Preliminary investigation into the development or acquisition of advanced digital post-mortem inspection systems for Irish abattoirs

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Summary

Following animal slaughter, the Official Veterinarians (OV) conduct a *post-mortem inspection* (PMI) of the carcass. Traditional meat inspection (EU 854/2004) is based on visual inspection, palpation and incision to identify clinical illness or pathological lesions in the animal or bird presented for slaughter. However, it is recognised that many currently relevant food safety hazards (microbiological and chemical residues) are "invisible" to such traditional meat inspection methods and accordingly the European Food Safety Authority (EFSA) published Scientific Opinions in 2011, 2012 and 2013, which called for a modernisation of meat safety assurance systems. It was considered that palpation/incisions used in current PMI poses a risk of microbial cross-contamination and the EFSA Opinions called for improved Food Chain Information (FCI), enabling risk-differentiation of animals presented for slaughter, and for low risk animals, a move to visual only (VOI) carcass inspection, while maintaining a detailed inspection with incision and palpation on high risk animals. These recommendations were subsequently adopted into EU Regulations (218/2014; 2017/625; 2019/624; 2019/627). Additionally, an EFSA Scientific Opinion in 2022 recommended monitoring of tail lesions in pig carcasses at slaughter to monitor pig welfare and enable feedback to farmers.

For many reasons, adoption of risk based and VOI PMI varies widely between different meat sectors and across EU Member States. However, once such a move is made it opens up the opportunity to move from current manual PMI, to the use of automated artificial intelligence and camera vision systems (CVS) to support PMI and animal welfare monitoring. Manual PMI is increasingly challenging, especially in the often high-speed lines operating in pig and poultry slaughter plants. CVS are based on high-resolution camera or image acquisition systems linked to artificial intelligence (AI) based models which process and analyse the images. Typically, in such systems, cameras are placed on the slaughter line in a fixed position or on a robot arm, and take images of the carcasses or viscera as they pass along the slaughter line. At a computer workstation the image is processed using artificial intelligence and the developed algorithm gives a result when, for example, a specific lesion or faecal material is detected. The EU is open to adoption of CVS systems, with Article 6 of EU Regulation 2019/627 setting out that '*Member States shall inform the Commission and other Member States on scientific and technological developments as referred to in Article 16(2)(b) of Regulation (EU) 2017/625 for consideration and further action as appropriate'*. The purpose of this is to indicate openness to innovation and encourage it in the EU. Advances in CVS to support PMI range from systems at the research and development stage, to in-plant pilot scale trials, through to adoption in slaughter plants.

With a view to scope out and review potential opportunities for Ireland to incorporate CVS into its PMI systems, the Department of Agriculture Food and the Marine (DAFM) Research under its Policy & Strategic Studies Research Call (2022PSS107) funded a project to

1. Review international developments on the use of CVS to collect PMI data on pathological lesions, identify faecal contamination on carcasses, or to monitor for indicators of animal welfare;
2. Assess feasibility of implementing such CVS systems into Irish abattoirs, taking into consideration technology readiness, practicalities such as space to install and ease of operation, cost and Intellectual property issues, and integration with existing data collection systems.

This report reviews the findings from the study for each of the sectoral areas (poultry, pigs, beef and lamb). The summary findings for each sector are summarised below.

Poultry

A key challenge for poultry PMI in Ireland is that larger slaughter plants are processing > 1 million birds a week, ~12,000 birds per hour and, indeed, the sector has ambitions to increase slaughter numbers further. This represents a major challenge for manual inspection of carcasses by the Veterinary Inspectors (VIs). Currently, PMI comprises a visual inspection of the carcass, both the outer carcass and internal cavity of bird and viscera. To meet requirements for welfare monitoring and export trade, footpad dermatitis is visually inspected (n=100) in slaughter lots. Records are still mainly manual. The potential use of CVS system in this sector would appear to have considerable benefits for the Competent Authority (CA) and the Food Business Operator (FBO) to support PMI at current or faster line speeds.

Some of the poultry sector are already using computer vision technology for carcass quality assessment on the line, post chilling, as birds enter the boning hall, so the sector is already familiar with this technology. International advances in CVS for poultry are being directed at 1) detection of multiple pathological lesions on carcasses and viscera; 2) identification of faecal contamination and 3) detection of footpad lesions.

One of the CVS systems reviewed in this study was VetInspector, a CVS developed by IHFood, Denmark who specialise in vision systems for the food sector, in collaboration with universities and researchers in Denmark. VetInspector uses multispectral image analysis and neural network algorithms to detect all poultry lesions and abnormalities, as listed in the post-mortem condemnation codes designated by the Danish Food Safety Authorities. The system employs a number of fixed cameras along the slaughter line, which take images of either the carcass or the viscera. Images are processed at a computer station by AI using a machine learned algorithm. It can reportedly operate at line speed of at least 12,000 birds /h. Vetinspector was presented to and approved by the European Commission in September 2021. Further developments and pilot trials in poultry plants to facilitate detection of faecal contamination are ongoing.

A CVS for footpad dermatitis, the Meyn Footpad Inspection System, was developed by Meyn Food Processors, The Netherlands. It allows the automatic scoring of poultry footpad lesions on the slaughter line. The system is based on a camera that captures images as the foot passes by in a shackle. Images are analysed using AI, which ranks any abnormalities according to a grading scorecard or quality parameters. The system is approved under the EU Broiler Directive (2007/43/EC). It is commercially available and is in use in poultry plants in Europe.

In Denmark, the VetInspector and Myen systems are now being combined to give a complete CVS based poultry inspection system.

Pigs

Large pig processors in Ireland are currently operating at a line speed of about ~200-500 pigs per hour (10,000 pigs a week). This represents a significant challenge for VIs to perform PMI manually, which is done at four stations; pluck, gastrointestinal content, carcass and final carcass inspection. Records are still mainly manual, but a new digital recording of PMI for pigs is currently being rolled out by DAFM. The digital recording system is a tablet (touchscreen) to be used by the VIs on the slaughter line to collect PMI data on specific lesions on lungs, liver, head, miscellaneous areas and on carcass, identifying the affected area and condition found. Data will feed into DAFM and the National Pig HealthCheck database, hosted by Animal Health Ireland (AHI), allowing feedback to farmers. VOI has not yet been implemented in Irish pig slaughter plants.

CVS under development for the pig sector are mainly directed at 1) detecting pathological lesions, specifically lung lesions related to pneumonia and pleurisy on the chest wall; 2) to detect faecal contamination on the carcass and 3) to monitor and record tail biting lesions. One of the CVS systems

reviewed in this study was the ADAL (automatic detection of abattoir lesions) technology developed by Farm4Trade (F4T), an Italian company specialising in artificial intelligence and digital technology for the agri-food sector. ADAL is an advanced vision system with 3D images taken by a camera mounted on a robot arm. The image is sent to a computer workstation that processes the images by AI and identifies and classifies the severity of lesions.

The ADAL system is currently undergoing pilot trials to detect pneumonia and pleurisy in pigs in selected Norwegian meat abattoirs as part of a research project (*EyeAM* led by Animalia Research Institute). The ADAL technology is also under trial to collect data on pig tail lesions and tail length as part of project, *TailScan*, an EU research project funded by EU parliament (2023-2025). As part of the project the ADAL prototype CVS equipment is being installed in selected pigs abattoirs in Italy, Spain, The Netherlands and Germany, to gather data on pig tail length and presence of lesions. The data will be compared with data on the same lesions collected manually and will facilitate development of the algorithm.

Beef

Beef slaughter plants in Ireland may process about 50 cattle per hour. PMI is carried out at four stations; head, pluck, gastrointestinal content and final carcass inspection, with considerable incision still being carried out. A primary focus at final carcass inspection is looking for faecal contamination which indicates a risk for the presence of key pathogens, such as Shiga toxigenic *E. coli* (STEC) and *Salmonella* spp., and may also impact shelf life obtained. A CVS to support this would be of value to the CA and FBO. One of the systems reviewed in the current study was the Beef AI Surface Checker developed by the Danish Meat Research Institute (DMRI). In this system a mounted camera takes images of the carcass surface inspection and an AI algorithm highlights on a screen in the slaughter plant in real time where the faecal contamination is, and this can direct operators where to remove the faecal contamination. It is commercially available and in use in beef abattoirs.

In New Zealand, a system called Veritide is a faecal detection technology employing fluorescence techniques and a mathematical algorithm to detect chlorophyll and its metabolites within faecal material found on the surface of meat. There are ongoing trials in abattoirs in New Zealand for this system and it is commercially available.

Lamb

Export lamb processors in Ireland are currently processing about 300-400 /h lamb (2500 to 3000 a day) There are 2 PMI stations on the slaughter line; one for visual inspection of the pluck and gastrointestinal content and a second station for visual inspection of the carcass. However, palpation and incisions for the surveillance of tuberculosis and fascioliasis is maintained for older animals (sheep having a permanent incisor erupted, or 12 months of age or more) for reasons of animal and human health surveillance. The challenges and opportunities for lamb would be very similar to the beef sector, although the line speed is faster. The current review identified no specific CVS under development, or trials specifically for lamb. Nonetheless, a CVS for faecal detection would be of benefit to both CAs and FBOs.

Other Emerging Technology

Hyperspectral imaging is an emergent technology which employs a combination of conventional imaging and spectroscopy. Many systems are under development to detect both faecal contamination and specific microorganisms (pathogens). It is a technology to keep a watching brief for future developments.

Conclusion

It is clear that to implement any CVS to support PMI in Ireland would need full and open collaboration between all actors involved, including DAFM, FSAI, Animal Health Ireland, FBOs, livestock producers and their practice veterinarians, with clarity on costs to each player, and the benefits and outcomes for all. Some sectors are currently more ready to adopt new technology than others, and different sectors have different requirements and potential benefits from adopting CVS technologies. It is noted that the use of CVS in the detection of pathological lesions will require that VOI inspection is in place in that meat sector. There are opportunities for CVS which detect faecal contamination which would have multi-actor benefits. CVS technology could be a very useful and automated way for monitoring specific lesions related to animal welfare.

Many countries throughout the world are moving towards a more risk-based meat inspection system, along with the use of innovative technologies. Under current EU legislation on official controls, new technology cannot replace traditional meat inspection, but it can be used as a supporting tool in the slaughter process. It is noted that many of the CVS are still at the pilot trial stage and indeed will have to be presented to, and approved by, the EU Commission prior to their implementation.

There is no doubt that the use of CVS is a rapidly developing area and has huge future potential as a support tool to PMI. A key benefit of CVS would be to allow screening out the low-risk slaughtered animals and more focused PMI on high-risk slaughtered animals where lesions or abnormalities are detected. CVS would allow large digital data recording and storage in databases, allowing farmer feedback. This would have clear benefit for animal health and welfare and, indeed, healthier herds/flocks should have fewer diseases, including food safety related risks. It is key to note that CVS is only a part of modernising meat inspection.

Contents

Abbreviations

ADAL: automatic detection of abattoir lesions

AHI: Animal Health Ireland

AI: artificial intelligence

AMI: ante-mortem inspection

App: *Actinobacillus pleuropneumoniae*

bTB: bovine tuberculosis

CA: Competent Authority

CC: carcass condemnation

CIS: carcass inspection system

CNN: convolutional neural network

COST: European Cooperation in Science and Technology

CVS: camera vision system

DAFM: Department of Agriculture, Food and the Marine

DL: deep learning

DL-PCB: dioxin-like polychlorinated biphenyls

DMRI: Danish Meat Research Institute

DPM: digital process monitoring

DTU: Technical University of Denmark

EFSA: European Food Safety Authority

EP: enzootic pneumonia

EU: European Union

F4T: Farm4Trade

FBO: food business operator

FCI: food chain information

FSAI: Food Safety Authority of Ireland

GPU: graphic processing unit

HEI: harmonised epidemiological indicator

ICBF: Irish Cattle Breeding Federation

MFI: multispectral fluorescence imaging

MI: meat inspection

ML: machine learning

MS: member states

NRP: National Residues Plan

OV: Official Veterinarian

PEPP: pleurisy evaluation of the parietal pleura

PMI: post mortem inspection

PRDC: porcine respiratory disease complex

RB-MSAS: risk-based meat safety assurance system

RD: respiratory disease

RIBMINS: Risk-based meat inspection and integrated meat safety assurance

SPES: slaughterhouse pleurisy evaluation system

SPPAS: Sustainable Poultry Products Assurance Scheme

TVI: temporary veterinary inspector

VCA: video content analysis

VI: veterinary inspector

VOI: visual only inspection

1. Introduction

Traditional *post-mortem* inspection (PMI) (EU Reg. 854/2004) is based on visual inspection, palpation and incision to identify clinical illness or pathological lesions, and it was designed mainly to prevent animals with diseases such as trichinellosis, brucellosis, tuberculosis, cysticercosis and taeniasis from entering the human food chain. The most relevant current hazards (microbiological/chemical residues), like *Campylobacter spp*, *Salmonella spp* and dioxins are "invisible" to traditional inspection methods. EFSA Scientific Opinions and Technical Specifications (EFSA, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2013c, 2013d)) have called for a risk-based modernisation of meat safety assurance systems, which was adopted in EU legislation on meat inspection (2019/624; 2019/627, 218/2014, 2017/625). This mandated a move to a visual-only inspection (VOI) for low-risk slaughter animals and a detailed inspection with incision and palpation on high-risk slaughter animals (Blagojevic et al., 2021). VOI avoids cross-contamination between carcasses via knives and hands (decreased number of incisions), but issues may arise if exporting meat to third countries where VOI is not accepted. The use of digital technology to support VOI, as part of risk based meat inspection is being slowly adopted in the EU. Equally, the relevance of PMI data to monitor animal health and welfare is recognised and a recent EFSA Scientific Opinion (EFSA, 2022) recommended monitoring of tail lesions in pig carcasses at slaughter as a means of monitoring tail biting during pig production.

EU funding supported a COST (European Cooperation in Science and Technology) Action project called RIBMINS (Risk-based meat inspection and integrated meat safety assurance; 2019-2023), an international network focused on modernisation of meat inspection primarily in Europe, but also overseas, through the development of risk-based meat safety assurance systems (RB-MSAS). The network aimed to help the full development and implementation of the general principles of RB-MSAS for the benefit of food safety, and protection of animal health and welfare. The RB-MSAS concept proposes a flexible, dynamic and longitudinally integrated system, comprising all preventive and control measures applied at the farm and abattoir stages of the meat chain, to achieve specific targets set for chilled carcasses (Blagojevic et al., 2021). The main components of the RB-MSAS are 1) categorise the farms and abattoirs according to their risk, using food chain information (FCI) and harmonised epidemiological indicators (HEI); 2) apply risk-based meat inspection and 3) make use of food safety management systems to assure abattoir process hygiene and have risk managers who coordinate the system. RIBMINIS concluded that, overall, high health status, coupled with good management and biosecurity are effective means to control most foodborne pathogens. Categorising abattoirs should be based on their ability to cope with the risk associated with the animals that are being received. Performance of the food safety management system and the abattoir's use of HEIs are an essential component of categorisation. Together, these two risk categorisations should enable risk managers to balance the level of risk represented by the slaughter animals and the risk-reducing capacity of the abattoir to achieve the food safety objective. However, no European country has yet formally included HEIs in abattoir risk categorisation, and no country is currently combining farm and abattoir risk categorisation systems (Alban et al., 2024).

Commission Delegated Regulation (EU) 2019/624 determines that *ante-mortem* inspection (AMI) and PMI can be performed by an official auxiliary under the supervision/responsibility of the Official Veterinarian (OV), following designed criteria and conditions. The exemption from this is that the competent authorities are permitted to decide that only a representative sample of poultry from each flock undergoes PMI, if the food business operator (FBO) has a system in place to the satisfaction of the OV, and which allows the detection and the separation of birds with abnormalities, contamination or defects.

Commission Implementing Regulation (EU) 2019/627 defines a list of reasons for declaring fresh meat unfit for human consumption, but the code lists in force vary substantially between the EU Member

States, while some do not have an official code list. A harmonised terminology meat inspection (MI) coding system for each species is required in order to allow comparison of data between abattoirs, regions and countries, respecting each national epidemiological situation, local food safety culture, trade agreements, improve decision-making and enable future use of CVS (Alban et al., 2022). Meat inspection relies heavily on human observation, and thus carries inherently the risks of subjectivity and variability between observers who have limited time to observe individual carcasses within an abattoir production line. Additionally, evaluation schemes of pathologies between countries and states are different (McKenna, Amaral, & Kyriazakis, 2020).

EU legislation on official controls in food production (EU 2019/627; EU 2017/625) allows for the use of computer vision systems (CVS; digital cameras, wide-angle imaging cameras, ultrasound scanners, high-tech thermo-imaging, camera technology spectroscopic analysis) and provides an opportunity for new technologies and a digital transformation of meat inspection (Antunović et al., 2021). A limited number of EU Member States (MS) are now doing trials on the use of CVS to support PMI. These CVS are based on high resolution camera or image acquisition systems linked to artificial intelligence (AI) based computer models which process and analyse the images. Most developments are to support PMI on high speed poultry and pig lines.

Such CVS generally have reported performance measures (sensitivity and specificity) of >80%. While a low number of false positives (specificity) is of importance for the FBO in order to minimise food waste, a low number of false negatives (sensitivity) is required for the production of safe meat.

For CVS to be integrated within the slaughter process, the results should be available in real time, enabling real time decisions to be made on the slaughter line. A CVS should be able to interact with a FCI database, allowing collection and handling of all data in a more efficient way. This will provide assurance of an easy forward and backward flow of information, with the overall aim of traceability, while improving foodborne outbreak investigations, the monitoring of antibiotic usage/presence of antimicrobial resistance, food safety, animal health and welfare and productivity (Sandberg et al., 2023). A key advantages of CVS would be the ability to run higher line speeds, with significant benefits to increase efficiency and reduce the impact of human error (Antunović et al., 2021). The use of new technology as a part of meat inspection would help resolve the shortage of personnel for official meat inspection ongoing in many European countries and contribute to freeing OVs/auxiliaries for other tasks and make better use of the resources available (Alban et al., 2024).

While many countries throughout the world are moving towards a more risk-based meat inspection system, along with the use of innovative technologies, under current EU legislation on official controls new technology cannot replace traditional meat inspection, but it can be used as a supporting tool in the slaughter process (Alban et al., 2024). Furthermore, new technologies must be presented for approval by the EU Commission prior to their implementation.

Other identified obstacles are existing trade agreements with third countries, which may require acceptance of equivalence of new systems and VOI against current PMI methods. There may be a high cost of implementation, dependent on the number of camera stations needed, and there may be inadequate FCI to implement risk-based meat inspection. Additionally, resistance to change in work practices by VIs may be an issue (Antunović et al., 2021). A harmonised lesion code system and condemnation criteria based on evidence are needed to improve decision-making, to permit comparative analysis beneficial for risk-based meat inspection and to enable wider and inter-country use of CVS. Evidence-based documentation and a multi-stakeholder collaboration, including different regions in the world, FBOs, CAs and academia, is recommended as a way to exchange evidence, experience, perception, establish common validation procedures for new technologies and, in doing so, support the updating of EU legislation to make possible the use of the new camera-based AI vision

technologies. In addition, modernised meat inspection is in the interest of all stakeholders, because food safety can be maintained, while food losses, environmental effects and costs are kept low (Alban et al., 2024).

2. Computer Vision System and Machine Learning

CVS are based on high resolution camera / image acquisition systems linked to artificial intelligence (AI) based computer models which process and analyse the images. Artificial intelligence refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals (European Commission, 2018). Several approaches have been pursued, from the beginning of the AI research era, to create machines that can simulate human intelligence. At present, the statistical learning approach appears as the dominant methodology, thanks to the success of deep learning (DL), especially in the field of visual object recognition (Krizhevsky et al 2012). Deep learning is a subset of machine learning (ML) and is based on networks of highly interconnected computer processors "neurons", capable of performing parallel computations for data processing and knowledge representation (Ramesh, et al 2004). The major limitation to achieving this performance is linked to the need to train the neural network by providing a significant amount of data to develop robust algorithms. In the field of image analysis, thousands of images are analysed and ML is used to train the system to identify and characterise specific targets in the images. This amount of data is aimed at guaranteeing a satisfactory level of generalization, the latter measurable by proposing to the model a set of examples never previously observed and to verify the performance of the neural network on the data set. The architecture of the DL method is based on the so-called "convolutional neural networks" (CNNs) for segmentation of images (Ronneberger et al 2015). Annotated images are forwarded to the network (input), the CNN converts the images into the final segmentation layers (output), which can be compared with the ones annotated by the veterinarians (Trachtman et al., 2020).

A consolidated approach for training the neural network is the supervised approach, which during training images, previously annotated by certified operators expert in the sector, are subjected to the neural network. The success of training the neural network lies in the ability of the neural network to learn the same segmentation criterion used by the expert operator. Once the training has been successfully concluded, the model is able to assist, or replace (partially or totally), human intervention on the segmentation. In particular, training begins with the acquisition as input, by the neural network, of the training dataset (including approximately 10,000 training images for each task to be learned by the neural network, and respective segmentations). This dataset was, prior to entering the neural network, processed using "Data Augmentation" techniques. This term identifies a set of techniques aimed at improving the generalization capacity of the network (i.e. the ability to adapt to new data never examined during the training phase) through operations on the dataset itself. Training ends when a predetermined number of training iterations have been reached (for example, when all available images have been subjected to the neural network 10 times, in random order), or when the difference between the output of the neural network and the annotated membership classes is less than or equal to a training threshold.

One of the main advantages of systems created with technologies based on AI is that, as the available data used for the training phases increases, the performance of these systems continues to improve. Where CVS are used for PMI, cameras are placed on the slaughter line in a fixed position, or on a robot arm, and take images of carcasses and viscera as they pass along the slaughter line. At a computer work station the image is processed using AI where a developed algorithm can give an immediate result when a specific lesion is detected, or can flag the location of faecal material. Moreover, the CVS

has the advantage of being able to analyse without interruption and at any time, the carcasses and organs on an automated line, making it possible to massively acquire and analyse data that would otherwise often be lost. This technology can now be used for assessments of pathological lesions on organs and/or half-carcasses by assigning a score which measure their severity and/or extent in a standardized manner and therefore makes the data comparable both between batches coming from the same farm and from other farms.

3. Poultry *Post-Mortem* Inspection

3.1 Overview of Poultry *Post-Mortem* Inspection

In traditional PMI of poultry carcass, the VI inspector visually examines, at an individual bird level, the external and internal surfaces of the carcasses and internal organs after evisceration for disease conditions and for any contamination that could make all, or part of, the carcass unfit for human consumption. PMI is focused on detecting diseases that leave visible marks such as ascites, edema, abscesses, hepatitis, emaciation and external factors, like dermatitis, poorly bled birds and faecal contamination. It is also used from an animal welfare perspective by detecting injuries, scratches, hematomas, broken wings, breast blisters and hock burns that provides information on welfare conditions during rearing, transport and handling.

Developments in slaughter technology have resulted in greatly increased slaughter line speeds (> 10,000 birds per hour) and poultry processing abattoirs want to increase their slaughter rates (15,000 birds per hour) but manual food safety inspection at these speeds is highly challenging. To maintain a high quality in future products, an automatic CVS is needed to support inspection (Jørgensen, 2018). The high speed of the slaughter lines reduces the sensitivity of lesion detection and of faecal contamination detection on the carcass by visual inspection. In 2012, EFSA adopted a Scientific Opinion (EFSA et al., 2012) on the public health hazards to be covered by PMI of poultry. It is now deemed by updated Regulation (EU) 2017/625 that a representative sample of each poultry flock can undergo daily inspection of the viscera and body cavities, with a detailed inspection to be carried out on a random sample of parts of birds or entire birds, from each flock, which have been declared unfit for human consumption following PMI. This is based on the FBO having a system in place to the satisfaction of the OV, which allows the detection and the separation of birds with abnormalities, contamination or defects. Further investigations may also be necessary where there is a reason to suspect that the meat from the birds concerned could be unfit for human consumption. Visual PMI contributes to preventing/reducing microbial risk to public health by detecting heavy contamination of carcasses by faecal material and/or spilled intestinal contents.

In some EU countries, automated inspection systems, consisting of cameras linked to analysing software, are being developed to support VIs' work. These range from detecting defects on the carcass or offal to screening for visible indicators of faecal contamination. If operational in real time, CVSs could aid the VIs by detecting and highlighting the carcass and viscera which should be pulled from the slaughter line for a detailed inspection by a VI. Moreover, in recent years, digitised information along the meat chain, including in the abattoir, have become more important, allowing a more efficient reporting of findings from MI to the farmer.

It is noted that EFSA Scientific Opinion and Technical specification (2012a, 2012b) identified *Campylobacter spp., Salmonella spp*. and ESBL/AmpC gene-carrying bacteria as the most relevant biological hazards in the context of meat inspection of poultry. As none of these are detected by

traditional visual meat inspection, establishing an integrated food safety assurance system, achievable through improved FCI and risk-based interventions, was proposed. This includes setting targets at carcass level and, when appropriate, flock level. Elements of the system would be risk categorisation of flocks based on FCI and classification of abattoirs according to their capability to reduce carcass faecal contamination. Chemical substances that might occur in poultry, dioxins, dioxin-like polychlorinated biphenyls (DL-PCB), and the banned antibiotics chloramphenicol, nitrofurans and nitroimidazoles were ranked as being of high potential concern. Sampling for chemical residues and contaminants should be based on the available FCI. Moreover, control programmes should be better integrated with feed controls and regularly updated to include new and emerging substances.

3.2 Overview of Poultry PMI in Ireland

Many poultry abattoirs operate an integrated system, farm to fork using manual FCI recording. This ensures that the four parties involved (farm, transport, FBO and AMI) have access to the same information. The Bord Bia Sustainable Poultry Products Assurance Scheme (SPPAS) is a fully integrated scheme, which requires processors to work in partnership with the breeder and production farms to provide the customer with sustainable and quality assured product. The scheme describes the essential sustainability criteria and quality assurance requirements for chicken, turkey and duck production from breeding farms, hatcheries and production farms, right through to factory processing and final despatch. When certified, the farmer will be issued with a Bord Bia assured certificate for the flock / production house, which requires regular audits to maintain certification.

At some abattoirs one million plus broilers are slaughtered per week (5 days), mainly for domestic consumption. Birds are moving at a speed line of ~ 12,000 per hour (3,5 per second), with a total of ~ 180,000 – 200,000 broilers slaughtered per day. Birds are delivered in crates by truck to the abattoir lairage according to a plan of incoming birds received, containing FCI such as including batch origin country and location, flock number, age, number of birds expected, transport, and 35 days weight (ducks), *Salmonella* test result (within 21 days prior to slaughter). If *Salmonella* positive the load must be slaughtered at the end of the production shift.

PMI is carried out by temporary veterinary inspectors (TVIs), VIs and Official Auxiliaries and is based on visual inspection of carcass, internal cavity of bird and viscera looking for generalised infectious conditions, as septicaemia, edema, ascites, abscesses and hepatitis and non-infectious systemic disease or anomalies, like emaciation (Figure 1). External conditions, such as dermatitis and scratches, ante-mortem injuries like bruising/haemorrhaging leg or wings and post-mortem injuries such as over scalding are also checked at PMI (Figure 2).

Figure 1 – Example of a condemned poultry carcasses

Figure 2 – Example of condemned poultry carcasses

If a carcass fails inspection for any reason it is pulled from the line, as is the corresponding viscera (and vice versa). The PMI stand is where official samples for *Salmonella* and *Campylobacter* testing and for the National Residue Plan (NRP) are taken. For each load PMI findings and total birds condemned are recorded manually (If >2% PMI are condemned an alert goes to DAFM). For each load PMI findings, such as emaciation, abnormal colour, ascites, edema, cellulitis, dermatitis, arthritis, and damage related to machinery are recorded manually on a PMI document.

An additional visual inspection for foot dermatitis scores is performed on selected birds (n=100) from the same load, one load per shift and feedback is sent to the farmer as footpad lesions/dermatitis can be related to litter type, presence of ammonia and wetness of the environment.

The poultry industry in Ireland, has continued to increase slaughter line speeds and it is increasingly challenging for inspection to be done manually by VI. Clearly, there is an opportunity for Ireland to investigate the uses of CVS to support PMI in poultry in line with other EU Member States. Some of the industry is already using CVS for carcass quality assessment on the line, post chilling, as birds go into the boning hall so the sector is already familiar with CVS technology.

3.3 Computer Vision Systems for Poultry

International advances in CVS for poultry are being directed at : 1) detection of multiple pathological lesions on carcasses and viscera 2) identification of faecal contamination and 3) detection of footpad lesions.

3.3.1 Pathological Lesions

In poultry, the most common pathologies are generalised infectious conditions, such as septicaemia, edema, ascites, abscesses and hepatitis and non-infectious systemic disease or anomalies, like emaciation.

3.3.1.1 VetInspector

A CVS system for poultry PMI, called VetInspector (IP - Inspection of poultry, IHFood, Patent DK201870637A1) has been developed, resulting from a collaboration between IHFood,a Danish company that specializes in machine vision systems, quality inspection and vision guided robots for the food industry, University of Copenhagen, Technical University of Denmark (DTU), Danish Meat Research Institute (DMRI) and the Danish poultry industry. The system was developed using ML algorithms to analyse the pictures, making use of an AI model that analyses the pictures captured at slaughter at any slaughter speed (Sandberg et al., 2023). The premise of the system is to use

multispectral image analysis and neural network algorithms to detect all lesions on the poultry carcass (dermatitis, scratches, arthritis, ascites, etc.) (Figure 3) and on viscera (hepatitis, serositis) (Figure 4), according to the Danish code list for poultry in the PMI done manually by the Food Safety Authority in Denmark (Alfifi et al., 2020; Jørgensen, 2018).

Figure 3 – VetInspector detection of lesions on carcasses

Figure 4 – VetInspector detection of lesions on viscera

The technological development of VetInspector started in 2011, with an investigation on whether image analyses could be useful for PMI. In 2014 validation and performance studies were carry out on the use of image analysis for veterinary inspection of carcasses and viscera in poultry abattoirs. Cameras were placed on line with nine pictures taken per bird which were angled to optimise picture quality. ML algorithms were developed to analyse the pictures and identify/demarcate the lesions on carcasses and in different organs. The model's ability to classify lesions correctly is continuously improving with every chicken photographed. The "correct" classification of the lesions (severity), was advised by an OV and a pathologist, supplemented with studies to define not approved carcasses versus approved carcasses. A large number of images were captured for the ML algorithm to classify the viscera and carcass into not approved or approved for human consumption. Additionally, sub-categories were made, e.g., different types of hepatitis. Ultimately, veterinarians classified pictures from ~3000 carcasses (veterinary students supervised by veterinarians) and of ~4,000 viscera sets (veterinarians). It is to be noted that diagnosing the viscera is not an easy task, even for veterinarians, especially at rates over three birds per second. Diseases develop over time and look different depending on the severity and are often correlated within a flock of broilers from the same farm. The colour and size of the organs can vary greatly due to natural causes, diseases can change an organ's visual appearance completely and organs are often occluded by each other or by fat. Additionally, the prevalence of some diseases is very low. This indicates that grading images is hugely difficult and can be subjective. In developing the method for the viscera, due to the fact that viscera has a non-rigid nature which results in a high variation in both the position and appearance of the organs, a good segmentation, into liver, lung, heart and other, is vital to overcome the problem of the location of the image to be analysed (Jørgensen, 2018) (Figure 5). In the implemented version of VetInspector, the Danish Food Safety Authority had to decide and inform the system about the type of lesions to be detected and which severity of the lesions leads to approved or not approved carcass status (Sandberg et al., 2023). Results from validation of agreement and performance demonstrated that there was disagreement between veterinarians doing the classification of severity, lesions and not approved status which indicated that the inspection task is indeed difficult and subjective. Severity was graded

using four levels of occurrence: no, low, medium and high based on area covered and intensity (Jørgensen, 2018).
Using the graded results that the group of veterinarians agreed on, as the cut off between not approved and approved, the apparent accuracy of VetInspector was ~ 90%.

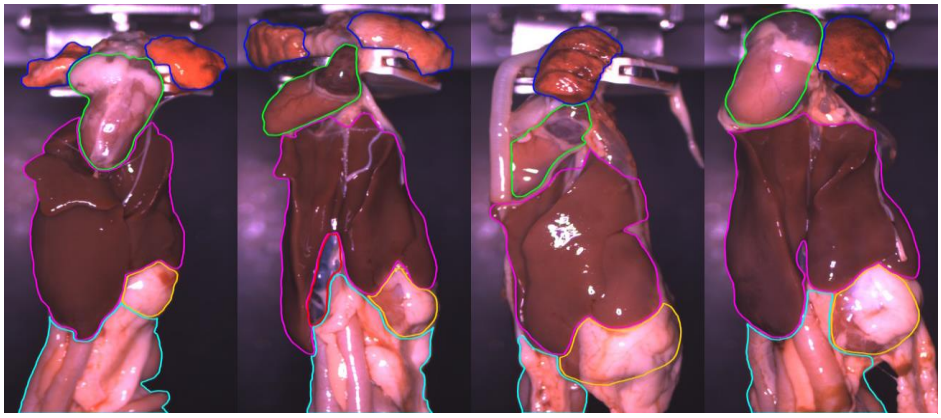

Figure 5 – Image of Viscera segmentation (Jørgensen et al, 2018)

In EU legislation, Article 6 of Regulation 2019/627 lays down "The Member States shall inform the Commission and other Member States on scientific and technological developments, as referred to in Article 16(2)(b) of Regulation (EU) 2017/625 for consideration and further action as appropriate." The purpose of Article 6 is to indicate openness to innovation and encourage it. In addition, the amendment in Article 25 (2b) of Regulation EU 2010/627 states that "The CA can decide that only a representative sample of chickens from a flock needs to undergo inspection, if the poultry abattoir has a system that the OV assesses as appropriate to use for detecting poultry with abnormalities, contamination or defects". Supported by this in September 2021, the VetInspector technology was presented to the European Commission and the first two VetInspector stations in Europe were accepted for use as a tool to support poultry meat inspection in Denmark (Sandberg et al., 2023). Currently VetInspector is being further developed to include detection of faecal/bile/gastrointestinal contamination of the poultry carcass. This collaborative development includes IH foods, DTU and Danpo poultry company. The results of this will then need to be presented to the European Commission for approval. Additionally an automated footpad station, from Meyn (described in Section 3.3.2.1) will be added to the VetInspector system in Denmark.

The version of VetInspector under development will likely involve placing 3 *post-mortem* stations along the slaughter line: 1) before evisceration, to identify carcasses lesions and 2) after evisceration {for detecting lesions on viscera and to detect carcass surface contamination (faecal, bile and gastrointestinal contamination)}. The system is now at the validation stage in Denmark.

In terms of practicalities, the VetInspector (original version, 2021) has been presented to, and approved, by the EU Commission. The PMI codes and pathologies for which it is set up are those listed by the Danish Food Safety Authority and so may differ from those listed in Ireland. Currently, the system would have to be validated in any new abattoir in which it is installed. Space is needed in the abattoir to install the cameras, and this may be multiple units. The system can operate at a line speed of at least 12,000 /h. The cost of each unit (camera and computer processing) is not yet available from the equipment provider, IH Foods. It is clear that this type of CVS technology would be of benefit to the FBO and VIs in allowing consistency in PMI and in providing feedback to farmers. Moreover, it will allow further increases in the speed of the slaughter line. The sector appears to be technology ready.

3.3.2 Animal Welfare

In poultry, footpad dermatitis, which affects the plantar region of the feet, is the most common type of contact dermatitis in broiler chickens. It is widely accepted that footpad dermatitis deserves consideration in the context of animal welfare and is related to litter quality, and, more specifically, the amount of moisture, ammonia, and other chemical substances contained within. Furthermore, footpad dermatitis has financial implications for producers and its evaluation is included in a European standard protocol for monitoring broiler welfare (Welfare Quality, 2009).

3.3.2.1 Meyn Footpad Inspection System

Meyn Food Processing Technology developed a video-imaging system, the Meyn Footpad Inspection System in conjunction with Wageningen University & Research to automatically score footpad lesions at the slaughter line. Since 2013, this system has been an approved method for scoring footpad lesions under the EU Broiler Directive (2007/43/EC) (Van Harn & De Jong, 2017). The camera captures an image as the feet pass by in the shackle, aided by a bright LED light for optimal resolution and a back plate for optimal contrast (Figure 7). The image is then transferred to the software which analyses the images based upon the relevant grading scorecard or quality parameters (Meyn, 2023) (Figure 7). This automatic system was installed in Flandrex commercial slaughter abattoir, Ommel, the Netherlands and a study to compare the CVS with a human expert assessment was performed. The automatic assessment of footpads at slaughter could be a very useful tool, but the agreement between the expert (human) assessment and the automatic system was poor and further investigation was needed (Vanderhasselt et al., 2013). For this reason, Wageningen University & Research, Livestock Research, at the request of the Ministry of Economic Affairs, conducted a limited revalidation of the video-imaging system, comparing footpad lesion score in a sample of each flock slaughtered on a particular day, inspected manually by a trained inspector, as well as by the camera system, and the results were compared. The results shows a large degree of correlation of the footpad lesion scores given by the video-imaging system and the trained inspector. Moreover, the video-imaging system is able to assess almost all chicken feet (99%) in a flock without slowing down the slaughter process, compared to only 100 feet in a flock that are commonly scored by Official Auxilary (OAs), in accordance with the protocol, independently of the size of the flock (representing only 0.33%-1.7% of the flock). Additionally, it will also measure more uniformly across all abattoirs and within abattoirs. Furthermore, results are shown in real time and stored digitally without manual interference (https://www.youtube.com/watch?v=9uCj7zWtP3U) (Meyn, 2023). However, although the video-imaging system is an approved method to assess footpad lesions at the slaughter line, the majority of poultry abattoirs continue to assess footpad lesions manually in accordance with the established protocol.

Figure 6 – Myen Footpad Inspection System

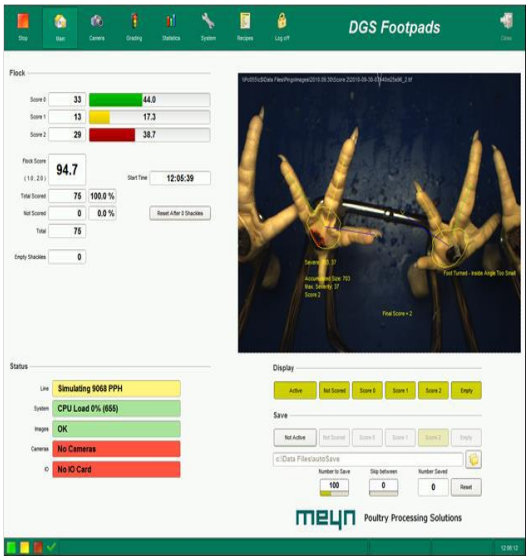

Figure 7 - Myen System Display

The Meyn Footpad Inspection System is an approved method for scoring footpad lesions under the EU Broiler Directive (2007/43/EC). The system would have to be validated in the abattoir where it is installed. Space for its installation would be needed. The cost of each unit is circa €80,000. The system would be of benefit to FBO and VIs, allowing a wider quality assessment for international trade, as well as producer feedback, and animal welfare.

3.3.3 Poultry Carcass Faecal Contamination

3.3.3.1 Spectral Fluorescent Imaging

It is well recognised that contamination of carcasses results when pathogens are transferred from the intestinal tract or faecal material on feet and feathers to the dressed carcass. Fluorescent spectral imaging to detect surface faecal and ingesta contamination on poultry carcasses may provide a solution to aid detection and direct mitigation steps. However, poultry diets do not provide sufficiently high levels of natural fluorophores for this system to be reliable (Lee *et al* 2013). Aberystwyth University andUniversity of Bristol, investigated the potential of chlorophyll-based feed additives to improve fluorescence of the faeces and narrow the excitation and emission wavelengths to aid in the development of a simple visualization system. The research indicated the potential use of chlorophyll markers to aid detection of faeces using simple front-face UV fluorescent approaches (Lee *et al*., 2013).

3.3.3.2 Multi/Hyperspectral Imaging

A hyperspectral imaging system in conjunction with appropriate image processing algorithms has demonstrated the potential for identifying surface faecal and ingesta contaminants on poultry carcasses. However, even though hyperspectral imaging techniques performed very well, further studies need to be conducted to investigate the effect of some feed ingredients to select the optimum wavelength to differentiate different sources of faecal and ingesta contaminants (Park *et al*, 2006). In one study a multispectral line-scan fluorescence imaging system was integrated at processing line speeds of one, three, and five birds per second and images of chicken carcasses with faecal contaminants were scanned. The results indicate that multispectral fluorescence imaging (MFI) has good potential for the detection of faeces on poultry carcasses, and it could be an alternative to the current manual inspection method in automated poultry processing abattoirs, but further study is necessary and additional research on poultry feed required (Seo et al., 2019).

3.3.4 Marel

Marel, an Icelandic company providing solutions, services and software to the poultry, meat and fish processing industries, launched IRIS Fillet Inspection (IRIS FI) for poultry processors. This IRIS FI camera solution is a tool for quality assurance of chicken fillets. Because of its ability to detect defects such as bruises, fat and skin, IRIS FI can be combined with Innova distribution software and a fillet distribution system, facilitating the removal of products that do not meet the quality criteria.

3.3.5 Baader

Baader, a German company using technology to assess the quality of fish, poultry and meat, and Linco Food Systems (member of the Baader Group) has been developing systems for quality chicken carcasses grading by detecting broken wings, red and blue bruises, faecal stains, remaining feathers, skin damage and footpad lesions (Jørgensen, 2018; Sandberg et al., 2023). ClassifEYE® 2.0, (Baader Linco), uses advanced cameras, AI and vision technology to allow a quick and accurate inspection of poultry products for defects, contaminants, and other quality issues (https://poultry.baader.com/distribution/vision-camera).

4. Pigs *Post-Mortem* Inspection

4.1 Overview of Pig *Post-Mortem* Inspection

Inspection of pigs at ante-mortem and post-mortem is carried out to mitigate public health risk and ensure diseased animals do not enter the human food chain. An EFSA Scientific Opinion (2011) collated a list of relevant biological hazards for which there is evidence (in the literature and/or in data provided by Member States) that they occur, or may occur, in pigs in Europe and that can be transmitted via food to humans (Rodrigues da Costa et al, 2021). The HEIs for pig meat inspection included *Salmonella spp*., *Yersinia enterocolitica*, *Toxoplasma gondii*, *Trichinella spp*., *Taenia solium* and mycobacteria. Nevertheless, ten years after the HEIs' specification were published, only two biological hazards (*Trichinella* and *Salmonella*) are included in official control programmes in EU MS. While *Trichinella* monitoring is mandatory, *Salmonella* control plans have been implemented by only a few countries. In countries where *Salmonella* in pigs is monitored at farm level, the status of the farm is described in the FCI. Such FCI is crucial for the risk manager to organise slaughter operations and implement hygienic measures, as well as for the CA to implement risk based meat inspection procedures (Bonardi et al., 2021). Moreover, modernisation with good quality FCI, linked to herd health planning, will not only improve food safety but will also expand our knowledge on prevalence of these zoonotic agents in pig populations.

Regulation EU 218/2014 amending (EC) 854/2004 mandated that on a risk basis, including epidemiological data, FCI, or the findings of AMI and/or PMI, it should be possible to assess prior to slaughter which pigs are suitable for visual meat inspection only, and which need more detailed inspection procedures (Felin et al, 2016). To protect public health, VOI implementation should, however, be integrated with other changes to meat inspection, including robust FCI systems, serological monitoring programs, accurate risk classification of herds, and further critical analysis of systemic issues in meat production that can impact food safety and public health (Riess & Hoelzer, 2020).

The most common pathologies in pigs are abscesses, arthritis, ascariasis (milk spot liver), pericarditis, pleuritic, pneumonia and tail biting (Alban et al., 2022). Examination of lung lesions at the abattoir is a useful method to estimate the importance of respiratory disease at farm, regional or national level (Fraile et al, 2010). Within pneumonias, porcine respiratory disease complex (PRDC) is a significant health issue that causes severe economic losses in the global pig industry. The severity and outcomes of PRDC are influenced by distinct factors, including the immune status of the animals, environmental factors (level of ammonia and dust) and farm management factors such as overcrowding and biosecurity strategies. These factors can disrupt the balance between herd immunity and pathogens, leading to disease outbreaks (Opriessnig et al, 2011).

Additionally, a recent EFSA Scientific Opinion (2022) recommended monitoring of tail lesions in pig carcasses at slaughter to monitor pig welfare and enable feedback to farmers.

4.2 Overview of Pig PMI in Ireland

Large pig processors in Ireland are currently operating at a line speed of about ~200-500 pigs per hour (10,000 pigs a week). This represents a significant challenge for VIs to perform PMI which is done at four stations; to examine the pluck, the gastrointestinal contents, carcass and final carcass inspection. Records are still mainly manual, but a new digital recording PMI for pigs is currently under roll out by DAFM.

The digital recording system utilises a tablet (touchscreen) to be used by the VIs on the slaughter line to allow input and counting of specific offal and carcass findings / lesions in the slaughter line. Offal inspection is recorded per batch and are divided into lungs (abscesses, pneumonia and pleurisy), liver (milk spot, abscesses and scaring), heart (pericarditis, endocarditis) and green offal (peritonitis, and contamination). Regarding the carcass inspection record, the system is divided into the carcass area affected (generalised or specific), the condition/type of lesion found. The PMI data inputted to the touch screens is saved to a staging server in the abattoir and then to DAFM and to the Pig HealthCheck database.

In Ireland in pig PMI, VOI has not been adopted, as most of the large abattoirs export pig meat to third countries that do not accept VOI, and, additionally, improved data and feed systems would need to be in place to risk rank pigs presented for slaughter.

Condemnation of offal may not result in full carcass condemnation, on the other hand if the carcass is condemned at station 4 the offal will also be condemned. Conditions leading to condemnation generally occur at a herd level, so feedback to the producer would be important. Currently PMI carcass condemnations are manually recorded.

Animal welfare is a considerable concern and there is potential, and indeed an EFSA recommendation, to use PMI as a way to record tail lesions (related to tail biting) and lung lesions. Carcass condemnation (CC) at MI is a major source of financial loss in the pig industry and abscesses caused by tail biting (a major welfare problem for pigs) is one of the reasons for CC.

In pig abattoirs, as slaughter line speeds get faster it is less practical and less accurate for inspection to be done manually by the VU, and there is therefore a need for Ireland to move to the use of digital data collection and to investigate opportunities around the AI/camera-based PMI systems to support data collection.

4.3 CVS for Pigs

CVS under development for the pig sector are mainly directed at: 1) detecting pathological lesions, specifically lung lesions, related to pneumonia and pleurisy on the chest wall; 2) to detect faecal contamination on the carcass and 3) to monitor and record tail biting lesions.

4.3.1 Pathological Lesions

Respiratory diseases, including pleurisy and pneumonia, are among the leading causes of economic loss, due to increased mortality, decreased daily weight gain and the cost of veterinary care. The impact of respiratory diseases is particularly relevant in growing/finishing pigs raised indoors with high stock density (Carr, 2018). The aetiology of porcine respiratory diseases is usually multifactorial, an important role being played by infectious agents, which often act together to cause PRDC. One of the major causative agents of PRDC is *Actinobacillus pleuropneumoniae* (App), which is responsible for porcine pleuropneumonia and *Mycoplasma hyopneumoniae* causing enzootic pneumonia (EP) (Gottschalk & Broes, 2019). Except for a few European countries (e.g., Switzerland, Norway, and Finland), *M. hyopneumoniae* can still be considered a ubiquitous pathogen in pig farming worldwide (Hattab et al., 2023).

Considering the relatively short lifespan of pigs, lesions can be still evident at slaughter, where they can be usefully recorded and scored (Trachtman et al., 2020). The impact of App in pig herds can be properly estimated at slaughterhouses, which are recognized as a key checkpoint for assessing the

health status of farm animals, as well as the effectiveness of strategies implemented to prevent or treat disease conditions (Fraile et al., 2010). The abattoir provides a unique and valuable feedback to the farm, as well as an important source of data for epidemiological studies (Trachtman et al., 2020).

Although relevant, scoring lesions in slaughtered pigs represents a very time-consuming and costly activity, thus making difficult their systematic recording. In pigs, the recording of lung lesions at slaughter is a common practice in many countries. Indeed, scoring systems for EP-like lesions have been developed, standardized and modified. Abattoir recording has thus been widely used for estimating the prevalence and severity of respiratory disease (RD), particularly EP, and has been used to evaluate RD risk factors (Merialdi et al., 2012). Several scoring methods have been developed over the last decades, in order to estimate the impact of diseases in slaughtered pigs, a special emphasis having been placed upon EP-like lesions (Garcia-Morante et al., 2016) and pleurisy (Sibila, Aragón, Fraile, & Segalés, 2014). EP-like lesions, characterized by cranioventral pulmonary consolidation (Figure 8), caused by many different bacteria, particularly *Mycoplasma hyopneumoniae* and *Pasteurella multocida*, and pleurisy are the most frequent findings in pig lungs at slaughter. The localization of pleurisy can be cranioventral or dorsocaudal and the border between the two areas is lined by the dorsal endpoints of interlobar fissures. Cranioventral pleural lesions are strongly associated with complicated EP-like lesions, whilst dorsocaudal lesions are considered suggestive of recovered pleuropneumoniae (Merialdi et al., 2012).

Figure 8 - *Enzootic pneumonia* –EP like lesions on

For pleurisy, the “slaughterhouse pleurisy evaluation system” (SPES) grid has been widely used to quantify the impact of *A. pleuropneumoniae* infection using an evaluation grid with values between 0 and 4, depending on the presence, extent, and position of pleural adherences/lesions. According to the SPES grid, a higher score is given to pleurisy of the diaphragmatic lung lobes (Merialdi et al., 2012), which are typically affected in the course of porcine pleuropneumonia (Gottschalk & Broes, 2019). Considering that pleurisy usually affects both pleural sheets, a new scoring method (“pleurisy evaluation of the parietal pleura”, PEPP) has been recently developed, based on the inspection of the parietal pleura. Similar to the SPES grid, the PEPP method also attributes a higher score to the lesions affecting the caudal portion of the chest wall (Figure 9). The SPES and PEPP methods have been demonstrated to provide well-matching results, the PEPP method being also effectively applicable on

digital images (Di Provvido, Trachtman, & Farina, 2019). As the presence of pleurisy and pneumonia have a negative influence on production parameters (Sibila et al., 2014), the prevalence and severity of these lesions at the abattoir appear to be good and useful indicators, either to address control measures or to follow up their efficiency at farm level (Merialdi et al., 2012). The PEPP has been used for supervised training of a CNN to score pleurisy on images (Di Provvido et al., 2019; Trachtman et al., 2020).

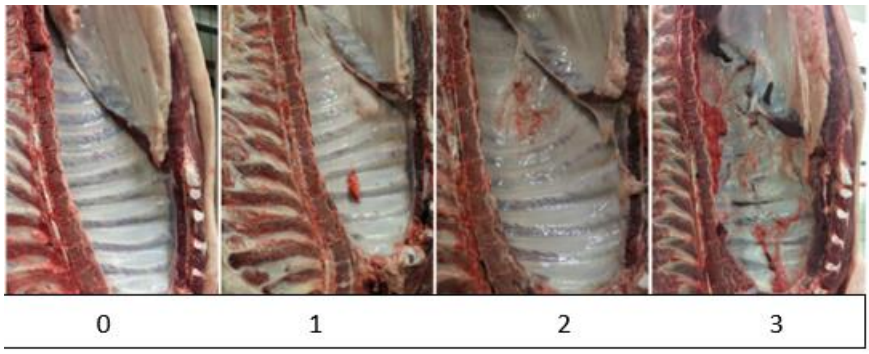

Figure 9 - Scoring pleurisy according to the simplified *"pleurisy evaluation of the parietal pleura"* (PEPP) method (adapted from Trachtman et al 2020)

4.3.1.1 Farm4Trade: Automatic Detection of Abattoir Lesions (ADAL)

Farm4Trade is an Italian based company who are developing computer vision solutions based on AI and digital productivity tools to supply chain traceability. F4T have developed innovative systems, ADAL (automatic detection of abattoir lesions) and ReaDOP (animal tattoo code scanning) that supports the automation of the manual and repetitive processes of MI and carcass tattoo identification**.** The ADAL technology is an advanced vision system for 3D image acquisition. Images are taken by a camera mounted on a robot arm which is linked to a workstation that processes the images and transfers them to a dedicated web-based platform. The images are processed by AI which annotates the anatomical region and proposes a disease status. The system is based on a developed algorithm, which related manual inspection versus the CVS. It is currently available for detection of lung lesions related to pneumonia and for evidence of pleurisy in carcasses (Figure 10). ReaDOP is an automated carcass tattoo code verification system, which is able to digitally read the producer's code on each pig, supporting real-time traceability in the supply chain and eliminating the manual repetitive and error-prone task of reading carcass codes. Both ADAL and ReaDOP technologies employ collaborative robots with an integrated AI vision system equipped with high-speed cameras. Three types of robotic workstations are envisioned to be positioned on the slaughter line, after slaughtering, to automate the following processes: Workstation 1: ReaDOP for alphanumeric tattoo reading on pigs thighs; Workstation 2: ADAL for 3D image capture and evaluation of pleural lesions on carcasses and; Workstation 3: ADAL for 3D image capture and evaluation of pneumonia lesions on organs (Figure 11).

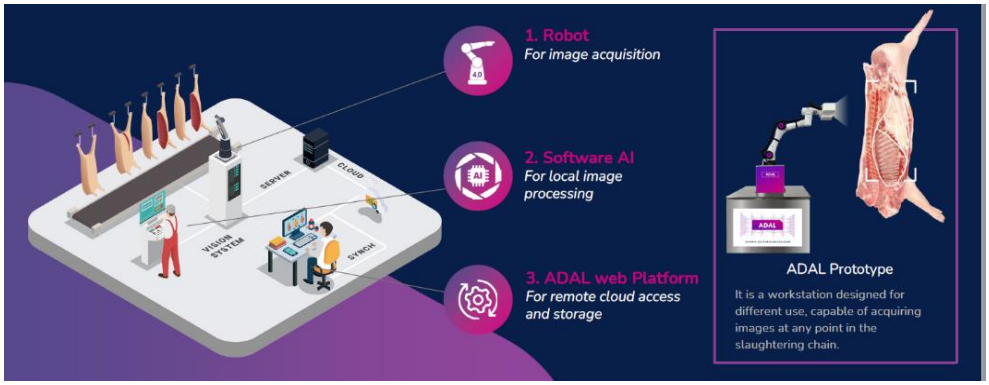

Figure 10 – ADAL system (Farm4Trade)

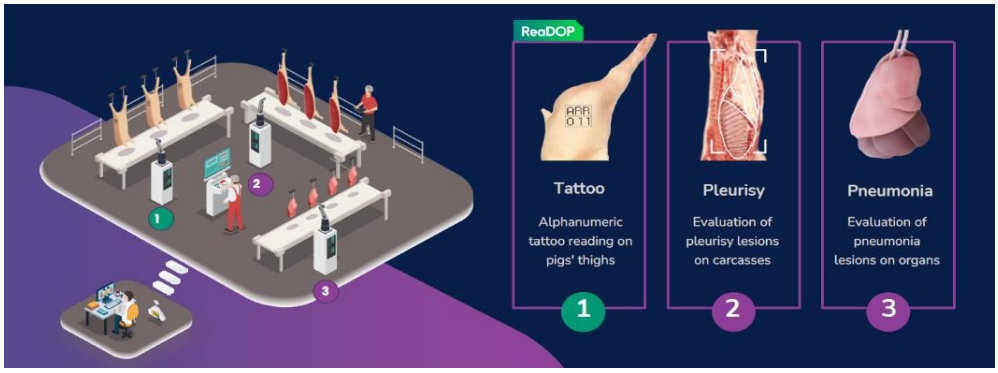

Figure 11 - ReaDOP and ADAL workstations (Farm4Trade)

For detection of pleurisy, the ADAL system uses a modified version of the PEPP method for supervised training of a CNN to score pleurisy on images. The PEPP method is based on the detection and quantification of pleurisy on the pleura parietal, i.e. the membrane that lines the internal surface of the chest wall. The modified PEPP method requires that the parietal pleura be divided into two easily identifiable areas: a first area extending from the 1st to the 5th intercostal space and a second area extending from the 6th to the last intercostal space (Farm4Trade, 2019). The modified PEPP method assigns the following scoring:

- 0 points in the absence of lesions; in the case of a healthy half-carcass, the parietal pleura appears smooth, wet and transparent and the intercostal spaces is easily appreciated;
- 1 point for pleurisy affecting the cranial chest wall, from the 1st to the 5th intercostal space, where a small fragment of lung adheres to the parietal pleura, at the level of the 4th intercostal space;
- 2 points for pleurisy affecting the caudal chest wall, from de 6th to the last intercostal space; at this level, the parietal pleura appears greyish-to-reddish and rough;
- 3 points for pleurisy affecting both the cranial and caudal chest wall, with presence of lung fragments adhering to the chest wall (Figure 12) (Trachtman et al., 2020).

This system offers at least two advantages, it is extremely simple and quick to implement and clearly distinguishes ventro-cranial lesions from dorsal-caudal ones. The latter are intimately connected with App infection, one of the causative agents of porcine pleuropneumoniae (Farm4Trade, 2019).

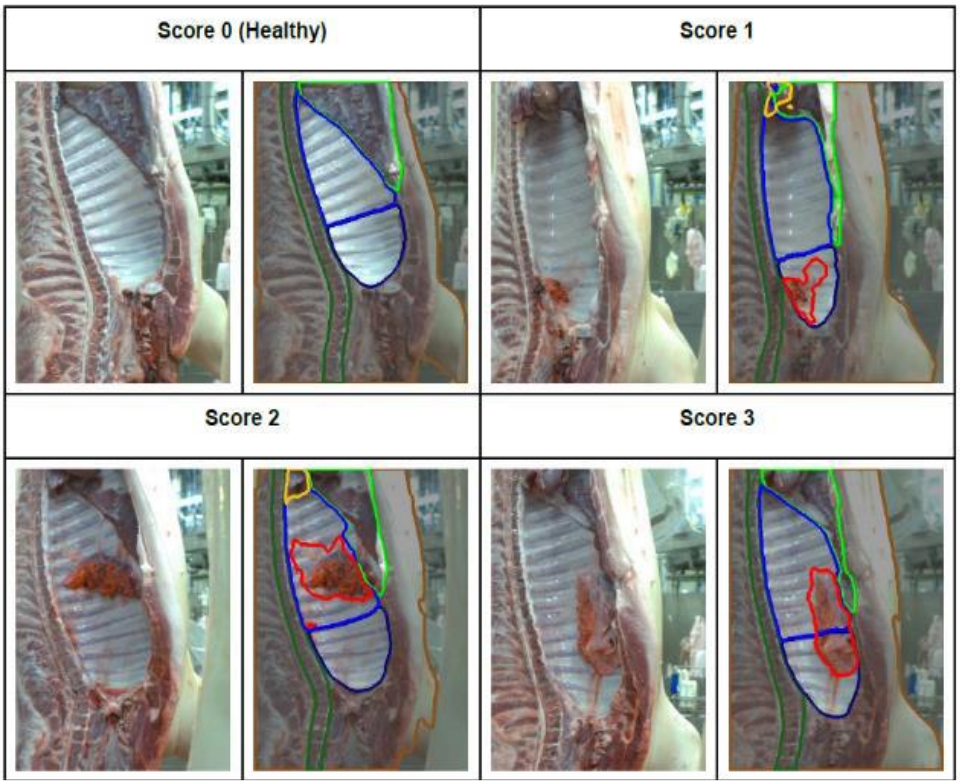

Figure 12 - Scores assigned by ADAL according to Trachtman et al. (2020)

For detection of pneumonia, in slaughtered pigs it is possible to evaluate and quantify the presence of lesions attributable to EP, resulting from *Mycoplasma hyopneumoniae* infection, often complicated by further secondary bacterial infections. EP has a chronic course and the lesions (typically bilateral, symmetrical and localized in correspondence with the cranio-ventral portions of the lungs) are usually still visible at the abattoir, albeit with some differences, based on the age at slaughter. Over the years, numerous systems have been developed for marking lung lesions. In most advanced production environments, the so-called "Madec grid" is used, which assigns a variable score from 0 to 4 to each of the 7 lung lobes as follows: 0 points if no lesions; 1 point if pneumonia involves < 25% of the lobe extension; 2 points if pneumonia involves 26-50% of the lobe extension; 3 points if pneumonia involves 51-75% of the lobe extension; and 4 points if pneumonia involves 76-100% of the extension of the lobe (Merialdi et al., 2012). The punctuation of pneumonia is relatively simple, although it shows a certain margin of subjectivity and can be made more complex by the presence of butchery artefacts. The ADAL AI based system, through the correct identification of lesions and artefacts, can therefore efficiently detect this pathology. At least 3,000 representative images (i.e. with balanced number of absence/presence of lesions of interest) of the animal's lungs are acquired. With reference to the method already presented, the number of processed images is equal to eight, and they correspond respectively to background, lung, lesion, artefact and the four lobes of interest. The lesion score is attributed according to the presence, location and extension of the individual lesions. The neural network operates as previously described, while the classifier is able to identify the overlap and extension between each lesion and the lobes (Farm4Trade, 2019). A camera in a robot arm linked to a workstation collects images, stores them and then analyses on computer to show the severity of pneumonia, by analysing the percentage of lung affected, and pleurisy, by analysing the carcass of chest wall affected on carcass (Figures 13, 14, 15).

F4T plans to expand the fields of application of the technology developed to other pathologies; studies both of health interest and related to animal welfare are being undertaken. The first ones F4T have

started to work on are evaluating skin lesions, which can be of infectious or traumatic origin. This helps to provide information on the welfare of animals on the farm, during transport and during slaughtering operations. These injuries can significantly affect product quality and processing, with repercussions for productivity and profitability of the entire supply chain.

Figure 13 - ADAL Workstation (Farm4Trade)

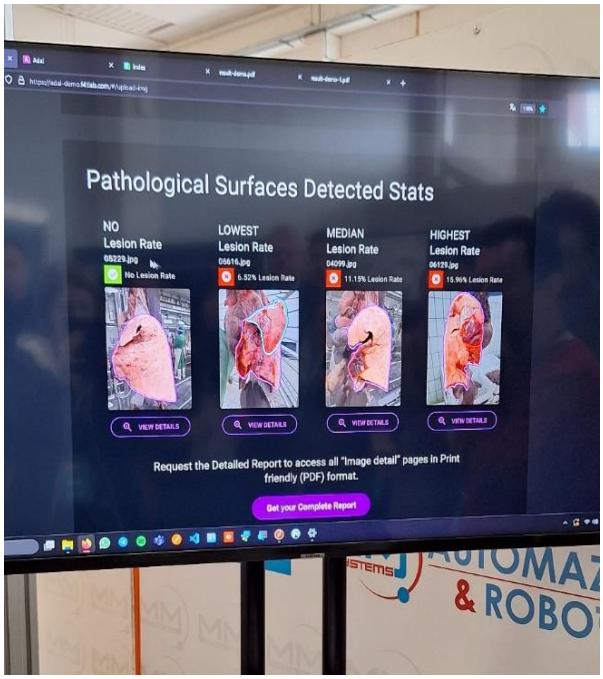

Figure 14 – Photograph severity of Lung Lesions (Farm4Trade)

Figure 15 - ADAL workstation (Farm4Trade)

4.3.1.1.1 Pilot Trials on ADAL

In September 2022, as part of a project called *EyeAM* – Digital Transformation of Meat Inspections, (2022-2025), carried out by Animalia (Norwegian Meat and Poultry Research Centre), in collaboration with meat companies (Fatland and Notura) in Norway, carried out the first pilot trials on the use of

ADAL equipment for monitoring the presence of lesions in slaughtered pigs that result from App and *Mycoplasma hyopneumoniae.*

The aim of the initial trial was to evaluate the feasibility of using a fully automated system for scoring pleurisy, using the ADAL AI-based system that employs deep learning algorithms and image processing techniques to analyse pictures of half carcasses captured during PMI. However, it is to be noted that this was a pilot trial to test the system and data generated was stored for research purposes and for voluntary data feedback to farmers.

The study was conducted using a camera robot prototype, consisting of a 6-axis collaborative robot equipped with two 4K cameras and sensors capable of capturing images along the slaughtering chain. The robot could support payloads of up to 5 kg and was equipped with a collision detection and trajectory reproduction system, making it ideal for use in scenarios involving human-robot collaboration. The prototype was positioned after the removal of viscera and showering operation, and it took pictures of half carcasses, with the aim to acquire the best pictures of the inner surface of all half-carcasses, including the chest wall. Several pictures were taken and screened from one of the two half-carcasses using an ad hoc developed algorithm. The algorithm was designed to automatically identify and extract the image of the pig chest wall with the best quality for pleurisy scoring by the modified PEPP method, and to eliminate images that were either too rotated or out of focus or had poor lighting conditions. The selected image for each pig was temporarily stored on a local server, uploaded to a cloud server, and analysed by the trained CNN. To optimise the CNN's performance, it was fine-tuned on a small set of approximately 300 images collected under similar abattoir conditions. The fine-tuning process involved adjusting the CNN's parameters and training it on the new data set to improve its accuracy in identifying pleurisy on chest walls. The fine-tuned CNNs of ADAL were then used to automatically detect and score pleurisy, as described in Trachtman *et al.* (2020). Over 50 working days a total of 37,769 pictures of half-carcasses were taken, with 19,029 pictures considered suitable for analysis by CNN. Of the 19,029 images analysed, pleurisy was detected by ADAL in 1,948 half-carcasses (10.24%). The majority of the pigs (89.76%) did not exhibit any signs of pleurisy. Among the pigs that exhibited pleurisy, the most common score was 2 (4.7%), followed by scores of 3 (3.84%) and 1 (1.7%) (Figure 16). The health status of the Norwegian pig population is very good in the sense that they are free from *M. hyopneumonia* (Grøntvedt *et al*, 2018).

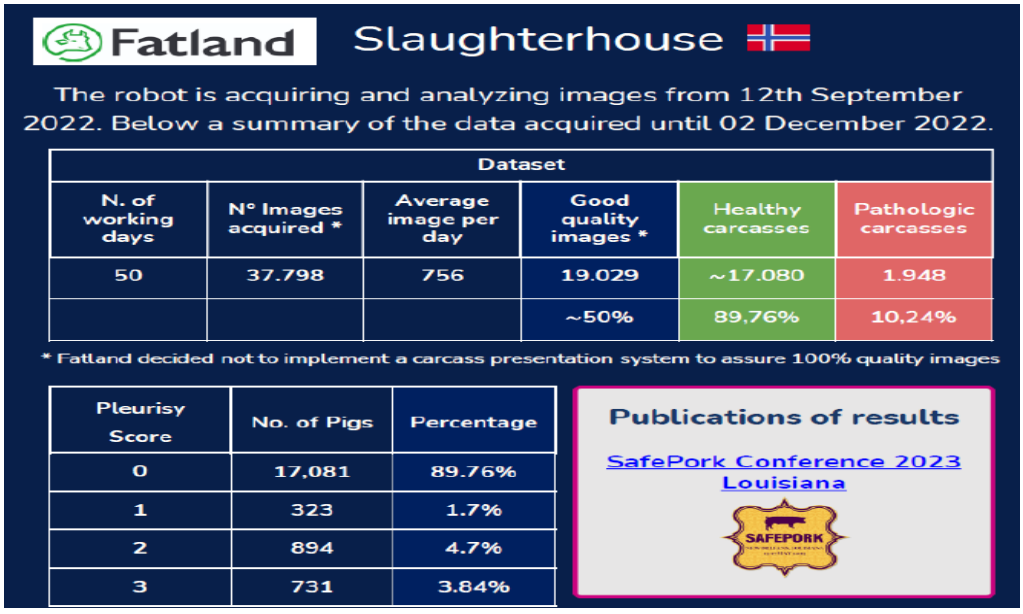

Figure 16 – Results from ADAL trial to detect pleurisy in pigs at the Fatland plant

This preliminary investigation under field conditions demonstrated the potential of AI-based technologies to improve disease control in pig populations and reduce the errors associated with traditional manual PMI. AI can efficiently record vast amounts of data at abattoirs, improving the health status and profitability of pig farming. Furthermore, the results suggested that AI-based technologies could provide a fast and cheap tool to systematically record lesions in slaughtered pigs, supplying useful data to all stakeholders in the pig industry.

In a second trial at Nortura abattoir in Sandeid, Norway the ADAL equipment has recently been installed to monitor the pluck (lungs) for the presence of pneumonia (Figure 17). This is a small abattoir with a line speed of 90 pigs/hour. The pluck is removed from the pig carcass and placed on an over head rail which passes in front of the camera and one image is taken for analysis (Figures 18 and 19). As of now, the system is in use as part of a research trial, with the data/images collected being sent to F4T for analysis, supporting the algorithm development and validation of the system in an abattoir.

Figure 17 – Photograph of pig pluck placed on over-head rail

Figure 18 – Photograph of ADAL equipment installed at Nortura Norway

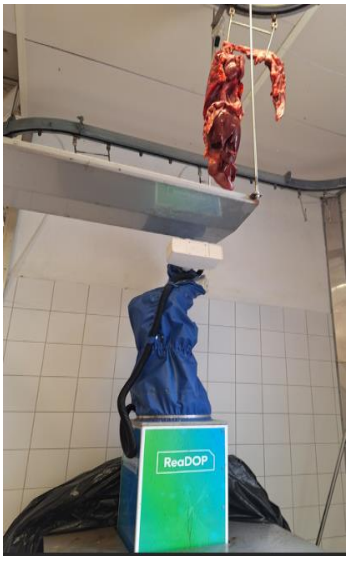

Figure 19: Photograph of lung passing in front of ADAL during test

The ADAL technology is also being trialled in *TailScan*, a project funded directly by the EU parliament (2023 to 2025) to record pig tail length and tail lesion severity on a pilot scale in four pig abattoirs across Europe (Martini in Italy, Incarlopsa in Spain, Vion Netherlands and Vion Germany). The project co-ordinator is Farm4Trade, with project partners at Universidad de León, Universitá di Bologna, Universitá di Teramo, Incarlopsa, Vion Group, Grupo Martini, MM Systems and Lintjeshof. The aim is to use the ADAL system to gather data on tail biting, as well the corresponding data collected visually by a VI. It will enable a comparison of manual and CVS data, as well as learning about the practical issues of using the CVS technology in a factory setting. Around 10,000 data sets will be collected and used to developed algorithms and machine learning tolls.

The ADAL computer vision system is still at the pilot trial stage and has not yet been presented for approval to the EU Commission. The operational speed is ~8 pigs/min. The cost of each unit (camera and computer processing) is estimated at €130,000 per station, including employee training, data backup and technical support. VOI and change in legislation would need to be implemented prior to implementing.

4.3.1.2 Advanced Agri-Tech Solutions

Advanced Agri-Tech Solutions is a privately owned company based in Yorkshire, UK , which is developing advanced technical solutions for the agri-food sector. The company has developed a bespoke camera-based system to detect lung lesions on pigs (personal communication: visual accuracy ~ 70 % veterinary inspectors and > 90% camera system). A camera is mounted in one position and images taken are examined by an experienced VI and an algorithm developed against visual inspection. The company is running a proof-of-concept trial in a large pig abattoir in Wales in an attempt to develop an AI-based PMI system to augment and ultimately reduce manual MI processes. There are plans to further develop it for pneumonia lesions and future use of cameras at AMI to record tail lesions, with information flow and feedback to pig producers.

4.3.2 Pig Carcass Faecal Contamination

4.3.2.1 VTK system

DMRI has developed a CVS system, VTK, for detecting faecal contamination on pigs. The system uses vision technology (advanced cameras, image processing), AI, and a graphic processing unit (GPU). Challenges with the use of vision in PMI are that these systems aim to cover all visible surfaces of the carcass, both geometric (like pneumonia) and spectral differences (contamination). It is difficult to be able to perceive the great variance in the appearance of contamination, for example from faecal or bile contamination and to annotate contamination on the image. Vision systems needs to collect sufficient training data for infrequent lesions, have the ability to detect very small particles and operate in high slaughterline speed. Light sources and cameras in combination are very important for the success of the VTK system (Figure 20). The VTK system takes a total of 48 pictures (24 high resolution images of each half of the carcass) from each carcass, followed by finding the pig surface in the picture and finally developing algorithms for faecal contamination. VTK is also being developed for

identifying bile on pigs, which is much easier to find than faeces. The algorithms will be part of the first release (Figure 21).

VTK is installed in a Danish abattoir to test the system and VTK is ready for extensive test and validation of the system's ability to find faeces, bile and chronic pleurisy and to collect data to support the decision to allow use of vision technology for PMI. The system shows where contamination is located and assist PMI when inspecting carcasses. There are several options of placement of the vision system on the line, early and/or later in the process.

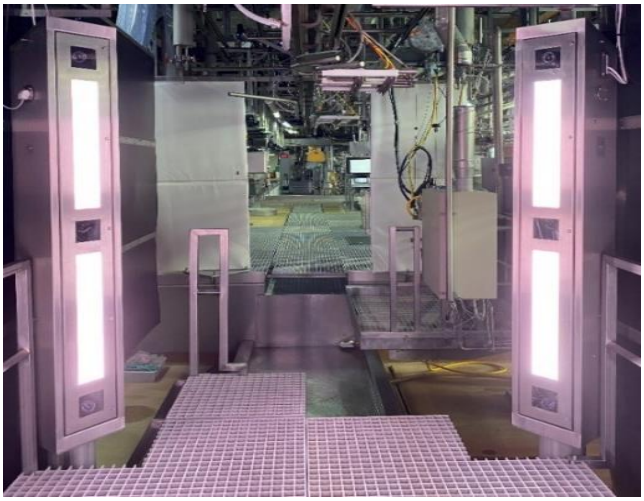

Figure 20 - VTK system, DMRI

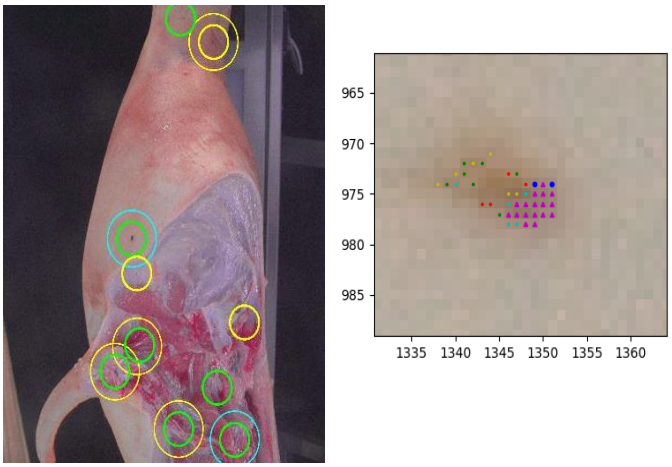

Figure 21 - Developing Algorithms for faecal contamination (DMRI)

4.3.3 Pig Ante-Mortem Inspection Technology

AI4Animals is an innovative camera surveillance system, in near real-time, developed by Deloitte to better monitor how animals are handled in slaughterhouses. The newly developed video software uses artificial intelligence to monitor how animals are being handled. Videos are automatically selected by the AI4Animals' algorithm and presented through a dashboard to be reviewed and, if required, action taken on the slaughter floor. This enables slaughterhouse employees to assess the

video images and take corrective actions in order to improve animal welfare. AI4Animals uses streaming camera footage and detects animals, people, and objects and how they interact, enabling detection of a diverse range of actions impacting animal wellbeing that the algorithm can detect, such as people walking directly against the direction of the pigs and animals staying behind for some time, while others continue. Additionally, it can detect the use of the mobile stunner and whether it has been applied according to protocol and detection of signs of life or consciousness of the animals.

Argus VCA (Video Content Analysis), is another automated animal welfare analysis, providing direct feedback in real-time to supervisors when a situation requires their attention, providing production monitoring efficiently. It enables a proof of welfare performance, that the incident is an isolated event and not a structural problem. Argus analyses animal behaviour, consciousness after stunning, equipment usage and much more. All signals from the facility are interpreted by AI to provide a valuable overview of animal welfare during processing.

5. Beef *Post-Mortem* Inspection

5.1 Overview of Beef *Post-Mortem* Inspection

Ante-mortem and PMI inspections of bovines are essential to verify compliance with requirements on human and animal health and animal welfare and to ensure diseased animals do not enter the human food chain. On 6 June 2013, EFSA adopted a scientific opinion on the human health hazards to be covered by the inspection of meat (bovine animals). That opinion identifies *Salmonella spp*. and pathogenic verocytotoxin-producing *Escherichia coli* as the most relevant hazards for meat inspections in bovine animals. It recommended the omission of palpation and incision during the PMI of animals subjected to routine slaughter, since it may reduce spreading and cross-contamination with the high-priority biological hazards. However, palpations and incisions during PMI, that are necessary to survey the occurrence of bovine tuberculosis (bTB,) and *Taenia saginata* (tapeworm) cysticercosis, should be maintained.

5.2 Overview of Beef PMI in Ireland

Export beef processors in Ireland are currently operating at a line speed ~ 50 per hour, about 300 to 400 a day, substantially slower than other species. There are three PMI stations for the head, the pluck and gastrointestinal content, and final carcass inspection. Inspection of the head includes visual inspection, palpation of the tongue and fauces, and incision of the lymph nodes and masseters. For pluck and gastrointestinal content current PMI requires visual inspection, palpation of the lungs, liver, gastric and mesenteric lymph nodes and incision of the bronchial and mediastinal lymph nodes, the liver and the gastric and mesenteric lymph nodes. A primary focus of the final carcass inspection is to look for any faecal contamination. If contamination is noted trimming can be done to remove the affected area, with subsequent approval of carcass. At station 2 a touchscreen technology is available to allow VIs to record their findings on liver (liver fluke) and lung pathology (pneumonia) and report back to farmers. The information is then transferred to the Irish Cattle Breeding Federation (ICBF) database, and reported back to farmers as part of the Beef HealthCheck programme. PMI findings are manually recorded, including information related to TVI identification and carcass number, bTB samples and reason for condemnation or detention (if further inspection is required). Currently, PMI condemnations are manually paper recorded with identification of the animal and the cause of

condemnation. There is potential for use of a CVS to support detection of faecal contamination at final carcass inspection and a system to support digital recording of data.

5.3 CVS for Bovine PMI

5.3.1 Bovine Pathological Lesions

There was little activity identified on this area during the review, although there is some early stage thinking in the PMI arena, largely being driven by AsureQuality, a New Zealand state-owned enterprise which provides PMI.

5.3.2 Bovine Faecal Contamination

5.3.2.1 Beef AI Surface Checker

DMRI have developed a digital process monitoring (DPM) Beef AI Surface Checker to support identification and targeted removal of surface contamination. The system assists VIs by detecting even the smallest unwanted contamination such as faeces, dark grease and dirt. The current AI Surface Checker records images of a specific area of the carcass surface, e.g. the hind legs, as the beef carcass passes by the installed cameras (Figure 22). An algorithm based on AI was trained by analysing a large amount of images, identifying and locating contamination. When the carcass enters the workstation, information regarding possible contamination is shown on a screen. The operator is thereby supported in the task to remove contamination from the carcass surface. The Beef AI Surface Checker is a two camera system. It is mounted on the line, after dehiding, with a monitor, to point out contamination for removal by the operator (Figure 23). It has the capacity for 120 carcasses per hour in standard configuration and the minimum detectable contamination size is 1 mm by 1 mm. It is in use since 2021 and commercially supplied since 2022, with a price of approximately €70,000. The algorithm needs to be retrained for each country/slaughterhouse's specificities. The vision technology system allows a consistent assessment of contamination, independent of the operator and a high level of food safety.

Figure 22 – Beef AI Surface Checker (DMRI)

Figure 23 - Screen Device (Beef AI Surface Checker, DMRI)

Faecal contamination comes from different sources, including the operator, knives and slaughtering equipment and from gut/stomach rupture when the rectum is removed, and the contamination appearance varies with the source. This poses a great challenge and requires a large amount of data material to develop an algorithm. New equipment for full carcass surface monitoring is now under development in collaboration with Frontmatec (Beef classification center – BCC-3), covering all four sides of half a carcass. This will involve 12 cameras in four towers and will be available later in 2024. There is an international interest in supply of full carcass monitoring for final inspection, but adoption of the technology is likely to be initially seen in large companies where quality is a focal point and where investments can be sustained due to higher production volumes.

In terms of practicalities the DMRI Beef AI Surface Checker is currently in use in European meat abattoirs. The system would have to be validated in any abattoir in which it is installed and there would be room needed in an abattoir to install camera devices and computer workstations. The equipment could be installed at different points on the slaughter line, i.e. could be directly after hide removal or at PM final inspection station. The cost per station is ~€70,000. Detection of faecal contamination would be of value to both the CA and FBO.

5.3.2.2 Veritide

Veritide is a New Zealand company that has developed a technology that identifies visible and non-visible faecal contamination on beef and lamb meat in real time. Veritide's faecal detection technology employs fluorescence techniques and a mathematical algorithm to detect chlorophyll and its metabolites within faecal material found on the surface of meat. Chlorophyll is optically very active and hence yields strong fluorescence signals for the silicon based detectors and sensors, however so does meat, such as collagen, fat and connective tissue. Veritide therefore needed to overcome the issue of false positives, which it did successfully by developing a mathematical model which enabled faecal fluorescence to be singled out from background meat fluorescence, such that only the light signal associated with chlorophyll florescence is captured and measured.

Hand held scanners are available to undertake spot checks of processed meat that it will detect both visible and non-visible faeces contamination (Figure 24). The hand held units shine a spot of blue light approximately 20mm in diameter onto the meat carcass or cut of meat. When a positive reading for faecal contamination is recorded the unit vibrates and the array of LEDs on the display lights up to indicate the level of intensity of the contamination. Contaminated meat can then be removed for re-processing or removed from the supply chain altogether. These units have broad application across the supply chain, including use by MI authorities, health and safety inspectors, meat wholesalers, food service companies and retail. A key benefit of hand held scanners is that a carcass or cut of meat can be tested in real time and the user can quickly and efficiently move on to another area and there is no wait for three days for swab results to be tested and returned from the laboratory. Some sites in New Zealand and Australia have these units and they are mainly an operator-driven activity,

The New Zealand Ministry for Primary Industries are working on a camera module, another product commercialised by Veritide, which has multiple use points in a meat processing abattoir, as an in-line mounted unit (e.g. above a conveyor belt) or as a fixed or moveable unit in a chiller, allowing large volumes of meat to be scanned quickly (Figure 25). The key benefit of the camera unit is that it covers a much greater area of the carcass (approximately 700mm x 700mm). It can take still or video images and instantly shows the location of faecal contamination and displays a 'figure of merit' indicating the magnitude of the contamination. The company have a large whole carcass scanner in development which is proposed to have imaging capabilities.

Figure 24 - Hand Held Scanner (Veritide)

Figure 25 - Carcass Scanner (Veritide)

5.3.2.3 VerifEYE - Solo™

VerifEYE Food Safety Technology, from eMerge Interactive, Inc, USA have developed an imaging system, called the Solo™, which identifies organic contamination on meat and other surfaces utilising a portable device similar in size and weight to a video camera. VerifEYE Carcass Inspection System (CIS) is a non-intrusive imaging system which identifies organic contamination in real-time on full bovine carcass sides on the rail within a slaughter abattoir (Burfoot et al, 2011). A VerifEYE investigation led to a high proportion of false negative and false positive results, confirmed by Burfoot et al. (2011). False negative results were attributed to the system being based on the premise that faeces of grass-fed bovines contains the digestion products of chlorophyll and its precursors, which fluoresce, but their levels can be highly variable depending on the animal diet. On the other hand, false positive results were a consequence of the wide range of excitation wavelengths delivered by the VerifiEYE, resulting in the fluorescence of non-faecal fluorophores naturally present in the carcass (carotene and haemoglobin). In conclusion, further developments need to be considered to allow the use of VerifiEYE for bovine carcass testing on the slaughter line (Sandberg et al., 2023).

6. Lamb *Post-Mortem* Inspection

6.1 Overview of Lamb *Post-Mortem* Inspection

In 2013, EFSA adopted a Scientific Opinion on the human health hazards to be covered by the inspection of meat from sheep and goats. That opinion identifies pathogenic verocytotoxin-producing *E. coli* as the most relevant hazard for meat inspections in sheep and goats. It also recommended omitting palpation and incisions to the greatest extent possible from the PMI of sheep and goats subject to routine slaughter. However, palpation and incisions for the surveillance of tuberculosis and fascioliasis should be maintained in older animals for reasons of animal and human health surveillance.

6.2 Overview of Lamb PMI in Ireland

Export lamb processors in Ireland are currently processing about 300 -400 /h, or 2,500 to 3,000 a day. There are two PMI stations on the slaughter line, one for visual inspection of the pluck and gastrointestinal content and the second station for visual inspection of the carcass. However, palpation and incisions for the surveillance of tuberculosis and fascioliasis is maintained in older animals (sheep having a permanent incisor erupted or 12 months of age or more) for reasons of animal and human health surveillance. About half of the heads are harvested for human consumption. Most of those that do not go for human consumption still have their tongues harvested. Therefore, all heads need to be inspected. Currently PMI condemnations are manually recorded with identification of the animal and cause of condemnation, but no record kept of offal PMI findings. Causes of condemnation include bruising, abscesses, odema/emaciation, toxaemia/septicaemia, presence of antibiotics and BSE and cohorts. Each month a digital report is sent to DAFM with the total number of condemnations broken down into the bruising, abscesses, emaciation and generalised infection.

There is potential for use of a CVS to support detection of faecal contamination at final carcass inspection.

6.3 CVS for Lamb

The challenges and opportunities for lamb would be very similar to the beef sector, although the line speed is a faster. This review identified no specific CVS system under development or trials for lamb other than Veritide to detect faecal contamination as described above (Section 5.3.2.2). A CVS faecal detection system would be of benefit to the CA and the FBO.

7. Conclusion and Next Steps

It is clear that the implementation of any CVS system to support PMI in Ireland would need full and open collaboration between all actors involved, including DAFM, FSAI, AHI, ICBF, the meat processors (FBO) and meat producers (farmers and practice veterinarians), with clarity on costs to each player, and the benefits and outcomes for all. Some sectors are currently more ready to adopt new technology than others, and different sector have different requirements and potential benefits from adopting CVS technologies. It is noted that the use of CVS for the detection of pathological lesions will require that risk based, VOI inspection is in place in that meat sector. There are opportunities for CVS, which detect faecal contamination, which would have multi-actor benefits. CVS technology could also be a useful and automated way for monitoring specific lesions related to animal welfare which could be fed back to farmers and drive overall welfare improvements. The cost to implement would include capital investment in the equipment (stand alone or mounted on a robot arm). Some abattoirs would require some retrofittng to accommodate the equipment, as space may not be available with current layouts. IT software, infrastructure and support would be required to support both data collation and analysis. This would require external support in the short to medium term from the supplier and for the on-site validation of the CVS technology.

Many countries throughout the world are moving towards a more risk-based meat inspection system along with the use of innovative technologies. Under current EU legislation on official controls new technology cannot replace traditional MI, but it can be used as a supporting tool in the slaughter process. It is noted that many of the CVS systems examined are still at the pilot trial stage and indeed will have to be presented to and approved by the EU Commission prior to their implementation.

There is no doubt that the use of CVS is a rapidly developing area and has huge future potential as a support tool to PMI. A key benefit of CVS would be to allow screening out of the low-risk slaughtered animals, enabling more focused PMI on high-risk slaughtered animals where lesions or abnormalities are detected. CVS would allow largescale digital data recording and storage in databases, facilitating farmer feedback, with clear benefit for animal health and welfare. Indeed, healthier herds/flocks should have less diseases, including food safety related problems. It is key to note that CVS is only a part of modernising MI. It is important that Ireland (DAFM) maintains contacts, especially in the EU, with those groups who are actively working in this area and starts planning with all actors in the chain as to how and what systems could be implemented in Ireland in the short to medium term.

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