EU PiG

EU PiG Innovation Group

Technical Report

Health Management

Deliverable D2.11

Authors:

Poul Bækbo, SEGES, Denmark

Claus Hansen, SEGES, Denmark

Ben Williams, AHDB, United Kingdom

Elena Lucia Sassu, Vetmeduni Vienna, Austria

Consortium Members of Work Package 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727933.

Challenge: Use of Slaughter Data to Improve Health Outcomes

Introduction

The EU PiG project aims to identify successfully on-farm applied good practices regarding specific challenges and share experience-based knowledge among participating member states. This fourth-technical report within the theme “Health Management” deals with the challenge “**Use of slaughter data to improve health outcomes**”.

The present technical report aims to provide both an overview of current challenges in application of slaughter data to improve on farm health and examples of solutions from five best practices implemented by pig producers in Europe.

Optimal health and continuous improvements in the pig industry are crucial to obtain sufficient productivity, health and welfare. Data-driven innovations and the application of benchmarking to optimize farm management have become increasingly important with the intensification and specialization of companies in agriculture. Registrations of pathological changes recorded at slaughter are thought to be of value in the estimation of both the health of slaughtered pigs and on-farm health status. Meat inspection data and farm data can be used by veterinary officers as a screening tool for detecting farms with potential health problems or by private enterprises as an efficient tool for quality control.

Currently, meat inspection data are available for farmers enabling them to evaluate the health status of delivered pigs. The present technical report describes cases where these data are used systematically to express and benchmark farm health status.

1. The Background to the Challenge

Conditions identified at slaughter indicate both financial losses to the industry but also reputational risk from perceived poor welfare. For example, pleurisy in pigs causes financial loss to producers in the form of saleable product being removed from the supply chain, known as a rectification. The incidents of pleurisy have been linked to health and welfare on pig farms which could cause reputational risk to production and certainly drives the usage of antibiotics as treatment for underlying health conditions. The incidence of diseases like pleurisy are relatively high across the EU (See table 1), with the identification often at slaughter rather than on farm.

Table 1 – Pleurisy prevalence, presented as percentage of individual affected pigs, in EU countries [1]

Country	Period	Prevalence (% of slaughtering)
Belgium	2000	16
	2009	20.8
Denmark	1987	14
	1998	24
	2000	25
Netherlands	1990	12
	2004	22.5
Norway	1991	41
Spain	2009	26.8
UK	1988	16
	2008	12.5

The ability to inform producers of the losses at slaughter and make changes on farm, to reduce the incidence, has the potential to increase income for producers substantially. Financial motivation should be seen as a key driver for uptake of innovation. Taking the lowest levels of pleurisy from Jäger et al. [1] of 12% and estimates of lost carcase value due to pleurisy rectifications, from data based on the UK's Pig Health Scheme and Collection and Communication of Inspection Results (CCIR) data (€2.31 per pig affected). It can be estimated across the slaughterings in the final quarter of 2019 (615,776,000 head of pork produced - data courtesy of Eurostat [2], shown in Table 2) that there would have been a loss of income of roughly €170.7 million to EU pork producers.

Table 2-Numbers derived from the Eurostat database at the point of calculation (June 2020)

Month	Head	Animals slaughtered
Month 10 (October 2019)	2´178.54 (000)	217´854´000
Month 11 (November 2019)	2´042.87 (000)	204´287´000
Month 12 (December 2019)	1´936.05 (000)	193´605´000

Correct and cost-efficient handling of diseases on farm level is indeed a challenge in all EU countries and is based on a lot of different information and farm specific registrations such as clinical signs of disease and recordings of productivity (ADG, FCR, mortality) as well as on data that can be obtained from the finishing pigs and sows delivered to the abattoir for slaughter (slaughter data). If these data are collected with regularity, they will allow the farmers and their veterinarians to intervene in a targeted way to obtain optimal health of the pigs.

Slaughter data can be split into two categories 1) meat inspection data on pathological changes of the slaughtered pig [3], and 2) technical data (weight, lean meat percent, variation of the weights of the pigs in a batch). The technical data can to some extent serve as a proxy for the pig health at the farm.

Meat inspection data on pathologies

In all EU countries meat inspection is performed on all finishers and sows at slaughter and pathological findings of the carcase and the viscera are registered. Typically, visual pathologies are registered and routine controls are performed. The recorded organ alterations vary between slaughterhouses and between countries.

Typical registrations are:

- Carcase: skin lesions (ex. mange), tail lesions (tail bite), ear necrosis, snout deviations (atrophic rhinitis) and shoulder lesions (sows)
- Bones and joints: fractures and arthritis
- Plucks (lungs, heart and liver): different characters and extent of pneumonia and pleurisy (lungs), endocarditis and pericarditis (heart) and hepatitis (e.g. caused by mycotoxins, parasitism) (liver)
- Kidney: nephritis and other lesions (e.g. caused by mycotoxins)
- Intestines: different forms of enteritis

Some lesions are pathognomonic pointing at one specific cause, but many lesions might need further diagnostic efforts to identify the cause. The pathological lesions will be of different age, thus allowing to some extent to estimate at which point throughout the animal´s life the issue occurred.

For some of the lesions the data from the routine meat inspection seem to be a poor indicator for the prevalence of the disease in the farm. For example the prevalence of tail lesions of undocked pigs at farm level does not reflect data from meat inspection [4]. One other challenge of using inspection data is that, even though the recordings of pathological changes at slaughter are regulated by the EU legislation [5], the registrations are subjected to variations not only from country to country, but also between abattoirs and even between meat inspectors. Variations in sensitivity can be significant and can impair a sound comparison between sites and/or over time. One study in four Danish abattoirs showed that the sensitivity varied from 39.2 % to 87.3 % in the period 1997-1998 [6]. All estimated specificities were over 93 %. The implication of this is that the prevalence of specific lesions registered at the meat inspection is only a rough estimate, and if one wishes to follow trends in disease prevalence over time as a surveillance tool for pig health, then one needs to use the same abattoir or even better, the same qualified person to do the registrations, for the time period in question. The use of automated data capture on the slaughter line has the potential to offer some standardisation and removal of human influence from interpretation of data [7].

2. Addressing the Challenge

The aim of this section is to point out different strategies for use of slaughter data to improve health in farms.

There have been multiple avenues of research into the use of slaughter data to calculate the costs of various management strategies on the value of the pig. At slaughter, producers largely lose value due to poor health for one of three reasons:

1. Poor final yield in terms of weight and fat depth due to the impacts of poor health and ill thrift;
2. Partial condemnation of the carcase, by partial removal of value products, often referred to as “trimming” (removal of undesirable or contaminated parts of the carcase);
3. Complete condemnation of carcases.

In the UK the percentage of pigs experiencing some form of rectification (partial loss of saleable yield to total condemnation) account for roughly 2.85% of all pigs slaughtered and the National Animal Disease Information Service (NADIS) estimate a cost from carcase condemnations to be worth £5 per finished pig[8]. There is variation across the EU with some studies citing condemnations as low as 0.24% [9] to 8.5% [10]. Variation is likely across systems due to changing health status, disease outbreaks, shifts in genetics, changing cycles of annual climate and vaccination strategies[11].

Whilst the use of slaughter data has been used to look at disease prevalence and has ramifications for tracing sources of change in the levels of antibiotic use, there is little published research that supports analysis of any of these non-disease factors when using slaughter data [9, 10]. Techniques that adjust for these factors should be considered when applying cluster detection methods to abattoir data [12].

In order to derive maximum value from slaughter data the following model needs to be in place:

1. Clear system to identify the individual animal or batch;
2. A system of data recording at the abattoir that allows rapid but accurate and standardized recording of health conditions and the resulting rectifications and condemnations;
3. A timely method for sharing this data with the producer/farmer;
4. A visual method of presenting the data that clearly links the causes of the rectifications and condemnations with the diseases likely as cause;
5. An estimate of the financial impact that has had on the sale of products.

In the EU the individual tagging of animals is becoming more frequent, but it is not routinely used (The UK utilises a herd mark across the entire batch, as a tattoo). This process, when used, allows the use of the individual pig ID in conjunction with Radio Frequency Identification Tagging (RFID)-equipped gambrels to chart all relevant information regarding the carcase to be linked to that animals ID. This not only gives the potential to give much more granular information regarding the impact of rectifications and condemnations but can also be used to link to on farm management systems.

Systems have evolved beyond the proof of concept phase with some supply chains starting to integrate the above model into their processes. In the Netherlands, WestFort Meat Products, as part of their sustainable pork value chain-KVD brand have designed such a model with Ultra High Frequency (UHF) ear tags allowing a certain amount of automation of the data gathering process [13] (https://sustainable-pork.com/). The use of UHF identifiers on farm and in the abattoir, allow all production data, from sire to slaughter, to be linked through one common identifying point; the UHF ID. In 2018 KDV produced data from 385,048 pigs equipped with UHF ear tags, which allowed through integration of on farm management data (health status, treatment with antibiotics and feed inputs) to market a 'higher welfare/standard' of pork. This premium product allowed a payment to be made to producers to offset the cost of implementation and as such incentivised industry uptake. From case studies such as this we can see that there is an appetite in the supply chain and at farm level, when the economics for change are considered. This, like many other projects, follows the concept of the triple bottom line: Profit, People and Planet [14, 15].

The linking of herd performance (on-farm) data and the slaughter data allows producers/farmers to look at root cause analysis in much more detail with the aim of rectifying underlying causes of disease at the farm level before they occur in subsequent production batches. There has been research into the use of slaughter data to change on-farm practice with the majority of work occurring between food business organisations (FBOs) and their suppliers (farmers). This is likely due to the confidential nature and competition that exists between FBOs within the supply chain. Where work has occurred it has attempted to utilise the visualisation of data as a tool to inform behaviours. Jansen et al. (2012)[16] showed that there are five main instruments (R.E.S.E.T. model: Regulations, Education, Social pressure, Economic incentives, Tools) that can be used to change mind-set and, the economic impact of slaughter data has been increasingly discussed in research. Tuovinen et al. (1994)[17] described losses equivalent to $0.81 per pig slaughtered in 1991, equivalent to approximately $1.75 per pig (€1.57) accounting for inflation in 2019. Across a 1000 sow unit with fertility measure of 35 piglets/sow/year, that's $61,250 or roughly €55,000. Working with a UK processor, AHDB calculated based on 2019 data, losses for all categories of condemnation or rectification of £4.32 per pig slaughtered (€4.84 per pig) in line with the NADIS estimate of £5 per pig.

Funding is available for many of the activities required to build the model described above. These are often under the guise of Knowledge Transfer Programmes, whereby SMEs (Small Medium Enterprises) form links with academia, industry representatives and NGOs to form partnerships that allow the outcomes to be disseminated on behalf of the industry. More information can be found at https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/keywords/knowledge-transfer. In the UK examples, these partnerships exist within the pork industry between integrated businesses and research institutions, linked to the AgriTech centres, e.g. Centre for Innovation Excellence in Livestock CIEL (https://www.cielivestock.co.uk/), and supported by regional funders such as InnovateUK (https://www.gov.uk/government/organisations/innovate-uk).

3. EU PiG Best Practice

In order to identify the top five best practices across all the EU PiG regions a series of criteria has been used, which are able to measure the effectiveness of the collected practices to match the specific challenge.

The following set of criteria have been scored for each practice.

- **Excellence/Technical Quality**
  - Clarity of the practice being proposed;
  - Soundness of the concept;
  - Knowledge exchange potential from the proposed practice;
  - Scientific and/or technical evidence supporting the proposed practice.
- **Impact**
  - The extent to which the practice addresses the challenges pointed out by the R-Pigs Groups;
  - Clear/obvious benefits/relevance to the industry;

   - Impact on cost of production on farm and/or provide added value to the farming business or economy;
   - The extent to which the proposed practice would result in enhanced technical expertise within the industry e.g. commercial exploitation, generation of new skills and/or attracting new entrants in to the industry;

- **Exploitation/Probability of Success**
   - The relevance of the practice to each MS or pig producing region/system;
   - Timeframes for uptake and realisation of benefits from implementation of the proposed practice are reasonable;
   - The extent to which there are clear opportunities for the industry to implement the practice/innovation;
   - Degree of development/adaptation of the practice to production systems of more than one Member State.

- **Innovation**
   - Evaluation of innovation (novelty) with the good practice;
   - Level of innovation according to the Technology Readiness Level (TRL).

Scores had to be in the range of 0-5 (to the nearest full number). When an evaluator identified significant shortcomings, this was reflected by a lower score for the criterion concerned. The guidelines for scoring are shown below (no half scores could be used).

0	The practice cannot be assessed due to missing or incomplete information.
1 – Poor	The practice is inadequately described, or there are serious inherent weaknesses.
2 – Fair	The practice broadly addresses the criterion, but there are significant weaknesses.
3 – Good	The practice addresses the criterion well, but a number of shortcomings are present.
4 – Very Good	The practice addresses the criterion very well, but a small number of shortcomings are present.
5 – Excellent	The practice successfully addresses all relevant aspects of the criterion. Any shortcomings are minor.

The selection of the top five best practices followed the procedure described below:

1. Members of the thematic group (TG) were asked to score all submitted best practices according to the defined guidelines and sent their scoring sheets to the TG leader;
2. In addition to the scores, TG members provided brief comments indicating weak points or particular strengths of submitted best practices;
3. A conference call was used to discuss the scoring results and select the top 5 best practices. During this call, the top 10 best practices were discussed based on the ranking submitted by thematic group members. The discussion of the top ranked best practices was started from the lowest rank, i.e. best practice with the highest average score, to rank number 10. A selection of the top 5 best practices was made during the call;
4. A summary of all discussions was sent out after the call to review the decision of the selected five best practices by thematic group members.

4. Results and Discussion

4.1. Validation of the top five best practices

The following top 5 best practices within the challenge of "Use of slaughter data to improve health outcomes" have been selected by the thematic group:

Title of best practice	Country
Use of Slaughter Data to Develop Dashboard system to improve pig herd health	Ireland
Ceva Lung Program : a Web tool to monitor the pulmonary health of my pigs	France
New slaughter data report helps to improve production	Finland
Use of slaughter data	Finland
IQ-Agrar PORTAL Online portal to support inter-organizational quality management in agriculture sector	Germany

Use of Slaughter Data to Develop Dashboard system to improve pig herd health - Ireland

This practice describes the development of a dashboard system to improve pig herd health. Feedback data on lung, hearth and liver health checks performed at the slaughter plant are incorporated into a dashboard together with other production and management parameters of the farm. This system integrates different tools: herd performance figures derived from the Teagasc e-Profit Monitoring (ePM) recording system, biosecurity assessment by using the Biocheck.UGent (https://biocheck.ugent.be/en), pluck health check (lungs, hearth and liver) using an app developed by CEVA Lung Program (https://www.ceva.com/Products/Swine/Ceva-Lung-Program-App), tail biting data and antimicrobial usage (AMU) data collected by Teagasc.

The main variables used for the dashboard are imported into an excel database used to generate a report which allows for benchmarking and setting targets. This report contains a summary of data about production, health assessment at slaughter, AMU and biosecurity. The farmer does not access the raw data, as some of the details on those reports might be too complex. All data are displayed as user-friendly graphs that allow for benchmarking and flag areas for improvement. If there is a problem on performance, they will discuss the complete report with the advisor; if there is a problem on biosecurity or lung lesions, they will discuss it with the veterinarian.

In this specific example, the follow up of the pigs in the slaughterhouse revealed the presence of high levels of pleurisy and pericarditis. Thanks to this, Patrick Ryan, the farmer, realised that some batches of animals were more affected then others. Those batches included mainly pigs that were behind in growth or those that were mixed with hospital pigs. Thus, he decided to create a separate flow for approx. 10% of the pigs that were behind in growth or were supposed to go to a hospital pen. Now those animals that need extra care stay apart from the rest of the herd till slaughter. The adoption of this measure resulted in reduced problems in most of the animals and reduced AMU, as only a small percentage with problems is treated. The weaner´s average daily weight gain (ADG) has increased from 433 to 486g/day.

Thus, the dashboard system helped the farmer to identify the problem and changed his focus into control it by improving batch management, reduced mixing and creating separated streams for weak pigs.

Thematic group members selected this practice and found that it successfully met all requirements (technical quality, impact, probability of success and innovation).

Pros:

1. It is a complete and innovative system: the combination of a broad set of parameters into a dashboard offers a good overview on the health status of the farm.
2. The reports are farmer-friendly and allow for benchmarking with the other project´s participants. By knowing how the others perform, the farmer can evaluate his own farm´s performances.

3. This practice provides a practical example of how slaughter data interpretation can lead to improving pig health. Farmers can identify the problem and act promptly to adopt measures to control it.
4. There is no conflict of interests. Even though the system is using CEVA app for the lung assessment, the pharmaceutical company is not part of the project, and slaughterhouse data are collected by Teagasc and other veterinarians. In 2021, it is planned to migrate the lung lesions to a new software developed by DAFM (Department of Agriculture, Food and Marine, in Ireland) that will link directly ante-mortem and post-mortem inspection of carcases with the system.

Cons:

The digital tool will take at least one year to be developed. On the other hand, in the meantime, the service has been delivered by Teagasc veterinarians, enabling the farmer to gradually adapt to the platform.

Moreover, next year the system will integrate two additional features: a questionnaire to evaluate problems related to tail biting and data from the *Salmonella* national plan.

Ceva Lung Program: a Web tool to monitor the pulmonary health of my pigs - France

This practice provides an example of the implementation of the CEVA lung programme (CLP) to improve pig health. It is well known that pulmonary health problems may cause pathological changes readily visible at slaughter and that the severity of the disease correlates with the pathological severity visible at slaughter. This tool applies this principle in a standardized manner evaluating the overall population pulmonary health.

The CLP can provide information about the frequency, severity and suspected origin of pathological changes most likely due to *M. hyopneumoniae* and *A. pleuropneumoniae*. The CLP is designed to assist in identifying the correct diagnosis of respiratory disease through the evaluation of lungs at slaughter. It enables the discovery of even subclinical infections that were not noted during the growing period. Finally, if used routinely, it can aid in the recognition of the dynamics of those infections in a defined period or seasonal differences. The lung scoring program is offered for free to veterinarians in Europe for specific farms and usually used on an ad hoc basis for a short period. The scoring of the lungs is usually performed by the same experienced person for each specific farm, thus there is a high validity of the scoring over time. This set-up differ from country to country.

The farmer described the practice as following: "*They check pneumonia and pleuritic lesions, with a lung lesion scoring system. The score is recorded on a web tool: «Ceva Lung Program» - CLP. It allows processing, summarizing the results and sending the final data. The vet has a free access to the data and shows them to me. This tool helps me to follow the pulmonary* *health of pigs. We can evaluate the efficacy of new vaccination protocols. In late 2017, I faced respiratory troubles on my young fatteners and an increasing number of runts. We had to give antibiotics, but it was not a sustainable way to solve this sanitary problem. So, we implemented a new vaccination protocol and it was a success. Improvements were seen in the farm but also at the slaughterhouse. The CLP data established that the new vaccination protocol led to a highest number of lungs without pneumonia lesions and to a low and stable mean pneumonia score (≤ 1.32). For each scoring recorded in the CLP tool, my veterinarian and I, know the economic losses induced by the pneumonia lesions scored. Thus, in my farm, pneumonia caused a mean loss of 1.2€/slaughtered pig in 2017, 1.1€ in 2018 and only 0.2€ in 2019. With this information I can estimate the return of investment of new measurements, like the implementation of a new vaccination protocol. The CLP application is in free access and you can download it on laptop, IOS and Android phone. A personal account must be created for you by the local CEVA Animal Health team (present in 110 countries all over the world). You have an adapted access to the CLP data, depending of your job (veterinarian, lung scoring operator…). For example, a veterinarian will have access to the lung score reports of all the farms that he/she follows. For farmers, CLP reports are coming through the veterinarian. The vet uses them to monitor the respiratory health of the fatteners*".

Thematic group members agreed on the relevance of this practice to the challenge and thus included it in the top 5 list.

Pros:

1. Good tool to evaluate lung lesions at slaughter.
2. It is already in use in several countries.
3. Results: different tools were applied and apparently vaccination gave the best result in disease reduction. The practice describes the application of a tool that leads to tangible results.
4. It supports the dialogue between the farmer and his/her veterinarian on how to increase the health of the pigs and the economic benefit on this specific farm. The CLP brings the farmer and the veterinarian together and allows for benchmarking the farm against its own data over time and against other farms.
5. It is very cost-efficient for the farmer, as he/she does not pay for the system, but only for medication, if needed.

Cons:

1. Conflict of interests: the system is linked to and financially covered by CEVA. This can represent a bias in relation to the use of vaccines as a solution to disease problems and in the selling of CEVA vaccines. Additionally, the CLP system is only running as long as CEVA supports it financially.
2. The farmer cannot get access to the slaughter data him/herself, but needs the veterinarian and the pharmaceutical company CEVA as intermediate.

3. This program only covers lung diseases.
4. It is not a continuous surveillance. It usually runs for a short period in a specific farm (only when problems are present).

By using the same person for the scoring of lesions on farm level, the CLP minimized errors linked to variation between abattoirs. Thus, if used continuously as a monitoring system, this tool might have a good impact on increasing pig health. Furthermore, as the CLP is the same all over EU (same data presentation/graphics) farmers and veterinarians can obtain more experience in using the system by networking.

Foreword to the two practices: "New slaughter data report helps to improve production" and "Use of slaughter data" submitted by Finland.

These two selected practices are related to the same Finnish health care system, which is run by the Association for Animal Disease Prevention ETT (Animal Health ETT - www.ett.fi). Animal Health ETT was founded in 1994 with most of the Finnish dairies, slaughterhouses and egg packaging companies as members. The activities of the association are funded by subscriptions and initiation fees. Sikava is a health classification register, which gathers data on medicine usage, meat inspection, animal welfare and the condition of farm buildings from over 95% of pig production in Finland. The register works in Internet and its website address is http://www.sikava.fi/.

The farmer joins the system by making a health care agreement with his/her veterinarian. After that the farmer can use the register for free, all the costs are paid by the slaughterhouse companies. The veterinarian must visit the farm 4-6 times a year or once in every batch, if it is an all-in-all-out finishing unit.

Meat inspection data are transferred via interface into the Sikava system from slaughterhouses. This means that data are easily accessible to the farmer and his/her veterinarian. The Sikava system gathers data of animal mortality and carcase condemnations as indicators of responsible pork production. If any of these indicators exceed certain limits, the slaughterhouse takes the farm into special attention and gives advices on how to make the situation better. Furthermore, the system has been used for research studies across farms, where farm specific risk factors have been pointed out for high disease prevalence and use of antibiotics [18].

New slaughter data report helps to improve production - Finland

This practice describes the use of a dashboard system that delivers production reports to the finishing farmers four times per year.

General description from the farm*: "The production report and slaughter data give important information about pig health and management success. We follow the report routinely. Our biggest advantage of it has been to optimize food setting. HK Scan renewed the report in the* *beginning of 2019 and finishing farms get it four times a year. Graphics show lean percentage and weight distribution and how they correlate. Average weight and lean percentage are also mentioned. The report also shows the amount of different meat inspection lesions and compares the amount to the national average of HK Scan. Our farm is often in the best or second-best quarter. The report also shows the loss of income due to lesions. The most important goal of the renewed report has been to increase the farmer's knowledge of their own production, animal health and welfare. On our farm we read the report every 3 months. After each batch the results are accessible online. The report shows that the investments in animal welfare and early disease prevention have paid off, since we have less lesions than the HK Scan average. When meat inspection and slaughter data is measured and followed, we can change it towards the better and react to health and management problems fast. But animals are so healthy we mostly use it to adjust feeding. By increasing knowledge of animal welfare and slaughter data we can improve the whole pig industry. By increasing animal welfare, we can decrease meat inspection lesions".*

Thematic group members selected this practice and found that it sufficiently met most of requirements (technical quality, impact, probability of success and innovation).

Pros:

1. The farmer can benchmark his/her own farm against the national average, thus motivating him/her to improve.
2. The system combines both meat inspection data and technical data.
3. The submitter provided a picture of the dashboard system that gave an idea on how the final user, the farmer, is going to visualize the data. The platform was judge to appear user-friendly by the most of the thematic group members.

Cons:

1. The farmer cannot access the slaughter data him/herself, without an agreement with a veterinarian.
2. Not enough data for the cost benefit analysis were provided in the description.

Use of slaughter data - Finland

This practice applies meat inspection data to improve herd health in a sow farm, which analyses weekly and quarterly reports from the finishing farms.

General description from the farm*: "The Pirteä Porsas piglet production farm originates from the nineties and is situated in southwestern Finland. In 2019 a massive modernization project was carried out. The farm is now in antibiotic free production and it is fully integrated with its owner´s finishing farms. There is a regular and detailed health, quality and economic report from the co-operative contract slaughterhouse Atria plc. The sow farm analyses these weekly and quarterly reports from the finishing farms on a regular basis. The following Key*

Performance Indicators (KPI) are considered: mortality, partial and total rejects (detailed with actual cause), % tail bitten pigs, rejected kg and €, cumulative and mean value of rejects, daily gain, growing capacity utilization (rotation speed per pig place), no. of AB treated/-free pigs. The results from this specific farm are compared among different finishing farms within all Atria group and between different farms with same piglet supplier. The pork production chain should use the production data much more detailed and effectively to gain a much better cost efficacy. KPI reports are used to manage health and production issues (vaccinations, feeding, general production management etc.) on sow farm. The farm has 1750 sows in production. The number of weaned piglets/sow/year is 33 and the number of weaned piglets/litter is 13.75".

Thematic group members selected this practice and found that it sufficiently met most of requirements (technical quality, impact, probability of success and innovation).

Pros:

1. The system allows for relevant benchmarking.
2. Innovative: this practices describes the use of slaughter data to improve health in a sow farm. Usually slaughter data are used by finishing farms.
3. Technical and production data are also considered: mortality, partial and total rejects (detailed with actual cause), % tail bitten pigs, rejected kg and €, cumulative and mean value of rejects, daily gain and growing capacity utilization (rotation speed per pig place).

Cons:

1. The farmer cannot access the slaughter data him/herself, without an agreement with a veterinarian.
2. No enough data for cost-benefit analysis. In the description is not stated how the sow farm uses the data coming from the finishing farms.

IQ-Agrar PORTAL Online portal to support inter-organizational quality management in agriculture sector - Germany

This practice describes IQ-Agrar PORTAL, an internet portal that collects and analyses data from marketing, animal health, farm management and quality assurance in agriculture. Up to 30 million data are processed every year. User specific analysis options and descriptive graphics are available. Individual filter options are given, based on the latest IT-Technologies. To calculate the losses in specific periods, it's possible to analyse single slaughter data as well as delivery periods for management and marketing decisions. Alarm lists, market and monitoring information are shown in widgets for quick overviews. For quality assurance, customers receive detailed information on antibiotics, salmonella or residue monitoring. Auditing management information, aspects of animal welfare and individual labels are presented. To get the possibility for proactive management, users can retrieve forecast analysis based on predictive calculation and in future analysis of profitability. Potential in management and marketing is revealed by scientific based analysis. The submitter claims that the use of this system results in higher profits and increased animal health due to optimal utilization of the slaughter data. Using this information, losses can be easily reduced by half.

This practice focuses on two general areas – "**farm health**" and "**optimization for profitability**". Farm health is optimized through a calculation of health index based on meat inspection data and optimization of profitability is reached using other registrations from the abattoir. Optimization of profitability adds value to the overall program but is not within the scope of the technical report and will not be discussed further. Farm health index is traditionally supplied to the farmer quarterly and calculated using statistical models[19], and include statistical corrections to calculate the index. This is calculated based on meat inspections recorded by the official veterinarian (or technicians). These provide recordings for lungs, pleura, heart, liver/intestinal, limb health and intactness (skin, ear, tail). Farms can benchmark health status over time and between farms.

All the thematic group members agreed to include this in the top 5 list, despite the fact that it was not associated to a farmer. This decision was made considering the importance of this portal, which enables the farmer to have direct access to a broad range of data.

Pros:

1. It is a complete system: *Salmonella*, antibiotic and residue monitoring combined with slaughter data, production parameters and tail biting. Moreover, the system allows to improve profitability together with animal health.
2. The farmer can have access to all data.
3. It can be easily implemented in other countries. Companies from other countries can participate in the QS scheme either directly or based on recognition of other standards and schemes.

Cons:

The practice does not provide an example of an on-farm implementation and it is not connected to a specific farmer.

Discussion on the application of meat inspection data to improve herd health.

Meat inspection on abattoirs is regulated by EU regulations [5]. Registrations performed in the meat inspection is based on very quick evaluations and prone to high variability among different technicians within each abattoir and systematic differences between abattoirs [6, 20].

This demands for a high degree of standardization among abattoirs. Recently, a scoring method that aims to combine meat inspection data, data on antibiotic usage, data from the quality assurance system (QS) and Salmonella monitoring programme has been developed in

Germany. The goal is to aggregate all the data in order to create an **animal health index** that allows the comparison and benchmark among pig farms according to their health status [21]. The calculation of a health index will supply the farmer with information on the disease history of his/her farm over time. The described system will enable the farmer to work progressively to lower the occurrence of pathological findings but probably not be applicable to deliver at specific health status for a smaller group of pigs. Additionally, benchmarking will be possible mainly for farms delivering to the same abattoir or group of abattoirs that have aligned the meat inspection accordingly to this system. Unfortunately, the system does not allow comparisons or benchmarking to other countries or abattoirs not aligned with the system. Future systems with objective meat inspection using vision algorithms and deep learning may improve the objectivity to an extent where more precise benchmarking across abattoirs will be possible.

The health index provides an overview of the macroscopical findings upon meat inspection over time. This index does not intend to replace a clinical examination [21]. It is the author's opinion that the application of meat inspection data enables an overview of general health status over time, but does not provide the farmer with sufficient precision in the quantification of the degree of health issues. On the other hand, the presence of typical lesions can help to reach a diagnosis and can enable the farmer to intervene accordingly.

4.2. Cost and benefit analysis of the EU PiG Ambassador

The best practice "**Use of slaughter data to develop a Dashboard System to improve herd health**" from Ireland was chosen as EU PiG ambassador 2020 for the challenge of "Use of slaughter data to improve health outcomes". This practice foresees the implementation of a dashboard system which helps the farmer to better interpret slaughterhouse data and, consequently, identify what can be improved on farm. Feedback data on the state of lungs and livers were incorporated into a dashboard system to look at various production and management parameters on the farm including: herd performance figures derived from the Teagasc e-Profit Monitoring (ePM) recording system, biosecurity assessment, pluck (lungs, heath and liver), tail check and antimicrobial benchmarking.

Costs (declared by the developer): The cost for the farmer is almost zero. These are activities normally carried out by the vet or advisor, but the integration of the information allows for benchmarking and setting targets.

Benefits (declared by the developer): The main benefit was providing information which enabled the farmer to focus his efforts where the problem was (a problem that he hadn't considered until he used the dashboard system). This has resulted in improved herd performance via improved pig health and associated reduced use of antibiotics. Weaner ADG has increased from 433 to 486g/day.

Costs and benefits of "Use of slaughter data to develop a Dashboard System to improve herd health" carried out by CRPA, Centro Richerche Produzioni Animali, Italy

In the following analysis the costs and benefits of the Dashboard system are presented in detail. The costs and benefits of this system have been analysed considering national variations in direct costs (labour and capital) and other factors such as feed, energy, maintenance and bedding material. The INTERPIG model has been used to carry out simulations on production costs and profitability of pig farms in Europe.

The use of the dashboard (and benchmarking) made the farmer realise the problem he had with mortality in weaners and consequently in finisher pigs. By using the Dashboard system the **mortality of weaners could be reduced by 33%** and the **mortality of piglets before weaning by 12.5%.** After a first decline of ADG and FCR of weaners due to the higher fragility of survived weaners, two years later the farmer turned back to the 2017 levels in ADG and FCR.

The table below shows the impact of the use of the Dashboard system on the technical performance data of the farm.

Table 1 – Change in technical performances due to the use of the Dashboard system

	Without Dashboard (2017)	With Dashboard (2019)	% change
Pigs weaned per sow/year	26.65	29.82	11.8
Pigs reared per sow/year	25.05	28.63	14.2
Pigs sold per sow/year	24.65	28.14	14.1
Pigs weaned per litter	12.28	12.58	2.4
Litters/sow/year	2.17	2.37	9.2
Pigs born alive per litter	13.4	13.5	0.7
Pre Weaning Mortality (%)	8.0%	7.0%	-12.5
Rearing Mortality (%)	6.0%	4.0%	-33.3
Finishing Mortality (%)	1.6%	1.6%	0

Table 2 – Production costs of pig meat without and with the use of the Dashboard system (€/kg live weight)

Cost items	Without Dashboard	With Dashboard
Feed, (Euro/kg live weight)	0.74	0.73
Other variable costs, (Euro/kg live weight)	0.19	0.17

Labour, (Euro/kg live weight)	0.11	0.10
Finance cost, (Euro/kg live weight)	0.15	0.16
Total costs (Euro/kg live weight)	1.19	1.17
Net profit (Euro/kg live weight)	**0.02**	**0.04**

NOTE:

• The category "other variable costs" includes veterinary costs, energy, maintenance and bedding material.

• The category "finance costs" contains costs related to depreciation of buildings and equipment and interests on invested capital and on anticipated expenditures.

The improvement in mortality rates has significant positive effects on all the sow performance indicators. Maintaining all other variables constant over time ("ceteris paribus" condition), the production costs of pig meat decline from 1.19 €/kg down to € 1.17 €/kg, which generates an **increase of net profit from 0.02 €/kg up to 0.04 €/kg (Table 2)**.

4.3. Expert Analysis

The cost-benefit analysis highlights that the implementation of appropriate measures in response to the problems observed at the slaughter brought about reduced rearing and pre-weaning mortality, but it did not influence finishing mortality. This could be a hint of an early problem that affected the pigs acutely in the nursery and then developed into a chronic form that persisted till slaughter. Importantly, the variable "other costs", which included among the others the veterinary costs, decreased with the implementation of this practices. This is mainly due to the application of targeted measures that allowed to reduce the use of antibiotics by restricting the therapy only to symptomatic animals and by keeping those animals in a separate pen until slaughter. The farmer together with the veterinarian decided to work on the management by improving the pig flow, avoiding mixing and treating only sick animals. This led to reduced mortality which resulted in an increase in the net profit.
The implementation of this practice in other member states is limited to the type of dataset (which kind of monitoring is done and which parameters are evaluated) available in that country.

4.4. Conclusions and advice to industry

If the industry were to adopt this practice, several considerations should be made.

The system relies on strong datasets and tight collaboration between the advisor/veterinarian and the farmer. These advisors need to be trained on how to use the system, interpret the data and advise the farmer on how to solve the problem. A common training is needed to guarantee the implementation of measures that comply with certain standards, such as strategies that support improvement of biosecurity and farm management over the misuse of herd antibiotic treatment.

The application of slaughter data to improve health involves both opportunities, but also great limitation. Slaughter data cannot replace clinical examination and cannot identify the course of infection, as it is based on post-mortem findings. Precision livestock techniques that identify early warnings of disease should run in parallel to routine inspection monitoring to achieve optimal results.

To compare meat inspection data over time or between farms a high degree of standardization or large amounts of data are needed. Much work has been done in the effort to use slaughter data to express level of welfare, but the lack of standardized registrations and of a direct link between on-farm animal welfare and pathological changes impair the achievement of this goal.

The application of a health index, as shown in the best practices, requires a high degree of standardization as well as statistical correction. This impairs the use of the health index as an absolute “number for health or welfare”, but it can be used as an overall comparison over time between farms that deliver pigs to same group of abattoirs.

5. The Future

In the way ahead, a more pronounced standardization is needed. This can possibly be done using vision algorithms to measure the extent of pathological changes in the carcase. Computer vision system has been used already to improve meat traceability and can recognize different meat cuts at different points along the slaughterhouse production line [22]. This kind of system could be designed to evaluate and score lesions present at the meat inspection.

More objective measurements are needed to improve a better usability of meat inspection data to express herd health. In this report, two best practices from Finland included technical parameters in the evaluation of recordings. These parameters might also be linked to level of health and can help to spot differences between batches of pigs. The integration of these data, including meat percentage and weight distribution, can provide the farmer with additional information to calculate overall health and productivity for individual batches.

References

1. Jager, H.C., et al., *Factors associated with pleurisy in pigs: a case-control analysis of slaughter pig data for England and Wales.* PLoS One, 2012. **7**(2): p. e29655.
2. Eurostat, *Total slaughtering Q4 across 27 EU Nations*. 2019.
3. Dalmau A, F.E., Manteca X, et al, *Health and welfare management of pigs based on slaughter line records.* J Dairy Vet Anim Res, 2014. **1**(3): p. 73-78.
4. Kongsted, H., L. Foldager, and J.T. Sorensen, *Data from routine meat inspection is a poor indicator of the prevalence of tail lesions in undocked pigs.* Porcine Health Manag, 2020. **6**: p. 10.
5. European Commission, *Commission Implementing Regulation (EU) 2019/627 of 15 March 2019 laying down uniform practical arrangements for the performance of official controls on products of animal origin intended for human consumption in accordance with Regulation (EU) 2017/625 of the European Parliament and of the Council and amending Commission Regulation (EC) No 2074/2005 as regards official controls*. 2019, March 15.
6. Enoe, C., et al., *The need for built-in validation of surveillance data so that changes in diagnostic performance of post-mortem meat inspection can be detected.* Prev Vet Med, 2003. **57**(3): p. 117-25.
7. Blömke, L., Kemper, N. *Automated assessment of animal welfare indicators in pigs at slaughter*. in *12th International Symposium on the Epidemiology and Control of Biological, Chemical and Physical Hazards in Pigs and Pork*. 2017. Foz do Iguaçu, Brazil.
8. NADIS. *Whole Carcass Condemnation*. Available from: https://www.nadis.org.uk/disease-a-z/pigs/whole-carcass-condemnation/.
9. Garcia-Diez, J., Coelho, A.C., *Causes and factors related to pig carcass condemnation.* Veterinarni Medicina, 2014. **59**(4): p. 194-201.
10. Martinez, J., et al., *Carcass condemnation causes of growth retarded pigs at slaughter.* Vet J, 2007. **174**(1): p. 160-4.
11. Amezcua, R., et al., *Patterns of condemnation rates in swine from a federally inspected abattoir in relation to disease outbreak information in Ontario (2005-2007).* Can Vet J, 2011. **52**(1): p. 35-42.
12. Thomas-Bachli, A.L., et al., *Suitability and limitations of portion-specific abattoir data as part of an early warning system for emerging diseases of swine in Ontario.* BMC Vet Res, 2012. **8**: p. 3.
13. KDV. Available from: https://sustainable-pork.com/.

14. Rowlands, I., *Corporate Potential: Cannibals with Forks.* Alternatives Journal, 1999. **25**(4): p. 42-43.

15. Slaper, T., Hall, T. *The Triple Bottom Line: What Is It and How Does It Work?* Indiana Business Review 2011; Available from: https://www.ibrc.indiana.edu/ibr/2011/spring/article2.html.

16. Jansen, J., Wessels, R, Lam, TJGM. *How to R.E.S.E.T farmer mindset? Experiences from The Netherlands*. in *Countdown Symposium*. 2012. Melbourne, Australia.

17. Tuovinen VK, G.Y., Straw, BE *Partial condemnations of swine carcasses – a descriptive study of meat inspection findings at Southwestern Finland's Cooperative Slaughterhouse.* Preventive Veterinary Medicine, 1994. **19**: p. 69-84.

18. Stygar, A.H., et al., *High biosecurity and welfare standards in fattening pig farms are associated with reduced antimicrobial use.* Animal, 2020: p. 1-9.

19. GmbH, Q.u.S. 2020; Available from: https://www.q-s.de/press-and-newsroom/information-about-the-qs-scheme.html.

20. EFSA, *Scientific Opinion on the public health hazards to be covered by inspection of meat (swine).* EFSA Journal, 2011. **9**(10).

21. Nienhaus, F., et al., *Health scores for farmed animals: Screening pig health with register data from public and private databases.* PLoS One, 2020. **15**(2): p. e0228497.

22. Larsen, A.B., et al., *Vision-based method for tracking meat cuts in slaughterhouses.* Meat Sci, 2014. **96**(1): p. 366-72.

Challenge: African Swine fever (ASF) biosecurity measures

ASF biosecurity good practices on farm and throughout the supply chain as well as National initiatives (supported by producers)

Introduction

The EU PiG project aims to identify successfully on-farm applied good practices regarding specific challenges and share experience-based knowledge among participating member states. This fourth-technical report within the theme “Health Management” deals with the challenge “**African Swine Fever biosecurity measures**”.

The purpose of the present technical report is to provide both an overview of current challenges in preventing African Swine Fever Virus (ASFV) from entering a pig farm and examples of solutions from five good practices implemented by pig producers in Europe. Pig farmers and farm advisors can use this report to learn more about how good practices have been implemented in the farms and what challenges these practices are able to tackle. It should be shown how different practices use different strategies to improve health on farms and their innovative reaction to various problems related to pig production.

African swine fever is a current major challenge for pig health and pork industry worldwide. The entry of the virus into a country brings about severe economic consequences due to restrictions in pork exports and due to strict eradication control policies. The latter require the culling of infected herds by using massive depopulation methods, which often have implications on animal welfare. In absence of treatment and vaccine, prevention by implementing biosecurity measure is, by now, the only available tool to combat this ongoing epidemic. By shedding light on this issue, potential gaps in knowledge should be detected which may eventually lead to better understanding what is needed in the future to improve productivity and health management in the swine industry.

1. The Background to the Challenge

In 2007, a high virulent strain of ASFV genotype II was introduced in Georgia and spread first from the Caucasus region to the adjacent Belarus and Ukraine and then to the Baltic region and Poland [1, 2]. In 2017 the virus reached other eastern European countries: Moldova, Czech Republic and Romania.

African Swine Fever (ASF) is a viral disease that affects domestic pigs, wild boar and feral pigs. Being a transboundary animal disease subjected to an eradication plan, the introduction of ASF in a country brings severe socio-economic consequences, affecting international trade of animals and animal products. In 2018, the virus reached China and started its rapid spread through Asia. The massive outbreak in the Asiatic region brought about an increase in the price of pig meat with advantages for European pork exporters like Denmark [3] and Spain [4]. Considering the economic threat that the entry of ASF poses to pig producers, European countries are highly interested in finding effective measures to prevent the spreading of the disease and hold their ASF-free status. Indeed, in the absence of treatment and vaccination, the implementation of strict biosecurity measures, both on farm and at national level, represents the only available tool to protect conventional herds from becoming infected.

The epidemiology of the virus is complex. Wild boars are susceptible to ASF infection and can transmit it to domestic pigs, thus playing an important epidemiological role in the maintenance of the disease cycle [5]. In Eastern European countries, 90% of outbreaks have occurred in wild boars. Up to now, several interconnected epidemiological cycles have been identified: sylvatic, domestic, tick-pig cycle [6], and recently an additional epidemiological pattern, the wild boar-habitat cycle, has been described [7]. The latter is characterized by both direct transmission through contact among infected wild boar and indirect transmission through contact with carcasses in the habitat or through sharing common food points. Recently, a study reported the presence of cannibalistic behaviour in wild boar in Czech Republic during the winter season [8]. Thus, removal of the carcasses is essential to reduce virus transmission in the infected areas and the viral detection in the carcasses can help to follow ASF geographical spread. The continuous presence of the virus in the affected wild boar population represents a serious challenge for the pig production sector as well as the wildlife management sector [5]. All conventional pig herds are susceptible to the virus infection and are thus in danger. However, backyard farms with outdoor systems are more at risk, due to high exposure of the pigs to wild boar contact.

To tackle ASF, it is necessary to act on two frontlines. On one side, the effort should aim to prevent the virus from entering the country through infected wild boars or illegal import of contaminated pork products. On the other side, as the disease status of the whole wild boar population is difficult to detect, preventive measures are required to impair the spillover from the sylvatic cycle onto the domestic one. The implementation of biosecurity measures is currently the only way to overcome this challenge.

2. Addressing the Challenge

The aim of this section is to point out different strategies for enhancing biosecurity measures to prevent ASFV from entering a country and from further spreading among pig farms.

For ASF-free countries, external biosecurity strategies at the national level are usually put in place to prevent the virus from entering the country via people, import of contaminated pork products or wild boar movements. However, once the disease has found its way into a new country or region, and especially when it enters the domestic swine production, the focus shifts towards bio-exclusion at farm level [9]. Anyway, the efforts should always run in parallel, on farm and at national level, since it could take time from the moment the first wild boar gets infected until it is detected. To evaluate which biosecurity measures could be effective in reducing the risk of ASF entering a country is necessary to first identify the risk factors for ASF spread across the countries.

Experts identified five biosecurity priorities for countries with high risk of virus exposure [9]. These are transportation, people, feed, biosecurity audits and mortality management.

(1) External trucks and vehicles represent a major source of pathogens that can enter a farm. Therefore, control of transportation routes and load-outs as well as installation of drying systems and truck washes to ensure truck disinfection could minimize the unavoidable risk associated with animal movements [10]. Anthropogenic factors seem to play an important role in facilitating the long-distance spread of ASFV from the domestic cycle to the wild boar-cycle and vice versa [5, 7].

(2) Important factors causing ASFV introduction in new areas and crossing international borders are uncontrolled movement of infected animals and their illegal trade [11]. This also includes movements of people carrying pork products from infected countries and wild boars getting infected by eating contaminated leftovers from truck drivers, hunters or people visiting the forest. Humans can facilitate the long-distance spread of the virus, initiating new isolated cluster of infection in areas that are far from the known outbreaks. Consequently, measures to reduce these risks should aim to sensitize the general public using awareness campaigns and to intensify both land and air border controls. Additionally, to lower the risk at the farm level, it is important to provide biosecurity trainings to farm workers and make them aware of the importance of avoiding activities that could put them in proximity to wild boars, such as picking mushrooms or hunting, and not bringing pork meat inside the farm [5].

(3) Another potential vector of the virus is represented by feed and feed ingredients imported from infected countries [12]. Recent research confirmed the capability of the virus to survive transoceanic shipping [13]. Preventive holding of feed-stuffs in storage prior to feed manufacturing, avoiding high-risk ingredients (e.g. rice hulls and corn cobs) from high-risk countries such as China, improving the overall ingredient traceability and source verification are all valid strategies that can minimize this specific risk [14].
(4) Farm biosecurity is fundamental in combating ASFV spread. Biosecurity audits using both internal and external third-party auditors can help in maintaining a high biosecurity standard [15].
(5) ASFV can survive for long time in buried pig carcasses [16]. Thus, the implementation of efficient carcass disposal of both domestic pigs and wild boars can reduce the risk of further spread through fomites, vectors and direct contact.

ASF is a transboundary animal disease with high impact on the pig sector which could lead to potential adverse effects on food security. The national economic impact from a hypothetical African swine fever (ASF) incursion has been estimated to be up to $2.03 billion over five years in Australia [17] and up to $50 billion over 10 years in US [18]. In Europe, the significance of the impacts depends on the country affected as well as the trade responses. An outbreak in Germany, for example, would result in up to €13 billion losses for all Europe [19].

Projects like ASFORCE (Targeted Research Effort on African swine fever), GARA (Global African Swine Fever Research Alliance) and the ASF-STOP COST action (https://www.asf-stop.com/) share the common goal of stopping further spread of ASF across European countries and globally. This effort is directed towards a better understanding of the epidemiology of ASF, studying and controlling the spread of ASF in the wild boar population and supporting the development of novel diagnostics and a vaccine. Importantly, the European Commission developed a document named “Strategic approach to the management of African Swine Fever for the EU” with the intent of harmonising the response against ASF across Member States [20].

3. EU PiG Best Practice

In order to identify the top five best practices across all the EU PiG regions a series of criteria has been used, which are able to measure the effectiveness of the collected practices to match the specific challenge.

The following set of criteria have been scored for each practice.

- **Excellence/Technical Quality**
    - Clarity of the practice being proposed;
    - Soundness of the concept;
    - Knowledge exchange potential from the proposed practice;
    - Scientific and/or technical evidence supporting the proposed practice.

- **Impact**
    - The extent to which the practice addresses the challenges pointed out by the R-Pigs Groups;
    - Clear/obvious benefits/relevance to the industry;
    - Impact on cost of production on farm and/or provide added value to the farming business or economy;
    - The extent to which the proposed practice would result in enhanced technical expertise within the industry e.g. commercial exploitation, generation of new skills and/or attracting new entrants in to the industry;

- **Exploitation/Probability of Success**
    - The relevance of the practice to each MS or pig producing region/system;
    - Timeframes for uptake and realisation of benefits from implementation of the proposed practice are reasonable;
    - The extent to which there are clear opportunities for the industry to implement the practice/innovation;
    - Degree of development/adaptation of the practice to production systems of more than one Member State

- **Innovation**
    - Evaluation of innovation (novelty) with the good practice
    - Level of innovation according to the Technology Readiness Level (TRL)

Scores had to be in the range of 0-5 (to the nearest full number). When an evaluator identified significant shortcomings, this was reflected by a lower score for the criterion concerned. The guidelines for scoring are shown below (no half scores could be used).

0	The practice cannot be assessed due to missing or incomplete information.
1 – Poor	The practice is inadequately described, or there are serious inherent weaknesses.
2 – Fair	The practice broadly addresses the criterion, but there are significant weaknesses.
3 – Good	The practice addresses the criterion well, but a number of shortcomings are present.
4 – Very Good	The practice addresses the criterion very well, but a small number of shortcomings are present.

5 – Excellent	The practice successfully addresses all relevant aspects of the criterion. Any shortcomings are minor.

The selection of the top five best practices followed the procedure described below:

1. Members of the thematic group (TG) were asked to score all submitted best practices according to the defined guidelines and sent their scoring sheets to the TG leader.
2. In addition to the scores, TG members provided brief comments indicating weak points or particular strengths of submitted best practices.
3. A conference call was used to discuss the scoring results and select the top 5 best practices. During this call, the top 10 best practices were discussed based on the ranking submitted by thematic group members. The discussion of the top ranked best practices was started from the lowest rank, i.e. best practice with the highest average score, to rank number 10. A selection of the top 5 best practices was made during the call.
4. A summary of all discussions was sent out after the call to review the decision of the selected five best practices by thematic group members.

4. Results and Discussion

4.1. Validation of the top five best practices

The following top 5 best practices within the challenge of “African swine fever (ASF) biosecurity measures” have been selected by the thematic group:

Title of best practice	Country
DrySist: Truck dry disinfection	Spain
Mortality management: in situ incineration	Spain
National TV Programme to highlight risk of ASF entering Ireland	Ireland
How to protect outdoor pigs against contact with wild boars	The Netherlands
Wildlife cages and collaboration with hunters	The Netherlands

DrySist: Truck dry disinfection - Spain

Truck movements represent one of the major risks of disease entry into a pig farm. Every single transfer of living animals or carcasses among farms with different health statuses poses a contamination risk. Trucks are the largest and sometimes the dirtiest fomite that can enter a pig farm [21]. Thus, in the process of lowering these risks, the adoption of adequate biosecurity protocols for barn workers and truck drivers together with an effective decontamination of the vehicle become critical [10]. Another important factor is the application of a proper traffic flow that aims at avoiding cross contamination between external and internal animal movements. Additionally, the implementation of fencing and gates to avoid entry of external feed trucks inside the perimeter of the farm zone is also recommended [21].

This best practice describes the use of a Thermo Assisted Drying and Decontamination (TADD) system, called DrySist®, for truck disinfection.

The system has been developed by Techtrans System SL (OPPgroup) and then implemented by Piensos Costa S.A. (integrated company) to disinfect trucks for animal transport. The disinfection is performed in 3 different truck´s compartments: trailer, wheels and chassis, and cabin. The process takes place inside an expandable tunnel: the cabin of the truck is manually disinfected following cleaning and disinfection protocol; the lower part of the truck is disinfected from the beginning of the process to produce a high penetration effect. The system is connected to the truck and pumps hot air into the container until it reaches 75ºC for 15 minutes. The whole process takes about 30 minutes and is electronically certified. The certificate can be received remotely in real time. The system can run either with diesel and electricity or propane and electricity. The system does not need the 3 resources running in parallel but only 2 of them (diesel/propane and electricity). The use of propane or diesel depends on the availability of these sources and its prices. The energy consumumption of the system is for electricity, 8-10kW/h, for diesel 30L/h, and for propane, 37Kg/h. It has to be noted that the individual farmers do not buy the disinfection plant. The integrated company or the cooperative does. The disinfection cost for one truck (loading 210 fattening pigs) is 100 euros and the installation of the plant costs around 156 000 euros.

Thematic group members selected this practice and found that it successfully met all requirements (technical quality, impact, probability of success and innovation).

Specifically, the following **benefits** were highlighted:

1. It acts on one of the major sources of pathogens’ entry into a farm.
2. It is electronically certified and once the disinfection is completed the certificate is sent remotely in real time.
3. It´s timesaving: the whole process takes 30 minutes.
4. It´s an alternative solution to the currently used chemical truck disinfection. The decontamination is done in a sustainable way, without the use of any chemicals.

Cons:

1. The installation of the system is rather expensive and only purchasable by integrated companies or cooperatives. Therefore, the implementation of the system in other countries depends also on the predominant type of pig production in that specific country. In Spain, most of the pig production is vertically integrated, while in Austria most of the pig producers are individual farmers.
2. Validation of the system is difficult since experiments with ASFV imply the use of a BLS3 facility. The truck would need to undergo contamination with ASF and thus enter a BSL3 facility, which is usually not equipped to work with huge objects as trucks.

Concerning the validation of the system, the company commented that it can be done by reviewing of the thermal resistance parameters of the viruses and associating them with the applied heat treatment of the DrySist. ASF virus is known to be highly resistant to low temperatures but it is heat inactivated by 56°C/70 minutes; 60°C/ 20 minutes. Thermal maps inside the trucks are created to elucidate the distribution of the temperature in the different sections of the truck, and in particular, to identify the coldest zones (critical for any heat process validation). If these coldest zones achieve the minimum temperature/time needed to inactivate ASFV, it can be assured that the whole truck treatment was successful and the virus, if present, was eliminated. The thermal processes are carried out, under industrial real conditions, in an industrial warehouse of the company Techtrans System SL where the forced hot air system is installed to evaluate its potential implementation in pig transport trucks, provided by different transport companies.

Mortality management: in situ incineration - Spain

Mortality management represents one of the major risks for ASF introduction into a farm. The first pigs dying in an outbreak will most likely die without a diagnosis of ASF. Those carcasses will be managed by normal processes, thus putting other farms at risk of being contaminated through the rendering truck [22]. Carcass disposal options include offsite landfill, incineration or rendering, as well as onsite composting, burial or burning [23]. Timely disposal is also important: onsite accumulation of carcasses prior disposal can attract flies, which can facilitate the spread of pathogens. Safe management of the carcass is not only a biosecurity but also an environmental issue as liquids may leach to groundwater during burial and burning can produce harmful air emissions. Among the onsite specific disposal options, composting seems to be the better strategy in terms of environmental sustainability and biosecurity [23]. Nevertheless, composting requires the fulfilment of several conditions such as adequate space to build the composting pile and sufficient distance to groundwater or water sources. Generally composting and other onsite disposal techniques are more appropriate for small and medium-scale livestock farms. The management of large amount of pig carcasses would likely require offsite techniques like incineration or rendering.

On-farm systems offer a higher biosecurity as mortality collection trucks do not enter the farm nor the farm trucks risk to get contaminated when delivering carcasses to the collection site or to the rendering plant [24]. Thus, the use of an on-site incinerator could represent a valid option for onsite carcass disposal for large-scale farms.

This best practice describes the use of an on-farm incinerator distributed by Addfield TB. This system has a capacity of 1,300kg and works with gas, 4 times a week. This system was implemented to avoid the transportation of the dead animals from one farm to the other and avoid the storage of the corpses inside the farm. The incinerator consists of a primary chamber with a multi-layered refractory lining using fire and insulation bricks to improve thermal efficiency and a secondary chamber. Importantly, a specially designed control panel can be used to manually customize incinerator parameters. Loading can be manual or mechanically through digger or hydraulic bin tipper. To be loaded no more than once per day prior to operation. The incineration process will reduce the waste to approximately 3% of volume. The ash should be removed before the following waste is loaded to ensure optimum burn rates (https://addfield.com/wp-content/uploads/2016/09/Addfield-TB-Agricultural-Incinerator-Datasheet.pdf).

The main benefits listed by the company are: 100% vertical biosecurity as the incineration process eliminates all contamination vectors; more autonomy and cost reduction as there is no need to take out an insurance, and inorganic waste is produced, which can be used as an inorganic fertilizer. The company reports also an economical benefit linked to the autonomy of mortality management: the removal of dead pigs costs 0.17-0.34 euros/kg while the incineration cost is about 0.05-0.087 euros/kg. The system was implemented at the farm in 4 months. The initial investment is around €70,000 for a product that has a lifespan of 30 years. The main running cost is due to gas consumption.

Thematic group members selected this practice and found that it met all requirements (technical quality, impact, probability of success and innovation). All thematic group members agreed on the importance of on-farm removing of dead pigs to avoid the risk of truck-related contamination.

Specifically, the following testimonials regarding **benefits** were discussed among the group of experts evaluating the good practices:

1. It allows timely removal of carcasses avoiding the storage of carcasses, which can attract potential pathogen carriers like flies and rodents
2. The practice covers one of the major challenges during an ASF outbreak.
3. It allows on-farm disposal of carcasses, thus eliminating the risk of external contamination. In case of an outbreak of ASF, culling and disposal can be performed on site, reducing the risk of spreading ASF to other farms.

Some potential **drawbacks** in the use of this system have been discussed:

1. COSTS: It´s relatively expensive (initial investment: €70,000) and the application of this practice is mostly feasible for big farms, which can guarantee a fast return of investment. Moreover, even though in the description of the practice the gas consumption is stated to be the main running cost, the amount is not specified. However, the company claims a 40% reduction in fuel consumption compared to alternative solutions, by using a multi layered brick-based refractory. Maintenance costs were missing in the description too.
2. IMPLEMENTATION DEPENDS ON THE SIZE OF THE FARM: The incinerator has a capacity of 1,300 kg, which corresponds to 13 pigs per day, when considering an average weight of 100kg/pig. Giving that the system can be used only once per day, a farm with 2000 pigs would need around 150 days to complete the stamping out, while a farm with 800 pigs would need around 60 days. Therefore, the size of the farm is an important parameter to consider for this kind of investment.

Incinerators are normally responsible for airborne emissions such as nitrogen oxide (NOx), carbon monoxide (CO), sulphur dioxide (SO2), particulate matter, metal compounds, organic compounds and PCDD/PCDF [25]. The presence of air pollution control equipment, such as secondary combustion chambers, afterburners and filtration, is fundamental to minimize the environmental impact of this system.

National TV Programme to highlight risk of ASF entering Ireland - Ireland

Prevention of ASFV entry into countries free of the disease depends on implementation of appropriate import policies and biosecurity measures, ensuring that neither infected live pigs nor pork products are introduced into areas free of ASF [26]. In countries like Ireland, where the geographical situation makes it difficult for wild boars to cross the borders, the main risk factor is represented by human behaviours. Therefore, the general public needs to be informed on the threat that ASF represents and what they can do to prevent its entry into a country. Measures should focus on implementing policies against illegal import of live pigs and pork products from affected countries and ensuring proper disposal of waste food from aircraft, ships and vehicles coming from affected countries. The virus indeed can survive for up to 18, 60, and 83 days in cured salami, pork belly and loin, respectively [27]. ASFV´s viability increases with low temperature: in meat stored at 4-8°C the virus can be detected over 84-to 155-day periods and in frozen meat it may remain infectious for up to 1,000 days [28].

This practice described a national TV program, which aimed at making the Irish population aware of the risk of ASFV entering Ireland. Teagasc Pig Development Department suggested that the TV show, Ear to the Ground, would run a programme to highlight the risk of ASF entering Ireland. Teagasc discussed the topic with the TV show research staff, gave background info and suggested farms for interview. The presenter Darragh Mc Cullogh and the TV crew went to visit the McAuliffe´s pig farms in Castleisland, Ireland (http://www.mainevalleypost.com/2020/01/09/castleisland-pig-farm-on-ear-to-the-groundtonight/). In the course of the programme, viewers were reminded that anyone who owns a pig, even a pet pig, needs to have a Pig Herd Number with the Department of Agriculture, Food and the Marine (DAFM) and that it is illegal to feed pig swill and kitchen scraps to farm animals. The show also visited Dublin airport to interview DAFM staff and see the sniffer dog in action (https://www.irishexaminer.com/breakingnews/ireland/josie-helping-to-save-nations-bacon-by-sniffing-out-pigmeat-at-airport-974361.html). The TV show has a weekly viewership of more than 400,000 people.

All the thematic group agreed on the importance of raising awareness among the general public in order to minimize the risk of ASFV entering Ireland through importing contaminated local pork products.

Thematic group members selected this practice and found that it sufficiently met most of requirements (technical quality, impact, probability of success and innovation).

Specifically, the following **benefits** were pinpointed:

1. INNOVATION. This is the only practice that has been submitted which addresses the importance of the general public in the epidemiology of this disease. It increases awareness, especially amongst non-farming community, of the risks of introducing ASF into Ireland.
2. IMPACT. The TV show has a weekly viewership of more than 400,000 people. This is around 10% of the total Irish population, which is a quite decent coverage.

Cons:

1. The practice is not implemented on a farm. However, it aims to protect pig farmers on a broader scale.

ASF prevention has to be implemented on-farm and outside the farm. The general public can play an important epidemiological role. The use of a national TV program can give visibility to this issue, but the target audience could be broadened by disseminating the videos through social media, creating podcasts and using radio channels.

How to protect outdoor pigs against contact with wild boars – The Netherlands

Wild boars are susceptible to ASF infection and can become a reservoir for the virus. ASF virus is extremely stable in the environment, with an increased resilience at low temperature. Once the virus enters a wild boar population, several factors can contribute to its perpetuation and transmission among wild boars: contact with carcasses of infected animals, direct or indirect contact with excretions at common feeding points, feeding on contaminated pork meat dropped by humans and hunting policies [5].Food availability is one of the main drivers of wild boar movements and reproduction[29]. To minimize the risk of ASF entering a pig farm through contact with an infected wild boar, we can act on two frontlines: reduce transmission of ASF within the wild boar population and prevent contact between domestic pigs and wild boars. Obviously, pigs kept outdoors are more exposed to this risk than those kept indoors. In the EU, the rearing of pigs outdoors is banned in ASF affected countries, while in the most of ASF-free countries the outdoor production is regulated at the national level with a defined set of measures to reduce probability of wild boars coming too close to outdoor pigs [30].

This practice describes a combination of measures aiming to avoid interaction between wild boars and pigs kept outdoor. This systematic research project includes: double fencing and electric fencing, nocturnal and diurnal cameras to control presence of wild boars in the proximity of the farm and against feeding by visitors, agreements with hunters to locate and hunt wild boar in the nearby region, use of a wild life cage, extra housing in case of threat/appearance of wild boar, and general surveillance. This research is conducted by the farmer, the HAS (hunting association) and the government. Government, animal welfare organizations and consumer groups are interested in nature-inclusive production. The research is still ongoing. The first results are promising.

Thematic group members selected this practice and found that it sufficiently met most of requirements (technical quality, impact, probability of success and innovation).

Pros:

1. This systematic approach is innovative, as it aims to tackle the problem from different angles.
2. It implies a close collaboration between farmers, hunters and government.
3. It targets one of the major challenges in the fight against ASFV entry in outdoor pig production.

Cons:

1. It´s not a finished project. The research is still ongoing, and the results are stated as promising, but no further information is given.
2. It lacks information about the costs of putting in place all these measures, which are unlikely to be negligible.
3. Lack of information about the hunting strategies and the type of cages that have been used. Wild boars are intelligent and learn quickly how to identify a trap and avoid it.

Wildlife cages and collaboration with hunters – The Netherlands

This practice is similar to the one discussed above, i.e. “How to protect outdoor pigs against contact with wild boars”, but is mainly focused on the use of wildlife cages as tool to protect domestic pigs from coming to contact with wild boars. Importantly, trapping was presented as valid alternative method of eradicating Classical Swine Fever from an area in Bulgaria where hunting and vaccination were not effective or not recommended [31]. More precisely, Alexandrov et al. reported a harvest of 79% of the local wild boar population using wooden box traps with wire fencing and maize baiting in an area near the river Danube in north-eastern Bulgaria [31].

The practice has been directly implemented by a farmer, Toon. In 2008 he noticed the presence of wild boars in the proximity of his farm. Thus, he made contact with government officials, hunters and nature associations to find a solution to this problem. Altogether they decided to use wildlife cages to capture wild boars. The first cage costs € 300. Two cages became a mobile cage of € 500. The newest model costs € 850, and can be expanded with a new system. This system costs € 3.500. If there is an animal within a specific area around the cage, the farmer gets a signal. He can watch live images via camera and drop the cage if necessary. In one year, seventy animals were caught by using these cages. To improve the system, bigger cages are required.

The success of the project attracted almost all the farmers of the region and Toon started the foundation "Land users Leenderbos and surroundings".

Thematic group members agreed on the relevance of this practice to the challenge and thus included it in the top 5 list.

Pros:

1. Tangible results are provided in the description of the practice. This could motivate the farmers to implement this practice in their farms.
2. The practice is an example of a farmer initiative that resulted in a foundation of farmers, hunters, governments and nature associations. Collaboration between different parties is fundamental in the management of wild boar population.

Cons:

1. Wild boars learn quickly how to avoid traps.
2. Lack of information on the wildlife cages and the trapping strategy. Are these cages located always at the same place or are they moved? What happens once the wild boar has been caught? If the animal is killed within the cage, then contaminated blood could drop into the soil and become a source of further ASF transmission.

4.2. Cost and benefit analysis of the EU PiG Ambassador

The best practice "**DrySist: truck dry disinfection**" from Spain was chosen as EU PiG ambassador 2020 for the challenge of "African Swine Fever biosecurity measures". This best practice foresees the implementation of a truck thermo-assisted disinfection system called DrySist. The system is connected to the truck and pumps hot air into the container until it reaches 75ºC for 15 minutes. The whole process takes about 30 minutes and is electronically certified. The certificate can be received remotely in real time.

Costs (declared by the company): The disinfection cost for one truck (loading 210 fattening pigs) is €100 and the installation of the plant costs around €156 000. The system can run either with diesel and electricity or propane and electricity. The energy consumption of the system is 8-10kW/h for electricity, 30L/h for diesel and 37Kg/h for propane.

Benefits (declared by the company): Pig farms that use this truck system experience a higher farm productivity through less diseases, lower mortality rates and a reduction of veterinary and medicine costs. Moreover, an improvement of the meat quality can be reached. An investment on innovative biosecurity systems, which reduces the use of water and time spent by personnel, is reducing the risk of disease outbreaks.

Costs and benefits of 'DrySist: truck dry disinfection' carried out by CRPA

The costs and benefits of this system have been analysed considering national variations in direct costs (labour and capital) and other factors such as feed, energy, maintenance and bedding material. The INTERPIG model has been used to carry out simulations on production costs and profitability of pig farms in Europe.

In the table below a series of assumptions have been made about the reduction in mortality rates, the reduction in veterinarian and medical costs, and the increase in investments costs (buildings and equipment). The baseline figures are the average pig production costs data for a pig farm with 1,100 sows in Spain in the year 2018.

	Without	With DrySist
Pre-weaning Mortality (%)	13.8%	10%
Rearing Mortality (%)	4.6%	3%
Finishing Mortality (%)	3.8%	2%
Veterinarian and medicine euro/sow/year	104	83
Veterinarian and medicine euro/slaughter pig	1.52	1.22
Building cost, euro/sow place	1,300	1,430
Building cost, euro/rearing pig place	140	154
Building cost, euro/finishing pig place	220	242

Based on these assumptions the production costs of pig farms in 2018 that will use the DrySist system will change as follows:

Cost items	Without	With DrySist
Feed, (Euro/kg live weight)	0.71	0.70
Other variable costs, (Euro/kg live weight)	0.18	0.17
Labour, (Euro/kg live weight)	0.07	0.07
Finance cost, (Euro/kg live weight)	0.10	0.11
Total costs (Euro/kg live weight)	1.06	1.04
Net profit (Euro/kg live weight)	0.02	0.04
Average net profit (Euro/kg live weight)	0.02	0.04

NOTE:

• The category "other variable costs" includes veterinary costs, energy, maintenance and bedding material.

• The category "finance costs" contains costs related to depreciation of buildings and equipment and interests on invested capital and on anticipated expenditures.

The improvement of the mortality rates and the **reduction in veterinarian and medical costs by 10%** can lead to a significant reduction in the production costs. These are only partially offset by an **increase in investment costs** at farm level **by 10%**. At the end **the net profit increases**, essentially because of the decline in the production costs.

The company further declared:

"*At macro level the benefits of the system have been evaluated at a group level of pig farms (about 20,000 sows) using the DrySist system comparing data of 2018-2019:*

1. *A reduction of 3 outbreaks (compared to year 2018) of **PRRS** has been observed which represents €800,000 of losses each phase (according to retrospective studies) phase 1, phase 2 and phase 3 for a total of: €2,400,000.*
2. *A reduction of 4 outbreaks (compared to year 2018) of **porcine epidemic diarrhoea** has been observed which represents (according to retrospective studies) €220,000 each outbreak for a total of €880,000*
3. *An overall reduction in medicine costs related to the **swine dysentery**´s treatment of 200,000 fattening pigs has resulted in a cost reduction of €600.000.*

The total estimated reduction for this group of farms is therefore €3,880,000".

4.3. Expert Analysis

Since the practice was implemented in Spain, an ASF-free country, it is difficult to evaluate the benefit of using the method to prevent the entry of this specific virus. Most of the calculations are based on the benefit obtained from the reduction of other diseases outbreaks (PRRS, PED and swine dysentery).

The pig practice, which implemented this method and was used to calculate the cost-benefit analysis, corresponds to a group of pig farms that are part of an integrated company. This type of business allows the amortization of the investment costs and the generation of net profit, while small-medium farms may have difficulties in reaching similar results.

4.4. Conclusions and advice to industry

If the industry were to adopt this practice, several considerations should be made.

Truck disinfection is a valid tool to minimize the risk of a pathogen´s entry into a farm. Nevertheless, this is a process that cannot stand alone, but needs other strategies to run in parallel. Among others, control of traffic flow inside and outside the farm, e.g. locating the site for the load-in and the one for the load-out in separate locations to avoid cross contamination between the vehicles, and compliance of truck drivers and farm workers to biosecurity protocols needs to be enforced. The producer should also provide proper equipment such as well-designed loading chutes and physical indicators to remind the workers to respect the division between dirty and clean areas [10].

In this regards the DrySist´s company affirms that "each producer implements different biosecurity protocols, depending on their farm situation, in parallel to the truck disinfection. In fact, before installing the disinfection plant, a biosecurity audit is carried out in order to determine the specific needs of each producer. The biosecurity audit is carried out by the disinfection company before the system is installed. The aim of this audit is to find out which is the best location for the disinfection plant installation as well as to study the best truck routes. The information obtained is used by the (disinfection company) technicians to maximize the efficiency of the system in the specific farm and install it in the optimum place. This service (the biosecurity audit) is included within the instalment process and it is done by technicians from the disinfection company.

Moreover, the economic benefit depends on the type of farm where the practice is applied.

5. The Future

The spread of ASF has a global socio-economic impact, hence tackling ASF requires a global effort. Multiple stakeholders share interest on stopping its spread and minimizing the losses. The epidemiology of ASF is strongly influenced by human behaviour and involves the interface across domestic animals, wildlife and environment. Moreover, ASF´s impact on the pig industry could lead to shortage in food supply and increase in meat price. The veterinary sector is not the only player that has interest in controlling this disease. The entry of this virus has consequences on animal welfare (how to perform optimal depopulation that ensures loss of consciousness of the animals and their immediate death as well as operator safety), environment (incorrect carcass disposal can contaminate ground water), and politics (in low-income countries the choice of culling healthy pigs can be challenging). Therefore, the response towards the current emergency requires a One Health approach and coordination between multiple disciplines.

Even though research towards the development of a safe vaccine is progressing [32], no commercially available vaccine exists so far. Thus, biosecurity measures both at national and local level are fundamental in reducing the risk of ASF entering and spreading within a country.

A single biosecurity plan does not fit all farms. Every farm should review the most critical points and design its own tailored plan.

References

1. Gallardo, C., et al., *Genetic variation among African swine fever genotype II viruses, eastern and central Europe.* Emerg Infect Dis, 2014. **20**(9): p. 1544-7.
2. Sanchez-Vizcaino, J.M., L. Mur, and B. Martinez-Lopez, *African swine fever (ASF): five years around Europe.* Vet Microbiol, 2013. **165**(1-2): p. 45-50.
3. Flittner, S. *A massive outbreak of swine-fever in China forces the Danish meat prices up*. 2020, February 7 Available from: https://scandasia.com/a-massive-outbreak-of-swine-fever-in-china-forces-the-danish-meat-prices-up/.
4. van Dooren, K. *Spain allowed to ship more pork to China*. 2020, April 29; Available from: https://www.pigprogress.net/World-of-Pigs1/Articles/2020/4/Spain-allowed-to-ship-more-pork-to-China-576604E/.
5. Guberti, V., Khomenko, S, Masiulis, M and Kerba, S, *African swine fever in wild boar ecology and biosecurity*. 2019, FAO, OIE and EC: Rome, Italy.
6. Costard, S., et al., *Epidemiology of African swine fever virus.* Virus Res, 2013. **173**(1): p. 191-7.
7. Chenais, E., et al., *Identification of Wild Boar-Habitat Epidemiologic Cycle in African Swine Fever Epizootic.* Emerg Infect Dis, 2018. **24**(4): p. 810-812.
8. Cukor, J., et al., *Confirmed cannibalism in wild boar and its possible role in African swine fever transmission.* Transbound Emerg Dis, 2020. **67**(3): p. 1068-1073.
9. García-Mochales, C.K., D; Čepulis; R; Karbowiak, P and Corns, PG. *ASF challenges the industry to prioritize and execute on Biosecurity: field recommendations from experts*. 2019, November 26; Available from: https://www.pig333.com/articles/asf-challenges-the-industry-to-prioritize-and-execute-on-biosecurity_15536/.
10. García-Mochales, C.A. *Biosecurity in load-ins and load-outs. Minimizing the unavoidable risk of animal movement*. 2019, June 25; Available from:

https://www.pig333.com/articles/biosecurity-to-minimize-the-unavoidable-risk-of-animal-movement_15083/.

11. Costard, S., et al., *Introduction of African swine fever into the European Union through illegal importation of pork and pork products.* PLoS One, 2013. **8**(4): p. e61104.

12. Niederwerder, M.C., et al., *Infectious Dose of African Swine Fever Virus When Consumed Naturally in Liquid or Feed.* Emerg Infect Dis, 2019. **25**(5): p. 891-897.

13. Stoian, A.M.M., et al., *Half-Life of African Swine Fever Virus in Shipped Feed.* Emerg Infect Dis, 2019. **25**(12): p. 2261-2263.

14. CPC. *WHAT'S HITCHING A RIDE IN YOUR FEED?* 2020; Available from: info@cpc-ccp.com.

15. Connor, J. *ASF fears prompting broader view of biosecurity*. 2019, June 26; Available from: https://thepigsite.com/news/2019/06/asf-fears-prompting-broader-view-of-biosecurity.

16. Zani, L., et al., *African swine fever virus survival in buried wild boar carcasses.* Transbound Emerg Dis, 2020.

17. ACIL ALLEN CONSULTING, *ANALYSIS OF AFRICAN SWINE FEVER INCURSION IN AUSTRALIA*. 2019, August, AUSTRALIAN PORK LIMITED.

18. Mikesell, S. *New economic study: African swine fever outbreak in the US could cost $50 billion*. 2020, April 3 Available from: https://thepigsite.com/articles/new-economic-study-african-swine-fever-outbreak-in-the-us-could-cost-50-billion.

19. Vuillermet, S., *Economic Impacts of an African Swine Fever (ASF) Introduction in Europe on the Trade Pattern of the Dutch Pork Sector.*, in *Business Economics*. 2019, September, Wageningen University and Research.

20. European Commission, *Strategic approach to the management of African Swine Fever for the EU* 2020.

21. Snider, C.A.G.-M.a.T. *Analyzing and modifying vehicle traffic patterns to improve external biosecurity*. 2019, September 2019; Available from: https://www.pig333.com/articles/analyzing-&-modifying-vehicle-traffic-patterns-to-improve-biosecurity_15314/.

22. Hess, A. *African swine fever: Top 5 biosecurity strategies*. 2020, March 12; Available from: https://www.nationalhogfarmer.com/animal-health/african-swine-fever-top-5-biosecurity-strategies.

23. Flory, M.a.M., L, *Carcass management for small- and medium-scale livestock farms-Practical considerations*, in *FOCUS ON*. 2018, October FAO: Rome, Italy.

24. Morrow, M.a.F., P *Alternative Methods for the Disposal of Swine Carcasses.* Animal Science Facts, 2001, January(Extension Swine Husbandry).

25. UNEP, *Guidelines on best available techniques and provisional guidance on best environmental practices- Destruction of animal carcasses*. 2007, May, Secretariat of the Stockholm Convention on Persistent Organic Pollutants: Gevena, Switzerland.

26. OIE. *African Swine Fever*. Information on acquatic and terrestrial animal diseases 2016, October; Available from: https://www.oie.int/en/animal-health-in-the-world/animal-diseases/african-swine-fever/.

27. Petrini, S., et al., *Survival of African swine fever virus (ASFV) in various traditional Italian dry-cured meat products.* Prev Vet Med, 2019. **162**: p. 126-130.

28. Sihvonen, L.H., *Scientific opinion on African swine fever.* EFSA Journal, 2015. **13**(7): p. 4163.

29. Cellina, S., *Effects of supplemental feeding on the body condition and reproductive state of wild boar Sus scrofa in Luxembourg*. 2008, University of Sussex: Dudelange, Luxembourg.

30. Martinez-Aviles, M., de la Torre, A, Prodanov-Radulovic, J and Bellini S. *Characterising outdoor pig production in Europe*. 2019, November 25; Available from: https://thepigsite.com/articles/characterising-outdoor-pig-production-in-europe.

31. Alexandrov, T., et al., *Trapping as an alternative method of eradicating classical swine fever in a wild boar population in Bulgaria.* Rev Sci Tech, 2011. **30**(3): p. 911-6.

32. Sang, H., et al., *Progress Toward Development of Effective and Safe African Swine Fever Virus Vaccines.* Front Vet Sci, 2020. **7**: p. 84.