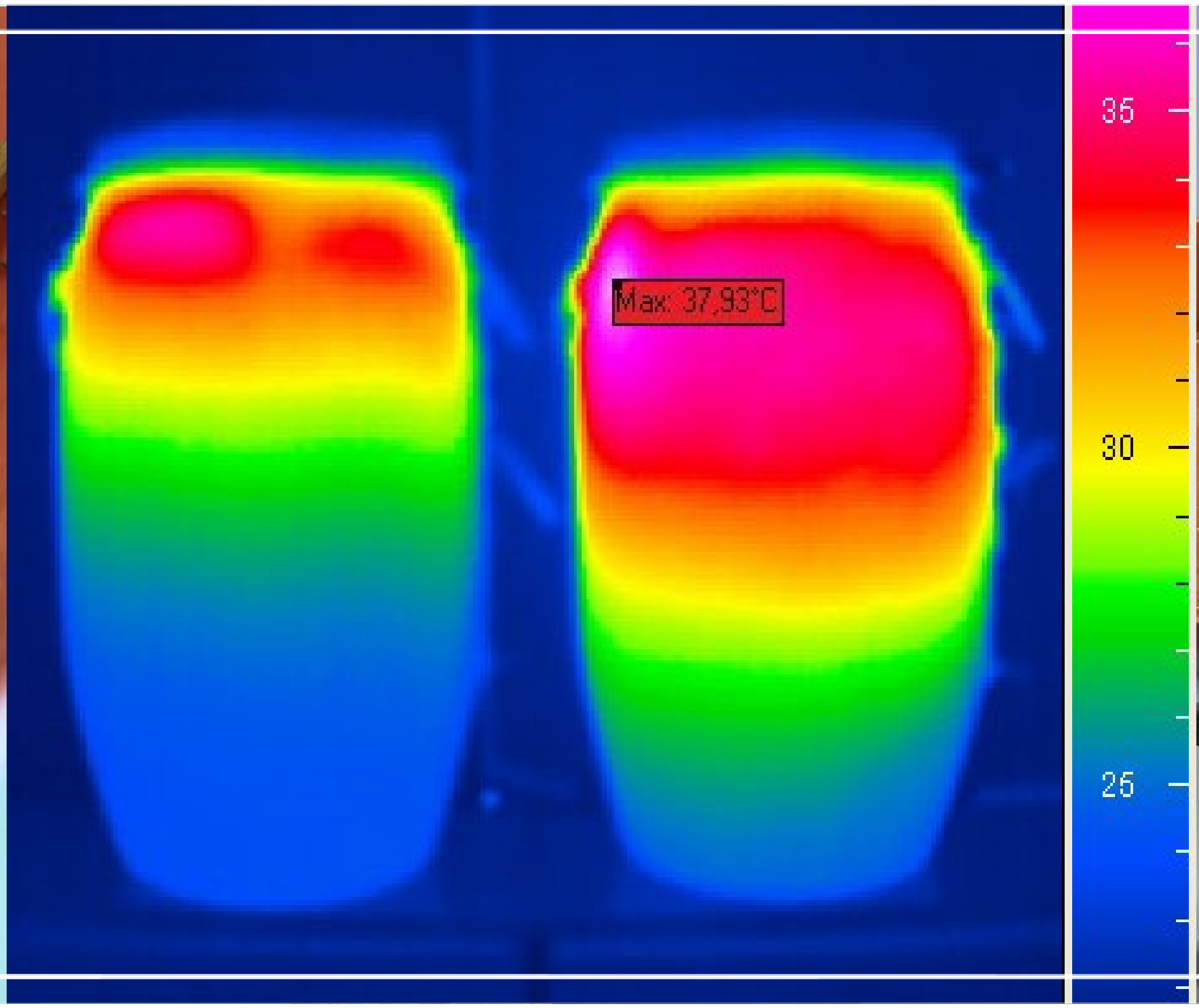
UNIVERSITÄT BONN

FARM ANIMAL TECHNOLOGY

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE

Freistaat SACHSEN

# Detecting aerobic changes in silages and silage-based rations on farms and in laboratory scale silos





Siriwan Martens and Christian Maack

XX International Silage Conference, 21-24 July 2025, Gainesville, FL, USA

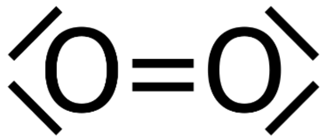
# Significance of aerobic deterioration of silages and silage based mixed rations

- Silage losses in the feedout phase: ↑ up to 20 % of DM (and more)
- Affects:
  - Hygienic quality
  - Energy value
  - Protein quality
  - Nutritive value
  - Palatability
- Waste of resources, economic loss

# Microbial development upon exposure to air

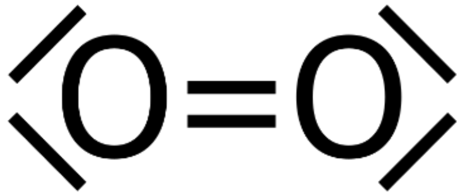
- „Classical“ process:

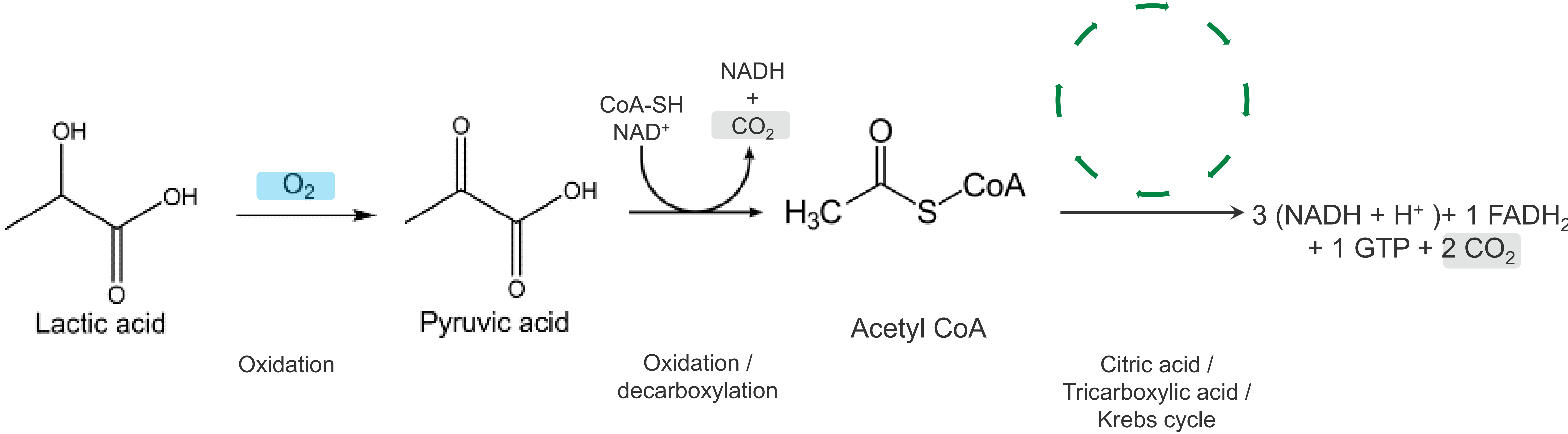
Yeast infestation at ↓pH and air ingress



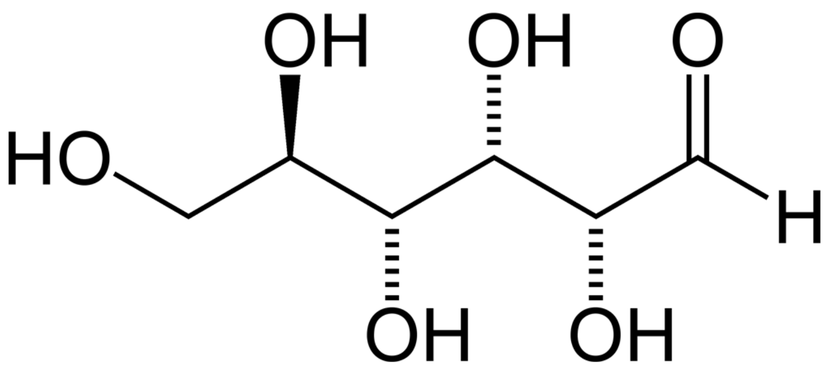
Stepwise outgrown by mould

# $O_2$ consumption



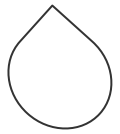


# Metabolization of nutrients

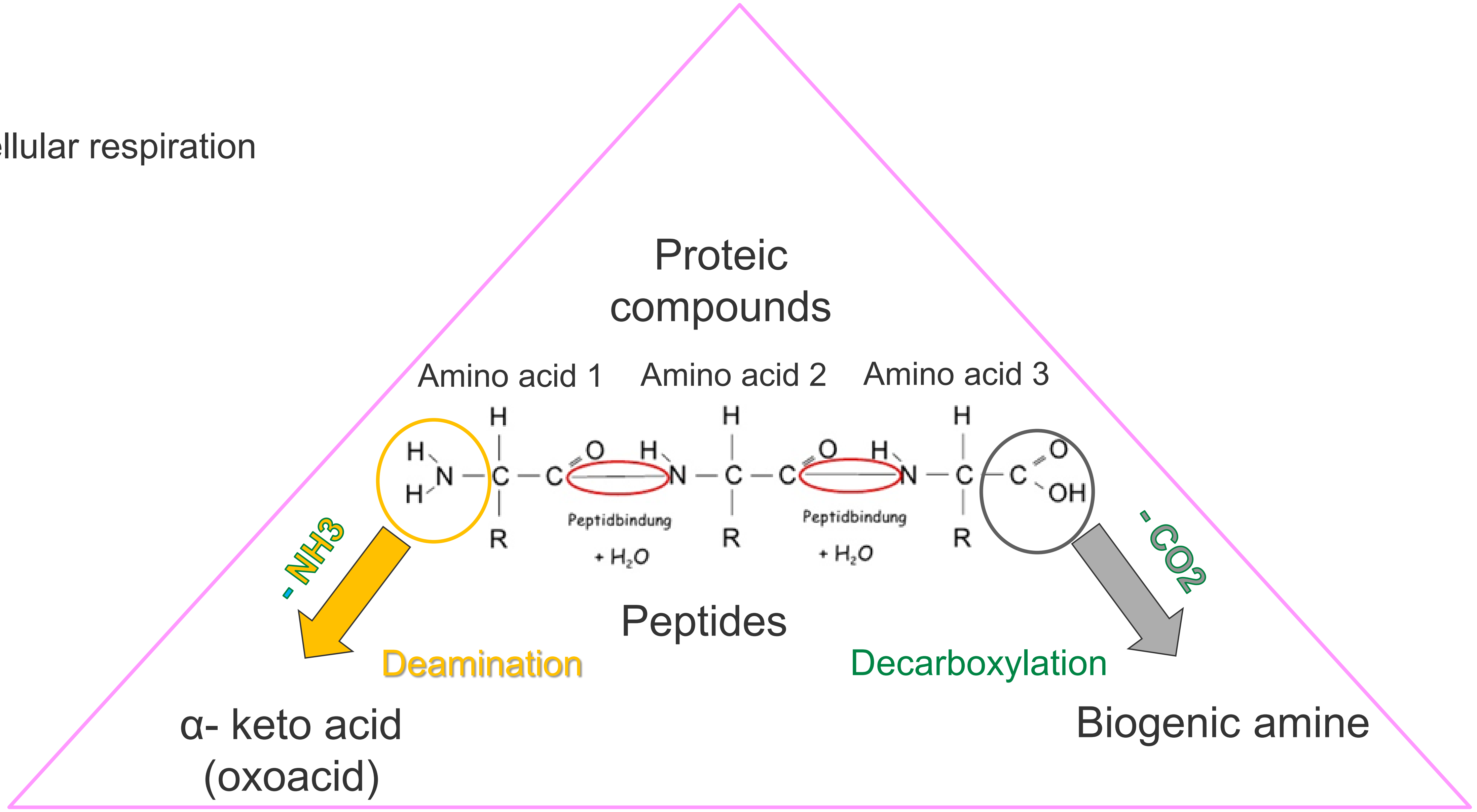



Carbohydrate:
Glucose

$+ 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + ATP$



Cellular respiration



# Metabolic end products

$CO_2$

$H_2O$

# Heat development

**Temperature increase:**

Up to now the only indicator commonly used to describe aerobic instability.

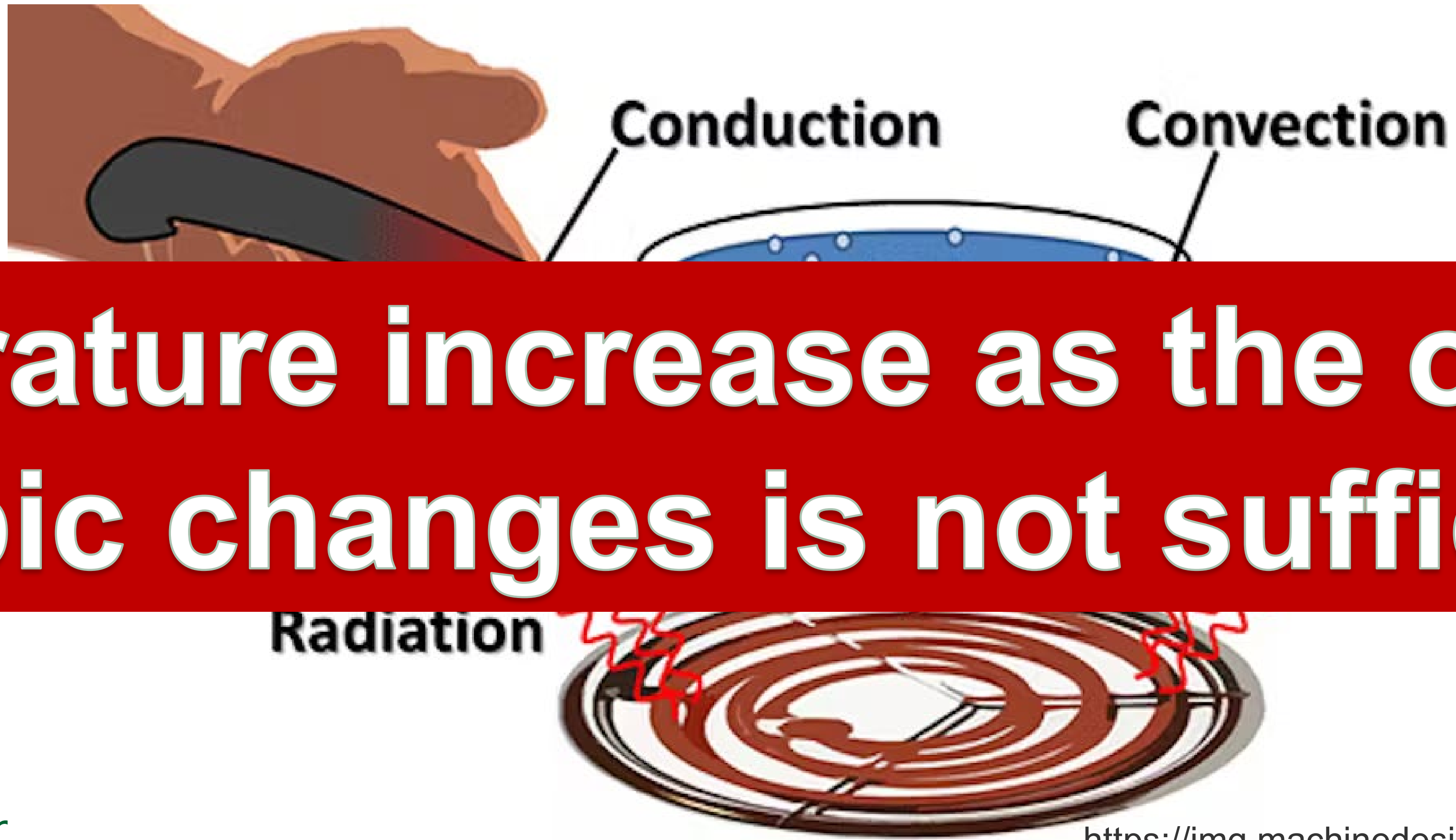
Which factors do influence the measured temperature?

Is the time to + 1/2/3 K a comparable absolute value?

Is it  sufficient to describe the onset & extent of aerobic changes?

# Heat transfer – Sources of heat losses

- **Thermal conduction (*Q*):** diffusion of heat within the silage and towards the silo wall
- **Convection:** mass transport in the flowing gas (!)
- **Radiation** ☼ emitted from the silage surface



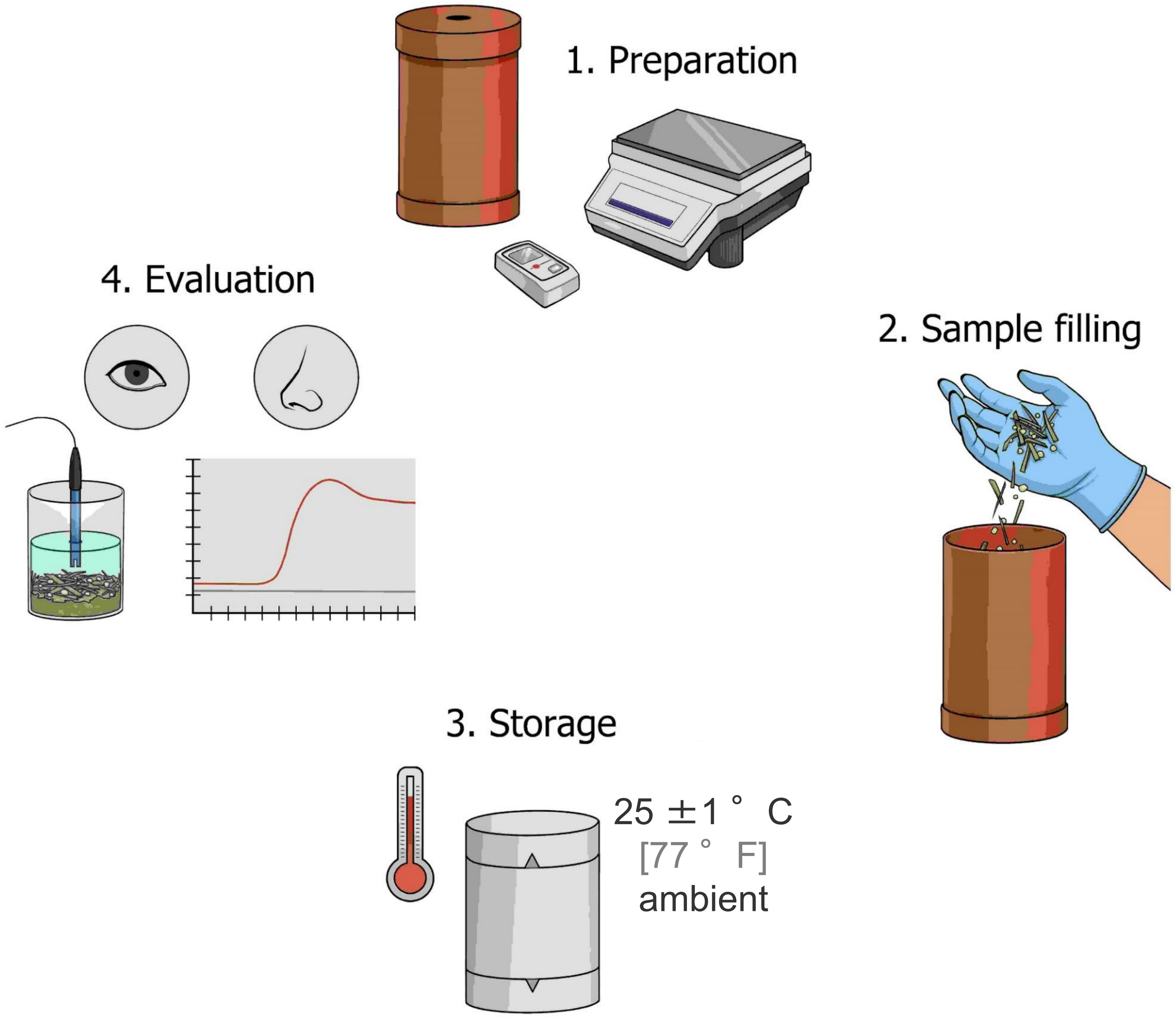

**Temperature increase as the only indicator for aerobic changes is not sufficiently reliable!**

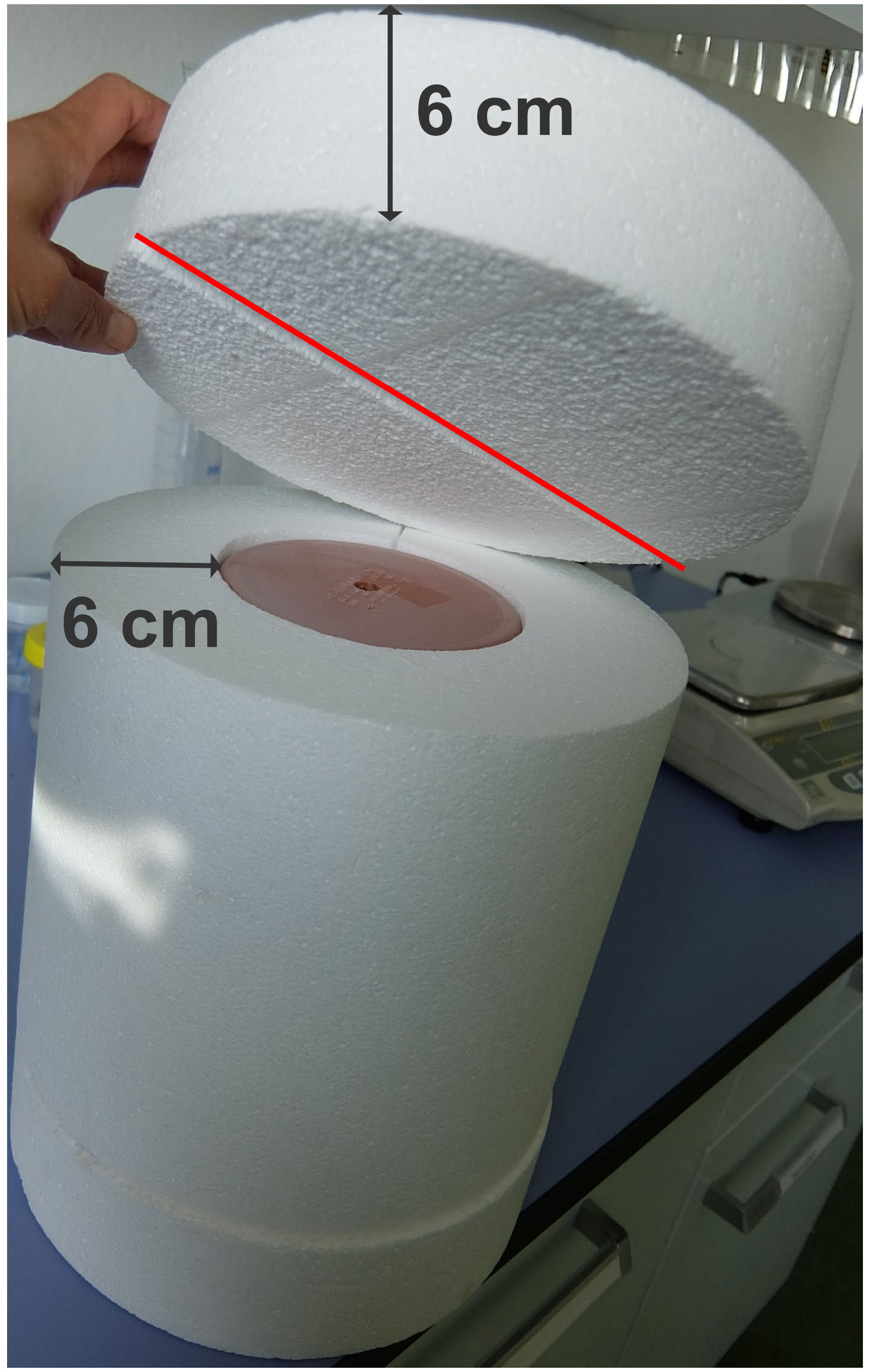
https://img.machinedesign.com/

# Indicators of aerobic changes

- $CO_2$ production
- (Condensed) water
- Temperature increase
- Increase in pH
- Appearance of yeasts and moulds
- Further sensory changes

# Experimental setup – implemented at 5 locations/institutions in Germany

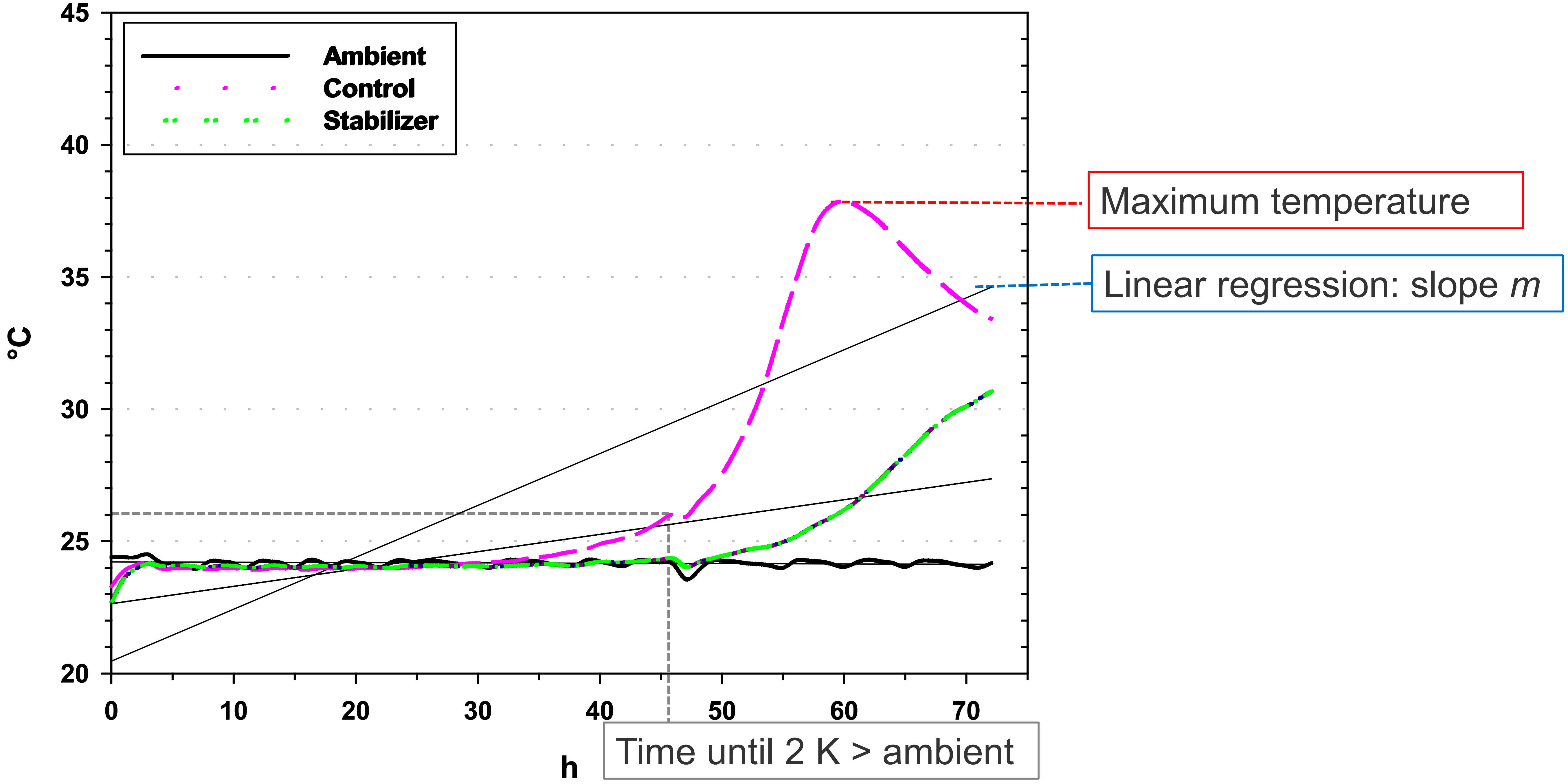



According to HONIG, 1990, modified

# Temperature increase – Example of fresh TMR without or with stabilizer

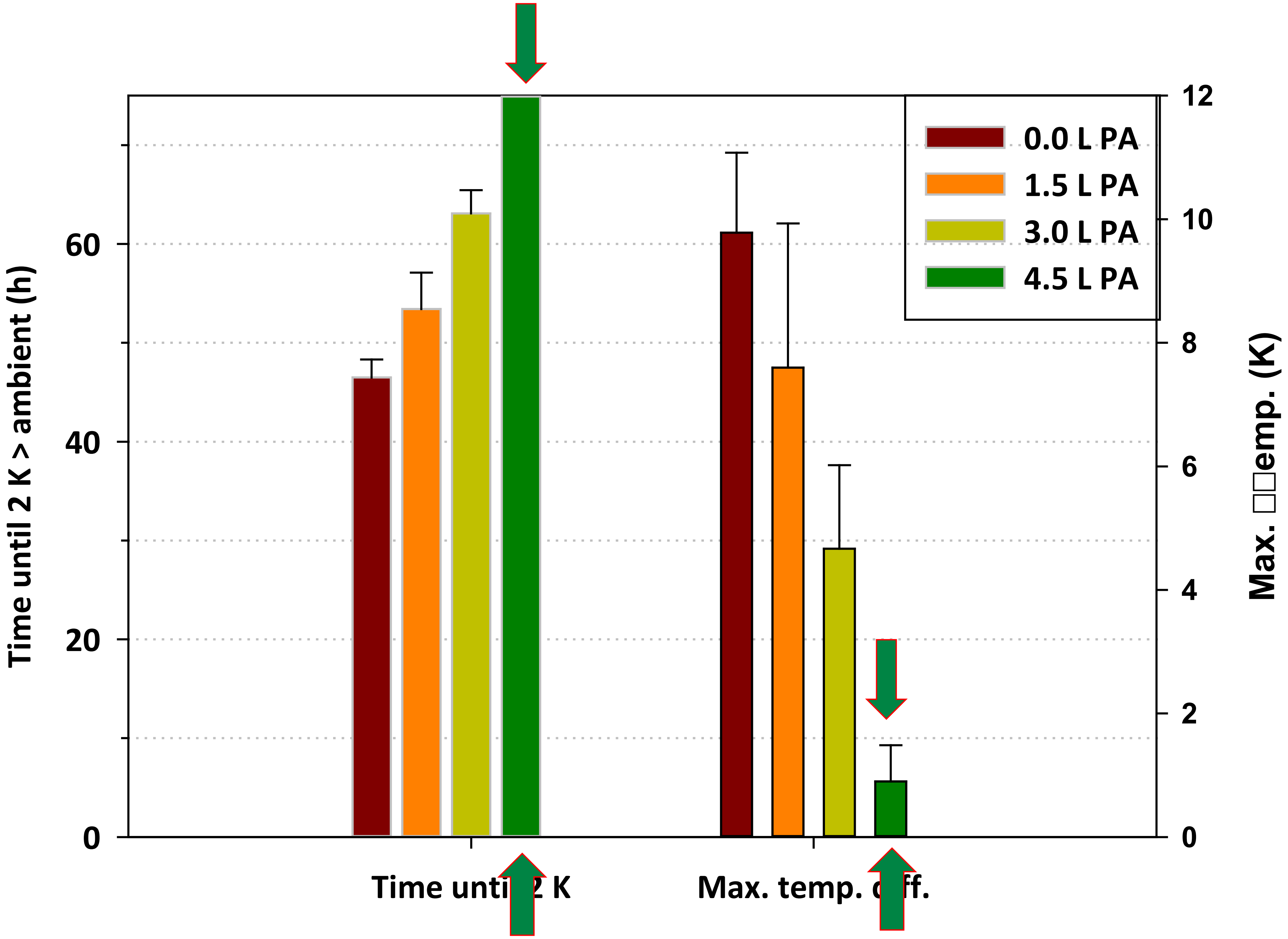
within 72 h at 25 ±1 ° C ambient




Schneider 2021, LfL

# Temperature – Example of fresh TMR treated with increasing concentrations of propionic acid

- Evaluated after 72 h of incubation at 25 °C

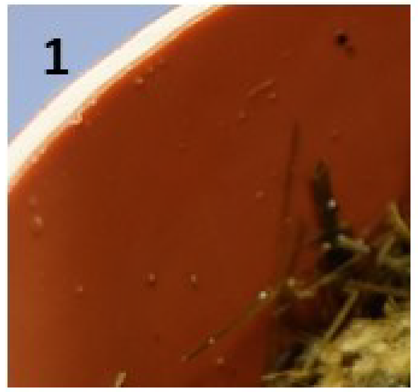



Treatments:
0.0 - 4.5 L **P**ropionic **A**cid/ t TMR

Virtually no temperature increase
→ "*aerobically stable!*"?

# Humidity score after aerobic stability test

- evaluate immediately after opening the lid





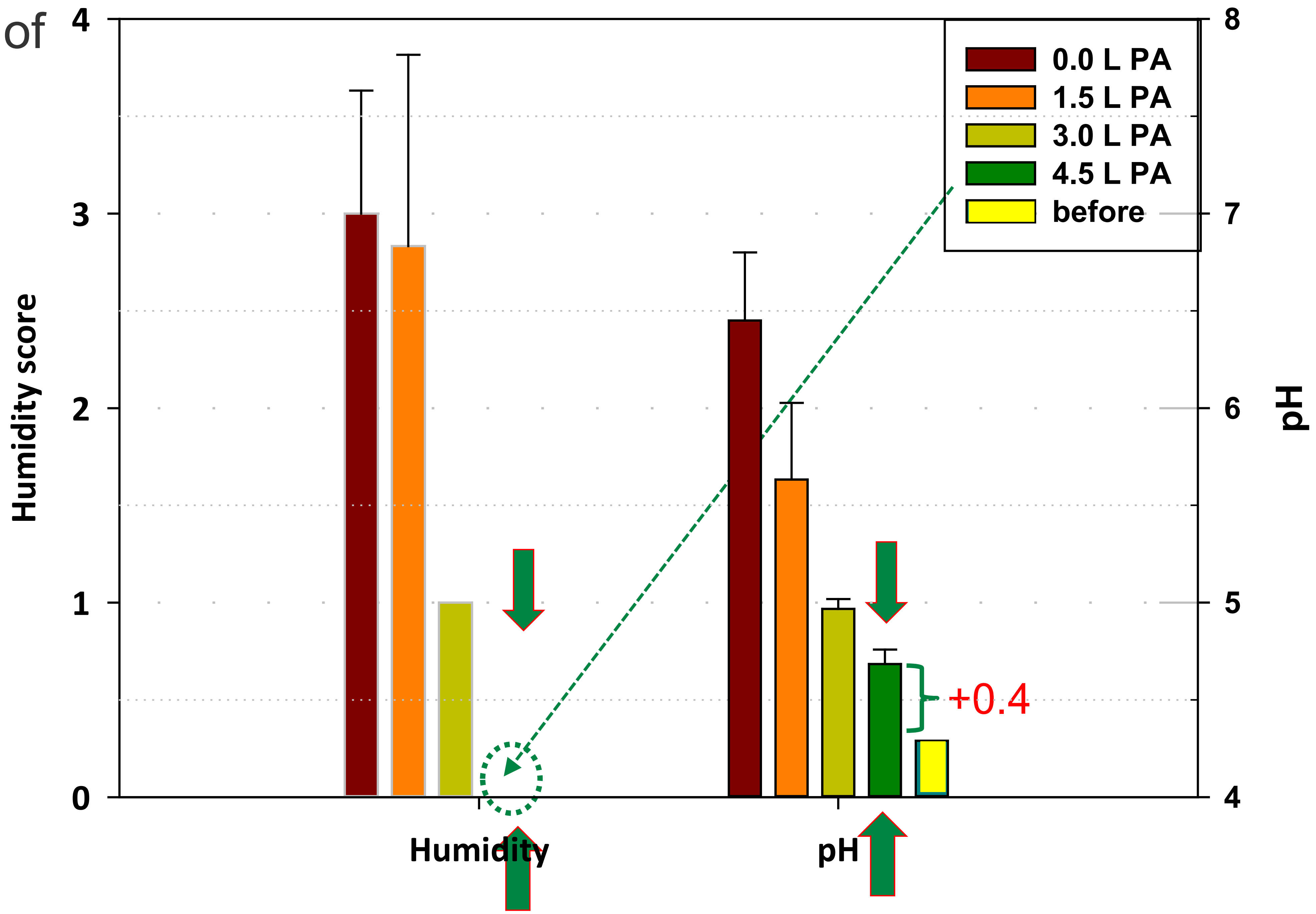

| | |
|---|---|
| 0 | No condensation |
| 1 | Light condensation at container wall |
| 2 | Wall continuously moist |
| 3 | Large drops at the wall<br>(but water does not merge to a pool in the lid) |
| 4 | Wall and lid very wet |


 siriwan.martens@lfulg.sachsen.de

# Humidity score  and pH increase

– Example of fresh TMR treated with increasing concentrations of propionic acid

- Evaluated after 72 h of incubation at 25 °C

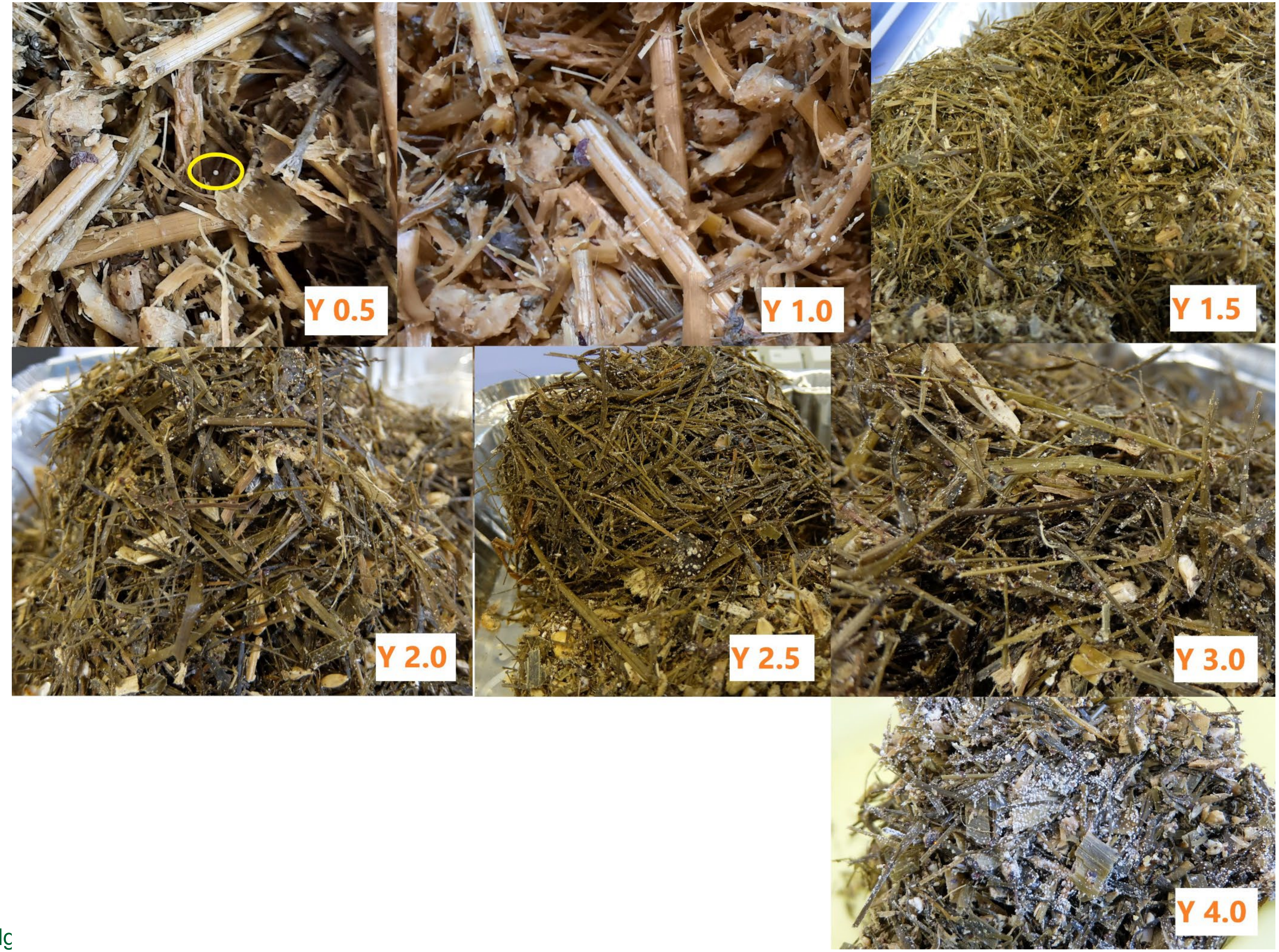




# Appearance of yeasts and moulds

| Points | Yeasts | Moulds |
|---|---|---|
| 0.0 | None visible | None visible |
| 0.5 | Traces of yeasts | A very small area of mould |
| 1.0 | Yeasts ~10% | ------- |
| 1.5 | More yeasts | Some small mould colonies |
| 2.0 | Yeasts continuously present | ------- |
| 2.5 | Yeasts continuously present | More mould colonies |
| 3.0 | Heavy presence of yeasts | Mould mycelium in every part |
| 4.0 | Completely deteriorated | Completely deteriorated |

According to PAHLOW, 1997

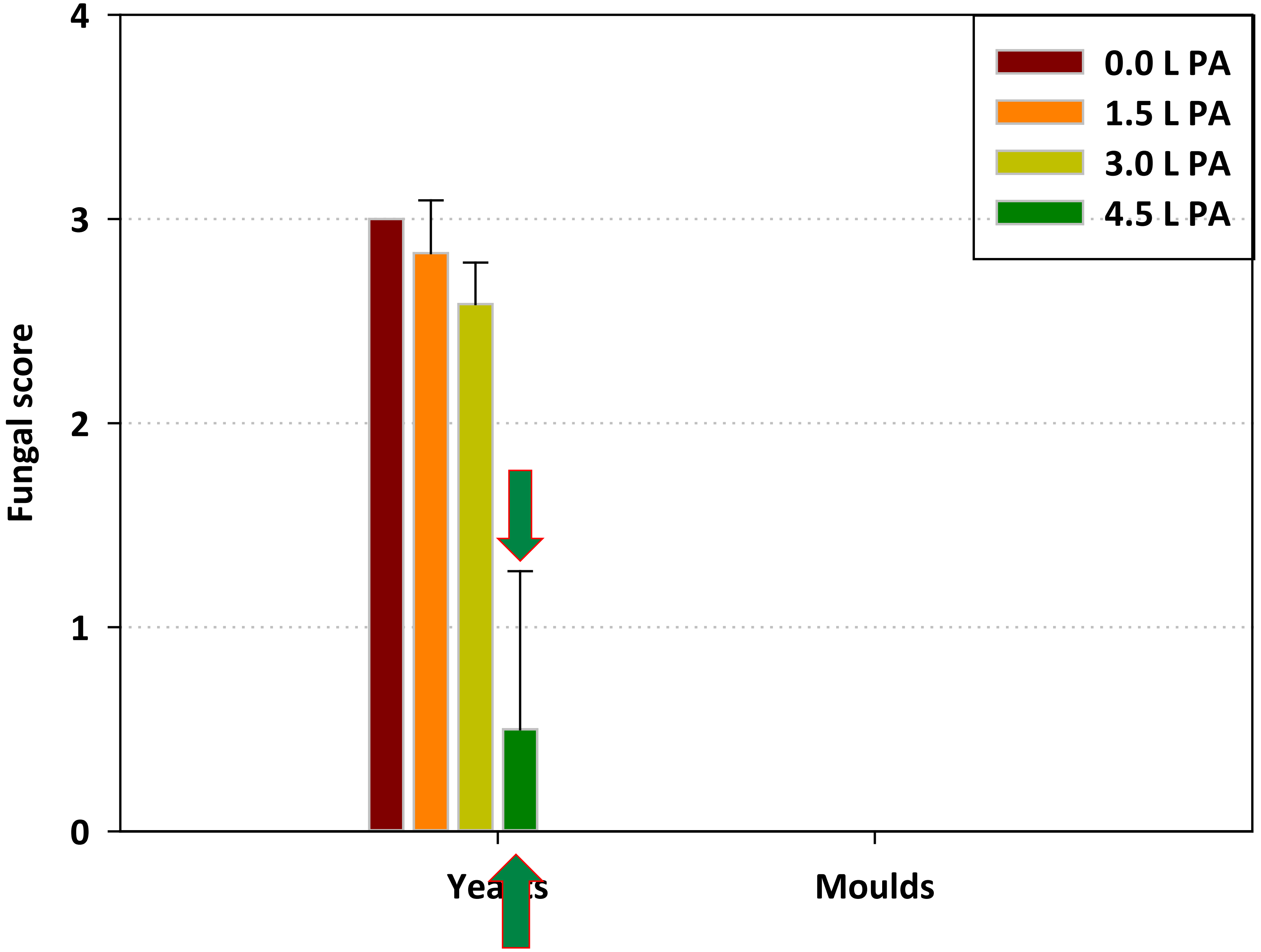
# Yeast score



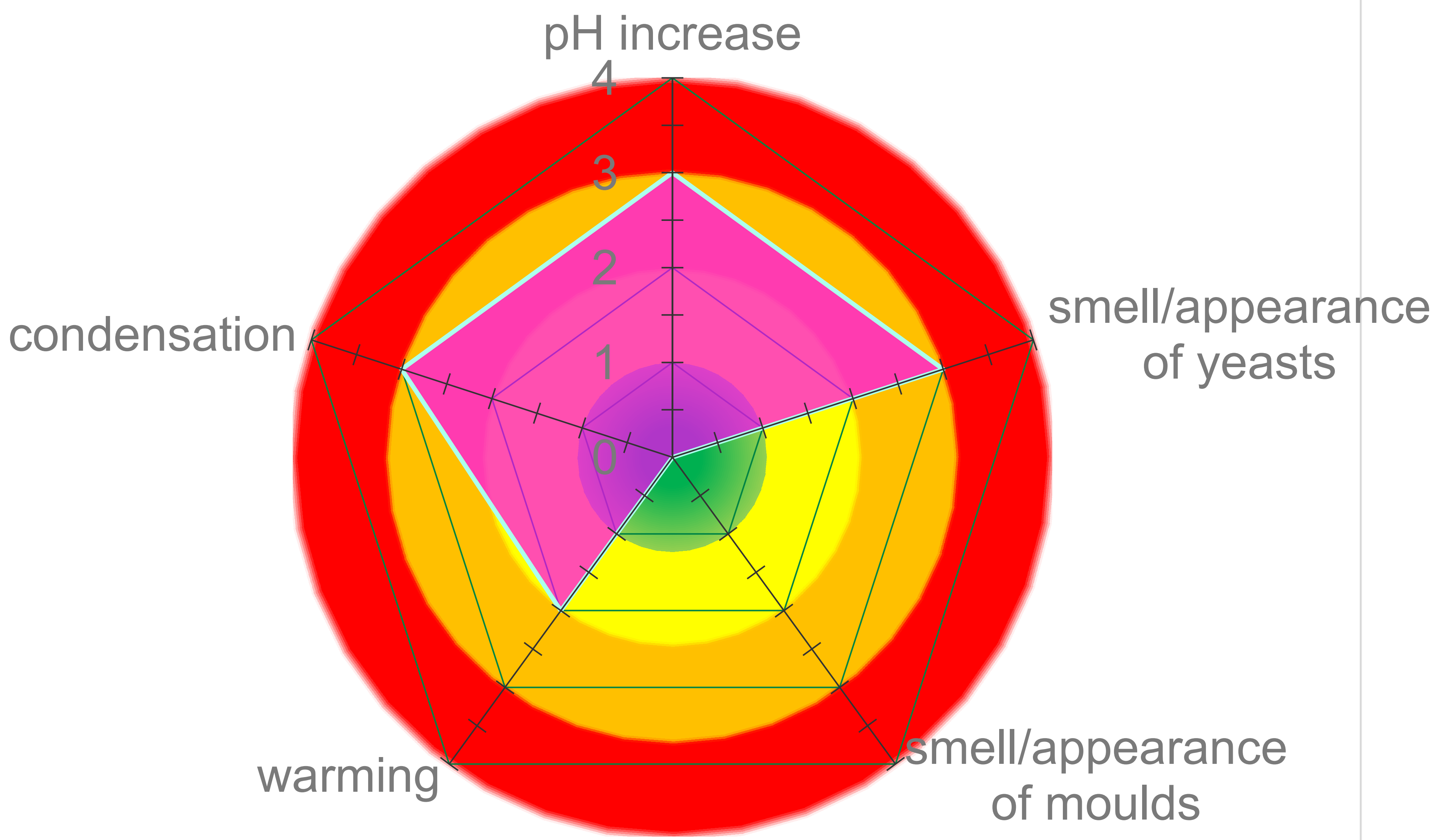
# Mould score

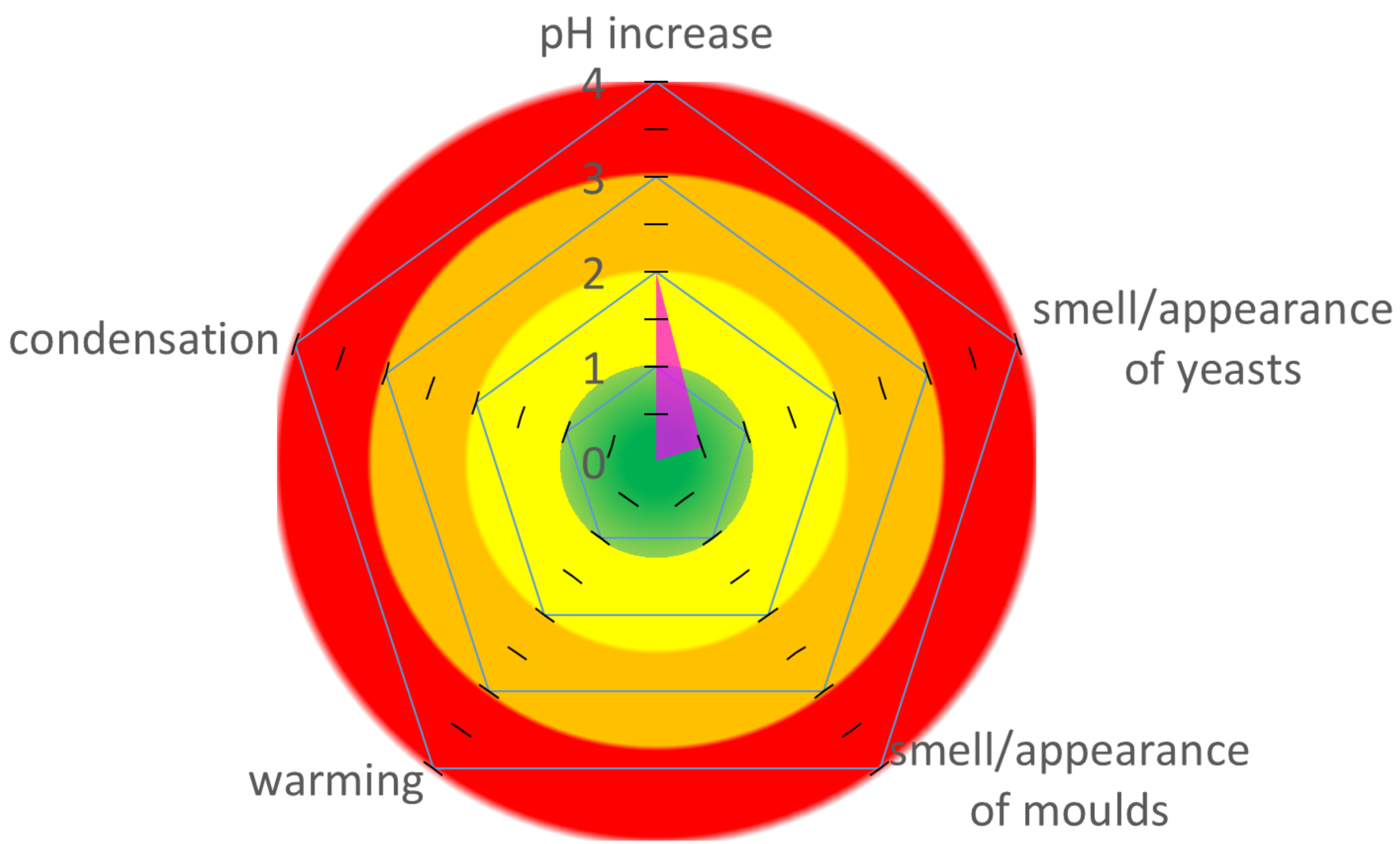
# Yeasts & moulds – Example of fresh TMR treated with increasing concentrations of propionic acid

- Evaluated after 72 h of incubation at 25 °C


# Evaluation of the effect of stabilizer concentration on aerobic changes – two examples of TMR



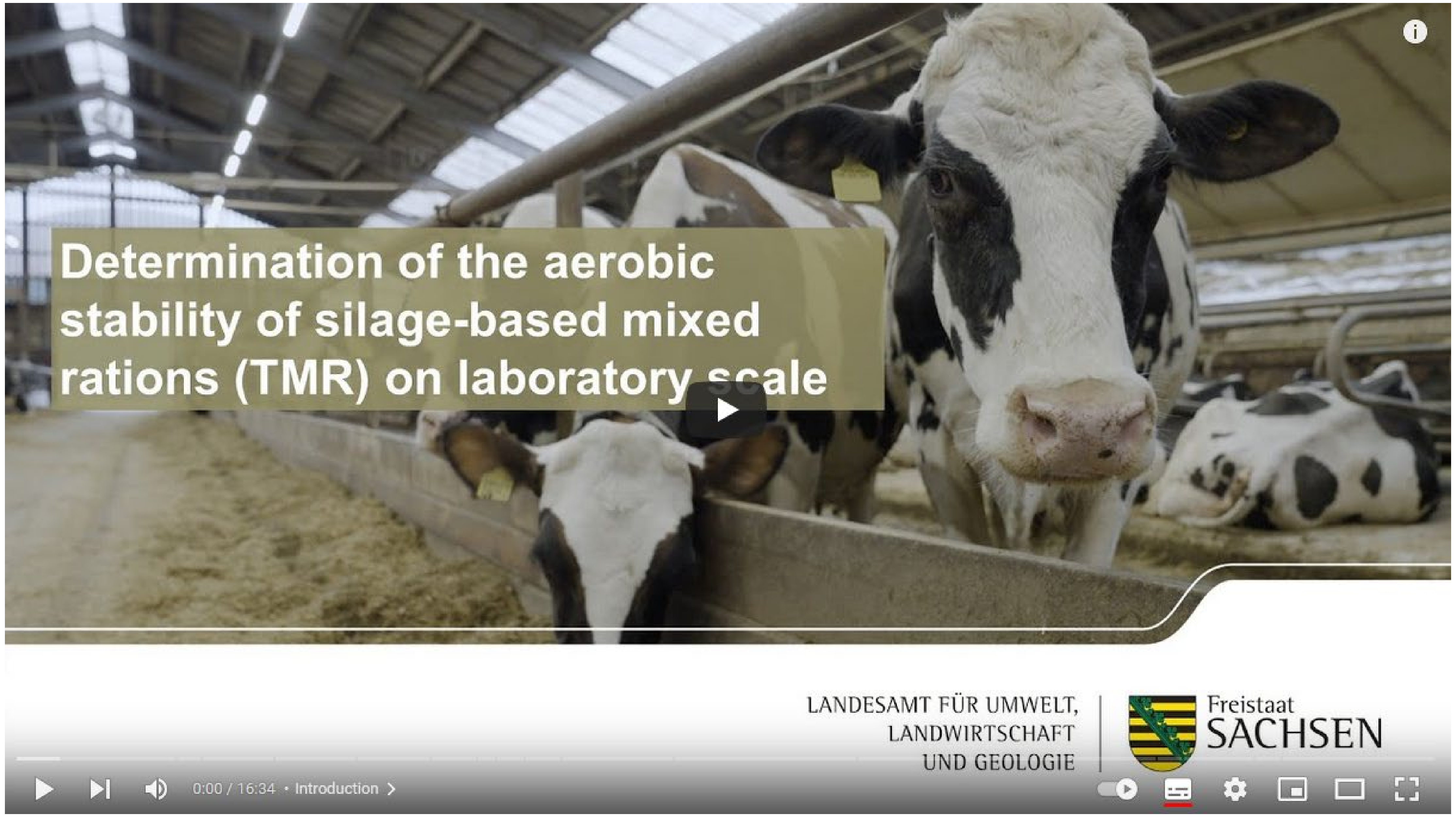




„Typical“ example - Control

„Atypical“ example – High PA

# Observation & measurement of indicators

- Part I: Simple laboratory approach: qualitative, semi-quantitative and quantitative assessment

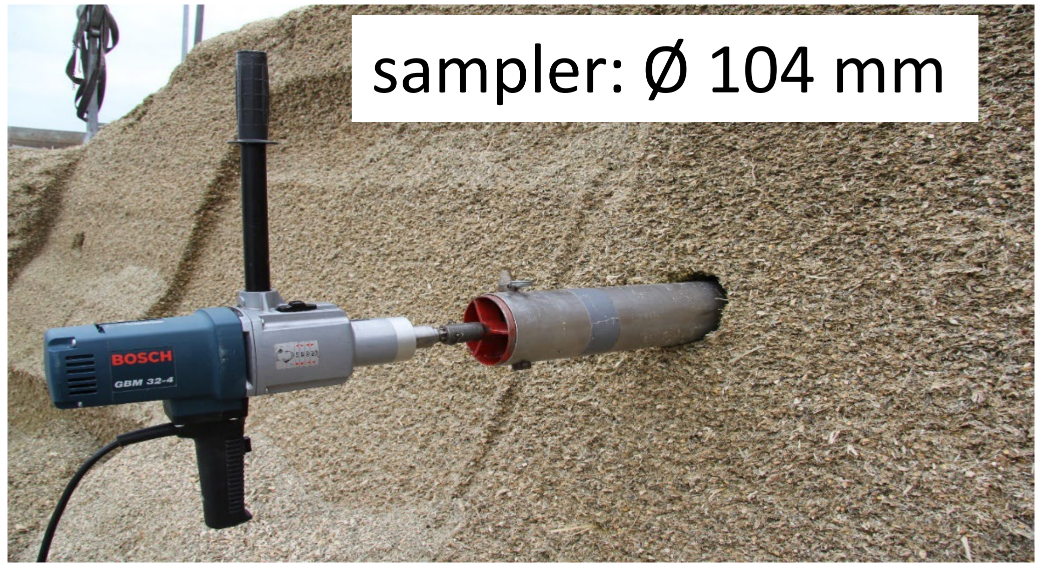


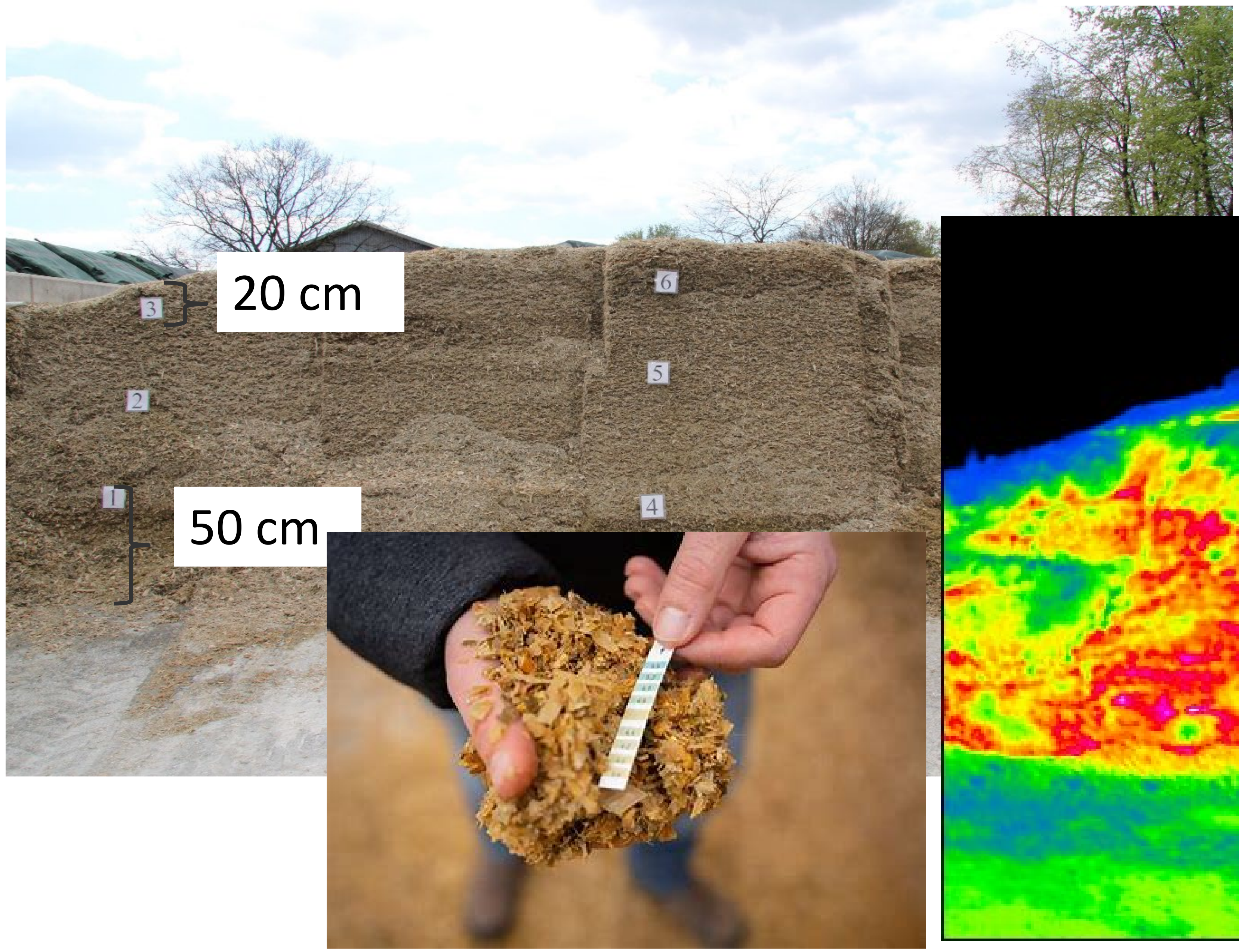


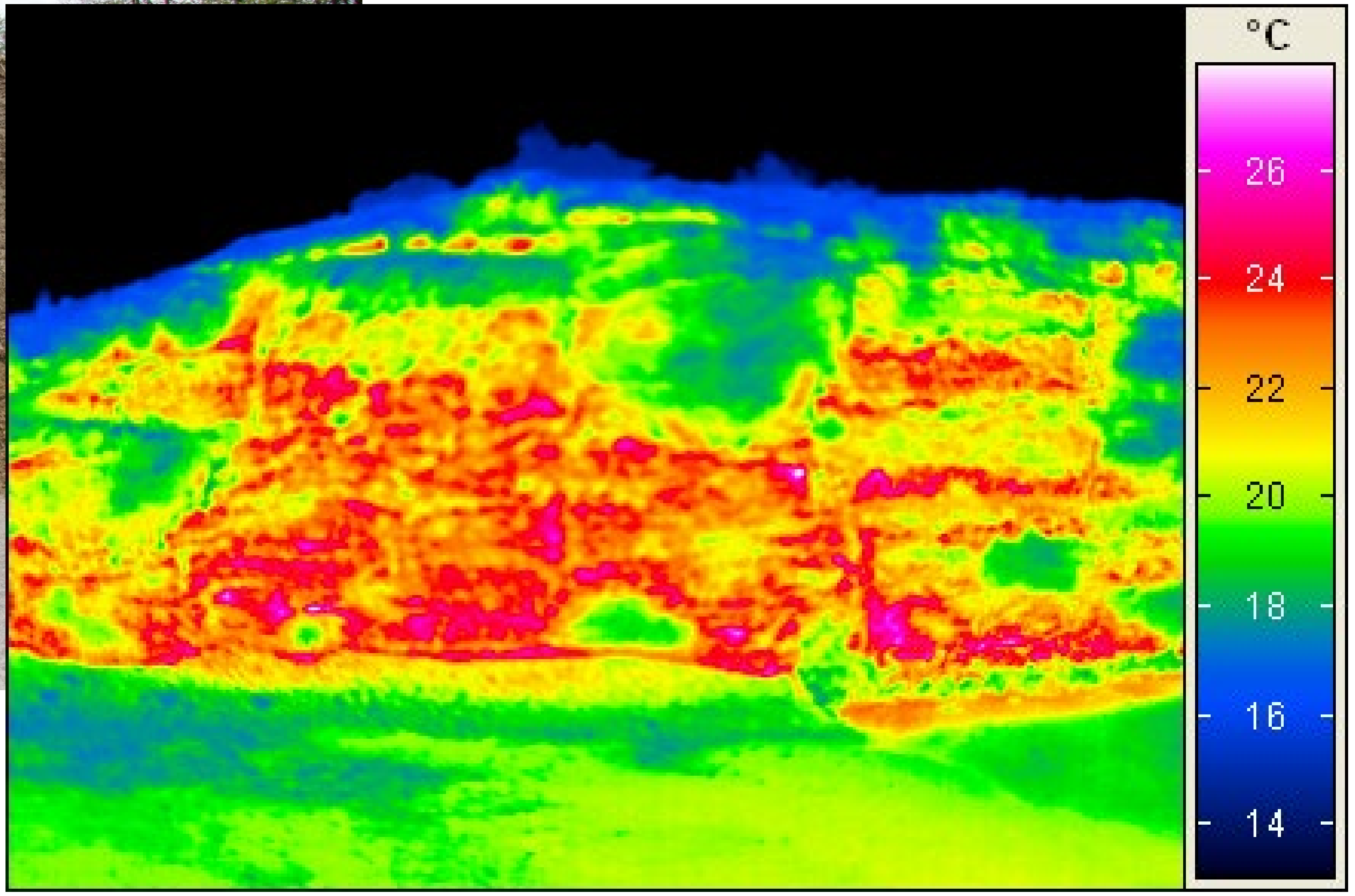
https://lsnq.de/tmraerobicstability

# Controlling and measurement at the silo face

- Measurement of density and DM by core sampling using a penetrometer



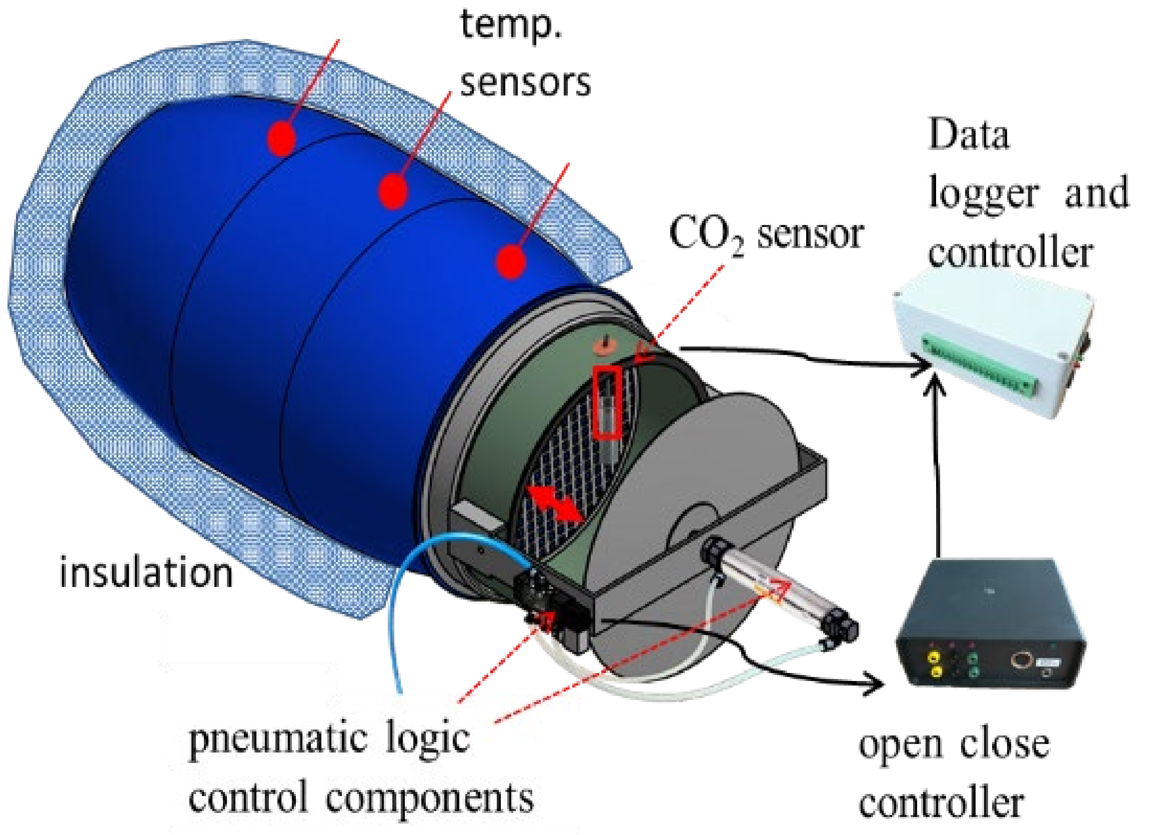




- Measurement of pH and temperature

Measurement of DM losses and emitted $CO_2$
is challenging ……… and more simple to do in small scale silos

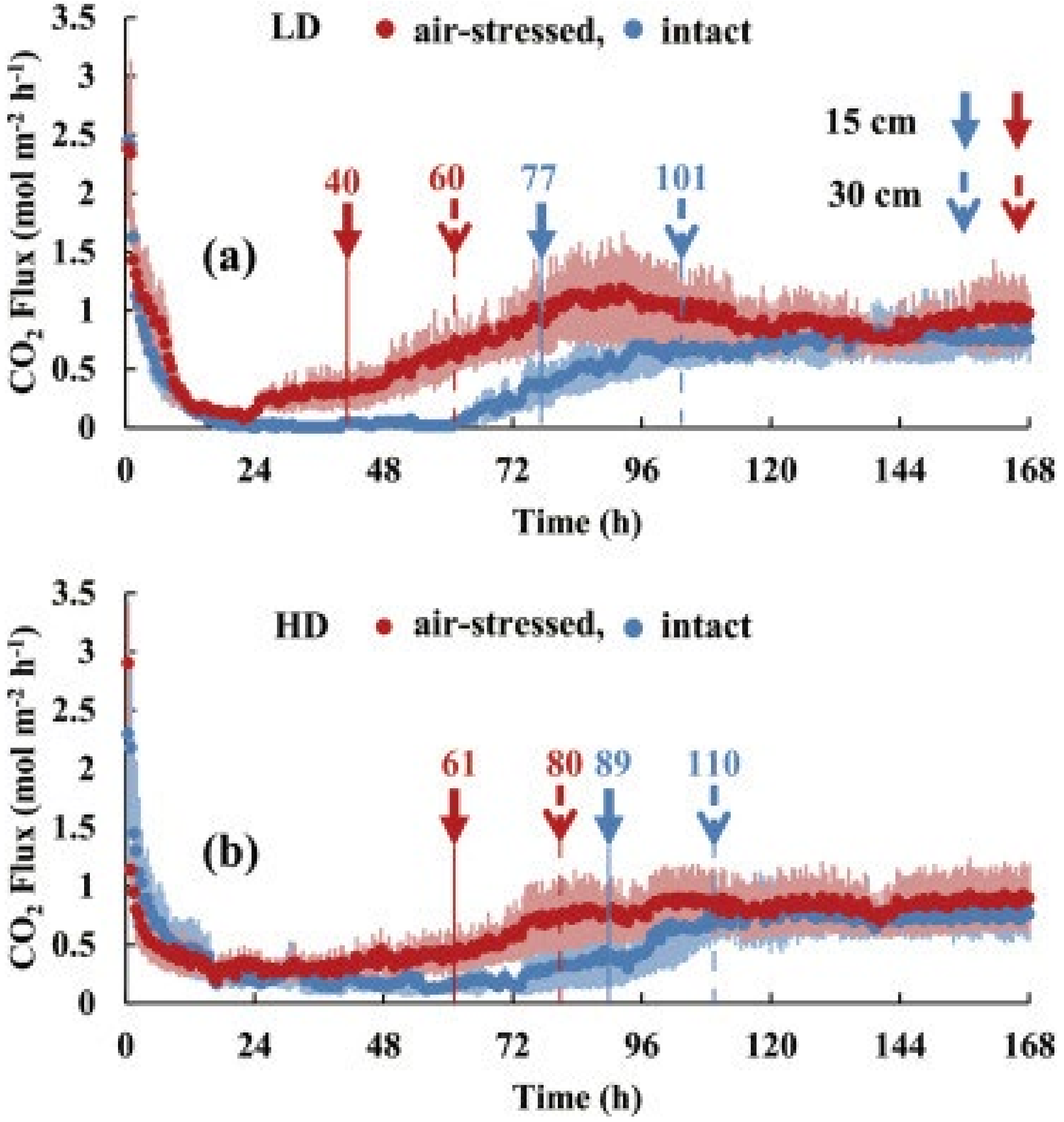
# Technical setup in small scale silos

- Simulation of an open silo face of different density using a 60 L barrel
- Automated measurement of $CO_2$ outflux and $O_2$ in the silage
- Temperature near the surface and in deeper layers




(G. Shan et al. 2021)

- High density leads to lower $CO_2$ outflow at the surface of the barrel
- Air stress at day 28 and 40 lead to shorter aerobic stability rising $CO_2$ emissions



# Technical setup in small scale silos

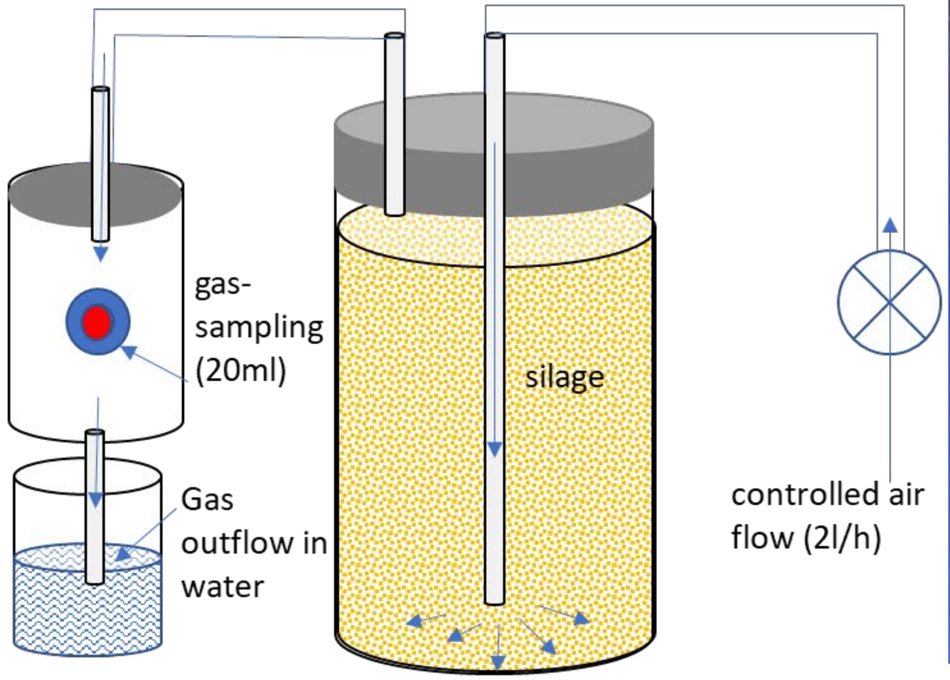
(Y. Sun 2025)

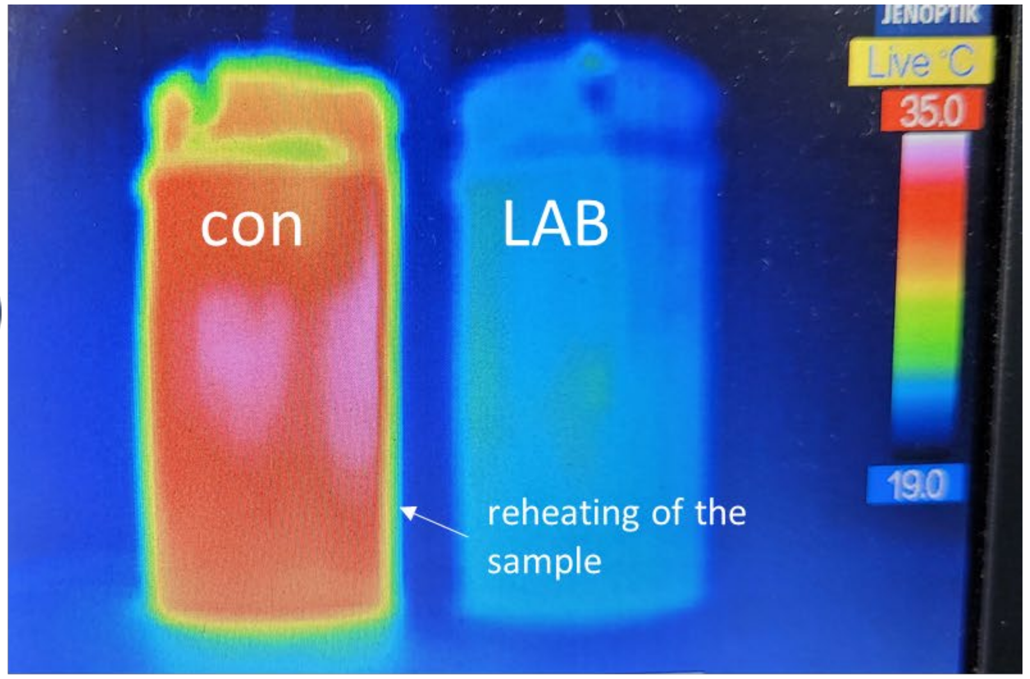
See Poster #41

# Test set up with complete gas control

- Collection of fermentation gases in bags
- Analysis of samples in glass vials

- Controlled ventilation during aerobic storage
- 2 L/h (1.5 L glass jar)
- Sampling the outflow in glass vials
- Recording the sample temperature inside the thermal insulation

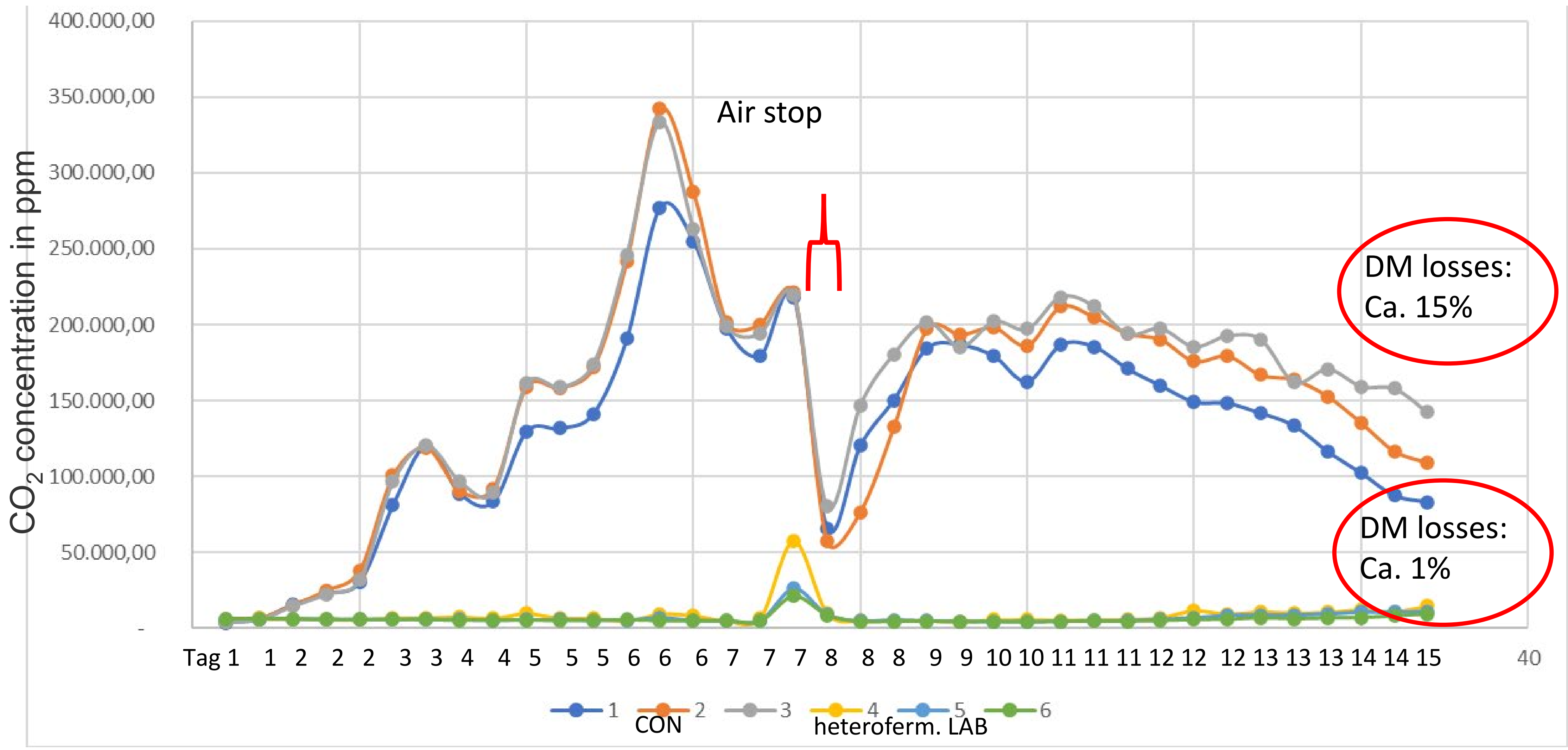



See Poster #161

# $CO_2$ concentration in outflow during aerobic storage with controlled air flow

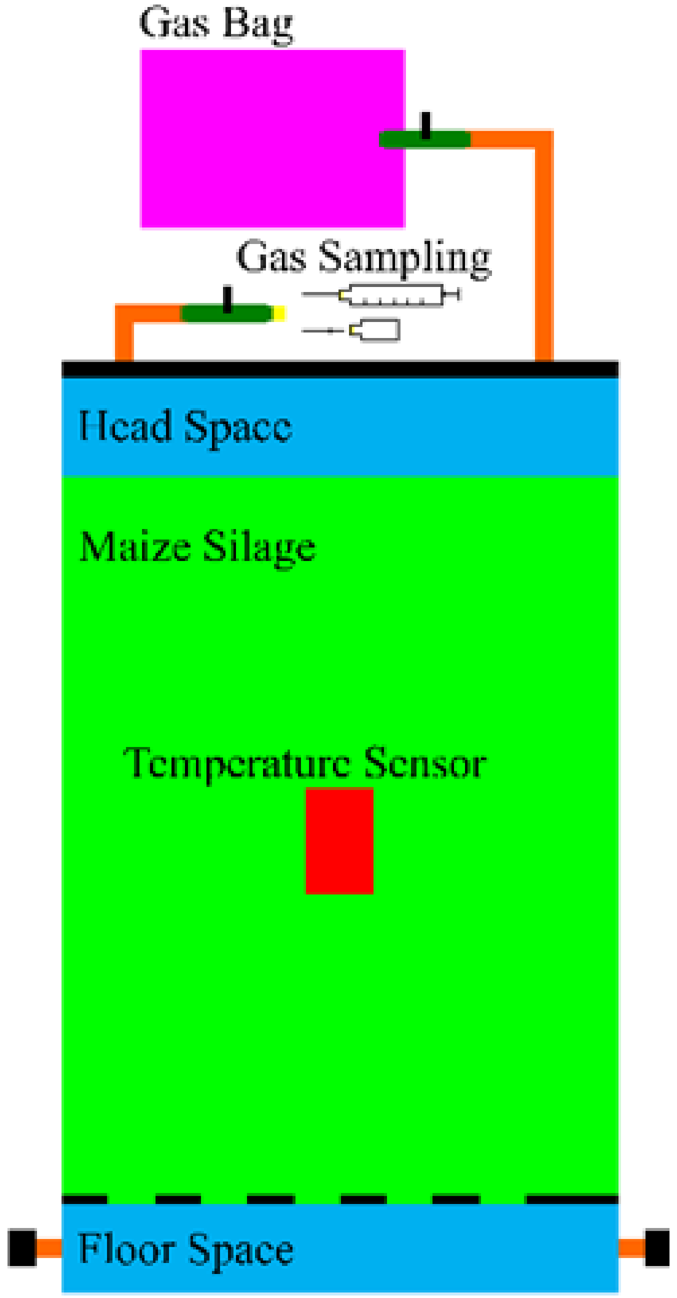
- Reheating of CON starts after 2 days
- Samples with heteroferm. LAB additive are stable over 14 days
- $CO_2$ in outflow rises up to 25% in CON
- Dry matter loss of LAB treatment < 1 %
- Total losses can be calculated by $CO_2$ sum



# Fermentation and ASTA test in 30 L barrel

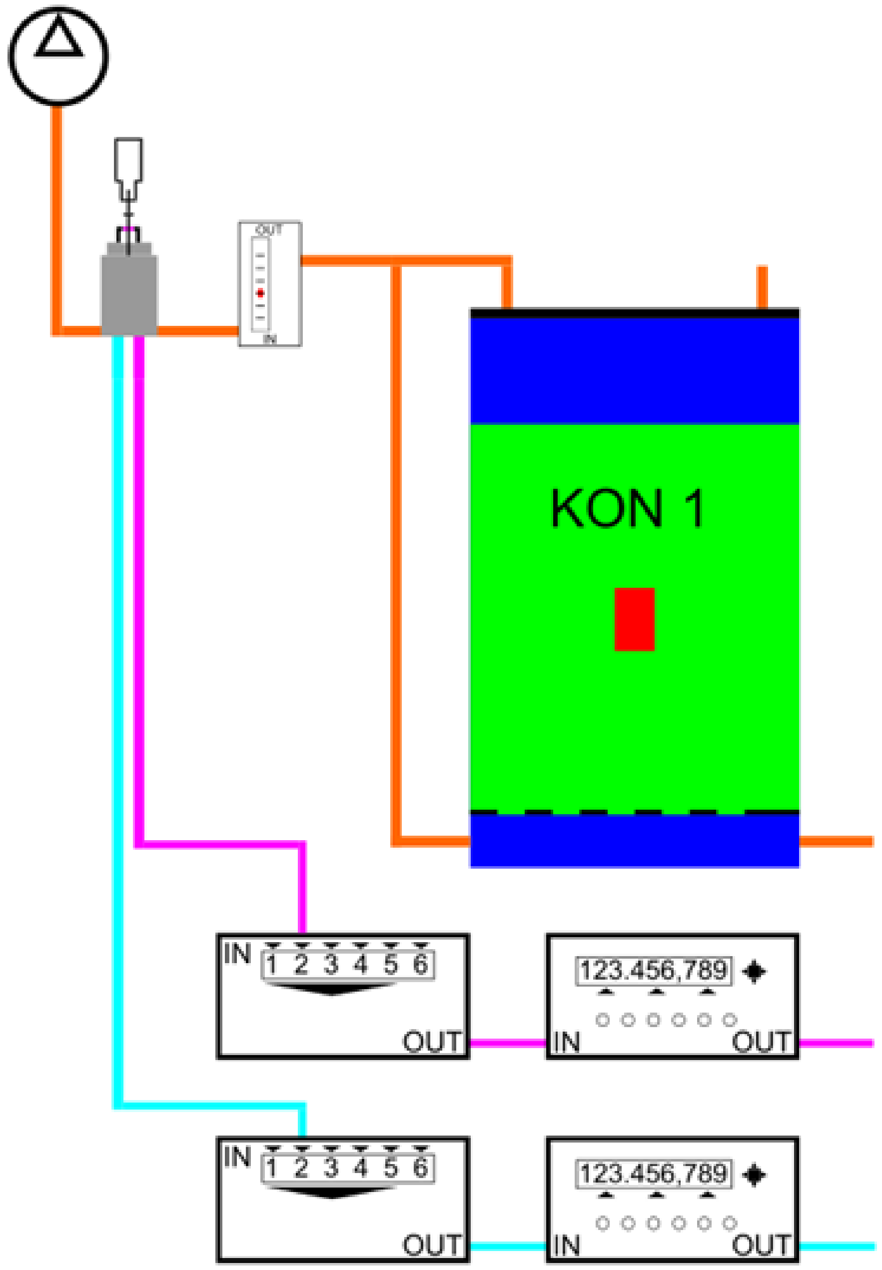
- Harvest crop (corn 42% DM) filled at low compaction
  - Airtight cover with connected gas bag (25 L)
  - Gas sampling on top
    - Temperature sensor inside the silage
    - Treatments:
      - CON: untreated control
      - BIO:
        - $10^6$ cfu (g FM)$^{-1}$ *Lentilactobacillus buchneri*
        - $10^5$ cfu (g FM)$^{-1}$ *Lactiplantibacillus plantarum*
      - CHE:
        - 0.5 g sodium benzoate (kg FM)$^{-1}$
        - 0.3 g  potassium sorbate (kg FM)$^{-1}$

anaerobic




(H. Deeken et al. 2024)

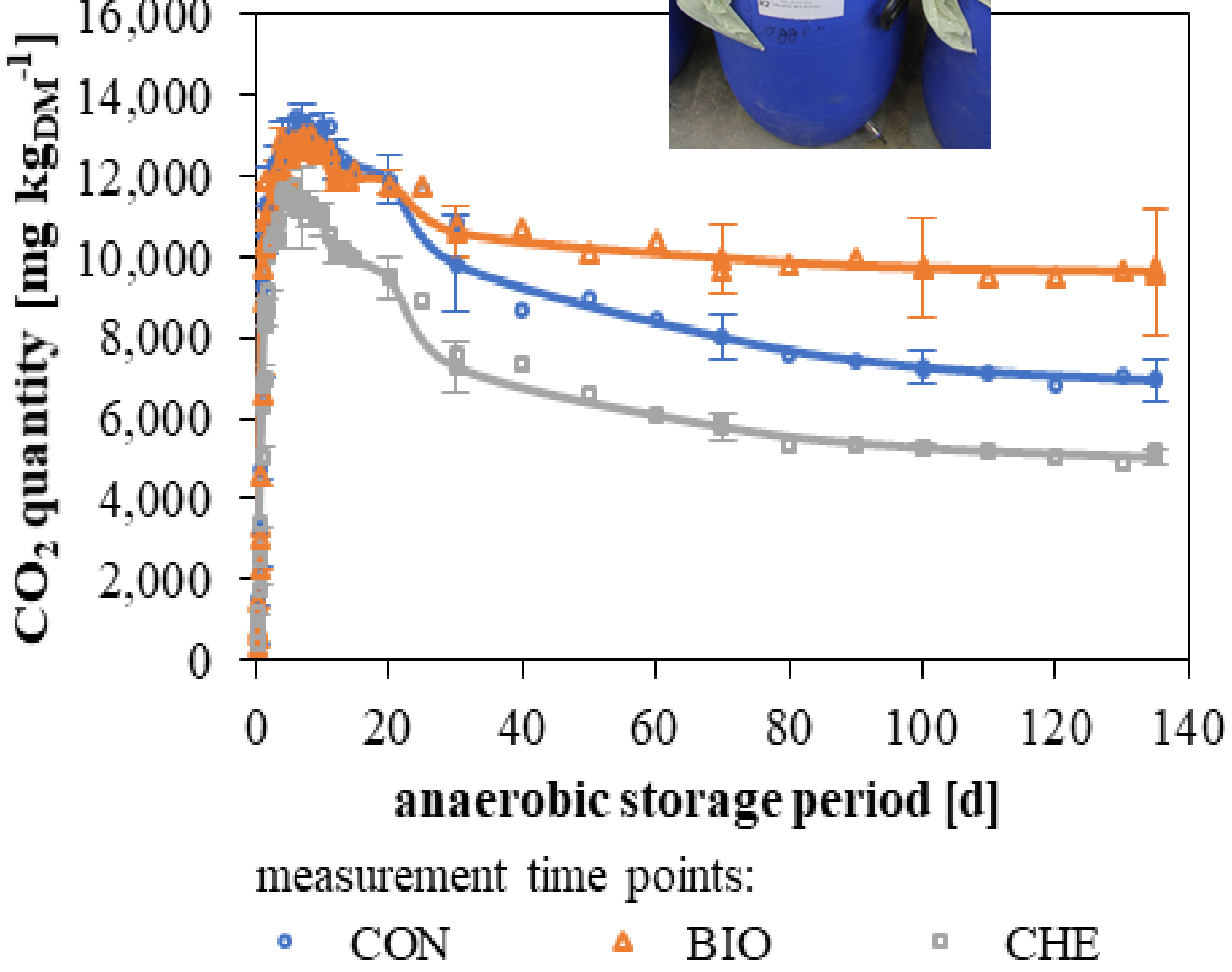
aerobic (ASTA)

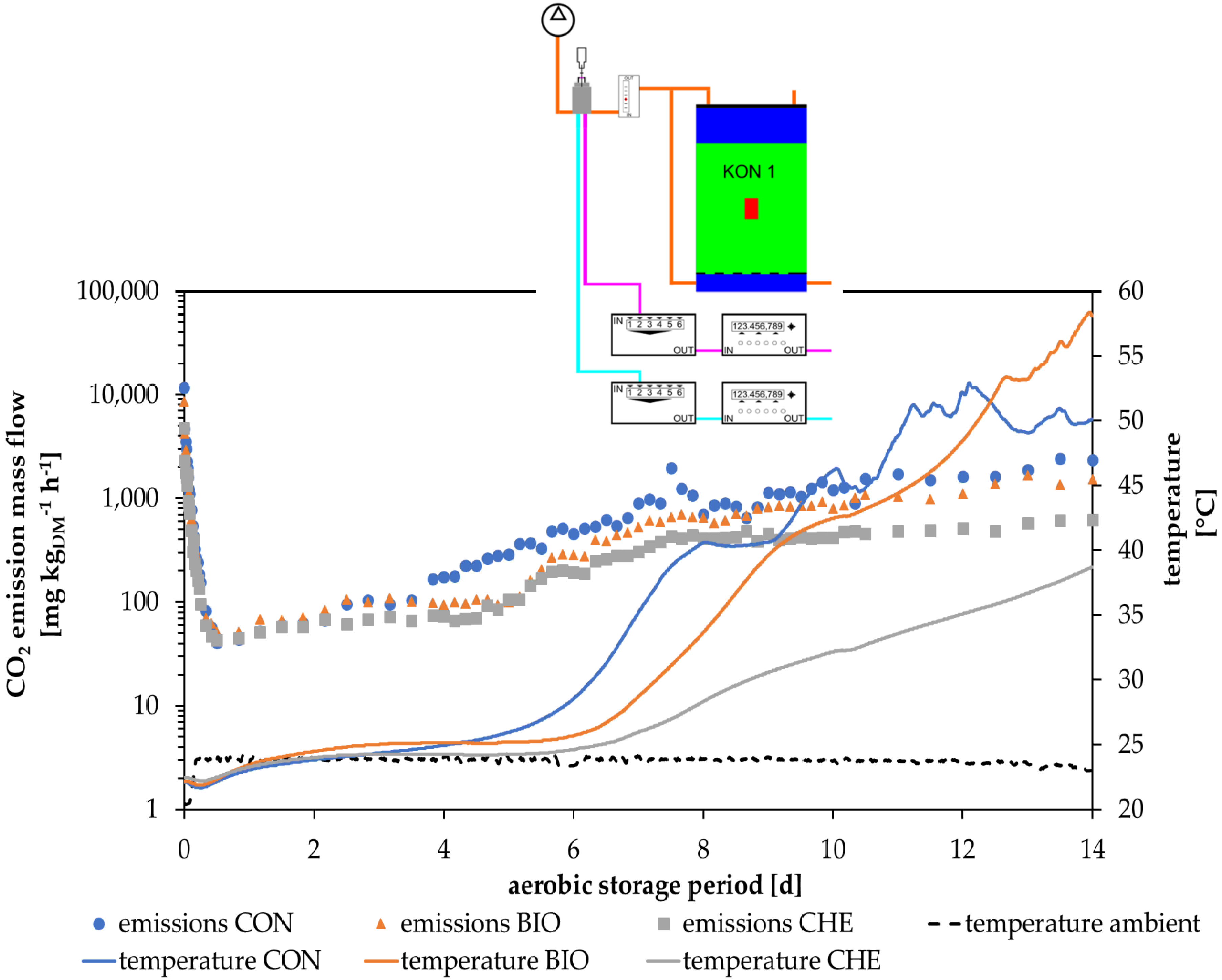



multi gas analyzer

# $CO_2$ formation during fermentation and aerobic stability test of corn silage (42% DM)

- Main part of gas formation in the first week
- >80% of the gas $CO_2$
- Chemical additive lowers gas formation
- BIO additive leads to 15% more gas and $CO_2$




(H. Deeken et al. 2024)

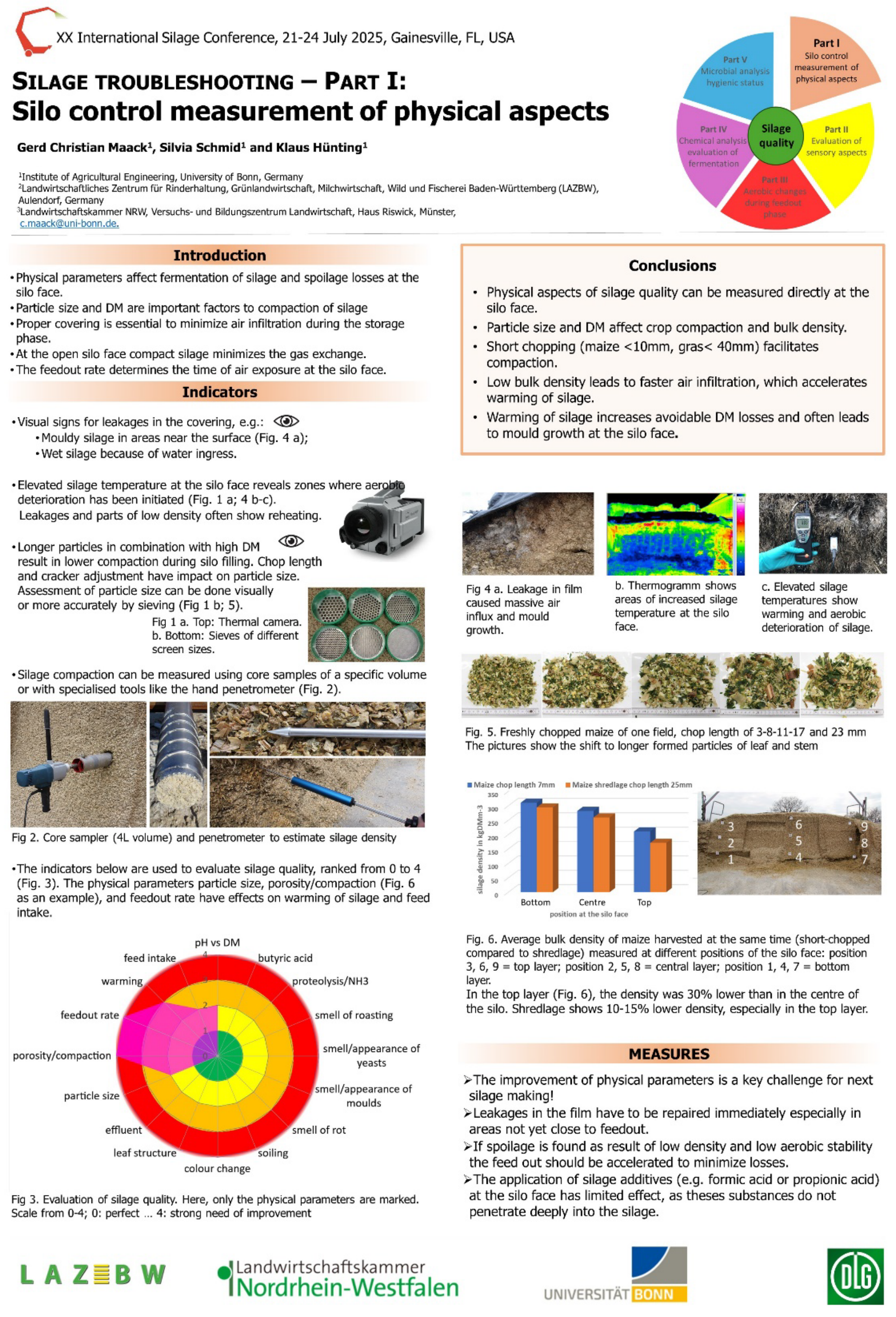
# Summary & Conclusion

- Aerobic changes in silages - still a wide field for research
- - and an important factor to minimize losses!
- Temperature increase (+2 K) has to be complemented by other spoilage indicators such as pH, $CO_2$, sensory evaluation!
- Different simple and elaborate techn(olog)ical approaches applicable and available!
- In practice, losses can be reduced by considering their cause at silage making!






# Thank you for your attention!


XX International Silage Conference, 21-24 July 2025, Gainesville, FL, USA

**SILAGE TROUBLESHOOTING – PART I:**
**Silo control measurement of physical aspects**

Gerd Christian Maack[1], Silvia Schmid[1] and Klaus Hünting[1]

[1]Institute of Agricultural Engineering, University of Bonn, Germany
[2]Landwirtschaftliches Zentrum für Rinderhaltung, Grünlandwirtschaft, Milchwirtschaft, Wild und Fischerei Baden-Württemberg (LAZBW), Aulendorf, Germany
[3]Landwirtschaftskammer NRW, Versuchs- und Bildungszentrum Landwirtschaft, Haus Riswick, Münster,
c.maack@uni-bonn.de

**Introduction**
- Physical parameters affect fermentation of silage and spoilage losses at the silo face.
- Particle size and DM are important factors to compaction of silage
- Proper covering is essential to minimize air infiltration during the storage phase.
- At the open silo face compact silage minimizes the gas exchange.
- The feedout rate determines the time of air exposure at the silo face.

**Indicators**
- Visual signs for leakages in the covering, e.g.:
  - Mouldy silage in areas near the surface (Fig. 4 a);
  - Wet silage because of water ingress.
- Elevated silage temperature at the silo face reveals zones where aerobic deterioration has been initiated (Fig. 1 a; 4 b-c). Leakages and parts of low density often show reheating.
- Longer particles in combination with high DM result in lower compaction during silo filling. Chop length and cracker adjustment have impact on particle size. Assessment of particle size can be done visually or more accurately by sieving (Fig 1 b; 5).

Fig 1 a. Top: Thermal camera. b. Bottom: Sieves of different screen sizes.

- Silage compaction can be measured using core samples of a specific volume or with specialised tools like the hand penetrometer (Fig. 2).

Fig 2. Core sampler (4L volume) and penetrometer to estimate silage density

- The indicators below are used to evaluate silage quality, ranked from 0 to 4 (Fig. 3). The physical parameters particle size, porosity/compaction (Fig. 6 as an example), and feedout rate have effects on warming of silage and feed intake.

Fig 3. Evaluation of silage quality. Here, only the physical parameters are marked. Scale from 0-4; 0: perfect … 4: strong need of improvement

**Conclusions**
- Physical aspects of silage quality can be measured directly at the silo face.
- Particle size and DM affect crop compaction and bulk density.
- Short chopping (maize <10mm, gras< 40mm) facilitates compaction.
- Low bulk density leads to faster air infiltration, which accelerates warming of silage.
- Warming of silage increases avoidable DM losses and often leads to mould growth at the silo face.

Fig 4 a. Leakage in film caused massive air influx and mould growth.
b. Thermogramm shows areas of increased silage temperature at the silo face.
c. Elevated silage temperatures show warming and aerobic deterioration of silage.

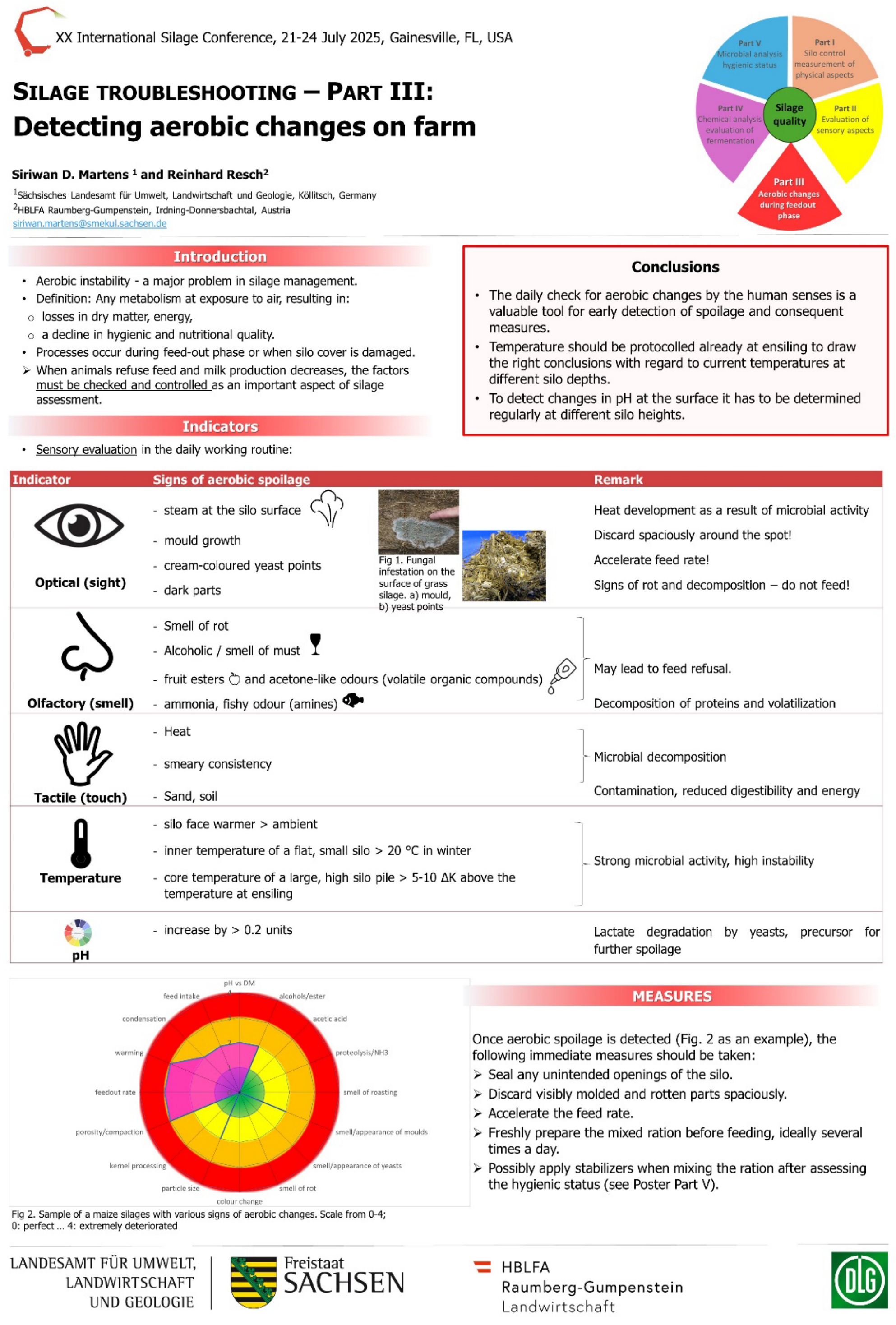
Fig. 5. Freshly chopped maize of one field, chop length of 3-8-11-17 and 23 mm The pictures show the shift to longer formed particles of leaf and stem

Fig. 6. Average bulk density of maize harvested at the same time (short-chopped compared to shredlage) measured at different positions of the silo face: position 3, 6, 9 = top layer; position 2, 5, 8 = central layer; position 1, 4, 7 = bottom layer.
In the top layer (Fig. 6), the density was 30% lower than in the centre of the silo. Shredlage shows 10-15% lower density, especially in the top layer.

**MEASURES**
- The improvement of physical parameters is a key challenge for next silage making!
- Leakages in the film have to be repaired immediately especially in areas not yet close to feedout.
- If spoilage is found as result of low density and low aerobic stability the feed out should be accelerated to minimize losses.
- The application of silage additives (e.g. formic acid or propionic acid) at the silo face has limited effect, as theses substances do not penetrate deeply into the silage.

*Thanks go to the colleagues of the University of Bonn and of the DLG Technical Comittee for Ensiling Agents.*

→ See Posters 116-121 in Session 1 and the Proceedings


XX International Silage Conference, 21-24 July 2025, Gainesville, FL, USA

**SILAGE TROUBLESHOOTING – PART III:**
**Detecting aerobic changes on farm**

Siriwan D. Martens [1] and Reinhard Resch[2]
[1]Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Köllitsch, Germany
[2]HBLFA Raumberg-Gumpenstein, Irdning-Donnersbachtal, Austria
siriwan.martens@smekul.sachsen.de

**Introduction**
- Aerobic instability - a major problem in silage management.
- Definition: Any metabolism in silage exposed to air, resulting in:
  - losses in dry matter, energy,
  - a decline in hygienic and nutritional quality.
- Processes occur during feed-out phase or when silo cover is damaged.
- When animals refuse feed and milk production decreases, the factors must be checked and controlled as an important aspect of silage assessment.

**Indicators**
- Sensory evaluation in the daily working routine:

**Conclusions**
- The daily check for aerobic changes by the human senses is a valuable tool for early detection of spoilage and consequent measures.
- Temperature should be protocolled already at ensiling to draw the right conclusions with regard to current temperatures at different silo depths.
- To detect changes in pH at the surface it has to be determined regularly at different silo heights.

| Indicator | Signs of aerobic spoilage | Remark |
|---|---|---|
| Optical (sight) | steam at the silo surface; mould growth; cream-coloured yeast points; dark parts | Heat development as a result of microbial activity; Discard spaciously around the spot!; Accelerate feed rate!; Signs of rot and decomposition – do not feed! |
| Olfactory (smell) | Smell of rot; Alcoholic / smell of must; fruit esters and acetone-like odours (volatile organic compounds); ammonia, fishy odour (amines) | May lead to feed refusal.; Decomposition of proteins and volatilization |
| Tactile (touch) | Heat; smeary consistency; Sand, soil | Microbial decomposition; Contamination, reduced digestibility and energy |
| Temperature | silo face warmer > ambient; inner temperature of a flat, small silo > 20 °C in winter; core temperature of a large, high silo pile > 5-10 ΔK above the temperature at ensiling | Strong microbial activity, high instability |
| pH | increase by > 0.2 units | Lactate degradation by yeasts, precursor for further spoilage |

Fig 1. Fungal infestation on the surface of grass silage. a) mould, b) yeast points

**MEASURES**
Once aerobic spoilage is detected (Fig. 2 as an example), the following immediate measures should be taken:
- Seal any unintended openings of the silo.
- Discard visibly molded and rotten parts spaciously.
- Accelerate the feed rate.
- Freshly prepare the mixed ration before feeding, ideally several times a day.
- Possibly apply stabilizers when mixing the ration after assessing the hygienic status (see Poster Part V).

Fig 2. Sample of a maize silages with various signs of aerobic changes. Scale from 0-4; 0: perfect … 4: extremely deteriorated