Technical University of Munich
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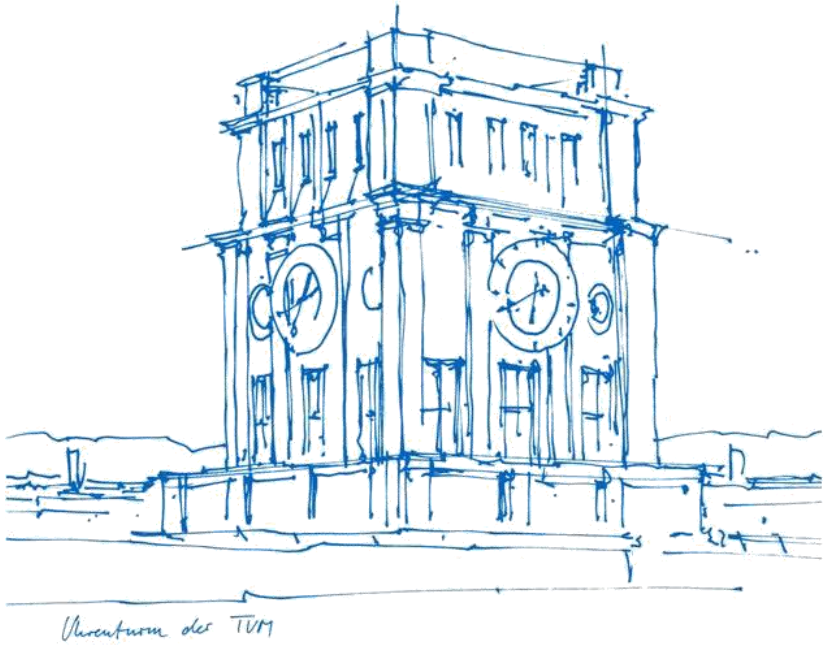
Optical methods to determine the gas atmosphere in various modified atmosphere packages: applications and correlation in meat spoilage

The 2nd International Electronic Conference on Foods - **"Future Foods and Food Technologies for a Sustainable World“**

Session 8: Food Packaging and Preservation



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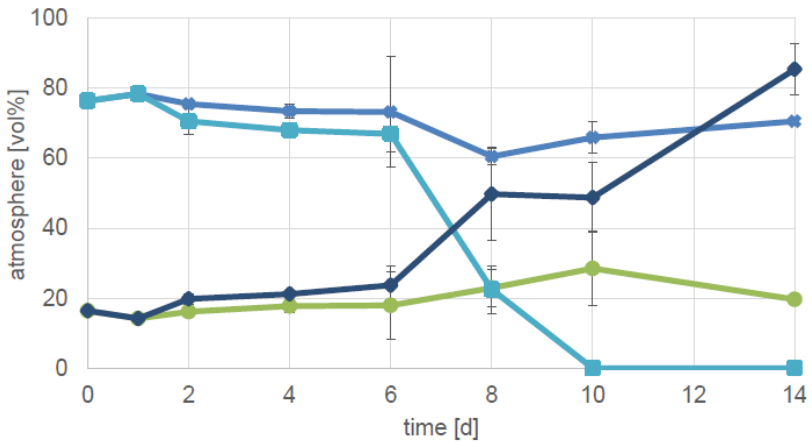
Motivation and Objectives

[1]



Oxygen at 4°C(●) and 10°C (●) and CO_2 at 4°C(●) and 10°C(●) [2].

Why non-destructive measurement systems?

- Food loss especially in Europe and North-America to 1/3 at the consumer
  → **Expired best before date often causative**

- Höll et al. stored poultry under high oxygen atmosphere in 2016
  - Invasive detection of O_2 and CO_2 of packaging headspace
  - Control of TVC (Total Viable Count)
- Critical Value of TVC for poultry defined at 10^7 CFU/g
  → **Reached at day 7 (10°C) or 9 (4°C)**
  → **Accompanied by a fast decrease of p_{O2} and increase of p_{CO2}**

Idea:

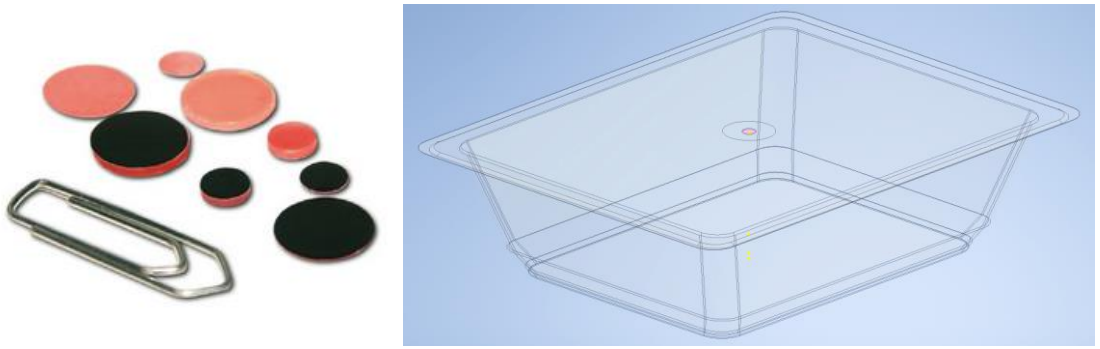
Gas development in the headspace of the packaging as a marker for microbiological spoilage

Measurement with non-destructive systems also allows wide application such as checks in the supermarket or process control in the food processing plant

Non-Destructive Measurement Devices

Oxygen (O_2)

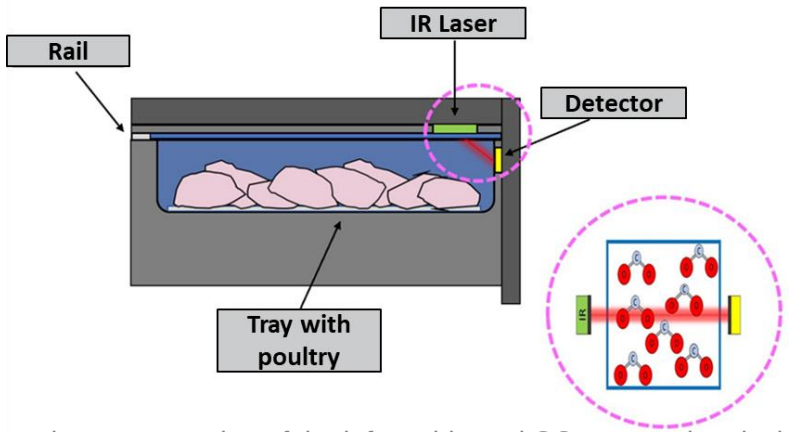
- Principle of O_2 measurement based on ***dynamic fluorescence quenching***
- Integration of fluorescent material into packaging (lid-film) via heat-sealing
- Annular seal between films enables potentially food-compliant integration into packaging



Used Sensors for the integration (left) [3] and schematic representation of the sealed-in sensor material into the lid film of a plastic tray (right)

Carbon Dioxide (CO_2)

- Principle of CO_2 measurement based on ***MIR (mid-infrared) absorption spectroscopy***
- λ_1=4.26µm, λ_2=4.45µm & λ_3=4.27µm
- Laser beam is guided through a corner of the package at 45°



Schematic representation of the infrared-based CO_2 measuring device

Experimental Set-Up

Storage Time: 15 days

80% O_2/ 20% CO_2 | **70% O_2/ 30% CO_2**

4°C | **10°C**

Non-destructive headspace analysis
Measurement: Daily (exc. 3 (filled) and 3/5/6/12&13 d (empty))

Total Viable Count
Measurement: 0/1/4/6/9/1/13/15 d

Sensory Analysis
Measurement: 0/1/4/6/8/11/14 d (4°C) or 0/1/4/6/8 d (10°C)

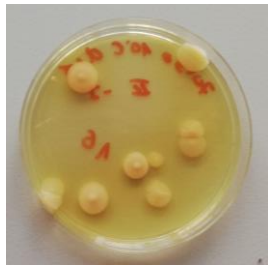
Empty | Filled (poultry)

O_2

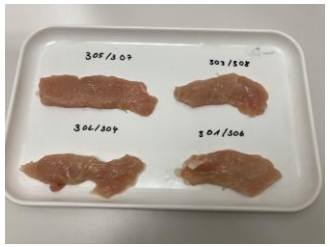
[4]

CO_2

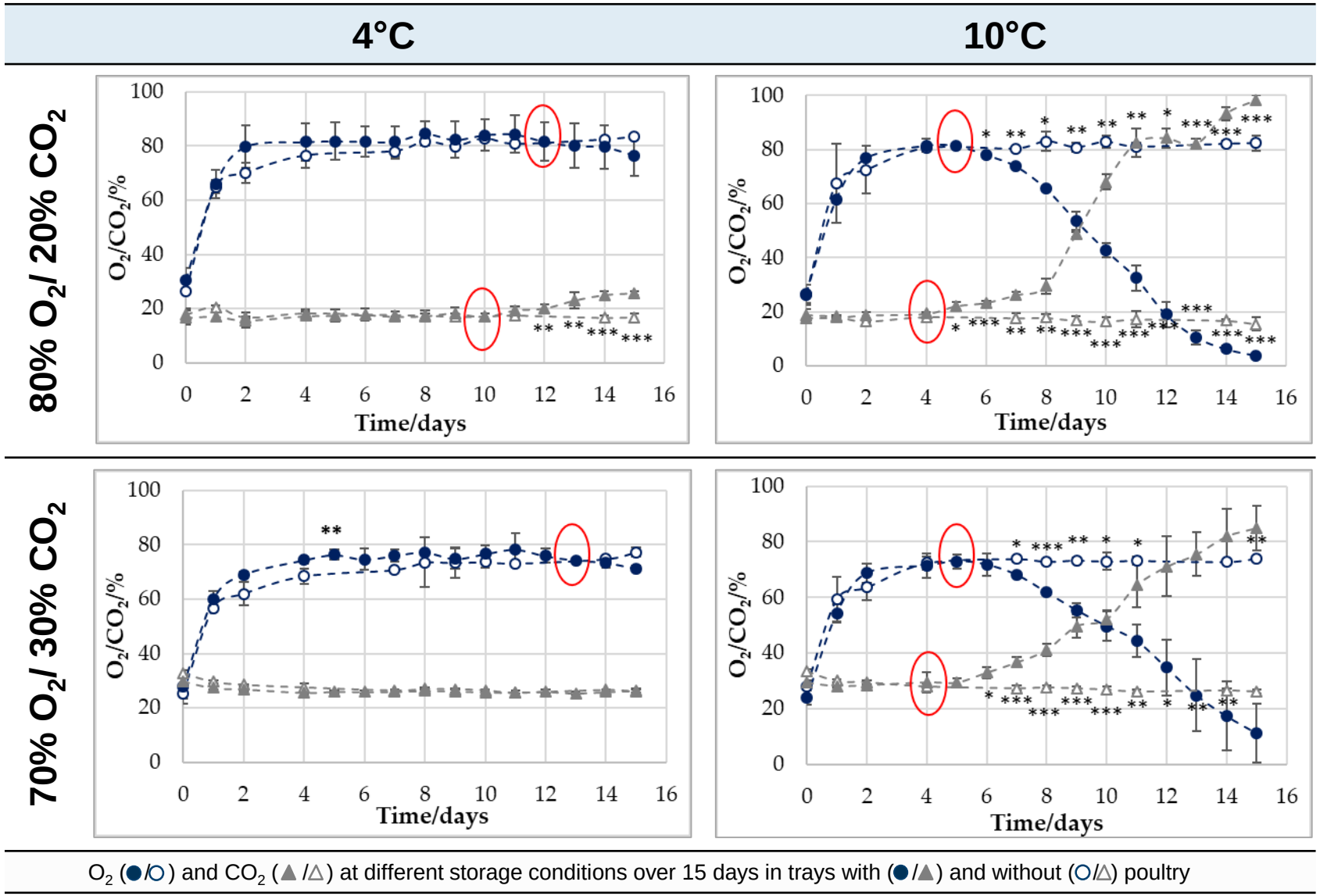
TVC



Sensory Analysis



Results – Development of headspace gas concentration



O_2 (●/○) and CO_2 (▲/△) at different storage conditions over 15 days in trays with (●/▲) and without (○/△) poultry

Development of gas composition in empty trays

- Hardly any change in the gas composition

Significant[1] change: empty vs. filled trays

- Poultry stored at 4°C showed deviations of CO_2 from day 12-15 for 80% O_2/ 20% CO_2 MAP
- Poultry stored at 10°C showed deviationsof O_2 and CO_2 for both gas compositions
- For O_2 values of 4°C stored samples, no significant difference between trays with and without product visible

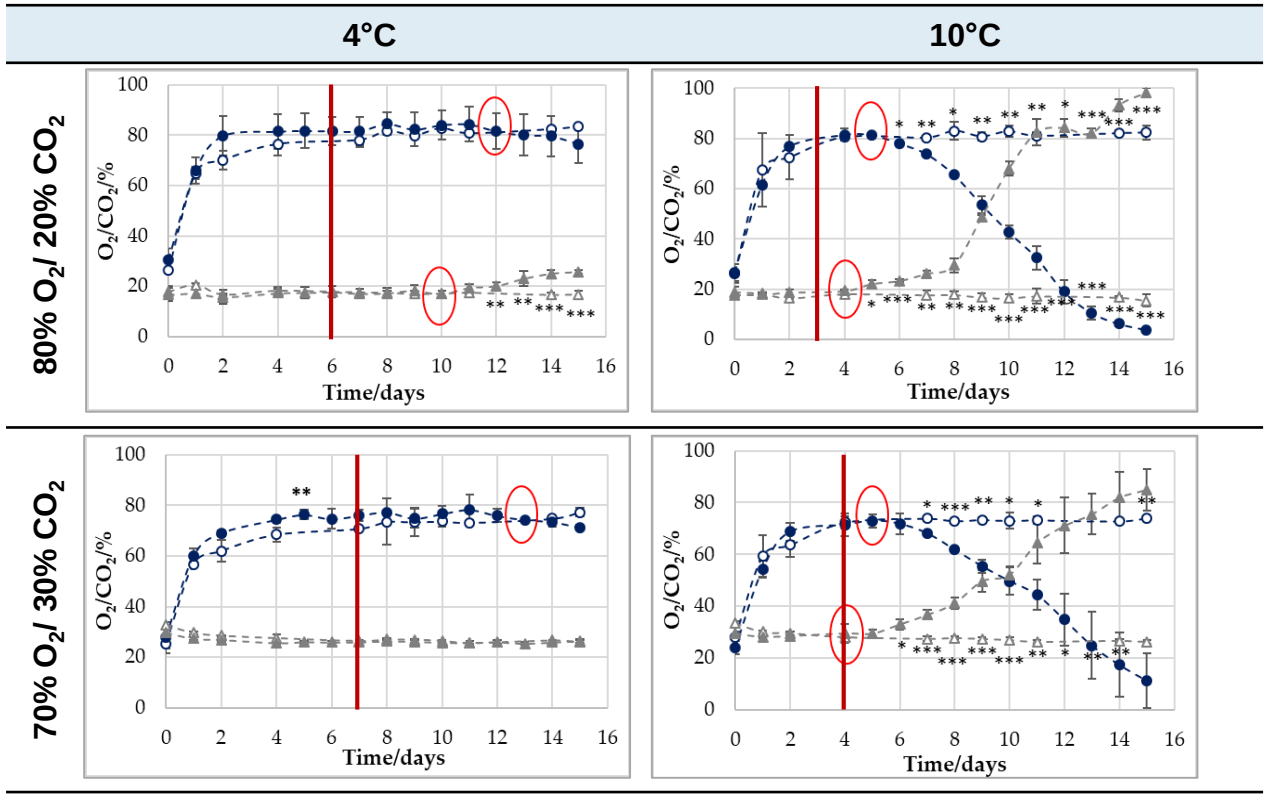
Cross-Over: empty vs. filled trays

- Cross-Over (◯) = gas value of filled tray intersects gas value of empty tray → indication for change of headspace atmosphere
- Appears 1 or 2 days before the first significant deviation
- For O_2 values of 4°C stored samples, only cross-over observed, where afterwards a decrease of O_2 of filled trays is indicated

[1] Level of significance (T-test): * P ≤ 0.05 ** P ≤ 0.01 *** P ≤ 0.001

Results – Microbiological analysis

	Day 0	Day 15	Shelf life expired at
80/20 4°C	$1.36x10^4$ CFUg^{-1}	$4.00x10^9$ CFUg^{-1}	Day 6
70/30 4°C	$1.27x10^4$ CFUg^{-1}	$4.29x10^9$ CFUg^{-1}	Day 7
80/20 10°C	$1.36x10^4$ CFUg^{-1}	$2.19x10^{10}$ CFUg^{-1}	Day 3
70/30 10°C	$1.27x10^4$ CFUg^{-1}	$4.47x10^9$ CFUg^{-1}	Day 4



End of Shelf life

Microbiologically spoiled **(red line)** when *TVC=10^7 CFU/g*

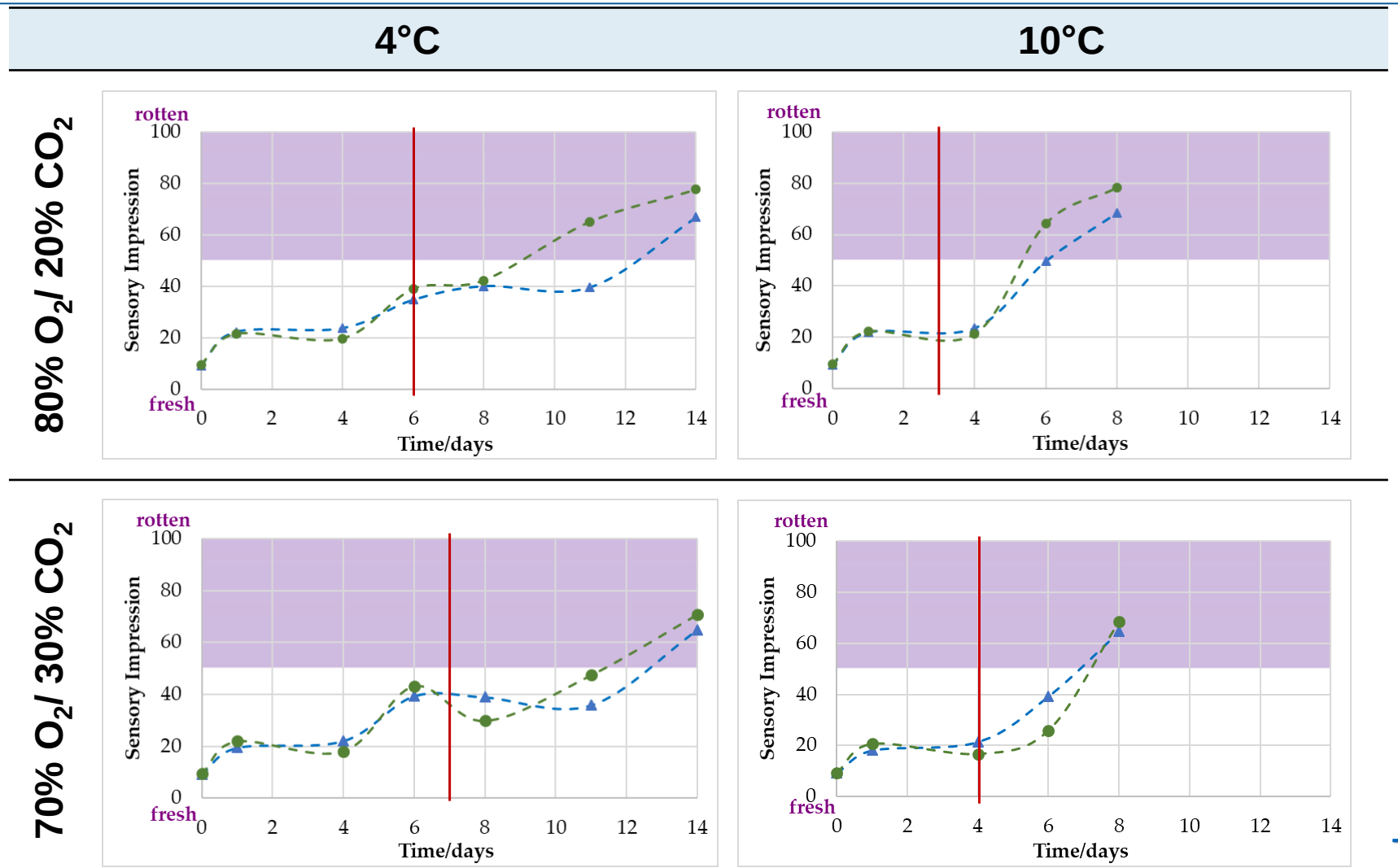
Shelf life vs. Gas development

- All samples were microbiologically spoiled prior to headspace gas change
- In contradiction to the previous study (Höll et al. 2016)

→ End of Shelf life ≠ Gas change

→ Cross-Over is a useful spoilage indicator at 10°C

Results – Sensory Evaluation



Visual (▲) and orthonasal (●) impression at different storage conditions over 8 or 15 days. Red line marks TVC > 10^7 CFUg^{-1}
Purple area marks the defined sensory limit of 50 scores.

Sensory Evaluation

Visual and orthonasal impression was evaluated on an analogue scale ranging from 0 to 100 (0 = not perceptible/fresh; 100 = strong perceptible/rotten).

50 Scores Limit

For the evaluation, a sample was defined as no longer acceptable, when the average value of the orthonasal or visual impression was ≥ 50.

Visual Impression

- 4°C stored samples „*fresh*“ until day 11
- 10°C stored samples „*fresh*“ until day 4 (80/20) or day 6 (70/30)

Orthonasal Impression

- 4°C stored samples „*fresh*“ until day 8 (80/20) or day 11 (70/30)
- 10°C stored samples „*fresh*“ until day 4 (80/20) or day 6 (70/30)

→ **Sensory Spoilage ≠ Microbiological Spoilage**

Correlation of the results - Discussion

	4°C		10°C	
	80/20	70/30	80/20	70/30
cross-over O_2	12	13	5	5
P≥0.05 O_2	-	-	6	7
cross-over CO_2	10	-	4	4
P≥0.05 CO_2	12	-	5	6
microbiologically spoiled	6	7	3	4
olfactory spoiled	11	14	6	8

P≥0.05 stands for the day of the first calculated statistical significance between empty and filled trays after reaching the cross-over, microbiologically spoiled indicates a TVC of 10^7 $CFUg^{-1}$ and olfactory spoiled stands for a classification of the sensory panel above the limit of 50 scores.

Possible Correlations:

- Yellow: Cross-Over & Microbiologically Spoilage
- Orange: Cross-Over & Olfactory Spoilage
- Green: Headspace gas change & Olfactory Spoilage

O_2/CO_2 & Microbiologically Spoilage

- Significant change of headspace gas composition not correlatable with microbiological limit of 10^7 CFU/g
- Cross-Over (esp. CO_2) for 10°C samples useful

→ **Cross-Over for detection of irregular storage conditions (e.g. cold chain interruption)**

- Spoilage under regular storage not detectable with O_2/CO_2 change

O_2/CO_2 & Sensory Spoilage

- Cross-over of 4°C stored samples well in common with olfactory spoilage
- Headspace change of 10°C stored samples correlateable with sensory spoilage

→ **O_2/CO_2 change = Sensory spoilage**

Conclusion and Outlook

- No individual shelf-life prediction for regular stored, high-oxygen packed poultry possible via measurement of the headspace gas atmosphere (O_2/CO_2)
- Other gas compositions and/or foods (e.g. red muscle beef) must be tested
- Volatile Organic Compounds as marker to be discussed

Applicability:

- Both measurement systems useful for non-destructive detection of O_2 and CO_2
- Control of cold-chain interruption/irregular storage conditions possible
- Further applications to be tested: process control for MAP production lines or detection of leakages in packages
  → Research regarding measuring precision for both systems is work in progress

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References

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[2] Höll, L.; Behr, J.; Vogel, R.F. Identification and growth dynamics of meat spoilage microorganisms in modified atmosphere packaged poultry meat by MALDI-TOF MS. *Food Microbiology* **2016**, *60*, 84–91.

[3] PreSens Precision Sensing GmbH. Oxygen Sensor Spot SP-PSt6-NAU. Available online: https://www.presens.de/de/produkte/detail/o2-sensorspot-sp-pst6-nau (accessed on 2 September 2021).

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