# PRECISION LIVESTOCK FARMING

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# ABOUT ME

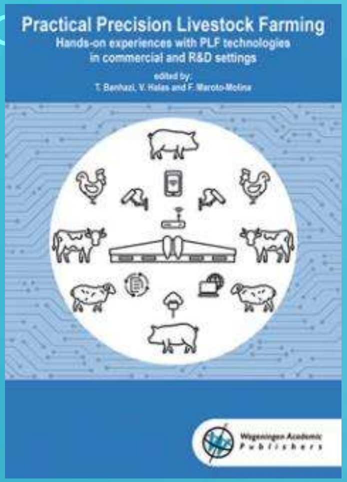
- Prof. Thomas Banhazi, Lecturer and Scientist
- Strong interest in commercialisation, involvement in companies in AU & EU
- (1) Precision livestock farming and (2) environment/climate management in and around livestock buildings
- Involved approx. 40 projects at the total value of AU$47M, including 12 large EU projects
- Published 3 Books, 25 book chapters, 65 journal articles, 165 conference papers, 120 industry reports/seminar/extension articles and 8 patents
- Supervised 35+ post-grad students (PhDs, Masters & Honours), contributed to 8 undergraduate courses, guest lectured in 5 countries
- I am hoping to share some of my experiences with you

# MY PROJECT AREAS

- Sensor developments, machine vision, data analysis/modelling, artificial intelligence, communication related studies on farms
- Automation, livestock equipment and robotics related to livestock production (poultry and pig farms)
- Environment/climate management, environmental sustainability, in and around livestock facilities (thermal conditions and air quality)
- Emission reduction from livestock farms
- Ventilation, hygiene/cleaning methods, manure/odour management
- Animal welfare, general livestock management issues (poultry, pig and dairy cattle production)
- On-farm research, commercialisation and patenting

# COURSE OBJECTIVES

- To understand the principles and the potential impact of new technologies on livestock production
- To combine theoretical foundations with technological expertise and data analysis skills
- To develop modern sensor and automation technologies for monitoring and optimizing animal health, welfare and production efficiency
- To develop a basic understanding of different data systems and multimodal Machine Learning as a method to fuse information from multiple sensors
- To promote interdisciplinary cooperation, hands-on exercises and insights into current trends in research and industry to enable students to develop and discuss innovative solutions in digitalized livestock farming




# WAP/BRILL PUBLICATION

***Practical Precision Livestock Farming book***
***'Hands-on experiences with PLF technologies in commercial and R&D settings'***
***T. Banhazi, V. Halas and F. Maroto-Molina***

*published by Wageningen Academic Publishers in September, 2022*

- Precision livestock farming (PLF) technologies have been heavily promoted in the past, but the **implementation of these technologies is not easy**.
- Numerous technical challenges need to be solved before PLF technologies will supply the desired information in a reliable and consistent manner. Farm **implementations regularly encounter difficulties**. The practical experience associated with these technologies do not always match their theoretical potential.
- 90+ authors from 16 countries were asked to report on the actual practical experiences technology developers and users had under farm conditions to try and understand this difference between practice and theory. This book aims to **eliminate the 'mystery' behind the 'Smart' PLF tools**, and presents the hard facts reported by individuals that have practical experience using these technologies.
- The book also explores various aspects of PLF, including the
  - **challenges associated with developing and using various technologies**,
  - (2) the importance of **training and ethical aspects** of PLF tools,
  - (3) the difficulties related to **commercialisation of PLF systems**.
- We hope that the **honest presentation of the pros and cons** of PLF management tools **will help the supporters of precision farming concepts to better use and interact with these modern technologies.**

# TOPICS/MODULES

| |
|---|
| Definition and conceptualization of precision livestock farming: history, goals and benefits |
| Farm Management Information Systems, Internet of Things and cloud computing |
| Integration of modern sensor technologies into agriculture production |
| Monitoring of health and behavior as an early warning system |
| Use cases of digital technologies in overall farm management |
| Practical exercises: digital sales, communication and documentation solutions |
| Multimodal Machine Learning (MML): Data heterogeneity, visual representations, language representations, signals and graphs |

# CONTACTS

For any assistance with course, please contact:
Prof. Dr. Simon Walther or Dr. Ehsan Yaghoubi

Other Lecturers involved:
Prof. Dr. Simon Walther
Prof. Dr. Daniel Werner
Dr. Ehsan Yaghoubi
Dr. Petra Thobe

# MODULE 2
# INTRODUCTION TO SMART ANIMAL PRODUCTION

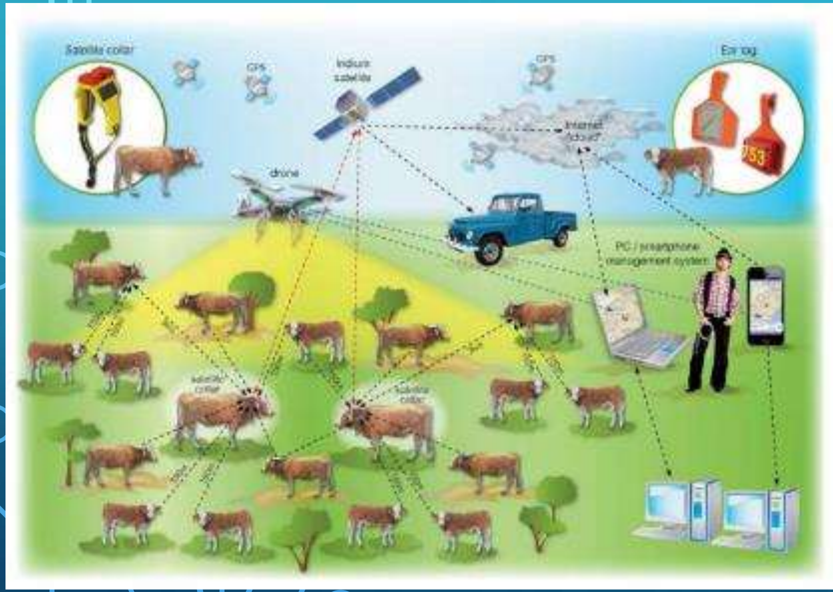
## LECTURE A: TECHNOLOGICAL ASPECTS

# MODULE OVERVIEW AND LEARNING OBJECTIVES

- Precision farming systems components
- AI use in livestock production
- Systematic recording of production, welfare and heath related information
- New opportunities for animal and production monitoring
- Multi-disciplinary development opportunities
- Knowledge based animal management concept

# WHAT IS PLF?

Precision Livestock Farming (PLF) is aimed at enhancing farm profitability/efficiency, social acceptance and sustainability by improving on-farm acquisition, management and utilisation of INFORMATION that can be used to improve the management of various livestock species





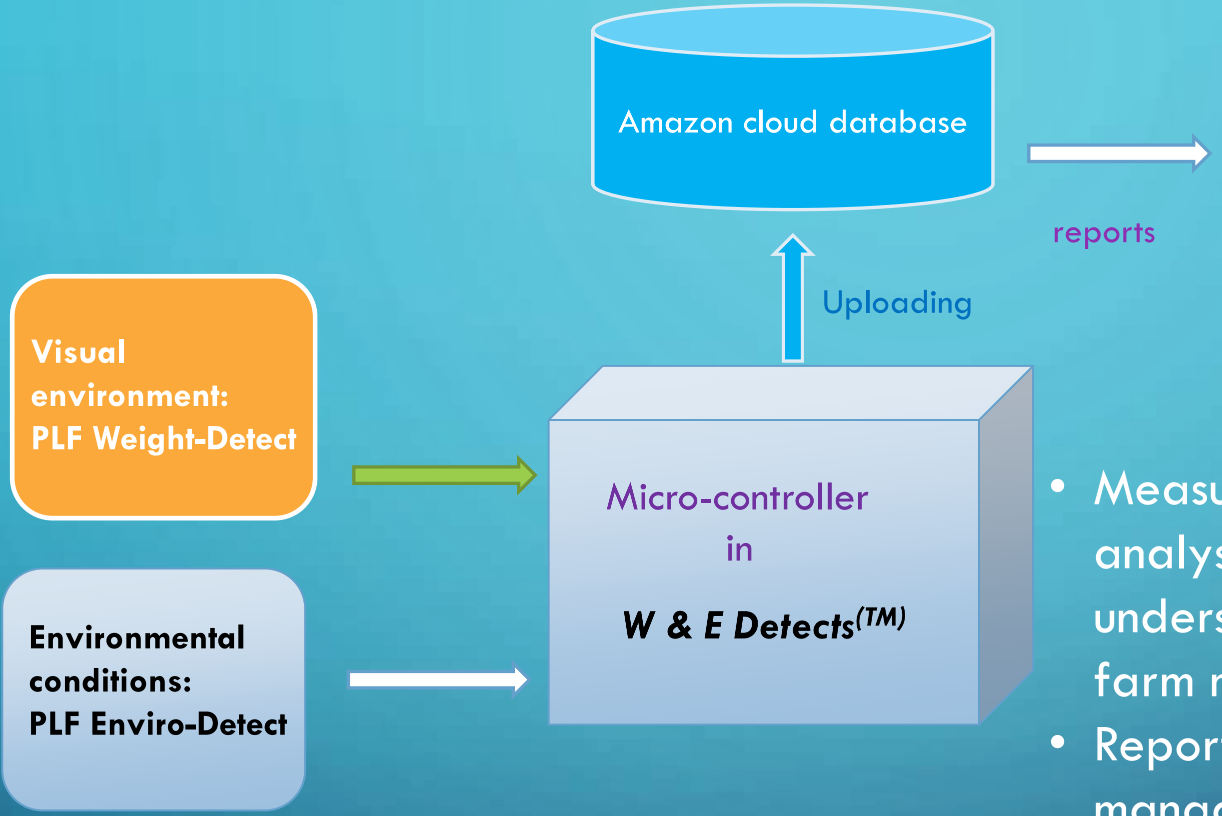
http://www.ong2zero.org/en/blog/ict-for-farming-videos-and-sms-to-protect-livestock-in-senegal/
https://www.businesslive.co.za/fm/features/2019-01-31-connected-cattle-how-technology-is-benefitting-rural-sa/

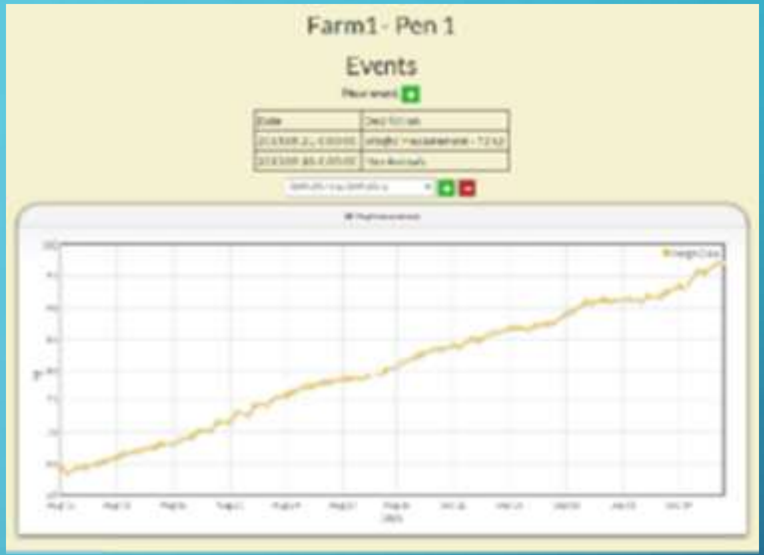
# SENSOR BASED SMART AGRICULTURE

- **Helps to understand the underlining processes on farms and their importance on profitability and sustainability (social and environmental)**
- **Automatically measures and analyses key variables**
- **Sets optimum values for variables to be controlled**
- **Potentially develops automated (semi-automated) control procedures**

https://www.roboticstomorrow.com/article/2014/12/robotic-farming-for-the-future/5238
https://start-life.nl/startups/agri/livestock-robotics/
https://www.youtube.com/watch?v=-XI4siKp-nU

# System developed




| Parameter | Resolution | Range | Accuracy |
|---|---|---|---|
| CO2(ppm) | 1 | 0-10000 | ±1% |
| NH3(ppm) | 0.5 | 0-100 | ±1% |
| Dust (ug m-3) | 10 | 0-1000 | ±1% |
| Temp (oC) | 0.1 | -40 to 125 | ±0.5% |
| RH (%) | 0.7 | 0 to 100 | ±3% |

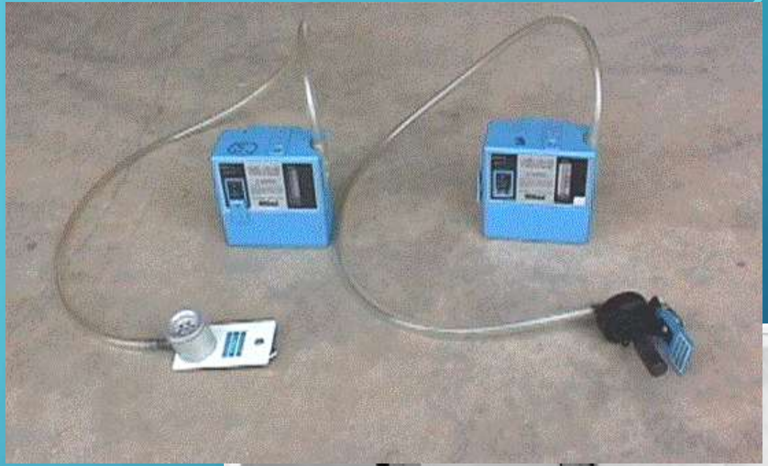
- Measurements taken are automatically analysed daily and presented in an easy to understand report which provides insight for farm management.
- Report results can be further analysed by management to benchmark system performance.
- ***System enables management to optimize the livestock production process, improve productivity, animal welfare and environmental sustainability***

# ENVIRO-DETECT™

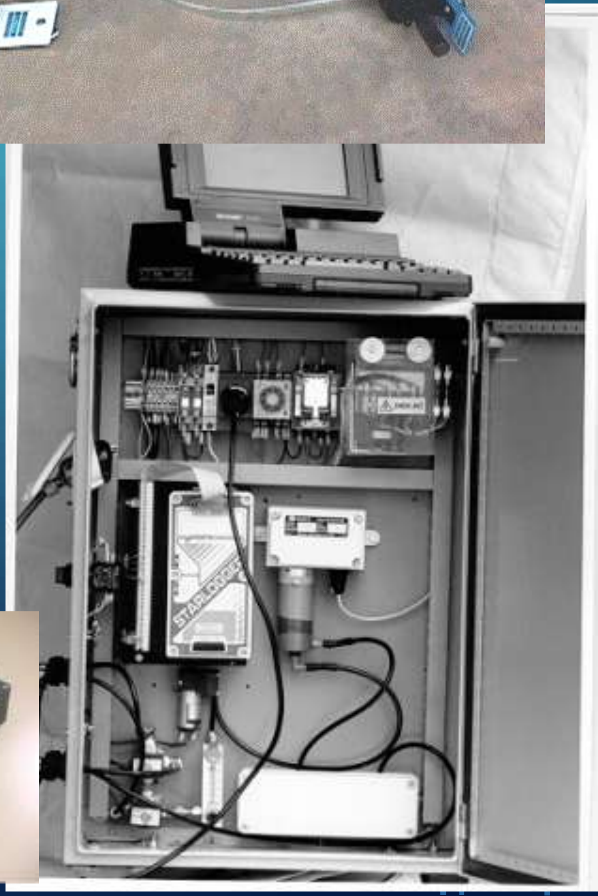
- Enviro-Detect™ was created to facilitate routine assessment of environmental conditions on commercial farms
- The unit contains cost-effective components for measuring ventilation rates, air temperature, relative humidity, the concentrations (EMISSIONS) of carbon dioxide, ammonia and dust (methane & airspeed)

**Banhazi T.M.** (2009) Development of a mobile air quality monitoring system. *Applied Engineering in Agriculture* **25(2) 281-290**

# EXPERIENCE WITH AIR QUALITY MONITORING INSTRUMENTATION USED FOR RESEARCH



- During previous research projects a variety of air quality sensors were used, but these sensors had to be individually deployed and operated, making the system cumbersome and labour intensive
- <u>It was impractical under commercial conditions</u>
- The research instrumentation had to be integrated, simplified and converted into a system that can be routinely used on commercial farms
- AIM: Therefore an accurate, low-cost, and user-friendly system for monitoring airborne pollutants had to be developed together with the data communication and data management systems that enable these measurements to be performed on a routine basis on commercial farms



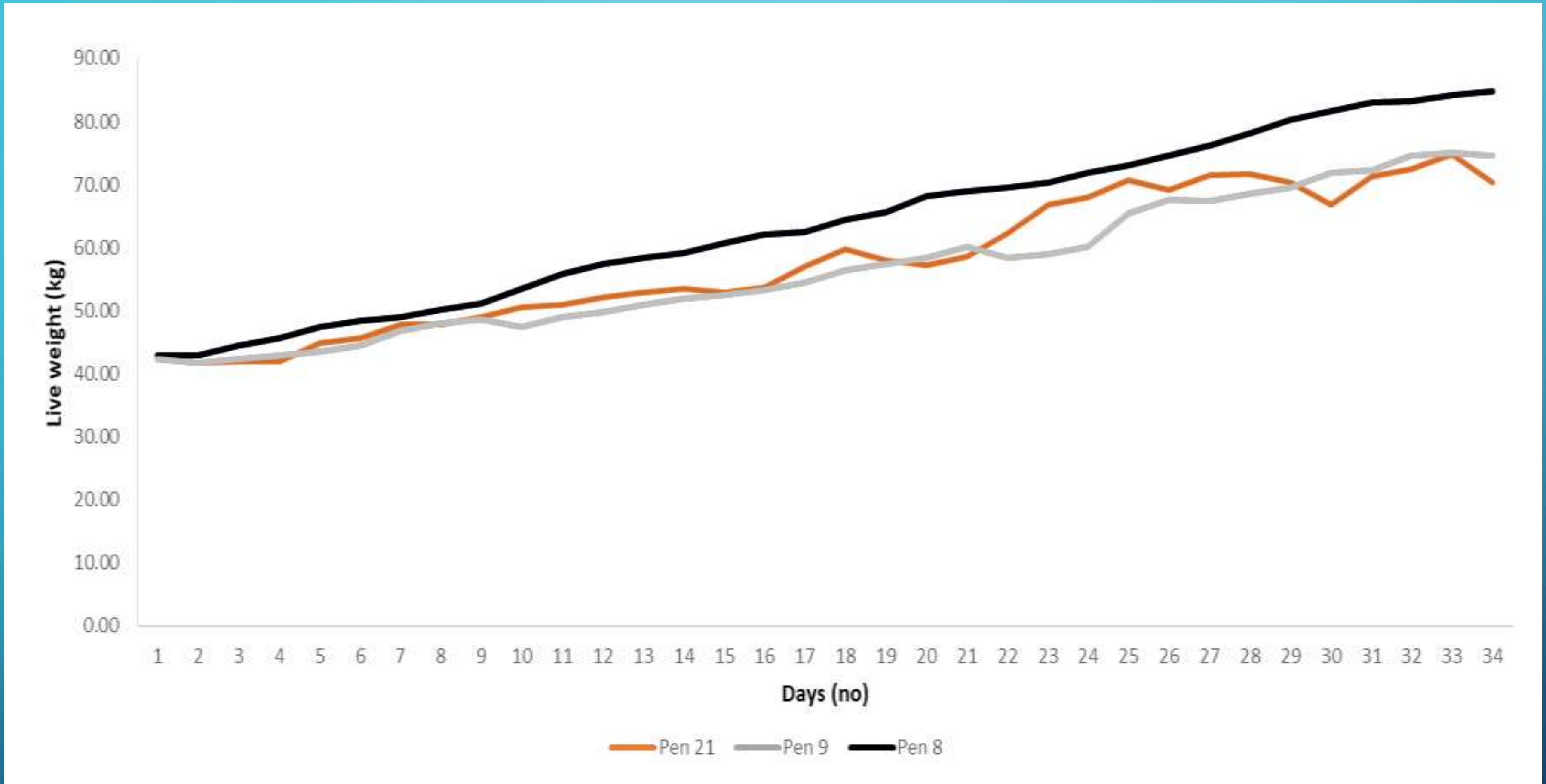
# SEVERAL VERSIONS WERE DEVELOPED OVER THE YEARS

- After on-farm implementation, improvements were made and trialled again on farms
- Development aims – Enviro-Detect had to be ROBUST, ACCURATE, COST-EFFECTIVE & EASY TO OPERATE:
    - Reduce the need to frequent maintenance
    - Improve cost effectives, while not compromising practically acceptable precision
    - Reduce size and weight to assist easy deployment and operation

# METHODOLOGY

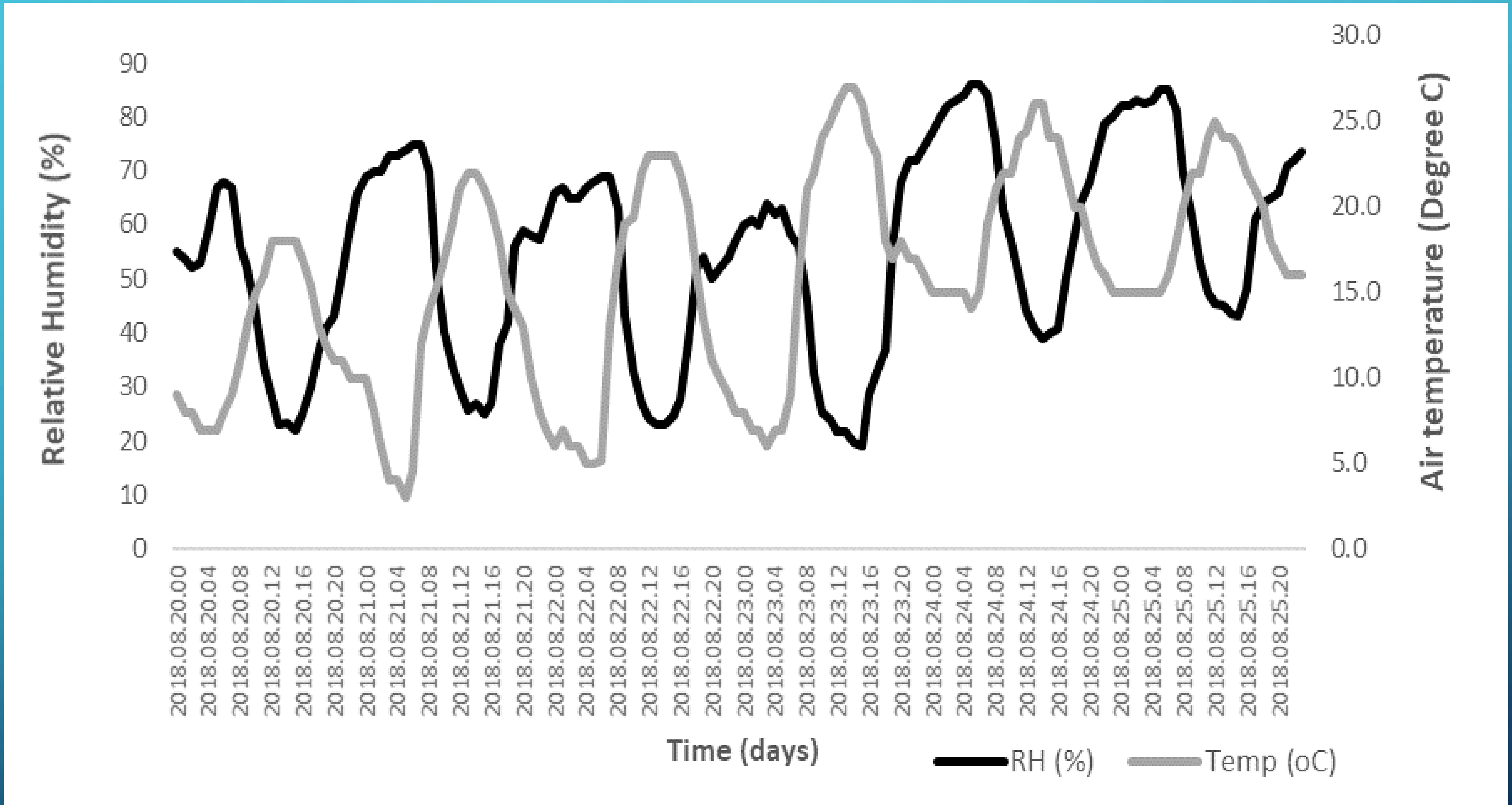
- Long-term weight and environment monitoring were carried out in 3 different grower/finisher pens on a farm in Queensland, Australia
- The pens monitored were located in traditional grower-finisher building with natural ventilation systems installed
- In each pen a Weight-Detect™ system was installed approximately in the middle of the pen at 2m height. In the same pens, Enviro-Detect™ devices were also installed
- Statistical analysis was undertaken on the collected environmental data using t-test principally to compare environmental parameters between different buildings

# DIFFERENCE IN ADG



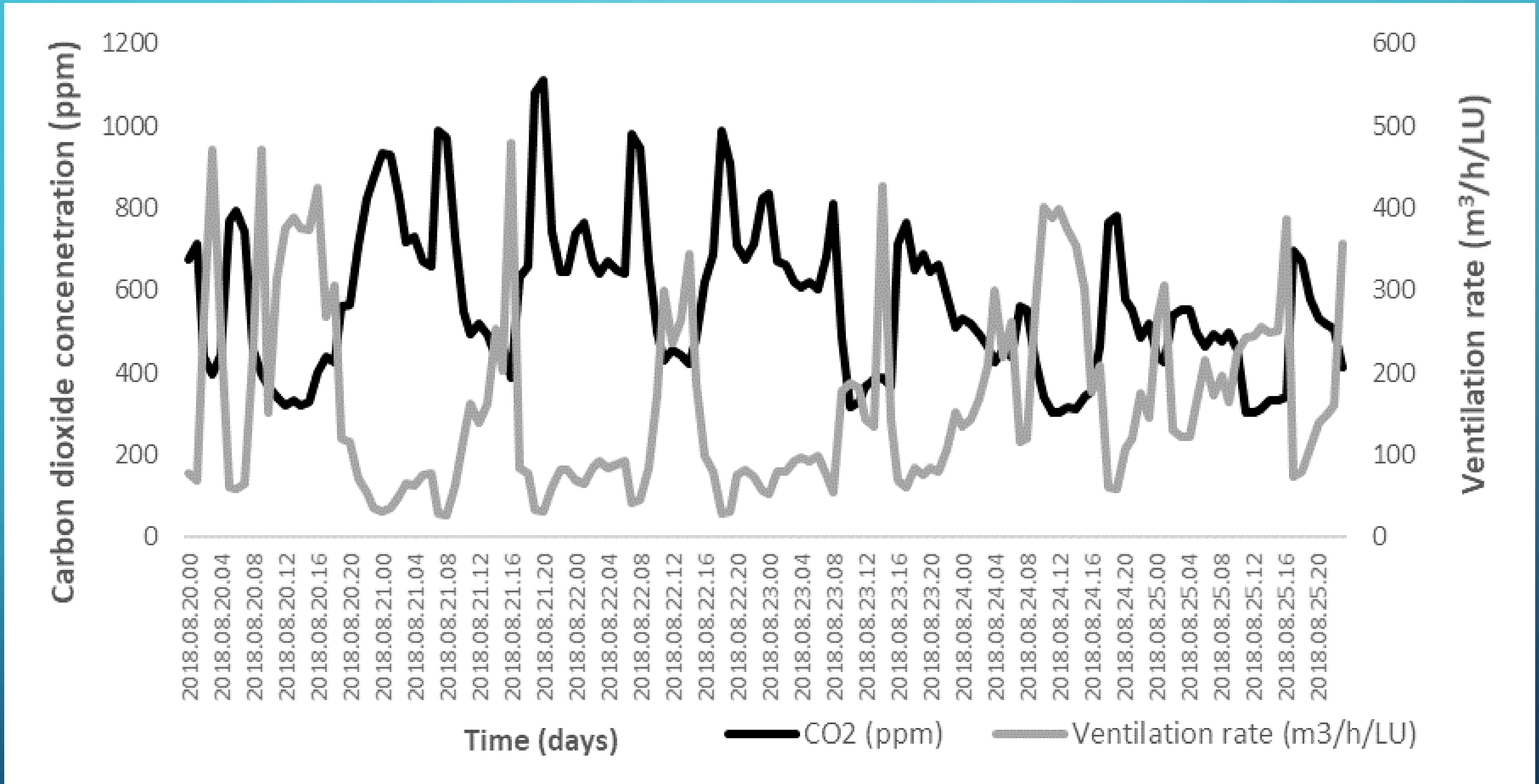

Live weights (kg) recorded on farm 'X' in different pens and different buildings during similar time period. Pigs started from identical starting weight. Pigs in pen 8 achieved an ADG of 1.20 kg over 34 days, while in pen 21 animals grew at a much lower rate achieving an ADG of 0.82 kg over the same 34-day period. Pigs in pen 9 grew at the rate of 0.95 kg (ADG) over 34 days.

# AIR TEMPERATURE & RELATIVE HUMIDITY



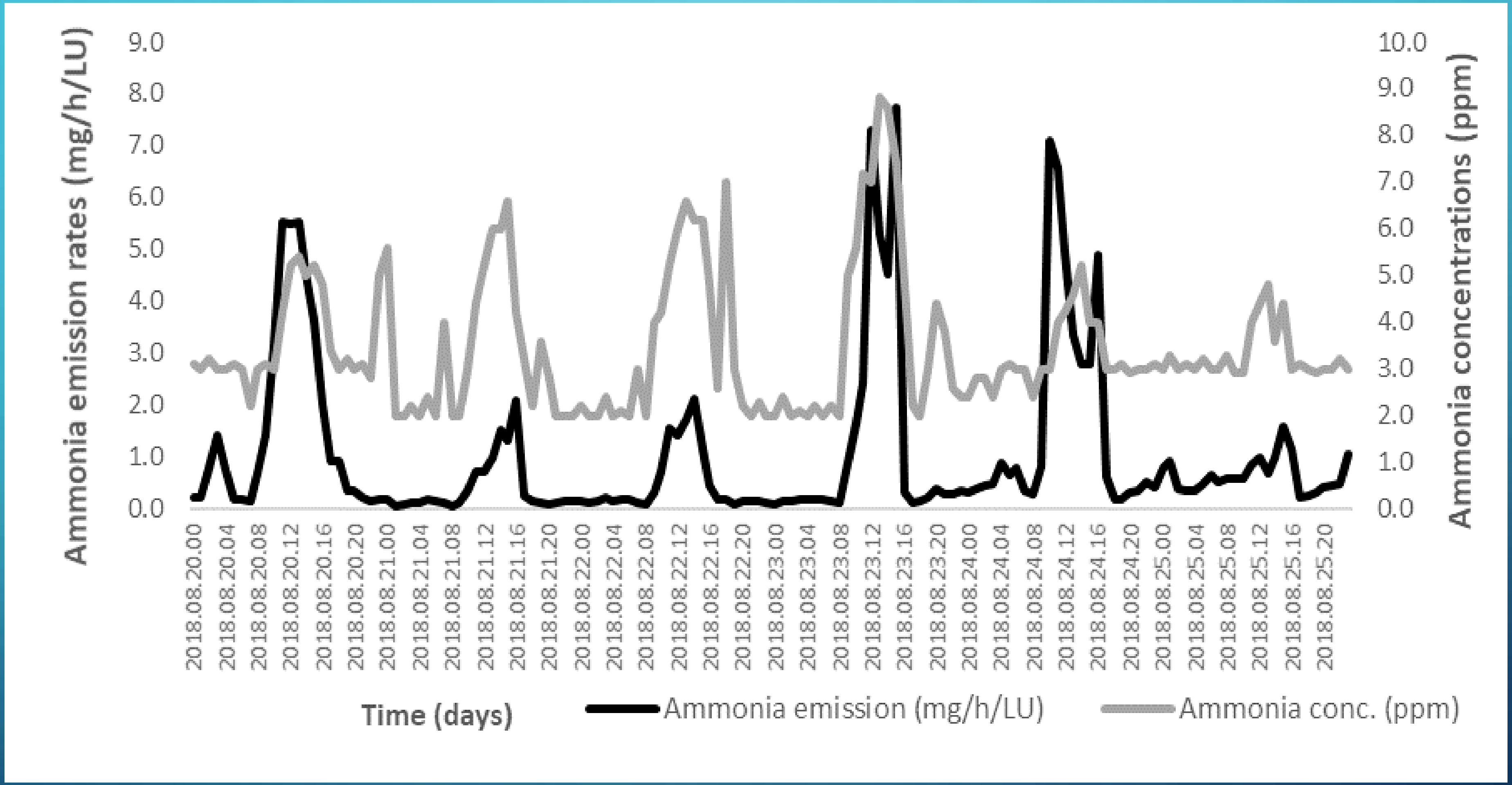

**Air temperature (ºC) and relative humidity (%) values measured continuously in one of the study buildings on farm 'X' over a 6-day period.**

# VENTILATION RATE & $CO_2$ CONCENTRATIONS




**Ventilation rate ($m^2/h/LU$ or Livestock Unit) and carbon dioxide concentrations (ppm) values measured continuously in one of the study buildings on farm 'X' over a 6-day period.**

# AMMONIA CONCENTRATIONS & EMISSIONS




**Ammonia concentrations (ppm) and ammonia emission rates (mg/h/LU or Livestock Unit) measured continuously in one of the study buildings on farm ‘X’ over a 6-day period.**

# DIFFERENCES IN BUILDING ENVIRONMENTS

| Parameters | Building A: pen 8 & 9 | Building B: pen 21 | P |
|---|---|---|---|
| Temperature (°C) | 19.8 | 17.4 | <0.05 |
| Humidity (%) | 63 | 57 | <0.05 |
| Carbon dioxide concentration (ppm) | 748 | 477 | <0.05 |
| Ventilation rates ($m^2/h/LU$) | 108 | 198 | <0.05 |
| Ammonia concentration (ppm) | 1.1 | 2.9 | <0.05 |
| Dust concentrations ($mg/m^3$) | 0.098 | 0.192 | <0.05 |

Environmental parameters in the different pens/buildings averaged over 34 days

# TEMP & HUM

- Humidity values in the two different buildings were similar
- There was 2.5 °C difference in air temperatures between the two buildings that might have been important and could partially explain the grow rate differences and resulting growth curve shape
- During winter time, when temperatures were actually as low as 5 °C on same days, this extra temperature lift could have been contributing to the more even growth patterns observed in building A (housing pen 8 and 9).
- As expected, there was a good negative correlation observed between the temperature and humidity measurements in this study ($r^2$ = - 59%)

# VENTILATION AND $CO_2$

- Circadian variation in ventilation rates as well as in the concentration of $CO_2$ that peaked during night-time
- Ventilation rates and $CO_2$ concentrations were negatively correlated (r2 = -84%),
- The data indicated that the general ventilation levels were adequate, and suitable for the winter period (100-200 m2/h/LU)
- In Australia, it is not unusual to see high ventilation rates during wintertime as well, due to the open nature of buildings utilizing natural ventilation systems
- Building B was over ventilated, but not building A. This has resulted in higher temperatures, lower dust and $NH_3$ concentrations in building A.

# VENTILATION AND $NH_3$

- Both high dust and $NH_3$ concentrations are often associated with high ventilation rates, due to the increased levels evaporation (in case of $NH_3$) and increased stirring of fine airborne particles by the increased air movements (in terms of dust levels).
- This has led to a statistically higher dust ($p<0.05$) and $NH_3$ ($p<0.05$) concentrations in building B.

# SUMMARY

- This study provided farm managers with information about the fluctuating ADGs that can be observed on farms under commercial conditions.
- Anecdotal evidence indicated that growth rates on farms could fluctuate significantly without being noticed in a timely manner.
- the shape of the growth was important and better performance was associated with a ‘smooth’ growth curve
- pigs that underperformed had typically a crooked growth curve and such irregular growth pattern indicated periodic stagnations peppered with periods of compensatory growth.

# ACKNOWLEDGEMENTS

Funded by the European Union (project "Animal Welfare Indicators at Slaughterhouses, aWISH", Horizon Europe under grant agreement ID: 101060818). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them. We would like to thank the members of the aWISH consortium, expert panel and stakeholder advisory board members for their valuable contributions.

ILVO Flanders research institute for agriculture, fisheries and food

BATALLÉ

UAB Universitat Autònoma de Barcelona

Innotech

When not otherwise stated, photos were taken by the members of the project team

# INTRODUCTION

- Environmental management is a critical component of good livestock management in these days, so both the thermal environment and the concentrations of various airborne pollutants within livestock buildings have to be continuously monitored, so farm managers can maintain optimal housing conditions.
- In turn, optimal housing conditions will positively impact on the health, welfare and production efficiency of various intensive livestock species and will reduce OH&S risks for farm workers.
- Furthermore, documenting airborne emission rates of various pollutants is also becoming important to ensure that farms can demonstrate their environmental sustainability.

# INTRODUCTION (OBJECTIVES)

- A variety of instruments can be used currently to undertake relevant measurements, but often various technologies need to be installed and operated separately to obtain all relevant information.
- One system (Enviro-Detect, ED, PLF Agritech, Brisbane, Australia) has been identified and introduced on a commercial pig farm in Spain as part of the EU funded aWISH project (HEurope grant 101060818) to
  - (1) assess if a single instrumentation can be used to measure all relevant environmental parameters in livestock buildings,
  - (2) assess the applicability and feasibility of the technology and
  - (3) use this information to assess the general welfare status of pigs.

# MATERIALS AND METHODS

- The pen located in the northern part of Spain in a traditional grower-finisher building with automatically controlled natural ventilation
- The study pigs were fed pelleted diet and were kept on fully slatted floors
- New/improved model of ED equipment was installed near the pens and air sampling tubes were installed above the experimental pen to deliver the air samples to the ED unit
- Temp/hum sensors were also installed just above the pigs (without allowing them to reach the cables)

# EXPERIMENTAL PEN

T. BANHAZI, A. BANHAZI, C. PHILLIPS, J. REIXACH, A. R. PEREZ, P. LLONCH, J. MASELYNE (2024) Enviro-Detect instrument used to measure environmental conditions within a Spanish livestock building ISAH conference proceedings, Thailand, 16-20 September, 2024

# MATERIALS AND METHODS

Temperature/relative humidity sensors and air sampling tubes were also installed outside to measure ambient thermal conditions and to sample outside air (as well as purge the ED instrument)

# M&M: DESCRIPTION OF ED INSTRUMENT

- The functionality of the ED instruments has been described previously, (Banhazi et al., 2009, 2022).
- The ED instruments utilize an off-the-shelf sensor components and a processing/communication center.
  - ED units acquire various measurements via sensor and pre-process the recorded data.
  - Data is sent to an Automated Data Analysis and Management System (ADAMS, a cloud hosted database) that undertakes automated analysis and generates reports (Banhazi, 2009, Banhazi et al., 2022). Technology patented in AU & USA

# RESULTS: DESCRIPTIVE STATISTICS (THERMAL ENVIRONMENT)

| | temp | hum | T/H index | Outside temp | Outsize hum | temp-diff |
|---|---|---|---|---|---|---|
| min | 12.9 | 27.6 | 55.8 | 0.1 | 16.4 | 12.0 |
| max | 29.4 | 97.5 | 74.5 | 32.0 | 95.7 | 19.8 |
| mean | 17.8 | 64.1 | 62.9 | 10.0 | 68.2 | 7.9 |
| range | 16.5 | 69.9 | 18.8 | 31.9 | 79.3 | 31.9 |
| SD | 2.0 | 11.7 | 2.7 | 5.4 | 18.7 | 4.8 |

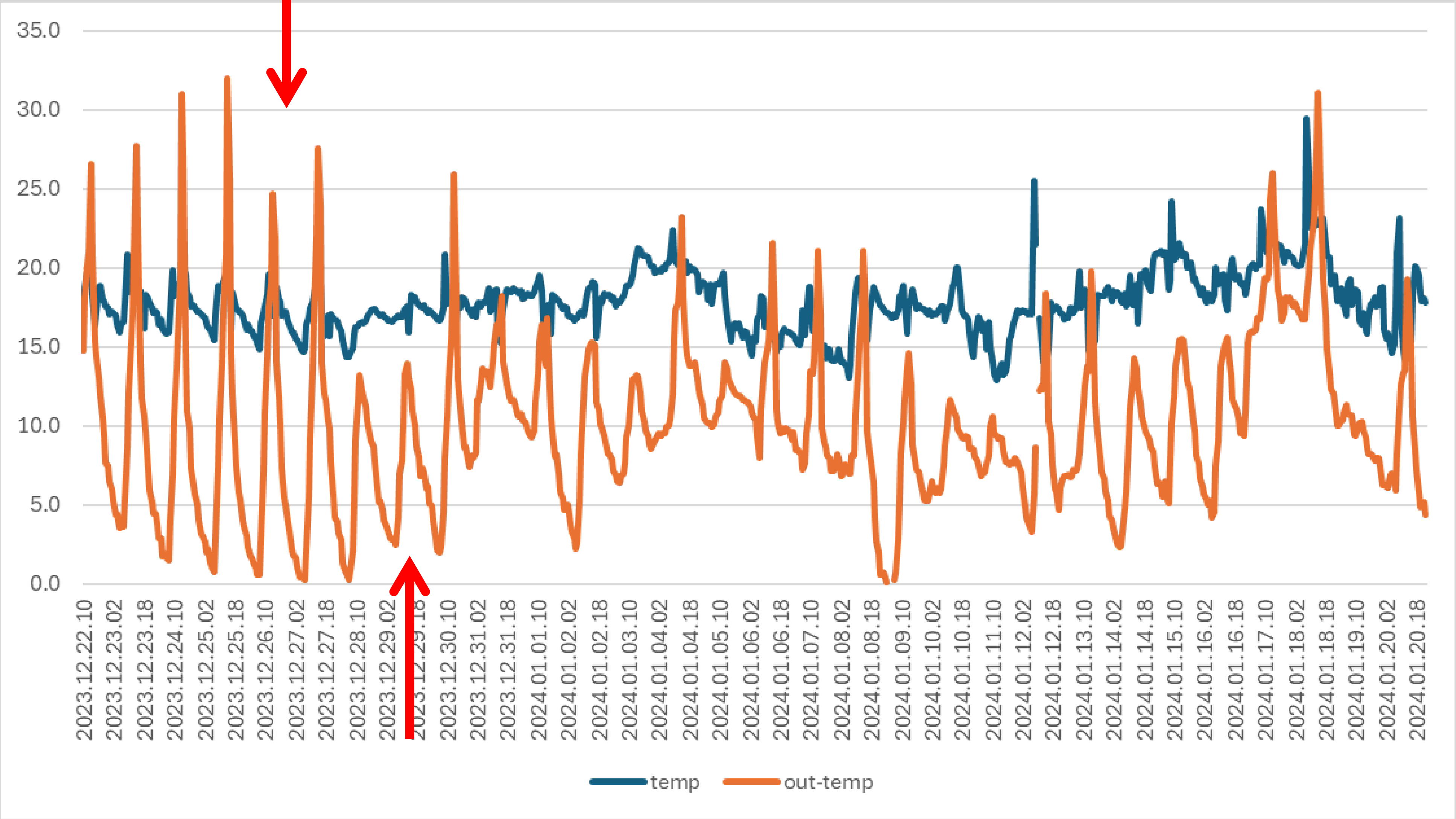
# THERMAL ENVIRONMENT

- Dataset recoded between 22/12/23 and 20/01/24
- Thermal conditions were adequate for the pigs during this winter period as the air temperatures within the building were relatively high 17.8 ± 2.0 oC and on average approximately 7.8 oC higher than outside temperatures (10.0 ± 5.4 oC).
- This "temperature lift" (TL) provided by this livestock building is greater than TLs observed in other countries with Mediterranean climate.

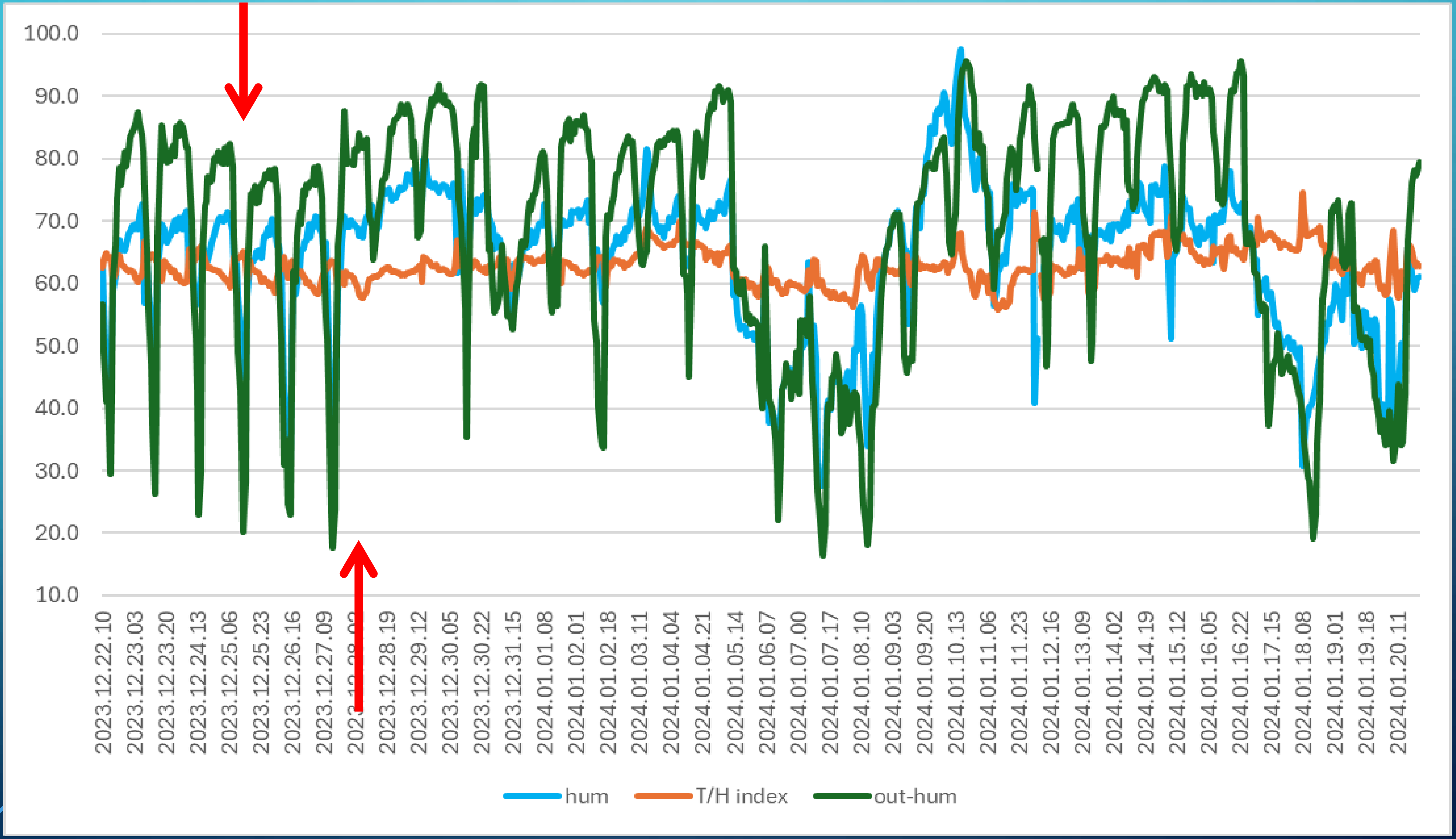
# THERMAL ENVIRONMENT

- The livestock building also reduced the extremes of temperatures internally as indicated by the difference in 'range' of the internal and external temperatures (16.5 and 31.9 oC, respectively).
- The measured internal relative humidity was 64.1 ± 11.7 % and humidity levels were somehow lower when compared to the external humidity levels 68.2 ± 18.7.

# INSIDE AND OUTSIDE TEMPERATURES



# INSIDE AND OUTSIDE RELATIVE HUMIDITY + TH INDEX



# RESULTS: DESCRIPTIVE STATISTICS (AERIAL ENVIRONMENT)

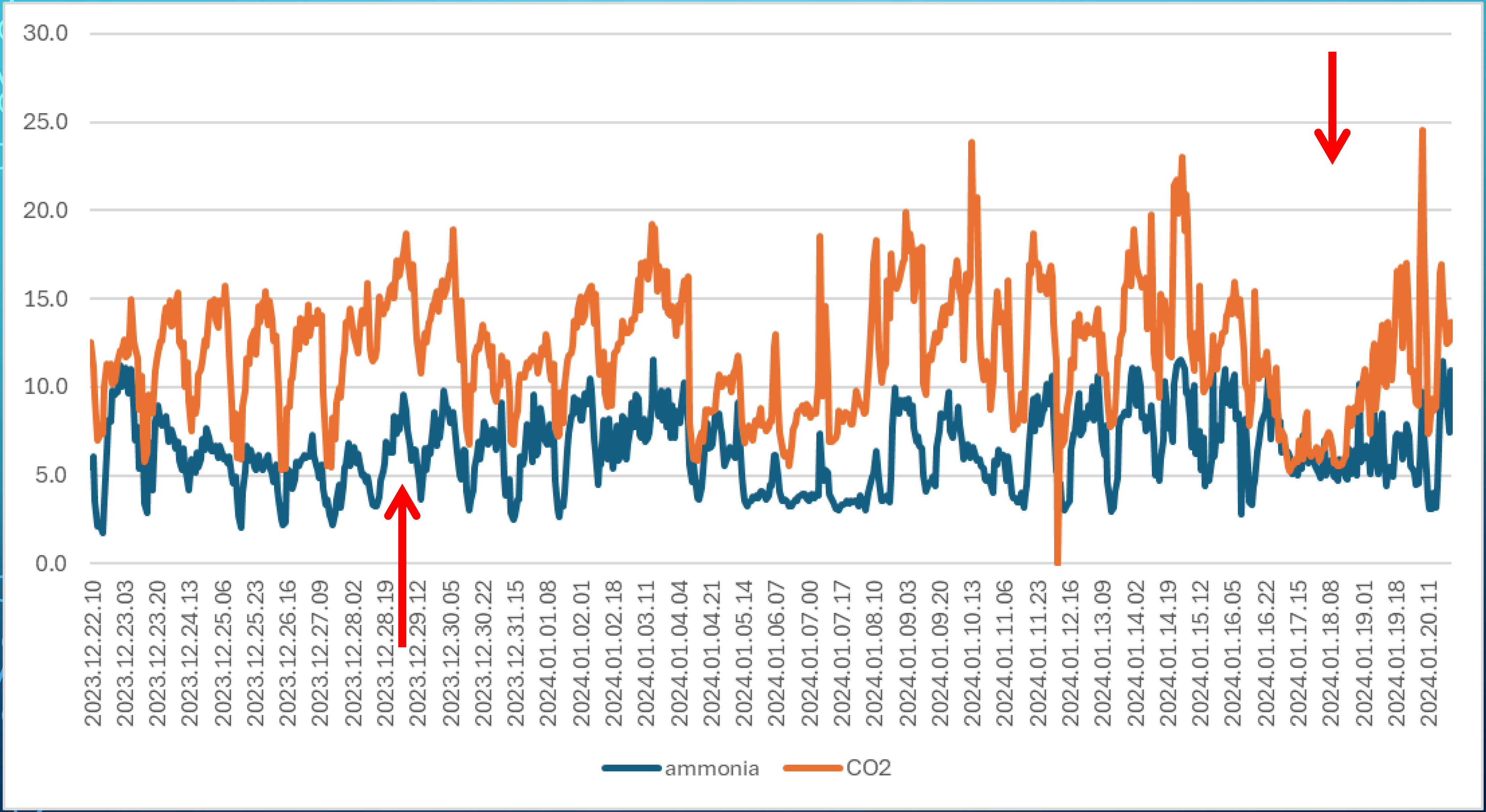
| | ammonia | dust | $CO_2$ | |
|---|---|---|---|---|
| min | 1.8 | 10.3 | 527.0 | |
| max | 11.6 | 11.2 | 2457.8 | |
| mean | 6.3 | 10.8 | 1190.5 | |
| range | 9.8 | 0.9 | 1930.8 | |
| SD | 2.1 | 0.1 | 349.9 | |

## AERIAL ENVIRONMENT

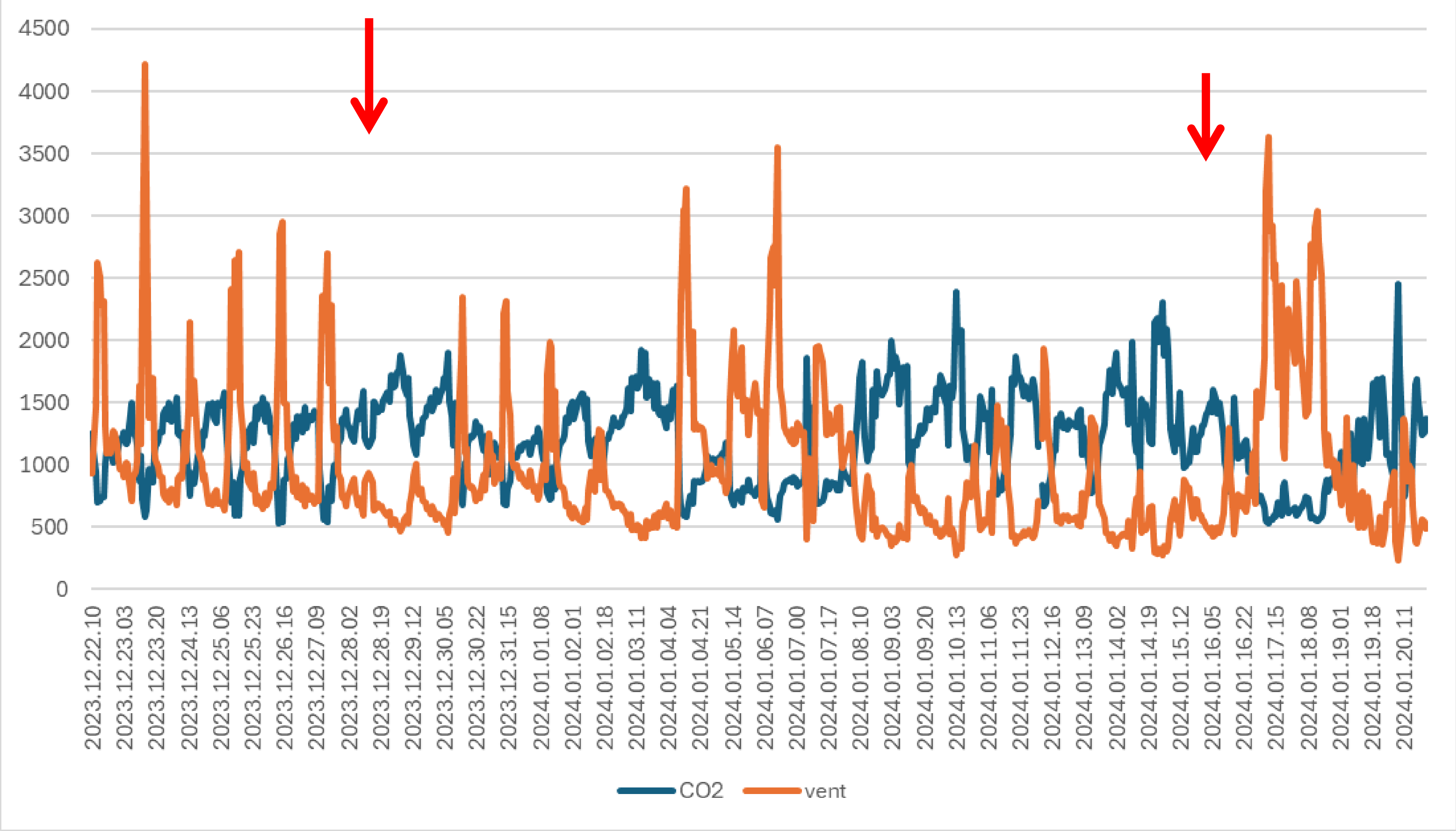
- Ammonia (6.3 ± 2.1 ppm) and airborne particle concentrations (10.8 ± 0.1 µg/m3) were low, indicating an optimal environment for the pigs to maximize production efficiency.

- Carbon dioxide concentrations (1190 ± 350 ppm) suggested that ventilations rates were controlled to provide a reduced ventilation rate during the winter period.

# AMMONIA AND CO2 CONCENTRATIONS



# VENTILATION RATES AND CO2 CONCENTRATIONS



# SUMMARY AND CONCLUSIONS

**These results highlighted the ED system's ability to continuously monitor and assess the environmental conditions within livestock building, allowing farm managers to implement corrective actions if/when required.**

# WEIGHT-DETECT™

- Designed to determine the average group weight of a pen of pigs
- Sample weights of the pigs within the pen are recorded non-invasively
- Several dimensional measurements are acquired from images to reliably predict live weight
- Weight-Detect™ will provide a performance record of animals on a daily basis

**Banhazi T.M.**, M. Tscharke, W. M. Ferdous, C. Saunders and S-H. Lee (2011) Improved image analysis based system to reliably predict the live weight of pigs on farm: Preliminary results *Australian Journal of Multi-disciplinary Engineering* **8 (2) 107-119**

# EVALUATION OF MEASUREMENT PRECISION - METHODOLOGY

- Long-term weight monitoring was carried out in 5 different grower/finisher buildings on 2 farms in QLD, Australia and in 3 different grower/finisher buildings on 3 farms in EU.
- The average pen weights (APWs) were predicted in a number of pens on these commercial farms using WD instruments.
- At the same time, manual weight-scales were used on the same pens to obtain measurements of APWs.
- All calculations were completed in ADAMS (Automated Data Analysis and Management System) which is a secure database maintained in Amazon cloud

# RESULTS – 1

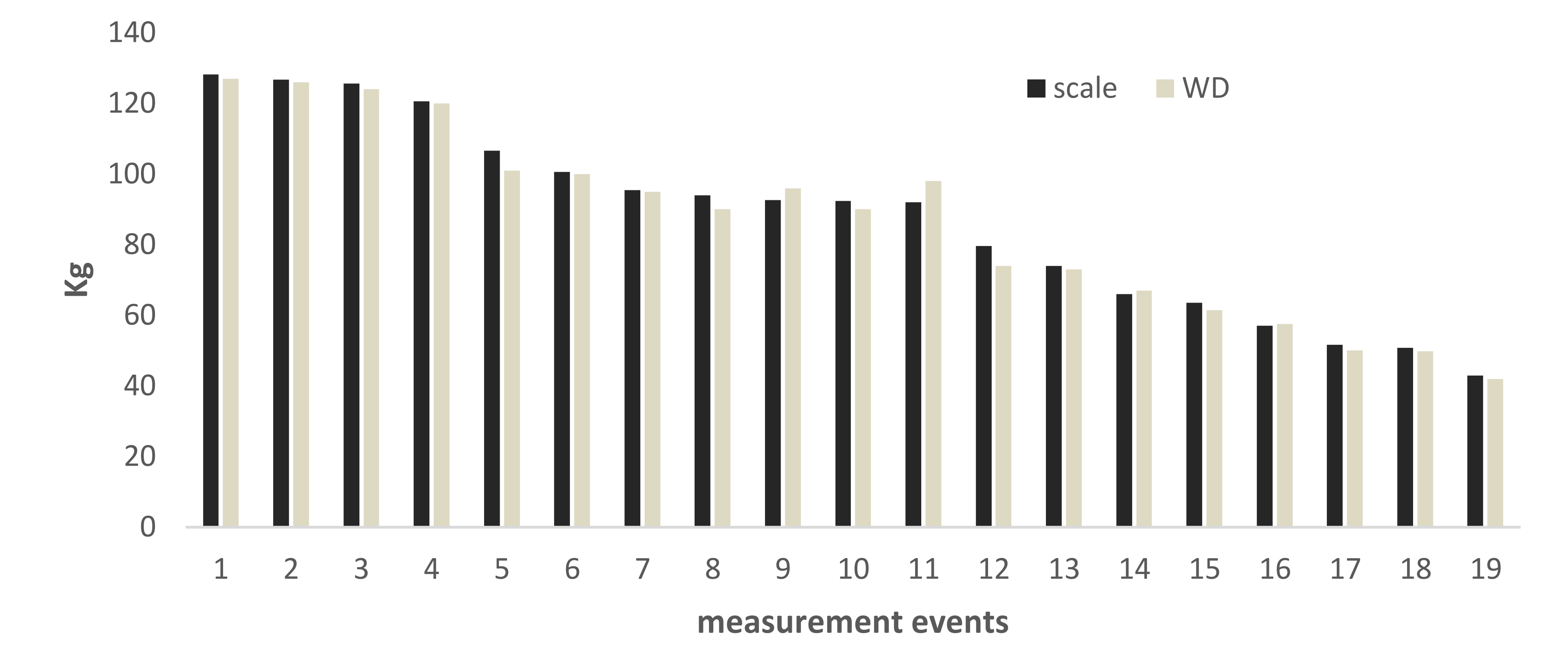



**Figure 1. Average Pen Weights (kg) recorded on the farms (combined dataset) during the period between 06/03/18 and 23/03/20. Manual scale measurements are depicted by the black bars while the corresponding Weight-Detect™ measurements are represented by the grey bars. During this study period 19 comparative measurements were undertaken.**

# RESULTS – 2

**Table 1. Descriptive statistics associated with the measurement errors of Average Pen Weights (kg) recorded on the farms (combined dataset) during the period between 06/03/18 and 23/03/20.**

| Descriptive statistic | Error (kg)[a] | Error (% )[b] | Comments |
|---|---|---|---|
| **maximum** | 5.96 | 7.57 | Largest difference (between the measured anc weights) observed was above 7.5% |
| **minimum** | 0.5 | 0.50 | Extremely small differences were observed below the expected 1-1.5 kg differences (i normally due to feed, water consumption and timing of faeces, urine release). |
| **average** | 2.11 | 2.55 | Average and median values were quite indicating a greater level of fluctuation in the d |
| **median** | 1.2 | 1.89 | |

**[a] Difference between measured and predicted weights expressed in kilograms**

**[b] Difference between measured and predicted weights expressed as percentage of body weights of pigs**

# LIMITING FACTORS

- **GOOD results**, but there are **limiting factors:**
- <u>**Animal behaviour**</u> will influence precision as predictions are based on **even sampling** of the animals. The disturbance of pigs in the pen will change the sampling rate and sampling distribution and thus will have an influence on precision.
- If animals are disproportionally represented in the images; the results will be skewed. Previous publications were "incorrect" (P. Schofield).

- **Correct camera placement** is important in terms of ensuring even sampling of the animals. Contrary to the general belief this is not best achieved by placing the camera above the feeder (Tscharke and Banhazi, 2013). The best camera placement should be specific to given pens

# SUMMARY

- The WD instrument proved to be able to collect information reliably on farms, but of course a number of other factors, such as (1) placement of the camera, (2) management of the farm and (3) animal behaviour can all influence the results generated.
- In addition, proper interpretation and use of collected data cannot be overemphasised.
- However, if PLF tools, such as continuous monitoring of pen weights, are properly introduced on commercial farms, the benefits of close monitoring could be significant.

# ACKNOWLEDGEMENTS

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# INTRODUCTION

- Regular monitoring of Average Pen Weights (APWs) and calculating associated Average Daily Gains (ADGs) are crucial to understand production efficiency (Hicks et al., 1998, Honeyman and Kent, 2001)
- Traditionally, this done via periodic and manual weight checks and thus on most farms, pigs undergo spot-check just a few times during their growth phase (Korthals, 2001, Banhazi et al., 2022c, Kollis et al., 2007).
- However, more frequent measurements of APWs and ADGs are recommended because short-term inefficiencies can significantly degrade overall growth efficiency (Banhazi and Black, 2009, Black and Banhazi, 2022, O'Connell et al., 2004, Willis et al., 2016).

# WEIGHT-DETECT™

- Designed to determine the average group weight of a pen of pigs
- Sample weights of the pigs within the pen are recorded non-invasively
- Several dimensional measurements are acquired from images to reliably predict live weight
- Weight-Detect™ will provide a performance record of animals on a daily basis


**Banhazi T.M.**, M. Tscharke, W. M. Ferdous, C. Saunders and S-H. Lee (2011) Improved image analysis based system to reliably predict the live weight of pigs on farm: Preliminary results *Australian Journal of Multi-disciplinary Engineering* **8 (2) 107-119**

# KNOWLEDGE GAP AND OBJECTIVES

- However, the full range of benefits from these technologies remains unclear, particularly in terms of their application for health and welfare monitoring.
- To explore these possibilities, a WD system has been installed on a commercial pig farm in Spain as part of the EU-funded aWISH project (HEurope grant 101060818) to:
  - assess the technology's feasibility and utility for monitoring pig health and welfare
  - quantify the advantages of utilizing weight monitoring tools specifically and PLF technologies generally on commercial farms

# MATERIALS AND METHODS

- The pen located in the northern part of Spain in a traditional grower-finisher building with automatically controlled natural ventilation
- The study pigs were fed pelleted diet and were kept on fully slatted floors
- New/improved model of WD equipment was installed at approximately 2.0 m height
- Corresponding manual weighing procedures were undertaken using an electronic scale (WA08, Meier-Brakenberg, Extertal, Germany)
- APWs were predicted daily, ADG values were calculated for specific periods and standard farm reports were emailed to the farm manager weekly by PLF Agritech staff.

# EXPERIMENTAL PEN

T. BANHAZI, M. DUNN, A. BANHAZI, J. REIXACH, A. R. PEREZ, P. LLONCH, J. MASELYNE (2024) Weight-Detect instrument predicted the onset of respiratory infection a week before clinical signs appeared ISAH conference proceedings, Thailand, 16-20 September, 2024

# M&M: DESCRIPTION OF WD INSTRUMENT

- The functionality of the WD instruments has been described previously, (Banhazi et al., 2011, 2012a,b).
- The WD instruments utilize an off-the-shelf 3D camera and the processing component of the WD system operates two processes:
  - One acquires depth images (after detecting 'pig shapes'), while the other handles the processing of these images in real-time.
  - Weight prediction is achieved by analyzing and extracting features and measurements from the captured images, generating corresponding weight estimates (Banhazi and Dunn, 2016, Banhazi et al., 2022b). Technology patented in AU, USA & EU.

# RESULTS: WEIGHT PREDICTION PRECISION

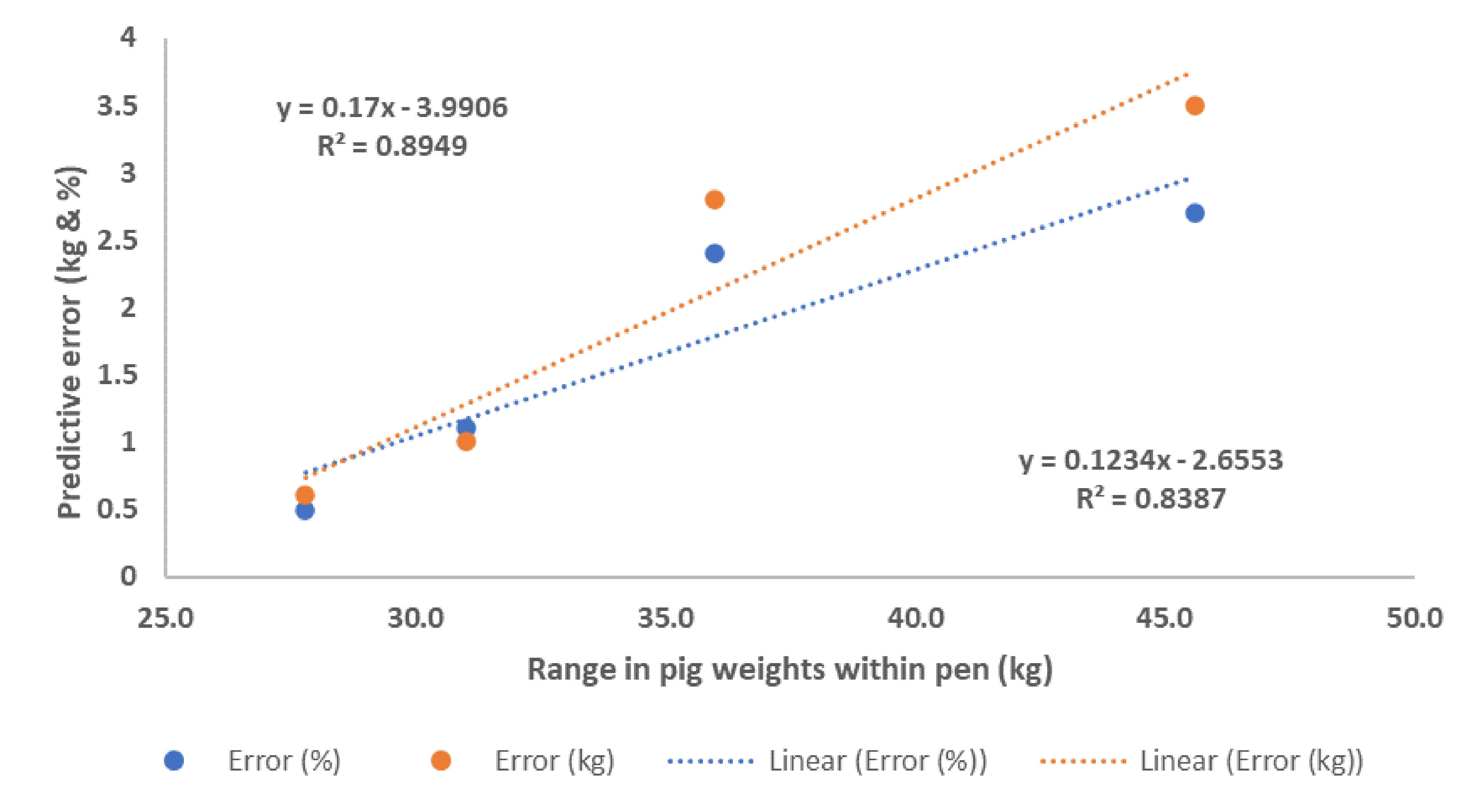
| Measurement days (date) | 27/03/2024 | 15/04/2024 | 30/04/2024 | 16/5/24 |
|---|---|---|---|---|
| Max weight in pen (kg) | 106.0 | 126.0 | 140.0 | 157.8 |
| Min. weight in pen (kg) | 75.0 | 98.2 | 104.0 | 112.2 |
| Range (kg) | 31.0 | 27.8 | 36.0 | 45.6 |
| Measured APW (kg) | 93.3 | 110.7 | 118.7 | 130.7 |
| Predicted APW (kg) | 94.3 | 111.3 | 115.9 | 127.2 |
| difference (kg) | 1.0 | 0.6 | 2.8 | 3.5 |
| difference (%) | 1.1 | 0.5 | 2.4 | 2.7 |

## WEIGHT PREDICTION OUTCOMES

- WD system was able to predict the APWs of the pigs with 1.1% (1.0 kg), 0.5% (0.6 kg), 2.4% (2.8 kg) and 2.7% (3.5 kg) precision respectively

- Range (spread) of the weight measurements were 31.0 kg, 27.8 kg, 36.0 kg and 45.6 kg, respectively. The pigs were uneven in this study pen which made weight prediction challenging (Banhazi et al., 2022b). Despite the circumstances, the WD unit performed with less than 3% error margin.

# ASSOCIATION BETWEEN RANGE AND ERROR MARGIN



## PRECISION OF WIGHT PREDICTION

- A clear positive correlation between increased error margin and increased spread of pigs' weights
- Various factors, including animal behavior, camera positioning, and farm management practices, can heavily influence accuracy, because accurate predictions depend on the even sampling of animals. When the system captures more images of smaller or larger pigs disproportionately, it can distort the predicted APWs
- Earlier studies incorrectly assumed that even sampling would naturally occur within pig pens (Schofield, 1990)

# THE IMPORTANCE OF REALISTIC EXPECTATIONS

- It is important to create realistic expectations in end-users about the expected precision of WD units.
- Many companies tend to overstate the precision and capabilities of such weighing systems, which can lead the development of unrealistic expectations.
- It is important to clearly communicate the reasons for any imprecisions, such as the timing of urine and faecal release, as well as feed and water intake
- Certain differences in weight acceptable and indeed expected (Liu et al., 2023).

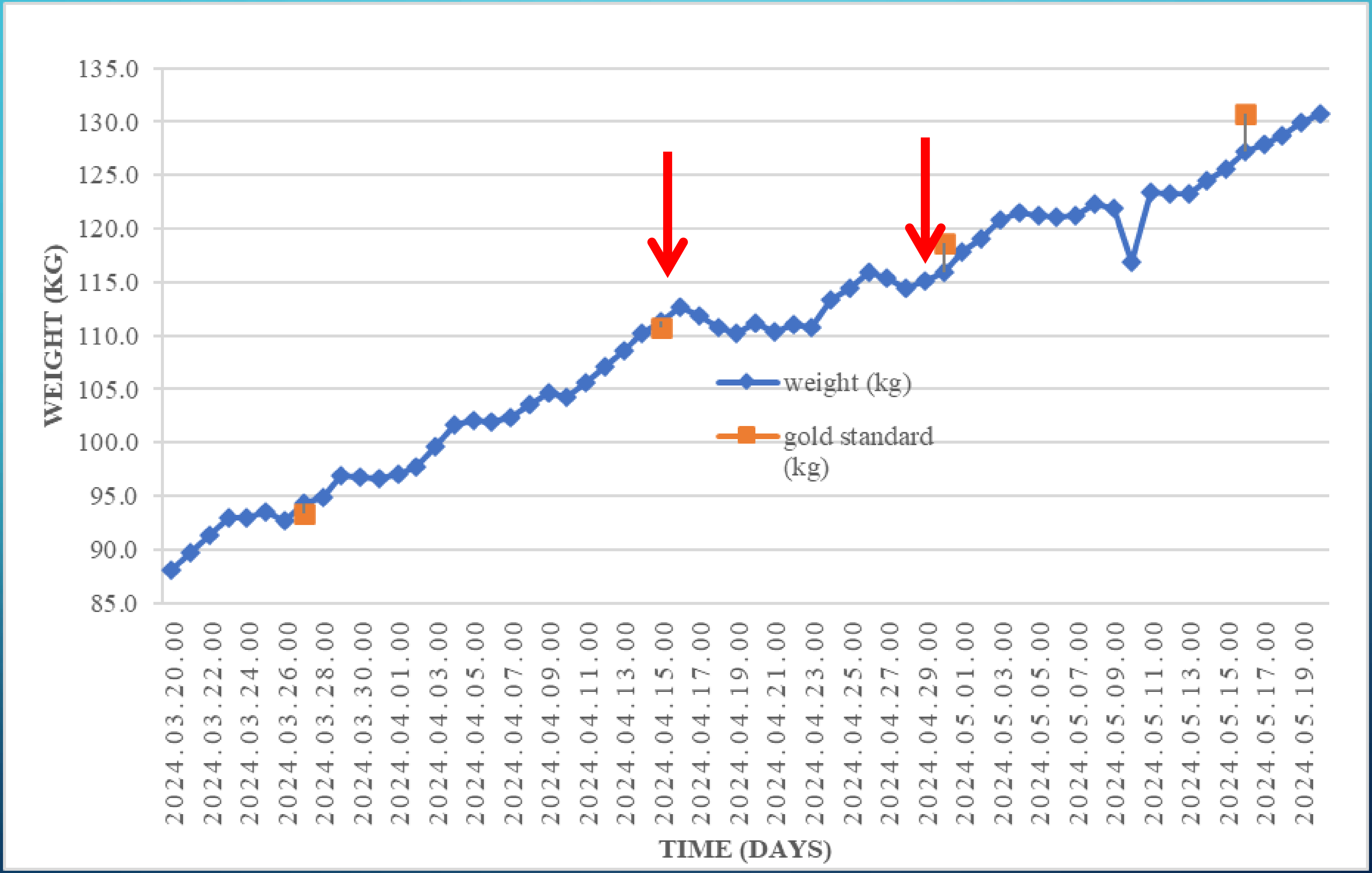
# IMPORTANT ASPECT: GROWTH CURVE MONITORING

| Measurement period (dates) | Weight gained (kg) | ADG (g/d) | ADG change (g/d) | comments |
|---|---|---|---|---|
| 20/03/24 – 16/04/24 | 24.7 | 882 | | Very good initial ADG |
| 17/04/24 – 30/04/24 | 4.0 | 286 | 596 decrease | ADG stagnation due to respiratory infection |
| 1/05/24 – 20/5/24 | 12.9 | 645 | 359 increase | ADG increase due to treatment/recovery |
| 20/03/24 – 20/5/24 | 42.8 | 690 | | Overall performance of the batch |

## GROWTH CURVE MONITORING

- WD unit was able to detect weight reduction in pigs six days before the clinical signs of a respiratory disease were noticed.
- Initially pigs grew very well (882 g/d) but between the 17/4/2024 and 30/04/2024 their ADG plummeted to just 286 g/d. The animals were diagnosed with respiratory disease on the 22/04/24
- This period of ADG stagnation (pigs only gained 4.0 kg) led to an approximate 14-day delay in reaching the target slaughter weight, (approx. 130 kg)

# GROWTH CURVE FOR THE WHOLE PERIOD

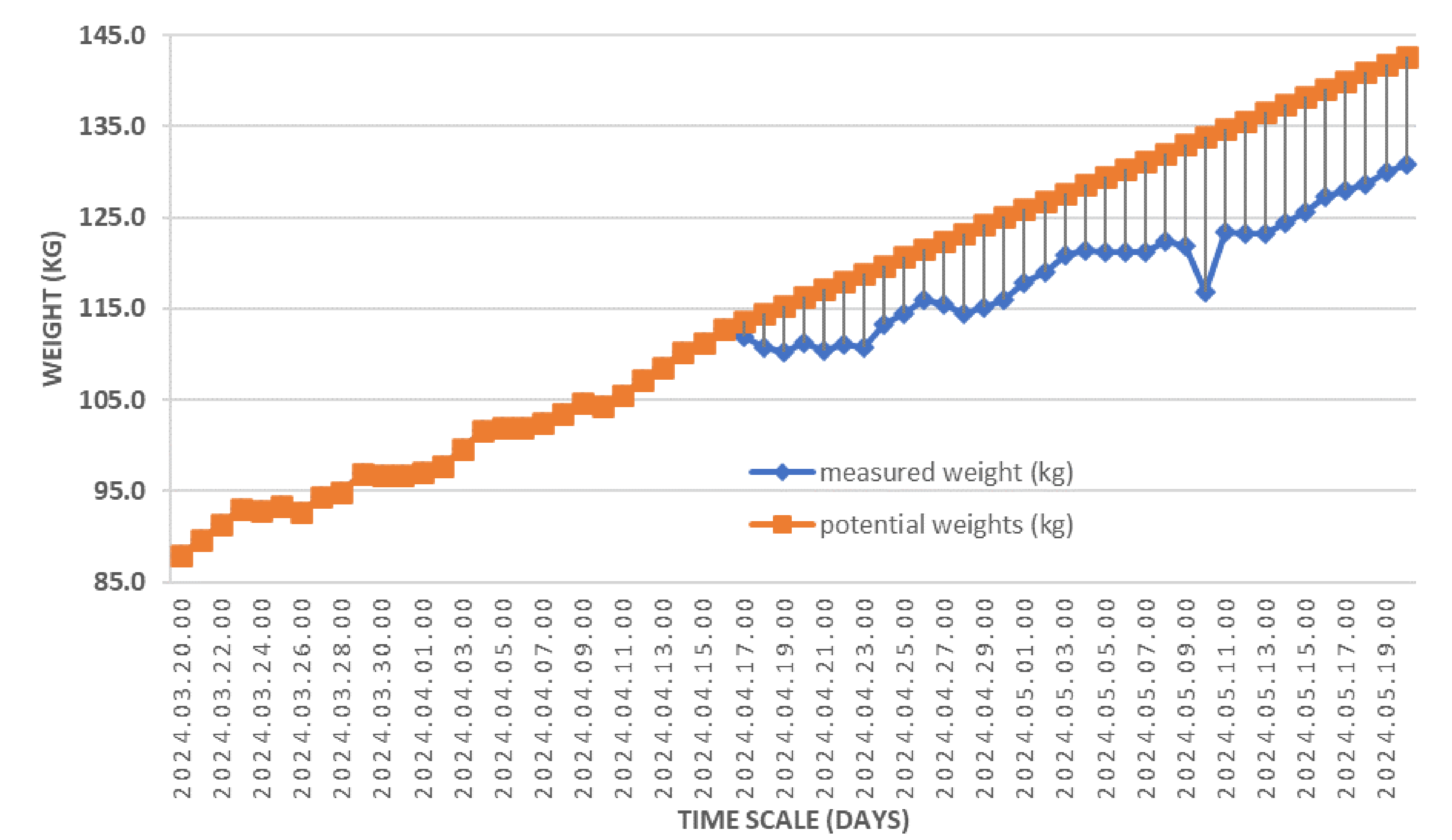


# GROWTH CURVE MONITORING

- WD (and similar) systems are able to map the growth curve, enabling producers to pinpoint periods of inefficiency and tackle problems. In this study, the specific economic benefit of the WD system was to provide an early warning about an impending respiratory disease
- When producers promptly address issues around suboptimal ADGs, the return on investment can be substantial
- Previous on-farm experiences demonstrated that automated weight monitoring can alert livestock managers about various additional management problems. (Banhazi et al., 2022a)

# WHAT-IF SCENARIO (MONITORED VS. POTENTIAL ADG)

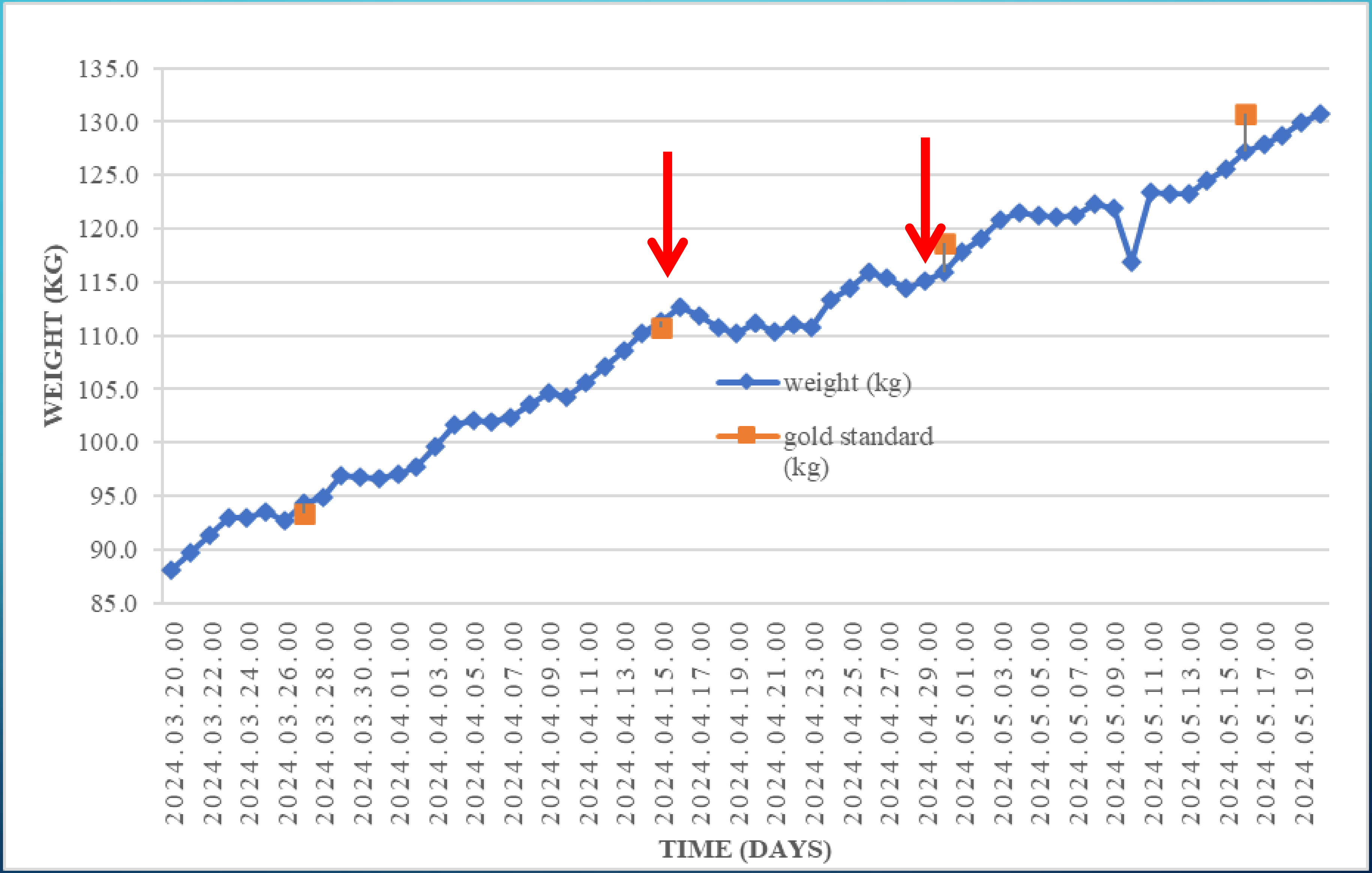
If the disease avoided and the pigs maintained their initial ADG of 882 g/d, they would have reached the target slaughter weight of 130 kg approx. 14 days sooner resulting in considerable cost savings



# MANAGEMENT IMPACT ON MEASUREMENTS PRECISION

- Farm management practices are impacting on the accuracy of WD systems. Any changes in farm management, including activities in or around the monitored pen can cause disturbances and can alter sampling distribution and consequently impacting on weight estimations (Doeschl-Wilson et al., 2005, Korthals, 2001).
- For instance, during this monitoring period, maintenance work conducted adjacent to the study pen on 10/05/24, caused a brief but noticeable dip in recorded weights.
- Therefore, any sudden fluctuations in weight should be interpreted in light of these management changes or environmental alterations affecting the animals.

# GROWTH CURVE FOR THE WHOLE PERIOD



# SUMMARY AND CONCLUSIONS

- WD system’s can alert livestock managers to health issues before clinical symptoms manifest.
- This early detection allows for the timely implementation of mitigation strategies, reducing the adverse effects of diseases on animal welfare and production efficiency.
- Although the WD instrument has proven dependable in collecting data, it's crucial to account for other influencing factors such as camera placement, farm management practices, and animal behavior.
- Nonetheless, this case study illustrates that integrating smart technologies into commercial farming can significantly enhance overall profitability

# ACKNOWLEDGEMENTS

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ILVO Flanders research institute for agriculture, fisheries and food

BATALLÉ

UAB Universitat Autònoma de Barcelona

carnex

Innotech

When not otherwise stated, photos were taken by the members of the project team

# IMPORTANCE OF RESPIRATORY DISEASES

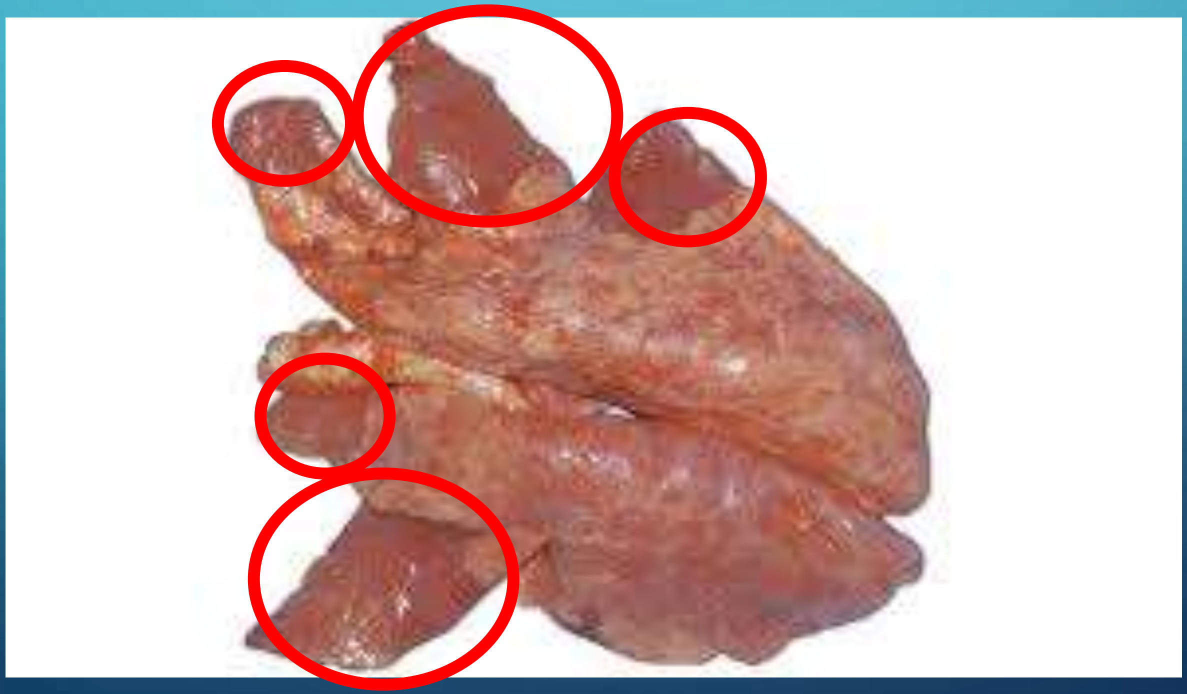
Respiratory diseases (RD) represent a major challenge for the pig industry, causing substantial economic losses.

Risk factors are often associated to suboptimal housing conditions (Banhazi, 2013, Banhazi et al., 2022, Murphy et al., 2012, Stark, 2000, Curtis et al., 1975, Crook et al., 1991, Donham et al., 1995)

Extra costs associated with increased mortality, veterinary care, reduced feed intake, sub-optimal average daily gain (ADG) and carcass/organ condemnation

# ENZOOTIC PNEUMONIA LESIONS

- Enzootic pneumonia (EP) is often subclinical, making the on-farm diagnosis difficult (Murphy et al., 2012)
- However, EP can be quite readily diagnosed during slaughtering, because the gross lesions are (relatively) easily observable by humans



# PIG HEALTH MONITORING SCHEME

The Pig Health Monitoring Scheme (PHMS) is the gold standard system for evaluating the health of pigs at slaughterhouses (Pointon et al., 1992, Rodriguez Carino et al., 1998, Holt et al., 2011)

PHMS employs skilled observers to conduct visual inspections immediately after slaughter to identify EP, as well as diseases such as sarcoptic mange, liver spots, pleurisy and pericarditis

Observers manually record the condition of pig on a printed form, then the scores are analyzed and detailed reports generated for producers and for their veterinarians

Unfortunately, the PHMS systems are expensive and inefficient. Thus, creating automated health inspections (via image analysis techniques) could make these systems more efficient and economically viable

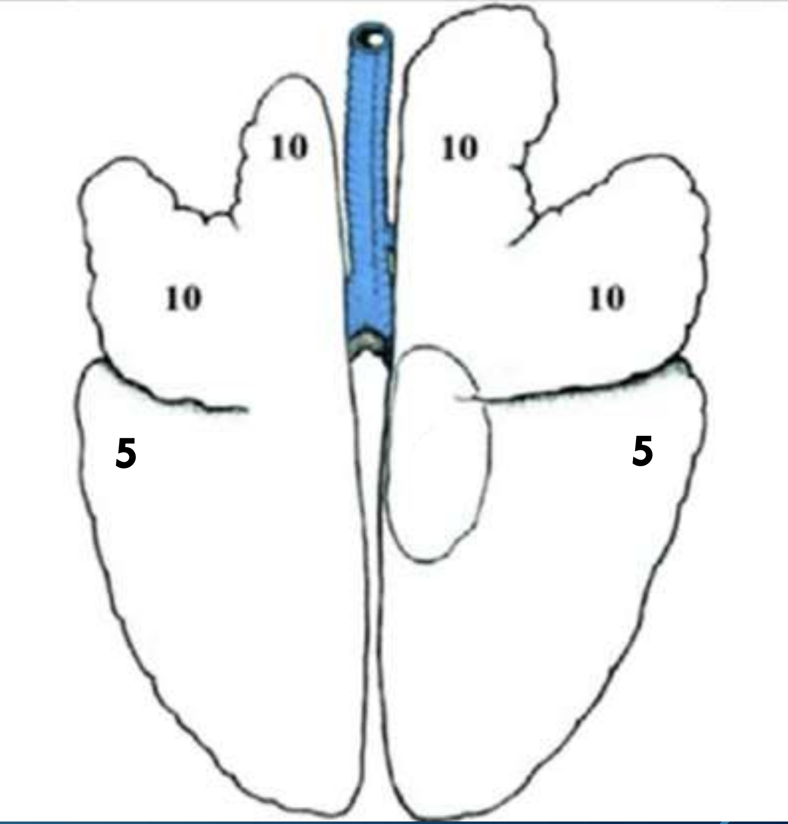
# PHMS LUNG SCORING SYSTEM

10 2-3? 2-3? 8-9? 5 SUM = 27 or 30

**Goodwin et al. [55]**

Two-dimensional

**Score: 0-50**




**NOT an exact science, especially when considering the available time for inspection due to processing speed**

# IMAGE ANALYSIS AS A POTENTIAL TOOL

**Image analysis (IA) methods combined with advanced data analysis techniques such as artificial intelligence, are already used to manage various complex processes in livestock production** (Cross et al., 1983, Schofield, 1990, Wouters et al., 1990, Park et al., 1998, Xin and Shao, 2002, Frost et al., 2004, Parsons et al., 2007, Banhazi et al., 2011, Mehdizadeh et al., 2015, Neves et al., 2015, Banhazi et al., 2022a, Cronin et al., 2008).

**However, the environment of a typical slaughterhouse poses significant challenges, as electrical instruments have to survive very harsh conditions**

**Thus, very few studies reported successful trials replicating PHMS inspection protocols (Bonicelli et al., 2021)**

# PROJECT OBJECTIVES

The aWISH project (HEurope, grant nr. 101060818) has created opportunities for R&D in this field (Maselyne et al., 2024) to:

| | |
|---|---|
| (1) create an automated and cost-effective method of assessing the respiratory health of pigs at slaughter and | (2) use this information to assess the general welfare status of pigs. |

It is hoped that the LD system will enhance the ability of veterinarians to treat animals in a more timely manner, thus improving the general health, welfare status and productivity of pigs

# PILOT SITES (2 & 6)

Prototype systems of LD installed at commercial slaughterhouses in Spain and Serbia

# M&M: DESCRIPTION OF LD INSTRUMENT

The experimental LD system was built from customized parts assembled into an IP67 enclosure

The main computer platform: Intel Celeron Jasper Lake with Ubuntu 20.04 operating system and with a recording system custom written in C++

Two separate USB3 cameras installed behind a transparent plastic lid to ensure clear FoV, with water and dust protection

Camera 1: 'wide-angle', inclusive view of lung samples

Camera 0: focused, detailed view of the lung samples

Captured images were stored onto a network accessible storage (NAS) drive

General flow for the image processing: (1) read images, (2) detect lung, (3) measure the extent of lesion and (4) log results in a secure folder

# IMAGE CAPTURE AND PROCESSING

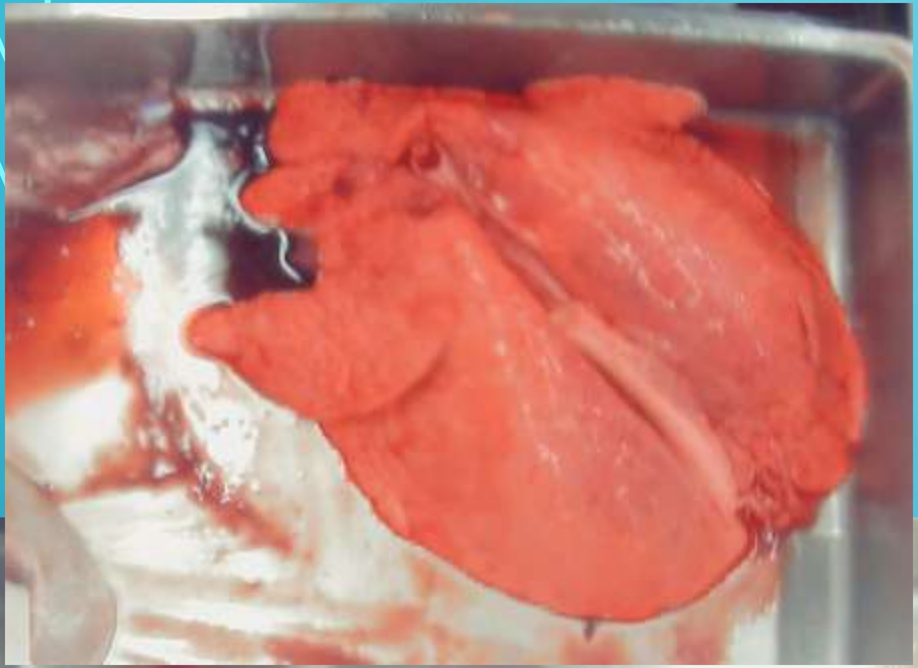
A subset of training images was labelled by selecting the region of interest and generating binary masks manually. These training images were manually segmented and saved to a training folder

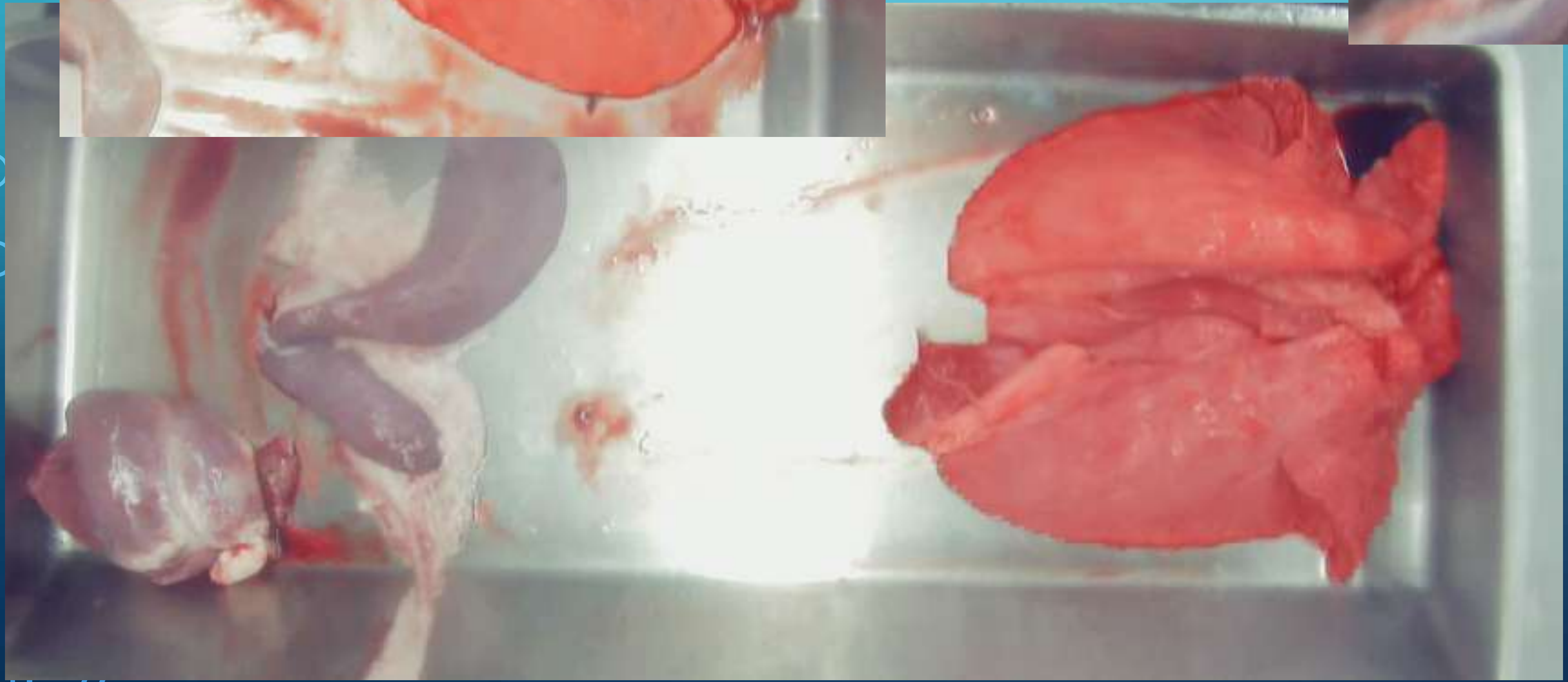
A variety of segmentation neural networks were evaluated, but eventually, a deep convolutional neural network (CNN) architecture was selected (Mohapatra et al., 2021, Traore et al., 2018, Badrinarayanan et al., 2017, Zhang et al., 2018).

At this stage, no further detail of the segmentation process can be given due to patenting considerations

# SEGMENTATION RESULTS; BINARY MASK CREATED

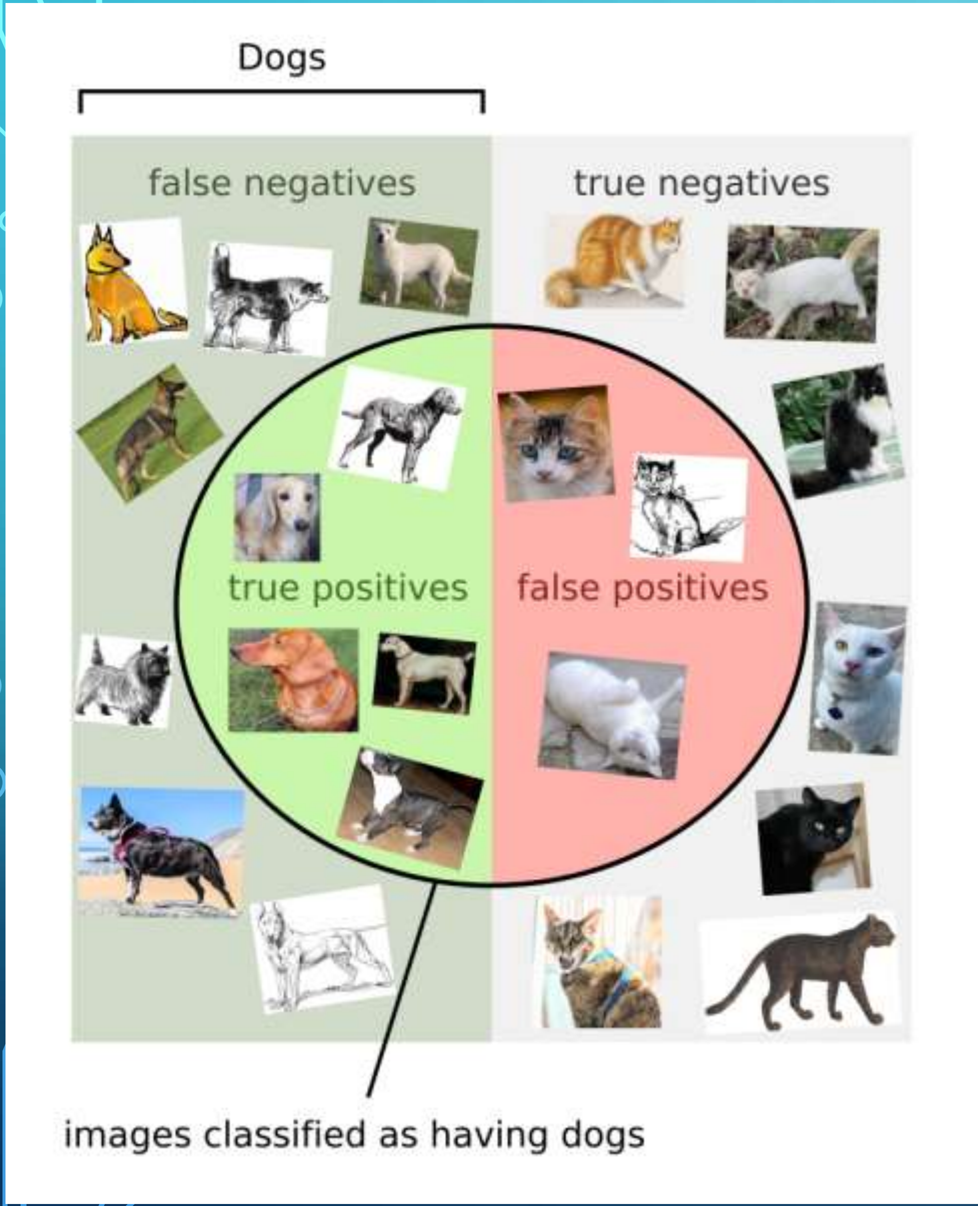
# PILOT 2: LUNG RECOGNITION





| Classification | % |
|---|---|
| fail | 9 |
| good | 53 |
| excellent | 38 |

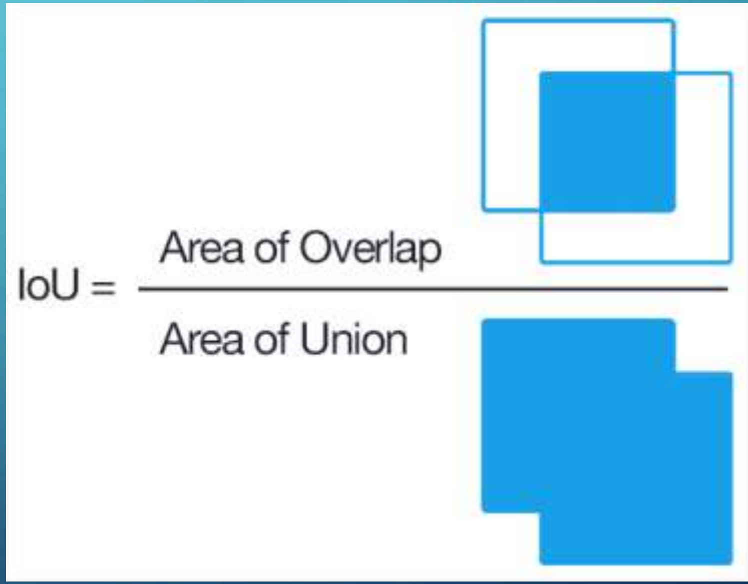
# UNDERSTANDING THE RESULTS OF IMAGE PROCESSING




**Accuracy = relevant pixels identified/all pixels identified**

**Recall = relevant pixels identified/all relevant pixels**

**IoU = Intersection over Union**




https://commons.wikimedia.org/w/index.php?curid=162544900

# RELEVANCE OF RESULTS FOR REAL LIFE CONDITIONS

- The situation is NOT B&W
- Red = manually ID-d lesion area
- Green = LD automatic ID

- Is it a TRU FN?
- Is it a TRU FP?
- Better/fairer evaluation of relevant precision:

Precision = all pixels ID-d as lesion manually  - all pixels ID-d as lesion automatically

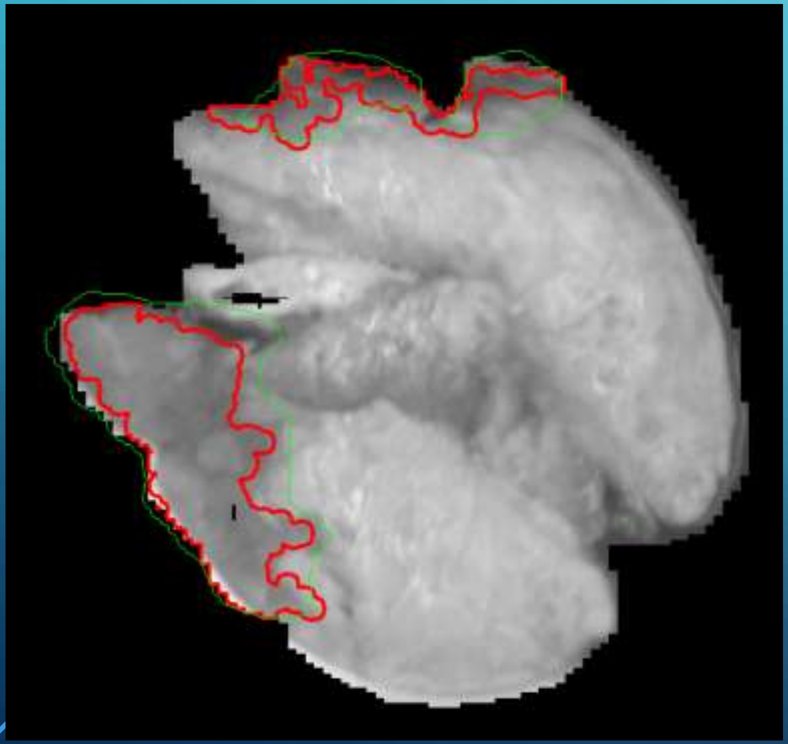
## RESULTS – PILOT 6 (TRAYS)

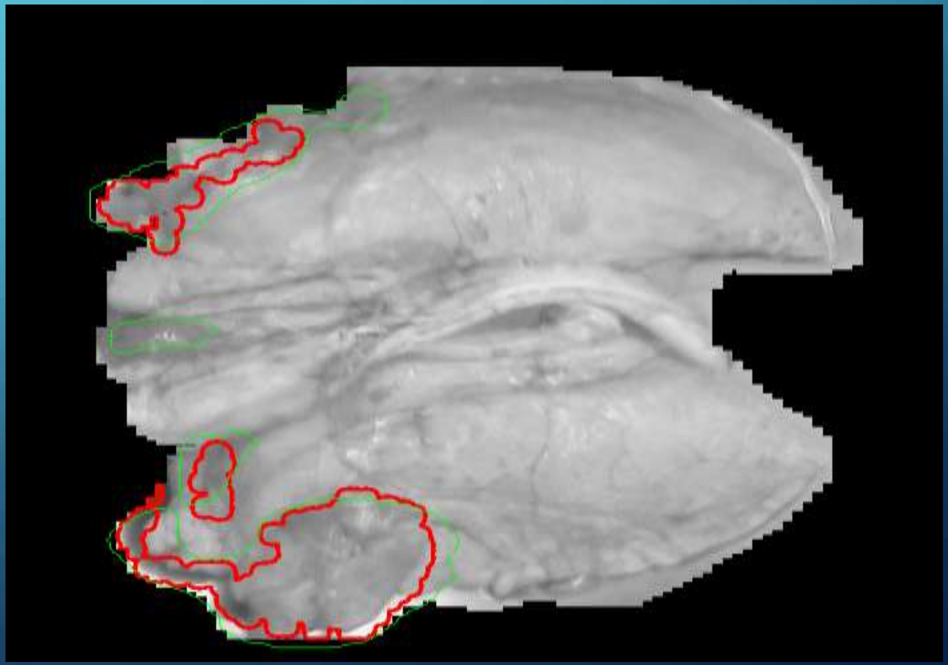
Precision = all manual lesion pixels - all automatic lesion pixels

FP = 3.28 % of lung area

FN = 2.16 % of lung area

| | Pixel | % |
|---|---|---|
| automatic | 14,166 | 6.9 |
| manual | 11,836 | 5.7 |
| Difference | 2,330 | 1.2 |





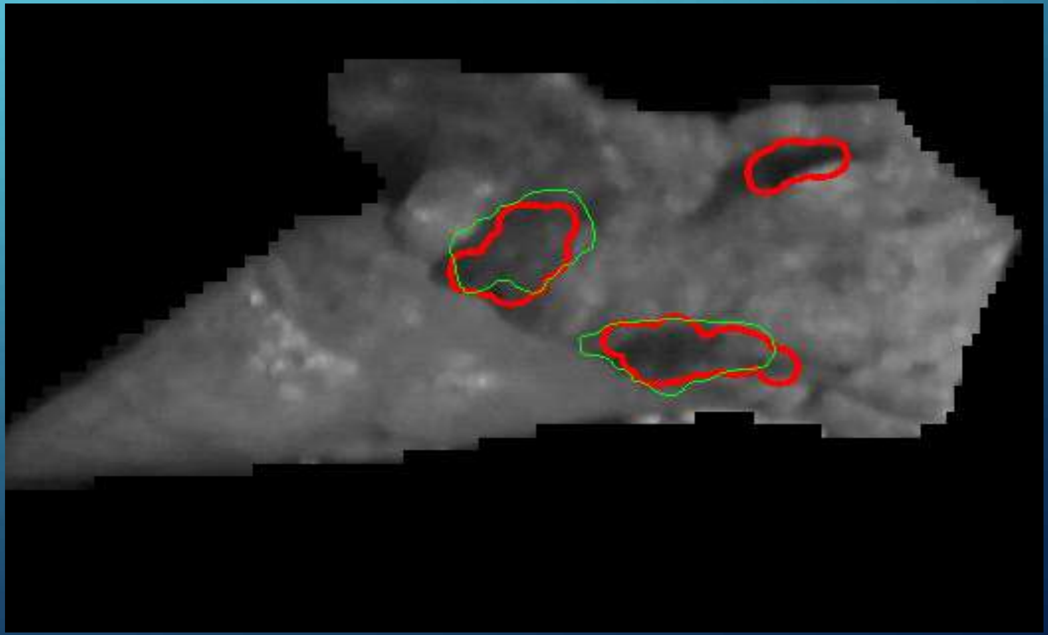
# RESULTS – PILOT 2 (HANGING)

Precision = all manual lesion pixels - all automatic lesion pixels

FP = 2.5 % of lung area

FN = 1.8 % of lung area

| | pixels | % |
|---|---|---|
| automated | 8,203 | 6.8 |
| manual | 8,320 | 6.9 |



# DEVELOPING A PRACTICAL PERSPECTIVE (PILOT 6 - TRAYS)

- Average lung size = 206,661 pixels
- Only approx. 50% of lung can be affected by EP like lesions
- Within 50% of the lung – 50 points can be allocated manually (PHMS score)
- Thus, 1 point = approx. 2,067 pixels

| | Pixel |
|---|---|
| automatic | 14,166 |
| manual | 11,836 |
| Difference | 2,330 |

| Error of manual scoring | Errors in pixel |
|---|---|
| 1 | 2067 |
| 2 | 4134 |
| 3 | 6201 |
| 4 | 8268 |
| 5 | 10335 |

- Practical perspective re: the true meaning of difference between manual and automatic scores. However, we believe that better placement of lungs (via SOP) will improve precision

# DEVELOPING A PRACTICAL PERSPECTIVE (PILOT 2 - HANGING)

- Average lung size = 120,000 pixels
- Only approx. 50% of lung can be affected by EP like lesions
- Within 50% of the lung – 50 points can be allocated manually (PHMS score)
- Thus, 1 point = approx. 1,200 pixels

| | pixels |
|---|---|
| automated | 8,203 |
| manual | 8,320 |

| Error of manual scoring | Errors in pixel |
|---|---|
| 1 | 1200 |
| 2 | 2400 |
| 3 | 3600 |
| 4 | 4800 |
| 5 | 6000 |

- Practical perspective re: the true meaning of difference between manual and automatic scores. However, we believe that further improvements will be implemented via selective assessment

# ISSUES TO DEAL WITH

- Establishing correlation between partial lung image vs. full lung image (occlusion/obstruction issues)
- Establish SOP for presentation of lungs in trays (Pilot 6)
- Just like for other technologies – it will be important to create realistic expectations in end-users about the expected precision of LD units (not every image will be useful)
- Slaughterhouse management practices will impact on the accuracy and applicability of LD systems.

# SUMMARY

- LD system's will alert livestock managers about the respiratory health status of the herd allowing farmers to treat respiratory problems in a timely manner in batches.
- This early detection will allow the early implementation of mitigation strategies (with reduced antibiotic use!), thus improving animal welfare and production efficiency.
- LD instrument development progressed well, but additional work is needed (i.e. obstruction, SOP, algorithms improvements etc.)
- Current achievements will enable the research team to progress further

# THANK YOU VERY MUCH FOR YOUR ATTENTION

Prof. Thomas Banhazi
Email: thomasbanhazi@plfag.com

Project starts

Project finished