitate implementation of the right detection technology** & **Minimizing losses**

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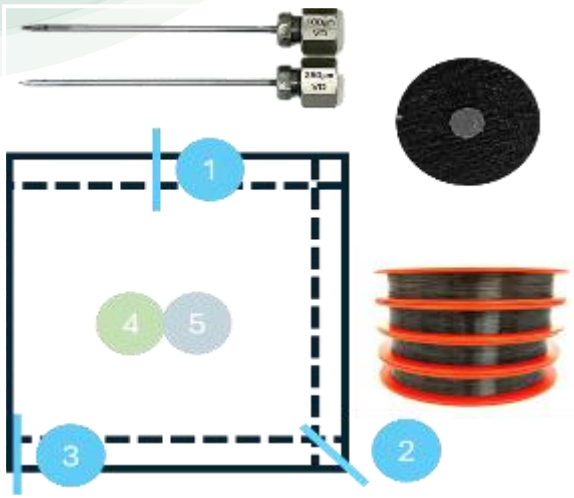
Focus Today



Design of Experiments

Commercial Packaging Concepts

Case Study: Oxygen Scavenger

Design of Experiments

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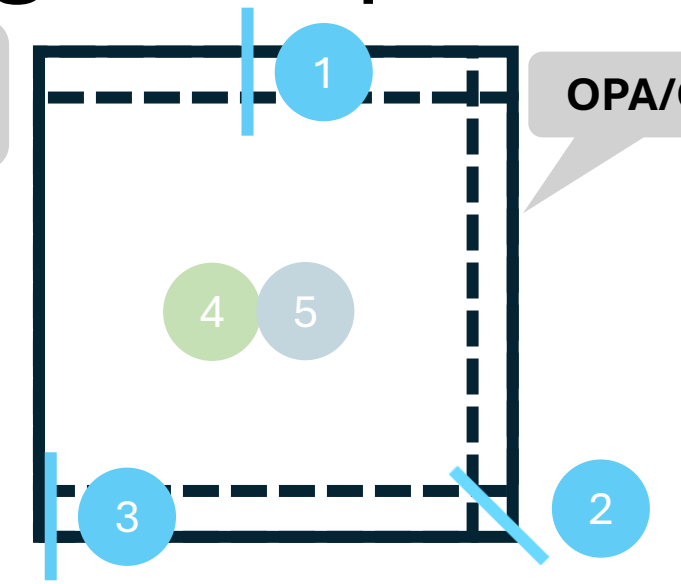
Design of Experiments

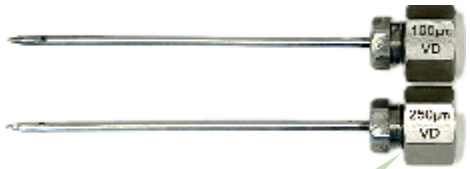
Heat Sealer HST-H3 - Labthink



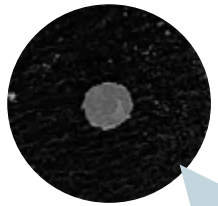
OPA/CPP

SLT - Oxipack

Wolfram Thread:
50 μm
1000 μm



Restriction Needles:
25 μm
50 μm
100 μm
250 μm



Lasered Orifice:
15 μm
25 μm
50 μm
100 μm

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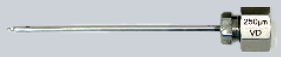
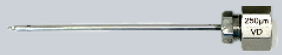
Leak Size

Pouch Size (cm x cm)	Defect Figure 1	Defect Size (µm)	Jump value (mbar)	Measurement 1 (mbar)	Measurement 2 (mbar)
10 x 10	None	None	5 ± 0.6	12 ± 2	5 ± 2
		15	5 ± 0.6	14 ± 1	9 ± 1.2
		25	6 ± 0.6	22 ± 1	16 ± 1
		50	9 ± 1.0	53 ± 1	44 ± 0.6
		100	22 ± 1	158 ± 8	103 ± 7
		250	96 ± 1	247 ± 20	3 ± 0.0

250 μm = large leak
Packaging empty before end of test!

Leak Geometry

Pouch Size (cm x cm)	Defect Figure 1	Defect Size (µm)	Jump value (mbar)	Measurement 1 (mbar)	Measurement 2 (mbar)
10 x 10	None	None	5 ± 0.6	12 ± 2	5 ± 2
		50[1]	6 ± 1	15 ± 5	9 ± 4
		50	8 ± 0.6	42 ± 0.0	35 ± 0.6
		50	9 ± 1.0	53 ± 1	44 ± 0.6

Not round

Tungsten leak = Channel leak = 1 cm
→ More restriction!

Restriction needle
→ slightly longer path > Lasered orifice (insignificant)

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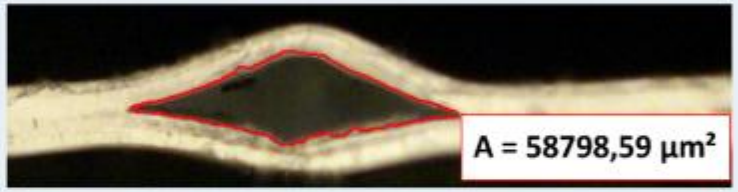
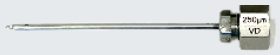
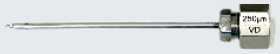
Caulkability

Not round

Wolfram Thread:
50 μm
~~1000 μm~~ → Too big

	PPWR (mono-PET)
Perfect cirkel	200 μm Wolfram $A = \pi r^2 = 31\,416\,\mu m^2$
Non-PPWR (OPP/CPA) 160°C – 1 s – 200 kPa	
PPWR (mono-PET) 160°C – 1 s – 200 kPa	
PPWR (mono-PET) 170°C – 1 s – 200 kPa	

Package dimensions

Pouch Size (cm x cm)	Defect Figure 1	Defect Size (µm)	Jump value (mbar)	Measurement 1 (mbar)	Measurement 2 (mbar)
10 x 10	None	None	5 ± 0.6	12 ± 2	5 ± 2
		100	22 ± 3	149 ± 2	113 ± 3
		250	96 ± 1	247 ± 20	3 ± 0.0
		100	22 ± 1	158 ± 8	103 ± 7
15 x 15	None	None	5 ± 0.0	12 ± 0.0	6 ± 0.6
		100	20 ± 1	147 ± 1	121 ± 0.0
		250	93 ± 1	377 ± 37	2 ± 0.6
		100	23 ± 1	173 ± 5	139 ± 4

No significant difference unless leak very big
Smaller pouch → less volume

Leak Location

Pouch Size (cm x cm)	Defect Figure 1	Defect Size (µm)	Jump value (mbar)	Measurement 1 (mbar)	Measurement 2 (mbar)
10 x 10	None	None	5 ± 0.6	12 ± 2	5 ± 2
		50[1]	6 ± 1	15 ± 5	9 ± 4
		50[1]	5 ± 0.6	13 ± 0.6	7 ± 0.6
		50[1]	6 ± 0.6	17 ± 4	11 ± 3

No significant difference

Non-Destructive Tests on Commercial Packaging

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Non-Destructive Test Methods

Vacuum Decay Leak Detection

SLT - Oxipack

PIT – Optimus Intstuments

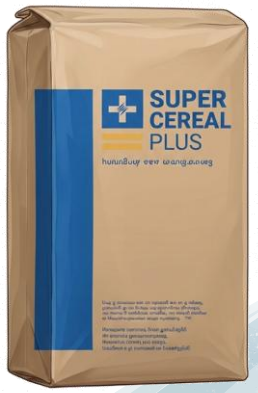
CO_2-Based Leak Detection

Inline: Leak-Master Mapmax – WITT

Offline: Leak-Master Pro – WITT

Packaging Concepts (1)

AI generated images to anonymise Packaging Concepts



		Atmospheric				100% N_2
Vacuum decay	SLT	☑	☑	☑	☑	☑
	PIT	☑	☑	☑	☑	☑
CO_2-based	Offline	☒	☒	No CO_2		
	Inline	☒	☒			

Packaging Concepts (2)

AI generated images to anonymise Packaging Concepts

Sensitivity!

		Mixtures containing CO_2			100% N_2	
Vacuum decay	SLT	☑	☑	☑	☑	☑
	PIT	☑	☑	☒ Custom CIT	☒ Custom CIT	☑
CO_2-based	Offline	☑	☑	☑	☒ No CO_2	☒ No CO_2
	Inline	☑	☑	☑	☒ No CO_2	☒ No CO_2

Packaging Concepts (3)

AI generated images to anonymise Packaging Concepts

		Atmospheric			Vacuum	Not specified (empty)
Vacuum decay	SLT	☒	☒	☒ Custom SLT	☒ No headspace	☒ Too big
	PIT	☒ High-viscosity product	☒	☒ Custom CIT	☒	☒
CO_2-based	Offline	☒	☒	☒ No CO_2	☒	☒
	Inline	☒	☒	☒	☒	☒

Case Study: Oxygen Scavenger

Case Study: Lava Cake

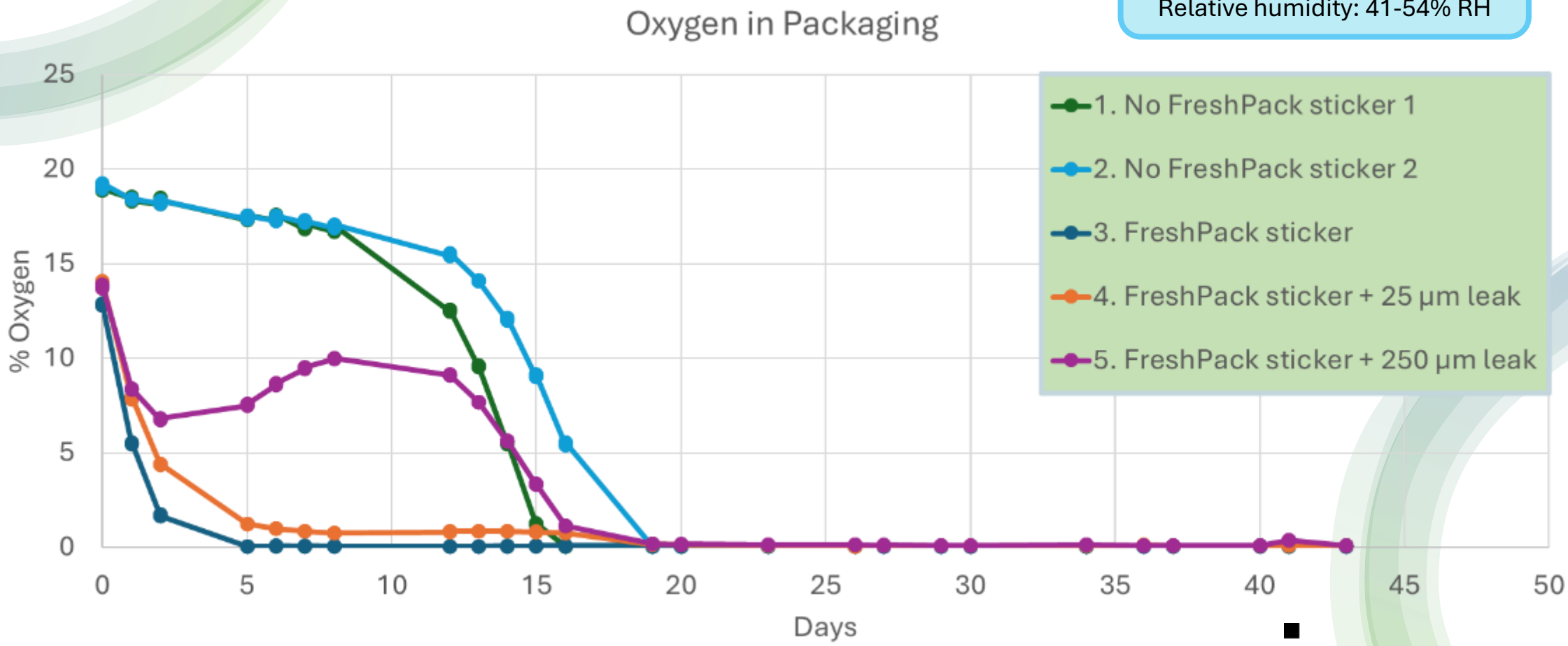
Restriction Needles:
25 μm
250 μm

Question: How much can oxygen scavengers compensate in case of micro-leaks?
Specific case of Moelleux: Packed with a FreshPack Sticker
→ Frozen → Defrosted: Sticker activated → In absence of oxygen quite shelf stable

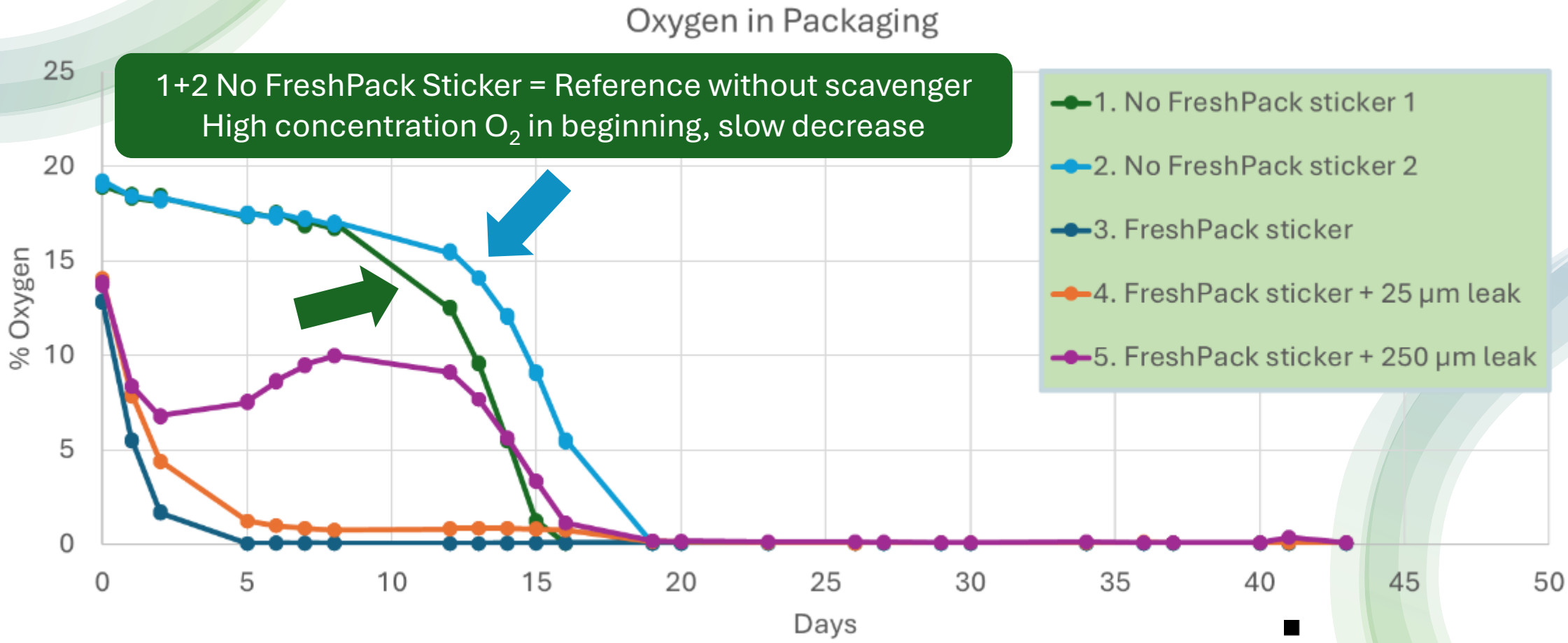
Approach: Optech O_2-sensors sealed with FreshPack Sticker in packaging containing moelleux. Defrost → Start measuring O_2 in packaging with and without restriction needles

Oxygen Ingress

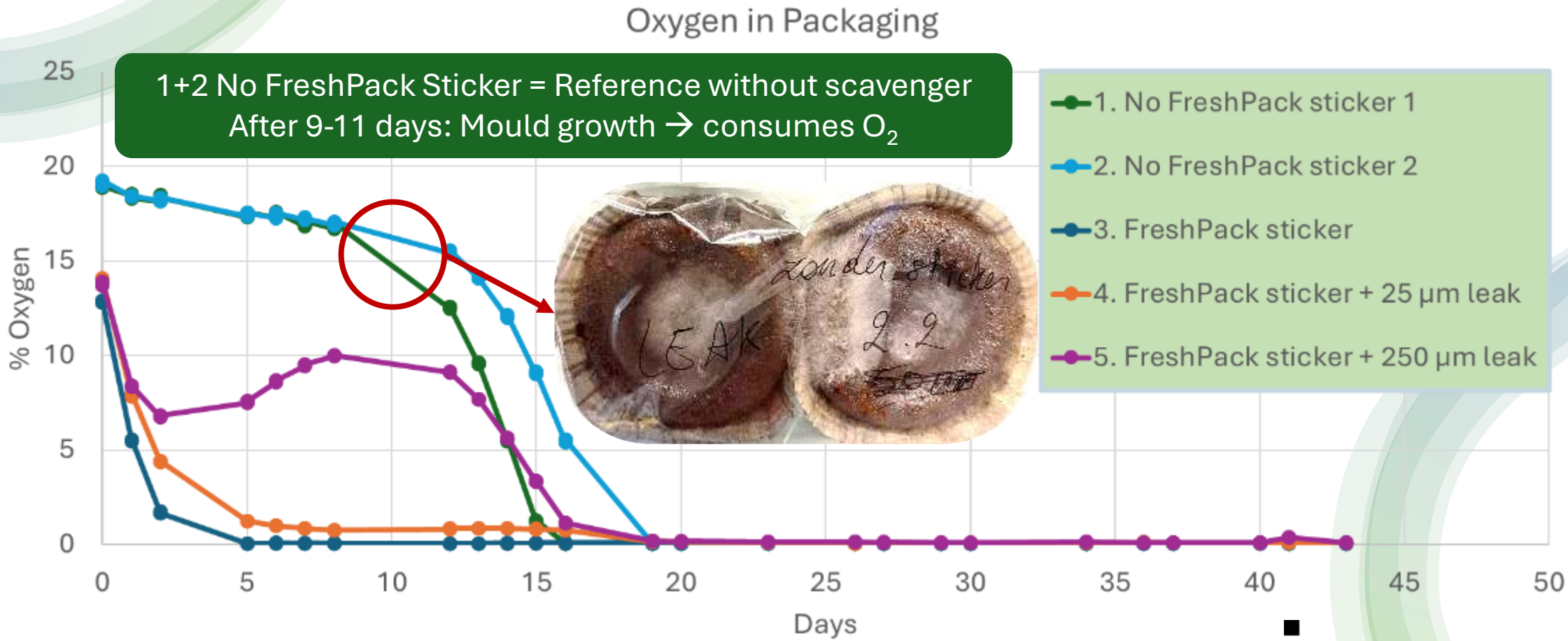
Conditions:
Temperature: RT 22,5-24,5°C
Relative humidity: 41-54% RH



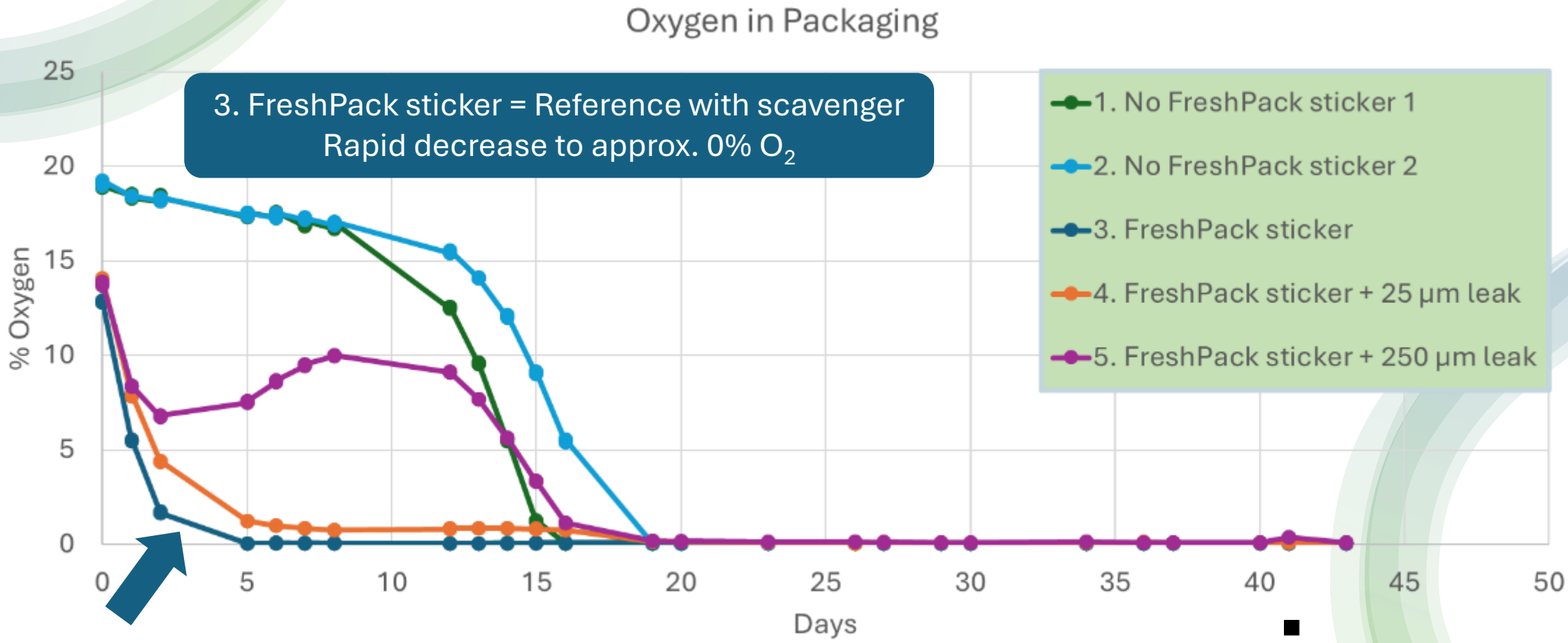
Oxygen Ingress



Oxygen Ingress

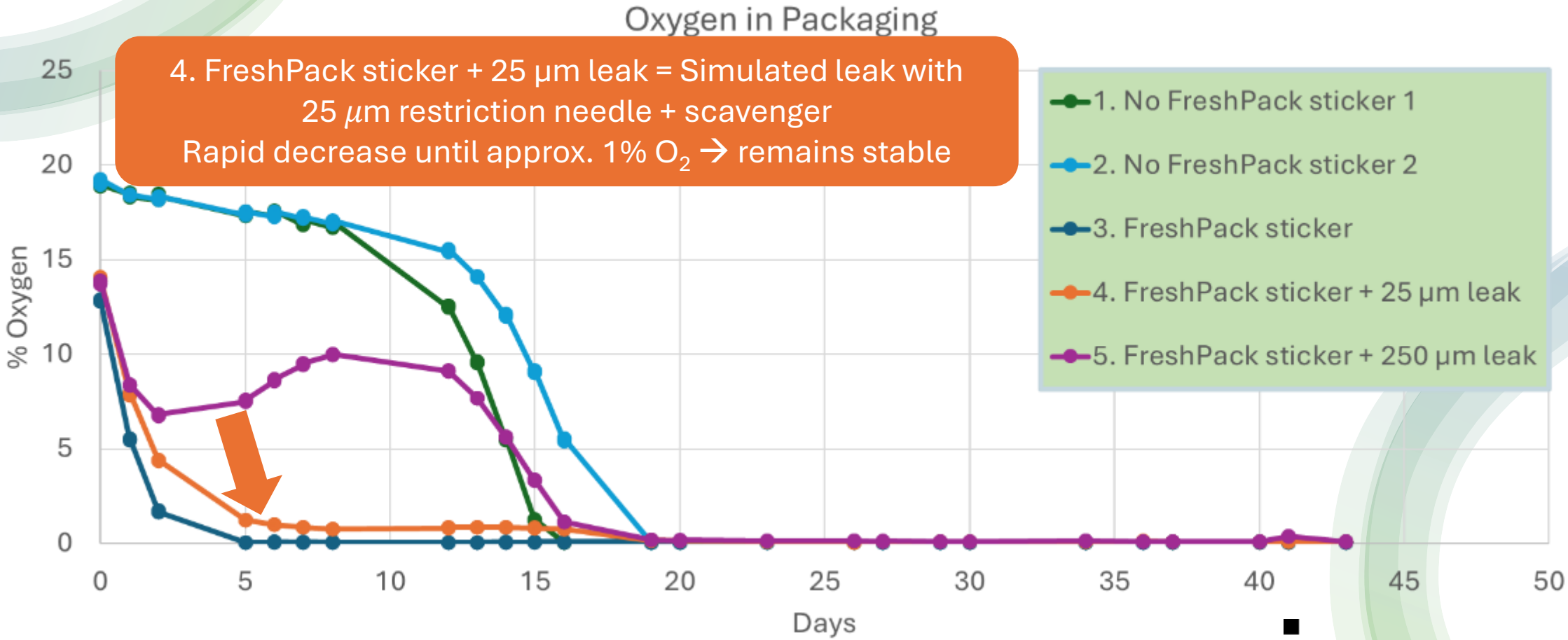


Oxygen Ingress



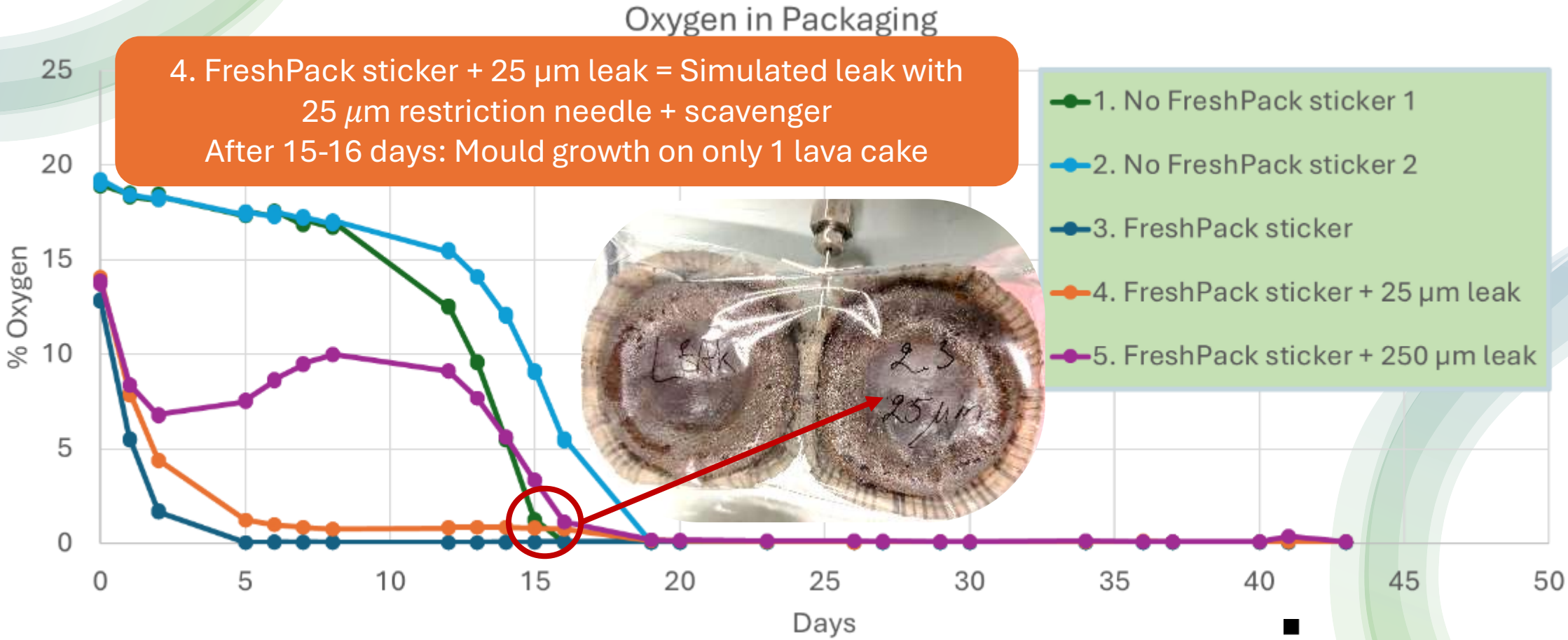
Oxygen Ingress

4. FreshPack sticker + 25 µm leak = Simulated leak with 25 μm restriction needle + scavenger
Rapid decrease until approx. 1% O_2 → remains stable

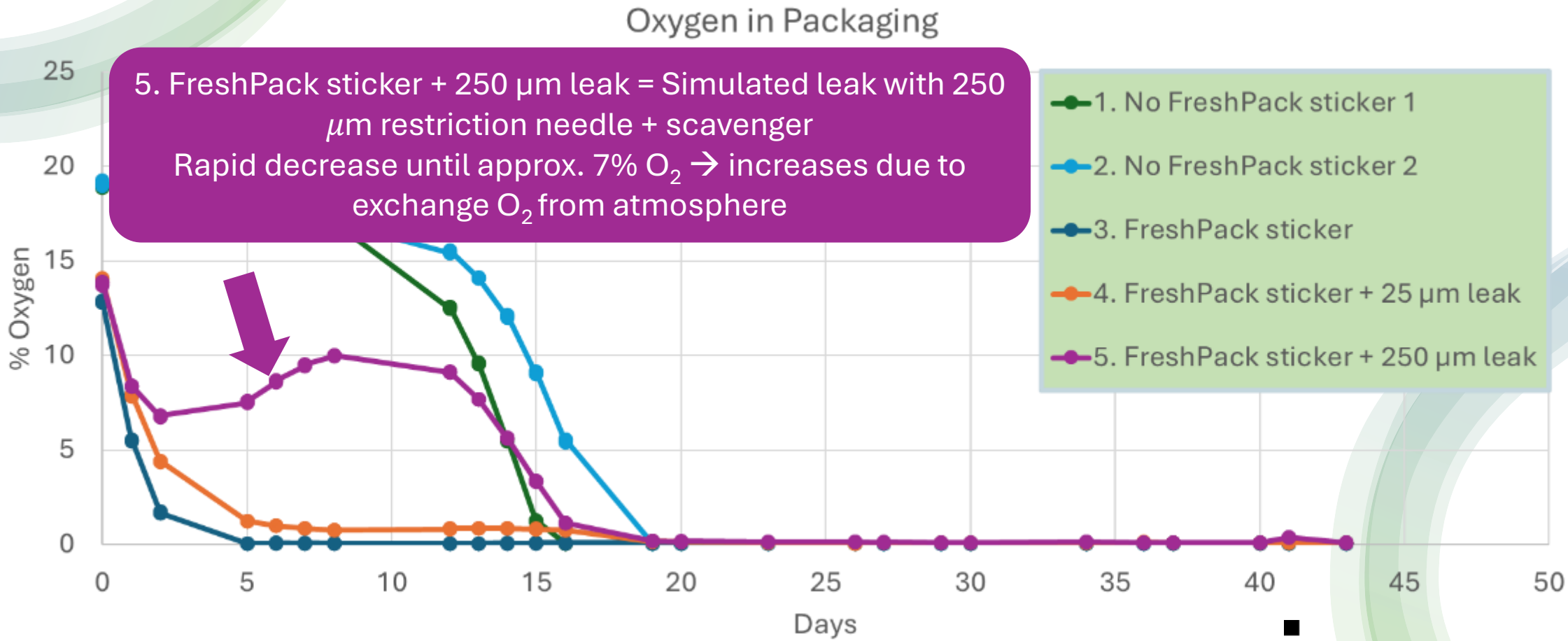


Oxygen Ingress

4. FreshPack sticker + 25 µm leak = Simulated leak with 25 μm restriction needle + scavenger
After 15-16 days: Mould growth on only 1 lava cake



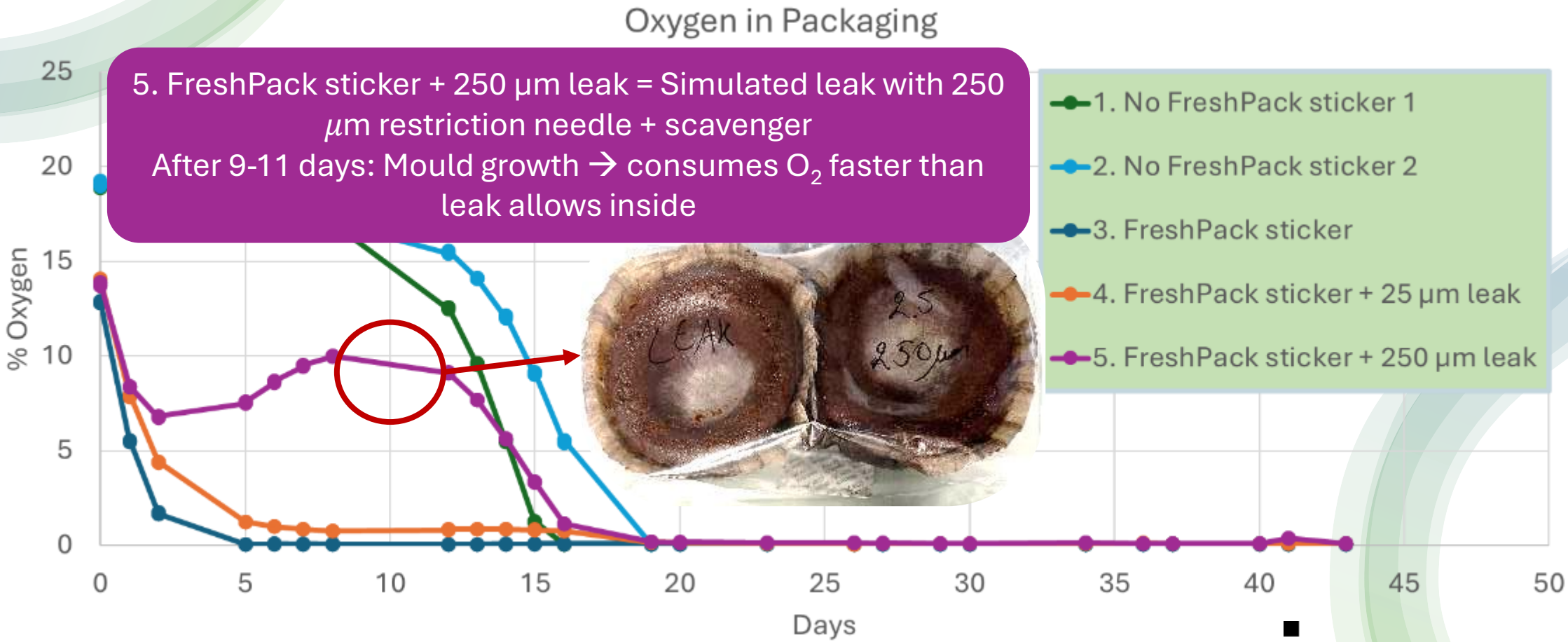
Oxygen Ingress



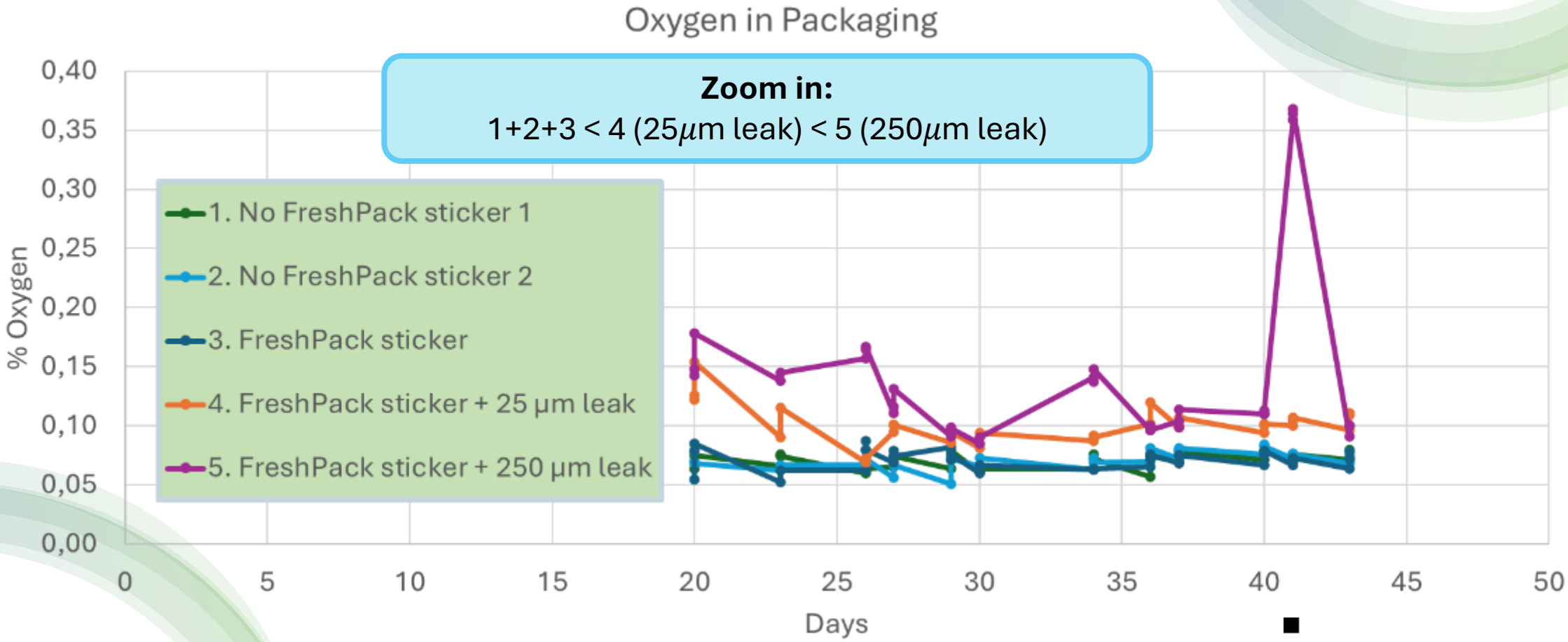
5. FreshPack sticker + 250 µm leak = Simulated leak with 250 μm restriction needle + scavenger
Rapid decrease until approx. 7% O_2 → increases due to exchange O_2 from atmosphere

Oxygen Ingress

5. FreshPack sticker + 250 µm leak = Simulated leak with 250 μm restriction needle + scavenger
After 9-11 days: Mould growth → consumes O_2 faster than leak allows inside



Oxygen Ingress

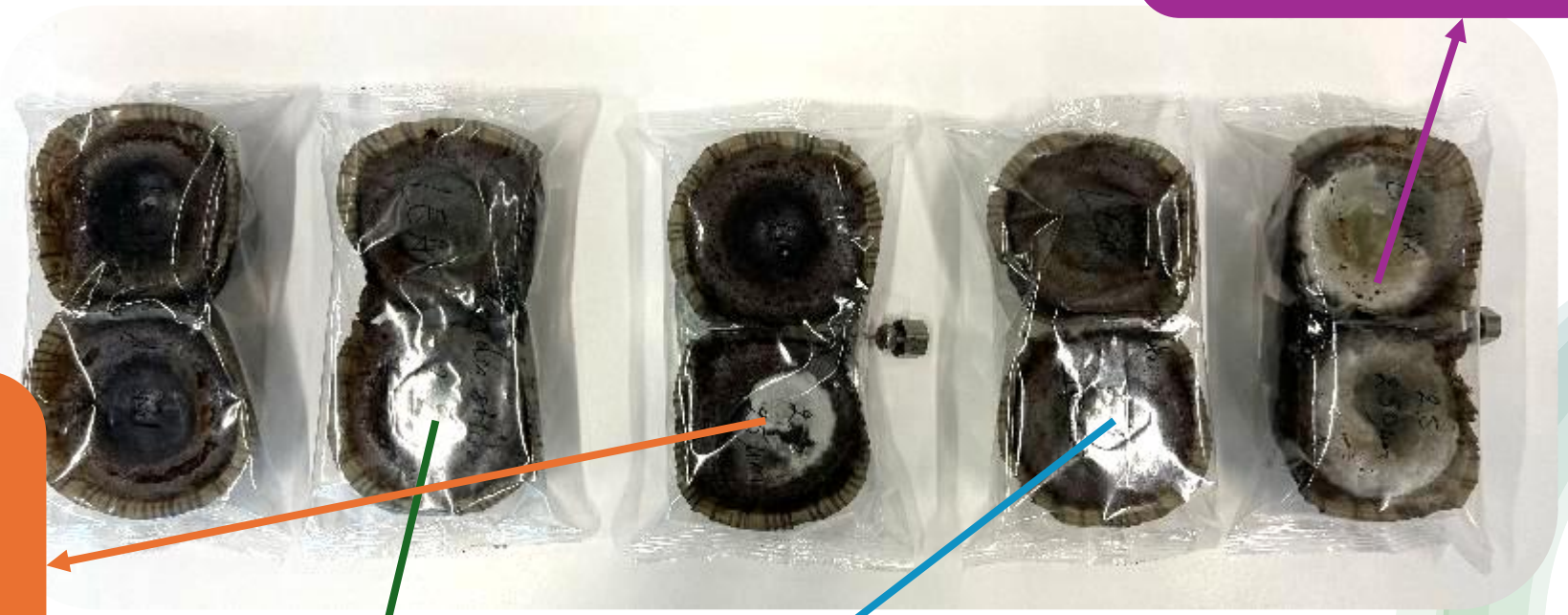


Visual Observations

Picture taken after 43 days
Expiration date at RT = 42 days

3. FreshPack sticker = Reference with scavenger = OK

5. Simulated leak with 250μm restriction needle + FreshPack Sticker
Mould receives O_2 via leak



4. Simulated leak with 25 μm restriction needle + FreshPack Sticker
Mould growth delayed→ still enough O_2 via leak, might die after a while

1+2 No FreshPack Sticker = Reference without scavenger
After O_2 consumed → mould dies

Conclusions

Conclusions

Leak detectability

- Factors: Leak size, leak geometry, package dimensions, internal atmosphere and product characteristics
- Channel leaks created by tungsten (caulkability) ≠ leaks created by lasered orifice + restriction needle

Non-Destructive testing

- No universal method
- Vacuum decay → effective with sufficient headspace ⇔ Not suitable for vacuum packaging, highly viscous liquid products, very small cavities and large liner bags
- CO_2-based → only effective if CO_2 is (still) present in packaging

Oxygen ingress & Scavengers

- Micro-leaks → accelerate spoilage (mould growth)
- Scavengers → partial compensation → effect decreases with increasing leak size

Thank you!

Questions?

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