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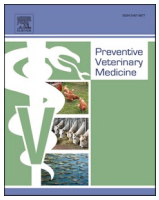

Large heterogeneity in biosecurity legislation in the intensive pig production across Europe

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ABSTRACT

Implementing biosecurity measures in the pig production is crucial to optimize animal health and reduce antimicrobial usage. A legal framework may help to ensure all stakeholders understand the need of biosecurity measures and to implement them correctly. Limited knowledge is available about how implementation of biosecurity measures is regulated in European countries. Therefore, the aim of this study was to identify which biosecurity measures were mandatory by national legislation and/or by pig sector organizations of European countries for the intensive pig production under normal circumstances (i.e. no (threat of) disease outbreaks). A questionnaire including 51 biosecurity measures, 32 on external and 19 on internal, was developed and sent to national country representatives. Twenty-four European countries, of which 18 belonging to the European Union, indicated which biosecurity measures were mandatory by law. Four countries, France, Spain, Italy and Romania had a single national pig-specific biosecurity legislation, while in the other countries multiple legislations had to be consulted to complete the questionnaire. In general, there was a high heterogeneity in the number of measures that were mandatory by law per country. Most biosecurity measures addressed in the national legislation focused on external biosecurity and were measures that can be easily audited when conducting a farm visit such as the presence of a hygiene lock, fencing around the farm and the existence of documentation. A significant ($p < 0.001$) positive correlation was observed between the presence of external and internal biosecurity measures in the legislation. Yet, no significant association was observed between the number of biosecurity measures present in the national legislation and the size of the pig production. Fourteen countries indicated which biosecurity measures were required by pig sector organizations for intensive pig farms. The median number of biosecurity measures mandatory by pig sector organizations but not by law was 13 with a minimum of one measure in Germany and a maximum of 24 in Croatia. Different countries apply different strategies to increase the level of biosecurity. Further research is needed to investigate the impact of the different strategies on the implementation of biosecurity on intensive pig farms in the countries.

1. Introduction

During the last few years, the European pig industry has faced challenges such as African swine fever (ASF) outbreaks (Chenais et al., 2019; European Food Safety Authority (EFSA) et al., 2024). Infections caused by different pathogens occur frequently on pig farms, leading to suffering, reduced welfare and causing major economic losses for the farmer and the pig sector in general (Boeters et al., 2023; Halasa et al., 2016; Niemi, et al., 2008). Such pathogens are transmitted in various ways, either directly through contact with infected domestic or wild animals or indirectly via vectors, semen, humans or contaminated feed, water and fomites by excretions from infected animals (domestic, wild animals or rodents) (Dunowska, 2018; Filippitzi et al., 2018; Makovska et al., 2023). To limit or even prevent the transmission of pathogens, biosecurity measures should be implemented on farms.

Biosecurity can be defined as a set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases to, from and within an animal population (Terrestrial Animal Health Code, 2024). All measures that aim to reduce the risk of pathogens entering or escaping a farm are referred to as external biosecurity measures, while those that aim to reduce the spread of pathogens within a farm are referred to as internal biosecurity measures (Collineau et al., 2017). The perception of the importance of biosecurity and its relationship to animal health has increased in recent years with the emergence and re-emergence of several difficult-to-control diseases such as ASF or porcine epidemic diarrhea. On-farm biosecurity and good farming practices are considered the most effective tool for preventing the introduction of ASF into pig herds (Martínez et al., 2021). In addition, by avoiding pathogen transmission, improved biosecurity can increase productivity and help to reduce the use of antibiotics and improve farm profitability (Alarcón et al., 2021; Collineau et al., 2017; Dhaka et al., 2023).

Today, pig production in Europe is very heterogeneous regarding farm types, biosecurity standards and production levels (Chantziaras et al., 2020; Makovska et al., 2024; Martínez et al., 2021). On commercial, intensive pig farms biosecurity measures are often already in place at higher levels compared to other farm types such as extensive and backyard farms, but even on those commercial farms, breaches in the biosecurity may occur, resulting in disease outbreaks (Bellini et al., 2021). Although good biosecurity has proven its benefit, farmers have several reasons for not implementing biosecurity measures such as: not practically feasible, lack of time, costly, perceived ineffectiveness and simply not willing to (Laanen et al., 2014; Svensson et al., 2019). To accommodate for this, it can be a strategy to enforce the implementation of biosecurity measures through the legislation or by pig sector organizations. At the European Union (EU) level, there is no specific legislation for the implementation of biosecurity measures in pig farm production under normal circumstances (i.e. no (threat of) disease outbreaks). The European Animal Health Law (AHL) states that besides surveillance and traceability, appropriate biosecurity measures should be taken to minimize the risk of the spread of diseases (Regulation (EU) 2016/429). The extent to which the AHL is incorporated into national or regional legislation, specifying biosecurity measures for pig farms, is determined by the member states. However, non-EU countries cannot rely on the AHL and fully depend on the presence of national or regional legislation to enforce the implementation of biosecurity measures on pig farms.

The current knowledge about how biosecurity is regulated and implemented on pig farms in different European countries and how legislation influences the implementation is limited. To investigate the link between both, legislation and implementation, a first step is to map the biosecurity legislations present in the different countries. Therefore, the aim of this study was to identify which prelisted biosecurity measures were addressed in the national legislation of European countries for the intensive pig production in the absence of disease outbreaks. Additionally, the study looked at biosecurity measures mandatory by entities other than law such as pig sector organizations in the different countries.

2. Materials and methods

2.1. Design of the questionnaire

A questionnaire, in the form of an excel document, was created by members from the EU-funded COST Action BETTER (https://better-biosecurity.eu/). During the initial stage of designing the questionnaire a core group of researchers developed a first draft in which external and internal biosecurity measures were selected. This draft was

discussed and reviewed several times with a larger group from the COST Action BETTER consortium members and pilot tested in Spain, Slovenia, and North Macedonia. The final questionnaire listed 51 biosecurity measures considered to be relevant for the intensive pig production and for each measure it was asked whether it was mandatory by law and/or mandatory by industry (pig sector organizations). For the question 'mandatory by law' the three answering options were 'yes', 'yes to some farms', and 'no' while for the question 'mandatory by industry' only two options were possible, namely 'yes' and 'no'. Furthermore, it was possible to write down notes and references for each biosecurity measure. The list included 32 external and 19 internal biosecurity measures further divided into 14 different categories. An overview of the categories and the number of biosecurity measures questioned for each of them is given in Table 1. The final questionnaire with a small glossary can be found in the supplementary materials (Supplementary file 1).

2.2. Data collection and validation

Among the COST Action BETTER consortium members, a call was made to identify one volunteer from each country who could coordinate data collection in his/her country. These volunteers, named country focal points (CFP), cooperated with other members of their country, and contacted key stakeholders or country experts to collect the required information. A total of 38 CFP agreed to participate in this study and were trained through an online meeting to clarify how to complete the survey, and unravel any doubts about the interpretation of the different biosecurity practices. Data were collected between January and August 2023.

To validate the submitted answers, the first author held semi-structured interviews of 15–30 minutes with the individual CFP or a country expert suggested by the CFP. Before the validation meeting, the submitted answers were reviewed to check for missing, conflicting, or unclear answers. If available, the referred legislation, often in the native language, was put in a translator to get a brief overview of the topic. During the validation meeting, the CFP or expert was first asked to shortly outline the structure of the intensive pig production in the country. Next, points of attention in the questionnaire, as identified by the first author, were discussed in detail. If necessary, changes were made and once all answers were clear and both the CFP or expert and the first author agreed, the final dataset for the country was considered validated. Finally, three extra questions were asked which could be answered immediately or afterwards via email as a final validation step; 1) "Is there one specific biosecurity legislation for the pig production in your country?", 2) "Are there other legislations in your country dealing with biosecurity?" and 3) "How many legislations were consulted in order to retrieve the information on biosecurity in your country?".

Table 1
Content of the questionnaire developed to inquire about biosecurity measures in the intensive pig production mandatory by law or by the pig sector organizations in European countries in the absence of disease outbreaks. A total of 51 biosecurity measures were divided into 14 different categories.

	Biosecurity categories	Number of measures in the category
External biosecurity	Farm location and environment	2
	Access and control of visitors	8
	Workers and foreign labor	3
	Purchasing policy – introducing new animals	6
	Purchasing policy – introducing animal products	1
	Introducing equipment	1
	Control of transport vehicles	5
	Manure removal	1
	Control of feed and water	2
	Pest control	2
	Carcass management	1
Internal biosecurity	Cleaning and disinfection	9
	Handling sick animals	2
	Disease management	8
	Total number of measures	**51**

2.3. Data analysis

The presence of national legislation addressing biosecurity measures for the pig production in the absence of disease outbreaks and the presence of biosecurity measures mandatory by pig sector organizations were analyzed descriptively by using RStudio (RStudio Team 2020, RStudio: integrated Development for R, PBS, Boston, MA). The presence of national legislation was evaluated by grouping the countries in two distinct ways. Firstly, to investigate if the status within the EU influenced the presence of national legislation addressing biosecurity measures for the intensive pig production, countries were grouped being EU-member, non-EU-member or EU-candidate (Anonymous). Secondly, to investigate if the size of the pig production in the country influenced the presence of national pig specific biosecurity legislation, the countries were artificially grouped based on the number of pigs in the country in 2023 (Eurostat and data browser, 2023). Based on these numbers the lower (Q1) and upper quartile (Q3) were calculated and the countries with the lowers 25 % of pigs were considered small pig producing countries and the countries with the highest 25 % of pigs as large pig producing countries. Small pig producing countries had less than 0.61 million pigs (Q1), medium pig producing countries between 6.33 and 0.61 million (IQR; interquartile range), and large pig producing countries had more than 6.33 million pigs (Q3). Differences in the presence of national legislation addressing biosecurity measures for the pig production between groups were assessed by performing an ANOVA and Tukey's Honest Significant Difference test using RStudio. An overview of the EU-status of the countries and the number of live pigs in 2023 is given in Supplementary file 2. To compare if external and internal biosecurity measures were addressed in the national legislation at the same level, the percentages of external and internal biosecurity measures present were calculated by dividing the number of external measures in a country by 32 and the number of internal measures by 19 to omit the influence of the non-equal number of measures questioned in both categories. Subsequently, the countries were ranked based on the presence of external and internal biosecurity measures in the legislation and a Spearman Rank correlation test was performed to investigate if the presence of biosecurity measures in both categories were linked to each other at country level. The result was considered significant if $p < 0.05$.

3. Results

3.1. Participating countries and presence of national biosecurity legislation

Data were obtained from 26 European countries, but only in 25 of them validation could be performed. In Ukraine, due to the continuous presence of ASF the last years, the legislation in force on the entire Ukrainian territory was a national ASF-specific legislation, covering all 51 biosecurity measures questioned. Therefore, Ukraine's data were not included in the descriptive and statistical analyses and are not shown in the figures. Before the ASF problem, the national legislation in Ukraine stated veterinary sanitary requirements for pig farms. In this study data from only 24 countries has been included. All 24 countries completed which biosecurity measures were mandatory by law and 14 also indicated which ones were mandatory by pig sector organizations of their countries. Answers were received from 18 countries belonging to the EU, three EU-candidates (Montenegro, North-Macedonia and Serbia), and three non-EU-members (Switzerland, Norway and Kosovo). Medium pig producing countries represented half of the answers, 12 out of 24 (IQR), while large and small ones were represented by six countries each (Q1 and Q3). A map with the countries participating in the study together with their classification regarding pig production is shown in Fig. 1.

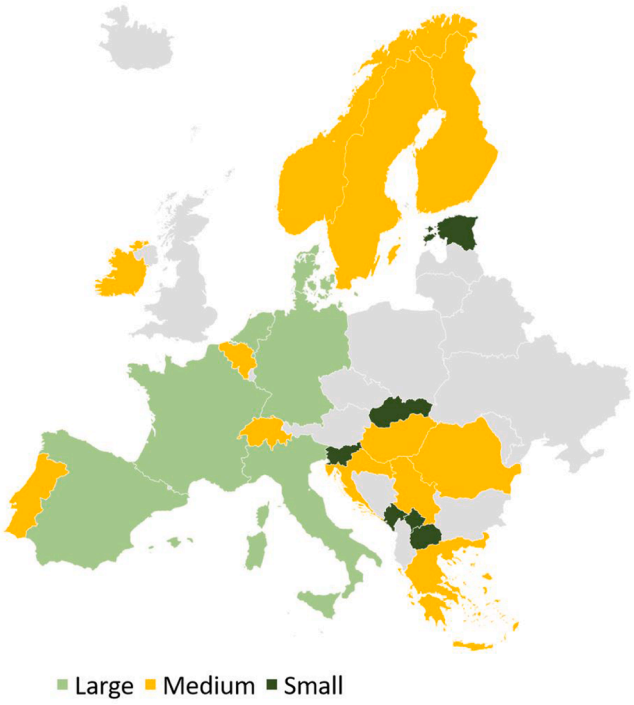

Fig. 1. Data about the presence of national legislation addressing biosecurity measures for the intensive pig production were submitted, validated and included for 24 European countries grouped by the size of the pig production. Grouping was done based on the number of live pigs in the country in 2023 (Eurostat and data browser, 2023). Large pig producing countries: ≥ 6.33 million (Q3); Medium pig producing countries: < 6.33 and > 0.61 million (IQR); Small pig producing countries: ≤ 0.61 million (Q1).

Most of the CFPs and/or country experts had to consult between two and five national legislations to complete the questionnaire. Only in France, Spain, Italy and Romania the general biosecurity requirements for intensive pig farms were present in a single national pig-specific biosecurity legislation, which were in force since 2018, 2020, 2022, and 2023 respectively.

3.2. Content of the national legislation on biosecurity

The number of biosecurity measures included in the national legislation of the different countries are represented in Fig. 2. Results showed that there is a high heterogeneity in the number of mandatory measures by law per country. The countries with the highest number of mandatory measures were Romania (n = 44), Italy (n = 33), France (n = 32), Spain (n = 32), and Slovakia (n = 32) while Ireland (n = 2), Estonia (n = 3) and Finland (n = 4) address the lowest number of biosecurity measures in their national legislation.

Large pig production countries had the highest median number of biosecurity measures addressed in their national legislation, namely 27, whereas in medium and small pig producing countries the median was 17 and 18.5, respectively (Fig. 3A). However, no statistically significant differences were observed between groups with p-values ranging from 0.26 to 0.99. The number of measures was also not related, nor statistically significant, to their membership to the EU, with p-values ranging from 0.85 to 0.98. The median number of biosecurity measures address in their national legislation being 18.5 in the EU-member states, 16 in the EU-candidate countries and 21 in the non-EU-member countries (Fig. 3B).

The percentage of external biosecurity measures present in the national legislation was higher than the percentage of internal biosecurity measures, with a median of 40.6 % (Q1 =31.3 and Q3 =62.5) and 28.9 % (Q1 =26.3 and Q3 =42.1), respectively.

An overview of percentage of external and internal biosecurity measures mandatory by law per country is provided in Fig. 4. In most of the countries, more attention was given to the external biosecurity with only four exceptions: Finland, Switzerland, Slovenia and Kosovo. Furthermore, based on the Spearman Rank Test, there was a significant ($p < 0.001$), positive correlation (R_s value of 0.75) between the ranks of external and internal biosecurity measures (Fig. 5).

External biosecurity measures were more frequently addressed in national legislation (seven out of ten) (Table 2). Twenty-three countries stated that it is forbidden to feed pigs with any kind of food waste, canteen or household leftovers. Infrastructures such as fences, presence of a sick bay or entrance to the farm through a hygiene lock were among the most frequent measures considered in national legislations. Other common measures were related to the existence of documentation such as on vaccination/treatments, certifications on cleaning and disinfection of animal vehicles, herd health plans, rodent control programs, and on farm routines such as providing farm-specific clothing (Table 2).

Measures that were most seldom considered in national legislations were often related to internal biosecurity (eight out of ten) and were associated to management (e.g., separating different age groups, following the all-in/all-out system) and cleaning and disinfection practices (Table 3). A pig-free period for people visiting farms and the minimum distance between farms was only regulated in three and four out of the 24 countries included in this study, respectively (Table 3). The frequency of all questioned biosecurity measures can be found in Supplementary file 3.

3.3. Biosecurity measures mandatory by pig sector organizations

Fourteen countries indicated which biosecurity measures were mandatory by pig sector organizations. In each of them, the sector required compliance to a certain number of biosecurity measures that were not mandatory through legislation (extra-legal biosecurity measures). The median number of extra-legal biosecurity measures requested by the pig sector organizations was 13 with a minimum of one extra-legal biosecurity measure in Germany and a maximum of 24 measures in Croatia (Fig. 6).

Those pig sector organizations that requested compliance to extra-legal biosecurity measures were mostly part of the larger food production chain. Slaughterhouses often required that the offered pigs originate from farms certified under the sector organization. Therefore, 90–100 % of the intensive pig farms present in the countries listed in Fig. 6 were certified under a sector organization and had to comply with the extra-legal biosecurity measures. In Croatia only 50 % of the intensive pig farms were certified under the sector organization for which the CFP provided the required biosecurity measures. Furthermore, in Estonia and Finland the sector organizations mentioned by the CFP only certified breeding farms.

Eight out of the top-ten extra-legal biosecurity measures mandatory by the pig sector organizations belonged to external biosecurity measures (Table 4). In eight countries the sector required a pig-free period for all visitors. Most extra-legal, external measures, focused on the entrance of external persons and purchase of animals. Furthermore, two extra-legal measures required the presence of certain documentation and one measure focused on cleaning and disinfection in the farrowing unit (Table 4).

4. Discussion

Data on biosecurity measures for the intensive pig production mandatory by national legislation in the absence of disease outbreaks or by the pig sector organizations were obtained from a number of countries in Europe via a questionnaire. Results evidenced that different countries have decided to follow different strategies to enhance the implementation of biosecurity measures. In some of them, the implementation is being forced by including a high number of specific

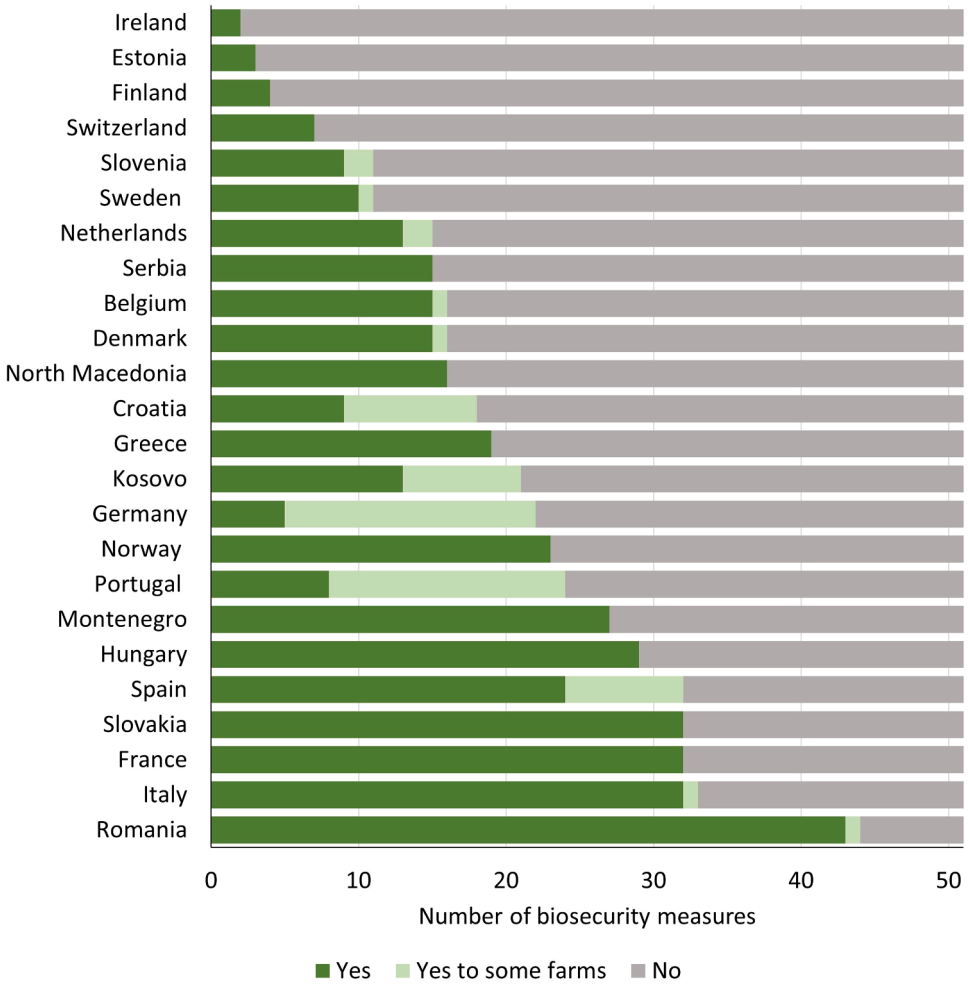

Fig. 2. Number of biosecurity measures (n = 51) mandatory by law for the intensive pig production in the absence of disease outbreaks in 24 European countries. The option "Yes to some farms" referred to a variety of exceptions per country such as diagnostic screening of newly introduced animals mandatory only for certain diseases or the ability of pigs to have outdoor access, among others.

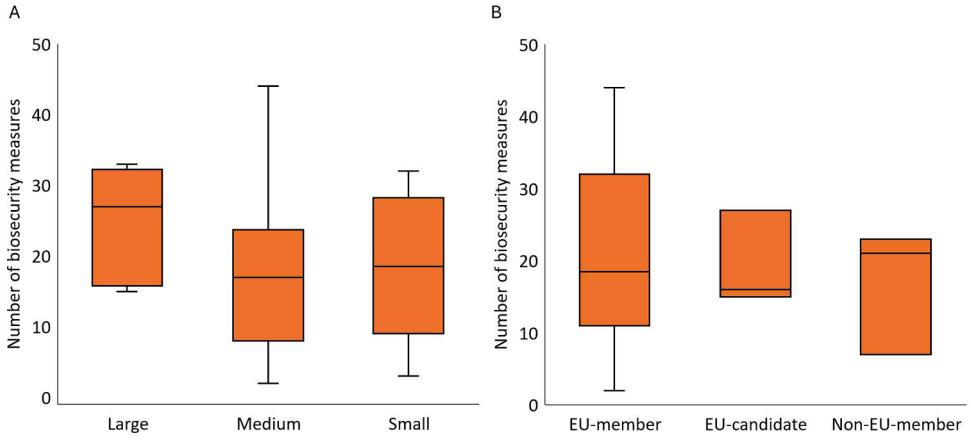

Fig. 3. Number of biosecurity measures (n = 51) mandatory by law for the intensive pig production in the absence of disease outbreaks based on the pig production and EU-status for 24 European countries. Countries were grouped based on **A:** the number of live pigs in 2023 (Eurostat and data browser, 2023). Large pig producing countries: ≥ 6.33 million (Q1); Medium pig producing countries: < 6.33 and > 0.61 million (IQR); Small pig producing countries: ≤ 0.61 million (Q3). **B:** their status in relation to their membership to the EU (Anonymous). No statistically significant differences were observed. Overview of the EU-status and the number of live pigs is given in Supplementary file 2.

biosecurity measures in national legislations, in others it is driven mainly by pig sector organizations, in others by both, or by other combinations not captured in this study. The strategy followed by each country might be influenced by a variety of factors such as cultural habits, economy, focus on export or import, or the structure of the pig industry (e.g. integration), among others.

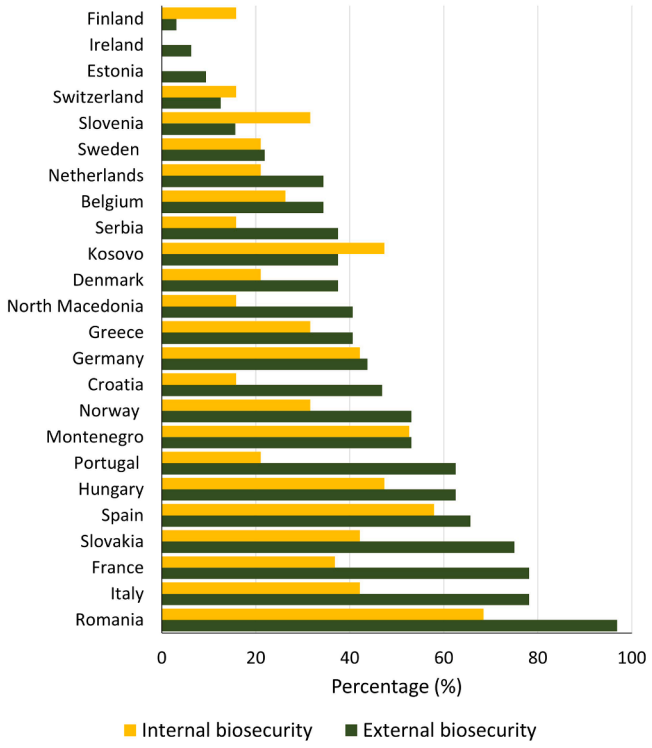

Fig. 4. Percentages of external and internal biosecurity measures mandatory by law for the intensive pig production in the absence of disease outbreaks for 24 European countries. The questionnaire developed to collect the data consisted of 32 external biosecurity measures and 19 internal biosecurity measures.

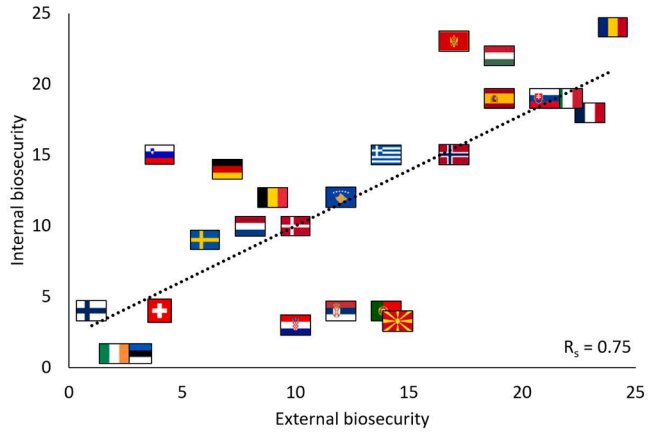

Fig. 5. Spearman Rank Correlation investigating the interaction between internal and external biosecurity measures present in the national legislation for the intensive pig production of 24 European countries in the absence of disease outbreaks. A significant ($p < 0.001$) positive correlation between the ranks of external and internal biosecurity measures was found. Country names with flags are provided in Supplementary file 2.

In relation to pig production, the study's findings indicated that the number of measures included in the national legislations per country did not depend on the size of the pig production in the country or EU membership status. However, three out of four countries with a single national pig-specific biosecurity legislation belonged to the large pig producing group. Due to the size of the pig production, the importance of export and the potential economic consequences in case of disease outbreaks, these large pig producing countries might have chosen to adopt more biosecurity measures in their national legislations. In addition to requiring biosecurity measures through national legislation,

Table 2
Top-10 biosecurity measures most frequently addressed in the national legislation for the intensive pig production in the absence of disease outbreaks in 24 European countries. In total, 51 biosecurity measures were questioned.

Category	Measure questioned	Frequency
External	It is forbidden to feed animals with any kind of food waste, canteen or household leftovers	23
Internal	Vaccination and treatment schemes are documented and controlled by e.g. veterinary services, industry	20
External	All transport vehicles must have official documentation certifying that they have been cleaned and disinfected	18
Internal	There is a separate pen for sick animals that prevents direct contact with healthy animals	18
Internal	A specific herd health plan is present and controlled by e.g. veterinary services, industry	18
External	Fencing around the pig farm is completed	17
External	Entrance through the farm is only possible through the hygiene lock	16
External	Farm specific clothing and boots are available for every employee	16
External	The health criteria for the boar station from where the sperm is purchased are defined	16
External	A rodent control program is present and documented on the farm	16

Frequency: number of countries stating that the biosecurity measures were mandatory by national legislation.

Table 3
Bottom-10 biosecurity measures that are least commonly addressed in the national legislation for the intensive pig production in the absence of disease outbreaks in 24 European countries. In total, 51 biosecurity measures were questioned.

Category	Measure questioned	Frequency
Internal	After cleaning and disinfection there is a suitable period of sanitary break in the nursery unit, before new animals enter the stable	4
External	A minimum distance to a neighboring farm is required	4
Internal	There is an all-in/all-out system in the fattening unit	3
Internal	After cleaning and disinfection there is a suitable period of sanitary break in the farrowing unit, before new animals enter the stable	3
External	A pig-free period is requested for all visitors	3
Internal	There is an all-in/all-out system is the nursery unit	2
Internal	Separate equipment, needles, gloves, etc. are used when handling animals in the sickbay	2
Internal	Animals of different ages are housed in different rooms in the fattening unit	2
Internal	Farm work and visits are performed according to predefined working lines	1
Internal	Animals of different ages are housed in different rooms in the nursery unit	1

Frequency: number of countries stating that the biosecurity measures were mandatory by national legislation.

measures can be made mandatory by the pig sector organizations, for example as a requirement to obtain and maintain certification under a quality label. As an example, the national legislation of Ireland required only two out of 51 biosecurity measures questioned while Bord Bia, the Irish Food Board certifying 99 % of the Irish pig producers, required a minimum of 12 additional biosecurity measures. Moreover the level of biosecurity of every pig farm in Ireland is annually assessed through a standardized biosecurity assessment and quantification tool. At least 20 extra-legal biosecurity measures were also requested by a pig sector organization in Finland, Serbia, Sweden and Croatia. Unfortunately, in this study we did not have access to biosecurity compliance data of all the countries. Therefore, it was not possible to assess which strategy (driven by legislation *versus* driven by sector organizations) might have a higher impact on the level of biosecurity implementation. Further studies collecting and analyzing biosecurity compliance data in different European countries would be of interest. Based upon our current

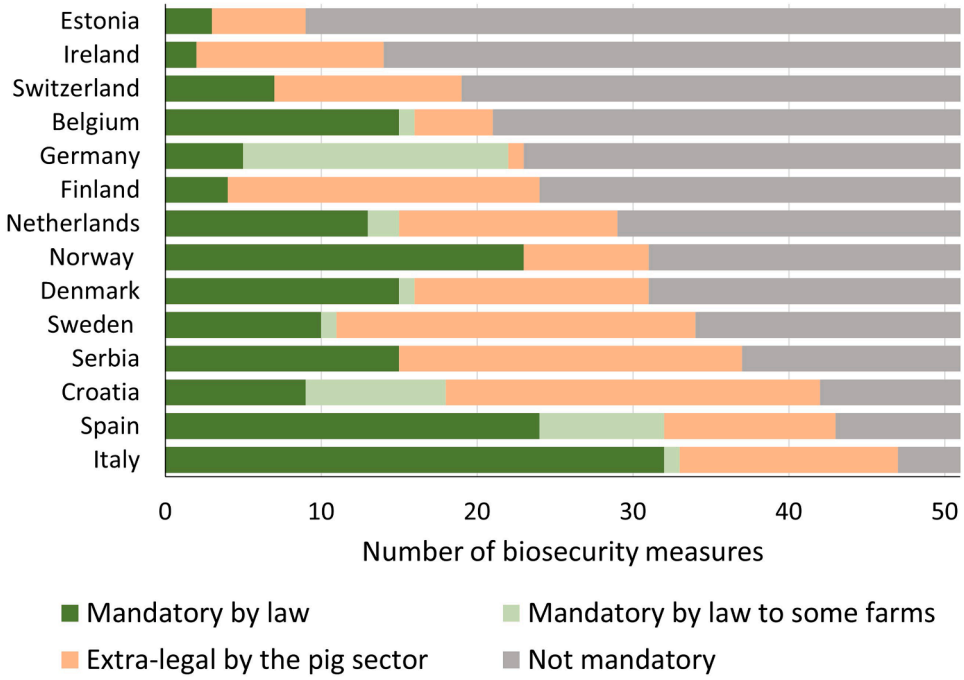

Fig. 6. Number of biosecurity measures (n = 51) mandatory by law or by the pig sector organizations in 14 European countries. The option "Yes to some farms" referred to a variety of exceptions per country such as diagnostic screening of newly introduced animals mandatory only for certain diseases or the ability of pigs to have outdoor access, among others. Extra-legal by the pig sector: biosecurity measures that were not mandatory through national legislation but required by the pig sector organizations.

Table 4
Top-10 extra-legal biosecurity measures mandatory by pig sector organizations but not by national legislation in the 14 European countries that provided data about biosecurity measures mandatory by the pig industry in their country.

Category	Measure questioned	Frequency
External	A pig-free period is requested for all visitors	8
External	Visitors are obliged to register before entering the stable	7
External	Newly introduced breeding animals are isolated in the quarantine stable and physically separated from other animals	7
External	Documentation that certifies the health status of newly introduced animals is required and controlled	7
External	The driver of the transport vehicle is not allowed to enter the barns	7
External	There exist a loading/unloading dock	7
External	There is a separate deadstock storage for dead pigs, placed outside the animal handling area	6
Internal	Cleaning and disinfection of stable and equipment are always done before restocking with new animals in the farrowing crates	6
Internal	The farm has a system for recording the animal health, breeding, reproduction and production data	6
External	Visitors use farm specific clothing or disposable coveralls in the farm	5

Frequency: number of countries stating that the biosecurity measures were mandatory by the pig sector but not by national legislation.

understanding we cannot conclude on whether the level of integration of specific biosecurity measures into the legislation also results into a better implementation of biosecurity measures in the field.

Enforcement of the implementation of biosecurity measures can be done at different levels. EU-member states should first of all comply with European legislation, such as Regulation (EC) 1069/2009 which prohibits feeding pigs with catering waste and processed proteins originating from pigs, and the AHL laying down the rules for the prevention and control of animal diseases which are transmissible to animals or to humans (Regulation (EC) 1069/2009; Regulation (EU) 2016/429). Only a small number of specific biosecurity measures are regulated at the EU level (e.g. prohibited to feed catering waste), for the others the EU typically provides regulatory frameworks suitable for all farming types on the territory. It states that biosecurity measures should be taken 'appropriate for' the species and categories kept, the type of production and the risks involved. The responsibility to translate this into more specific national legislation is left to the member states. Norway, a non-EU member, is a member of the European Free Trade Association and therefore integrated the AHL in the national legislation (Dyrehelseforskriften, 2022). Having national legislation on biosecurity may have stimulated farmers to adopt certain measures, even if they were not obliged to follow it (e.g. based on farm size) (Oliveira et al., 2018). Furthermore, farmers perceived the government to play a crucial role in the communication and the adoption of biosecurity measures on farms (Gunn et al., 2008; Renault et al., 2021).

As important as the obligation to implement biosecurity measures (either promoted by law or sectorial organizations) is auditing the compliance on the farms and acting upon the results. Most pig sector organizations perform biosecurity audits on farms on a regular basis as compliance to the (extra-) legal biosecurity measures is required to become and remain certified. Being certified under a quality system, often including biosecurity aspects, is important for farmers as it may ensure the quality of their products and their place in the market (Karipidis et al., 2009; To et al., 2012). This results in a higher motivation of the farmers to comply with the sector standards and their biosecurity requirements. Aside from the pig sector organizations, the national law can state that it is mandatory to assess the biosecurity levels on pig farms. In Belgium for example, yearly, a biosecurity audit has to be completed on each pig farm by the herd veterinarian, since 2021 (Royal Decree (BE) 2020/41319). This is also the case in other European countries such as Ireland and Finland.

This study demonstrated that both national legislators and pig sector organizations focused more on external biosecurity compared to internal biosecurity. However, implementing high level of internal biosecurity measures is also important since prevention of pathogen introduction with external biosecurity measures is never 100 % guaranteed and a number of pathogens cannot be fully avoid but can be

controlled through internal biosecurity measures (Dewulf and Van Immerseel, 2018). Biosecurity measures most commonly addressed in the legislation included cleaning and disinfection of transport vehicles, the presence of a hygiene lock and farm specific clothing for employees. The pig sector extended this list of external biosecurity measures focusing more on the purchase of animals and the entrance of external persons such as transporters and visitors. Furthermore, both legislators and sector organizations seem to attach importance to documentation such as vaccination schemes, herd health plans, visitor registers, cleaning and disinfection certifications and rodent control programs. It is notable that the biosecurity measures prioritized by national legislation as well as the extra-legal measures by the pig sector organizations were structural or related to documentation which can be easily, visually checked when performing a biosecurity audit. On the other hand, the biosecurity measures the least commonly addressed were measures to which the compliance is difficult to check during a farm visit. This might be due to the fact that often legislation is developed in the framework of the presence or an imminent threat of an epidemic disease (e.g. foot and mouth disease, classical swine fever, African swine fever, …) for which the goal is evidently to fully avoid the introduction of the pathogen. In studies that assessed the biosecurity on pig farms in Europe using the Biocheck.UGent™ scoring system, the overall external biosecurity score was higher on sow farms and farrow-to-finish farms compared to the overall internal biosecurity score while on fattening farms, the overall internal biosecurity score tended to be higher (Kruse et al., 2020; Chantziaras et al., 2020; Rodrigues da Costa et al., 2019). The world average for total external and internal biosecurity scores for the 27,687 commercial pig farms that assessed the biosecurity with the Biocheck.UGent™ scoring system was 74 % and 67 %, respectively (Biocheck.UGent).

This study is the first to give an overview of the biosecurity measures mandatory for the intensive pig sector in absence of disease outbreaks by national legislation on such a large scale, including 24 European countries. However, the methodology applied to collect these data had limitations. Firstly, the questionnaire was distributed to COST Action BETTER consortium members who volunteered to be CFP. These volunteers were most often biosecurity experts but not necessarily experts in national legislation. Seeking for the help of an expert was highly recommended but not obliged. Secondly, besides Spain, France, Italy and Romania, the biosecurity measures indicated in the national legislation were often scattered among multiple pieces of legislation making it challenging to give a complete overview. Furthermore, the biosecurity measures stated in the questionnaire were very detailed. For example, the questionnaire did not only ask if there was a quarantine stable to isolate purchased animals but also if it was physically separated from the healthy animals. Therefore, it is possible that more simple biosecurity measures or measures not mentioned in the questionnaire that were mandatory by law were missed. On the other hand, it was decided to focus on biosecurity measures mandatory for the intensive pig production under normal circumstances, i.e. no (threat of) disease outbreaks. All countries indicated to have legislation specifying biosecurity measures obligatory in case of disease outbreaks such as ASF.

Only 14 from the 24 countries provided data on biosecurity measures mandatory by industry and the percentage and type of farms covered by that sector organizations differed. Most likely, more and other pig sector organizations are active in the different countries, requiring compliance to certain biosecurity measures. The lack of data could be because those organization requirements were not publicly available or beyond the knowledge of the CFP and therefore, not mentioned when completing the questionnaire.

The final responsibility for the implementation of biosecurity measures on intensive pig farms lies with the farmer. The EU AHL states; the operator is responsible for the health of the kept animals, responsible use of veterinary medicines, minimizing the risk of the spread of diseases, and practicing good animal husbandry (Regulation (EU), 2016/429). However, some local geographical risk factors, such as the density of domestic pig and wild boar populations, are beyond the control of farmers and should definitely be included in national or regional prevention programs (Rusinà et al., 2023). Furthermore, farmers indicated that the variety of recommendations and legislations is confusing and clearer information and communication is needed which is a shared responsibility between legislators and (field) veterinarians (Renault et al., 2021).

5. Conclusion

This study demonstrated a large variety in the presence of national legislation on biosecurity in general in the intensive pig production in European countries; some had a single national pig-specific biosecurity legislation while in most others the mandatory biosecurity measures were scattered among multiple legislations. Furthermore, the pig sector organizations might to a certain extend require compliance with extra-legal biosecurity measures. How and if these different approaches result in differences in the implementation of biosecurity measures on intensive pig farms needs to be further investigated.

Ethics approval and consent to participate

Due to the nature of the study formal approval from an Ethics Committee was not required.

Consent for publication

Not applicable

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Declaration of Competing Interest

All the authors declare no conflicts of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2025.106439.

Data Availability

The data that support the findings of this study are available from the corresponding author upon request.

References

Alarcón, L.V., Allepuz, A., Mateu, E., 2021. Biosecurity in pig farms: a review. Porc. Health Manag. 7, 1–15. https://doi.org/10.1186/s40813-020-00181-z.

Anonymous, European Union. Principles, countries, history. ⟨https://european-union.europa.eu/principles-countries-history_en⟩ (accessed 27 January 2025).

Bellini, S., Casadei, G., De Lorenzi, G., Tamba, M., 2021. A review of risk factors of African Swine Fever incursion in pig farming within the European Union scenario. Pathogens 10, 84. https://doi.org/10.3390/pathogens10010084.

Biocheck.UGent. Worldwide statistics. ⟨https://biocheckgent.com/en/worldwide?country=world&questionnaire= 57&species= 1⟩ (Accessed 27 January 2025).

Boeters, M., Garcia-Morante, B., van Schaik, G., Segalés, J., Rushton, J., Steenveld, W., 2023. The economic impact of endemic respiratory disease in pigs and related interventions – a systematic review. Porc. Health Manag. 9, 45. https://doi.org/10.1186/s40813-023-00342-w.

Chantziaras, I., Dewulf, J., Van Limbergen, T., Stadejek, T., Niemi, J., Kyriazakis, I., Maes, D., 2020. Biosecurity levels of pig fattening farms from four EU countries and links with the farm characteristics. Livest. Sci. 237, 104037. https://doi.org/10.1016/j.livsci.2020.104037.

Chenais, E., Depner, K., Guberti, V., Dietze, K., Viltrop, A., Ståhl, K., 2019. Epidemiological considerations on African swine fever in Europe 2014-2018. Porc. Health Manag. 5, 6. https://doi.org/10.1186/s40813-018-0109-2.

Collineau, L., Rojo-Gimeno, C., Léger, A., Backhans, A., Loesken, S., Nielsen, E.O., Postma, M., Emanuelson, U., grosse Beilage, E., Sjölund, M., Wauters, E., Stärk, K.D. C., Dewulf, J., Belloc, C., Krebs, S., 2017. Herd-specific interventions to reduce antimicrobial usage in pig production without jeopardising technical and economic performance. Prev. Vet. Med. 144, 167–178. https://doi.org/10.1016/j.prevetmed.2017.05.023.

Dewulf, J., Van Immerseel, F., 2018. General principles of biosecurity in animal production and veterinary medicine. In: Dewulf, J., Van Immerseel, F. (Eds.), Biosecurity in animal production and veterinary medicine. Acco, Leuven, pp. 63–76.

Dhaka, P., Chantziaras, I., Vijay, D., Bedi, J.S., Makovska, I., Biebaut, E., Dewulf, J., 2023. Can improved farm biosecurity reduce the need for antimicrobials in food animals? A scoping review. Antibiotics 12, 893. https://doi.org/10.3390/antibiotics12050893.

Dunowska, M., 2018. Circles of disease transmission. In: Dewulf, J., Van Immerseel, F. (Eds.), Biosecurity in Animal Production and Veterinary Medicine. Acco, Leuven, pp. 27–62.

Dyrehelseforskriften, Forskrift om dyrehelse, FOR-2022-04-06-631 of 28 April 2022. Lovdata. ⟨https://lovdata.no/dokument/SF/forskrift/2022-04-06-631⟩ (Accessed 26 April 2024).

European Food Safety Authority (EFSA), Ståhl, Karl, Boklund, A.E., Podgórski, T., Vergne, T., Cortiñas Abrahantes, J., Cattaneo, E., Papanikolaou, A., Mur, L., 2024. Epidemiological analysis of African swine fever in the European Union during 2023. Efsa J. 22 (5). https://doi.org/10.2903/j.efsa.2024.8809.

Eurostat, data browser, 2023. Animal population by NUTS 2 regions. ⟨https://ec.europa.eu/eurostat/databrowser/view/agr_r_animal_custom_8798672/default/table?lang=en⟩ (Accessed 27 January 2025).

Filippitzi, M.-E., Kruse, A.B., Postma, M., Sarrazin, S., Maes, D., Alban, L., Nielsen, L.R., Dewulf, J., 2018. Review of transmission routes of 24 infectious diseases preventable by biosecurity measures and comparison of the implementation of these measures in pig herds in six European countries. Transbound. Emerg. Dis. 65 (2), 381–398. https://doi.org/10.1111/tbed.12758.

Gunn, G.J., Heffernan, C., Hall, M., McLeod, A., Hovi, M., 2008. Measuring and comparing constraints to improved biosecurity amongst GB farmers, veterinarians and the auxiliary industries. Prev. Vet. Med. 84 (3-4), 310–323. https://doi.org/10.1016/j.prevetmed.2007.12.003.

Halasa, T., Bøtner, A., Mortensen, S., Christensen, H., Toft, N., Boklund, A., 2016. Simulating the epidemiological and economic effects of African swine fever epidemic in industrialized swine populations. Vet. Microbiol. 193, 7–16. https://doi.org/10.1016/j.vetmic.2016.08.004.

Karipidis, P., Athanassiadis, K., Aggelopoulos, S., Giompliakis, E., 2009. Factors affecting the adoption of quality assurance systems in small food enterprises. Food Control 20, 93–98. https://doi.org/10.1016/j.foodcont.2008.02.008.

Kruse, A.B., Nielsen, L.R., Alban, L., 2020. Herd typologies based on multivariate analysis of biosecurity, productivity, antimicrobial and vaccine use data from Danish sow herds. Prev. Vet. Med. 181, 104487. https://doi.org/10.1016/j.prevetmed.2018.06.008.

Laanen, M., Maes, D., Hendriksen, C., Gelaude, P., De Vliegher, S., Rosseel, Y., Dewulf, J., 2014. Pig, cattle and poultry farmers with a known interest in research have comparable perspectives on disease prevention and on-farm biosecurity. Prev. Vet. Med. 115 (1-2), 1–9. https://doi.org/10.1016/j.prevetmed.2014.03.015.

Makovska, I., Chantziaras, I., Caekebeke, N., Dhaka, P., Dewulf, J., 2024. Assessment of cleaning and disinfection practices on pig farms across ten European countries. Animals 14, 593. https://doi.org/10.3390/ani14040593.

Makovska, I., Dhaka, P., Chantziaras, I., Pessoa, J., Dewulf, J., 2023. The role of wildlife and pests in the transmission of pathogenic agents to domestic pigs: a systematic review. Animals 13, 1830. https://doi.org/10.3390/ani13111830.

Martínez, M., de la Torre, A., Sánchez-Vizcaíno, J.M., Bellini, S., 2021. Biosecurity measures against African swine fever in domestic pigs. In: Lacolina, L., Penrith, M.-L., Bellini, S., Chenais, E., Jori, F., Montoya, M., Ståhl, K., Gavier-Widén, D. (Eds.), Understanding and Combatting African Swine Fever. Academic Publishers, Wageningen, pp. 263–281.

Niemi, J.K., Lehtonen, H., Pietola, K., Lyytikäinen, T., Raulo, S., 2008. Simulated financial losses of classical swine fever epidemics in the Finnish pig production sector. Prev. Vet. Med. 84, 194–212. https://doi.org/10.1016/j.prevetmed.2007.12.006.

Oliveira, V.H.S., Anneberg, I., Voss, H., Sørensen, J.T., Thomsen, P.T., 2018. Attitudes of Danish farmers towards biosecurity. Livest. Sci. 214, 153–160. https://doi.org/10.1016/j.livsci.2018.06.004.

Regulation (EC) 1069/2009 of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) 1774/2002. European Parliament and Council. ⟨https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1069⟩ (Accessed 26 April 2024).

Regulation (EU) 2016/429 of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health (Animal Health Law). European Parliament and Council. ⟨https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32016R0429⟩ (accessed 3 April 2024).

Renault, V., Humblet, M.-F., Pham, P.N., Saegerman, C., 2021. Biosecurity at cattle farms: strengths, weaknesses, opportunities and threats. Pathogens 10, 1315. https://doi.org/10.3390/pathogens10101315.

Rodrigues da Costa, M., Gasa, J., Calderón Díaz, J.A., Postma, M., Dewulf, J., McCutcheon, G., Manzanilla, E.G., 2019. Using the Biocheck.UGent™ scoring tool in Irish farrow-to-finish pig farms: assessing biosecurity and its relation to productive performance. Porc. Health Manag. 5, 4. https://doi.org/10.1186/s40813-018-0113-6.

Royal Decree (BE) 2020/41319 of 11 May 2020 tot wijziging van het koninklijk besluit van 18 juni 2014 houdende maatregelen ter voorkoming van aangifteplichtige varkensziekten. Belgisch Staatsblad of 20 May 2020. ⟨https://www.ejustice.just.fgov.be/mopdf/2020/05/20_1.pdf⟩ (Accessed 29 April 2024).

Rusinà, A., Valentini, F., Scollo, A., Franceschini, G., Salvato, S., Cappa, V., Bellato, A., Mannelli, A., Bellini, S., 2023. Semi-quantitative risk assessment of African swine fever virus introduction in outdoor pig farms. Pathogens 12 (5), 709. https://doi.org/10.3390/pathogens12050709.

Svensson, C., Lind, N., Reyher, K.K., Bard, A.M., Emanuelson, U., 2019. Trust, feasibility, and priorities influence Swedish dairy farmers' adherence and nonadherence to veterinary advice. J. Dairy Sci. 102, 10360–10368. https://doi.org/10.3168/jds.2019-16470.

Terrestrial Animal Health Code: Glossary. OIE, 2024. ⟨https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/?id= 169&L= 1&htmfile=glossaire.htm⟩ (Accessed 19 November 2024 2024).

To, W.M., Lee, P.K.C., Yu, B.T.W., 2012. Benefits of implementing management system standards: a case study certified companies in the Pearl River Delta, China. TQM J. 24 (1), 17–28. https://doi.org/10.1108/17542731211191195.