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Differences in code terminology and frequency of findings in meat inspection of finishing pigs in seven European countries

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ABSTRACT

The overall objectives of meat inspection are to contribute to food safety, animal welfare, and animal health. In the European Union (EU), there is a request for a modernised meat inspection system that addresses these objectives in a more valid, feasible and cost-effective way than does the traditional system. One part of the modernisation deals with the coding system to register meat inspection findings. Although unified standards are set at the EU level for judgement criteria regarding fitness of meat for consumption, different national systems are in force. The question is the extent of the differences and whether there is a basis for harmonisation. To investigate this, information was gathered about the code systems in Denmark, Finland, Germany, Italy, Norway, Portugal and Spain. Moreover, meat inspection data covering pigs slaughtered in 2019 were collected. A comparison of the number of codes available, the terminology and the frequencies of the findings registered was undertaken. Codes with a similar meaning were grouped. Hereby, two lists were compiled showing the most common codes leading to total and to partial condemnation. Substantial variations in the percentage of condemned pigs and in the terms used were identified, and possible reasons behind this are discussed. Moreover, a strengths-weaknesses-opportunities-threats (SWOT)-like analysis was applied to the coding systems. Finally, the reasons for unfitness of meat given in the EU Food Inspection Regulation 2019/627 were compared to the national code lists. The results show the systems in force varied substantially, and each system had its advantages and disadvantages. The diverse terminology observed made it a challenge to compare data between countries. Development of harmonised terminology for meat inspection findings is suggested, enabling comparison of data between abattoirs, regions, and countries, while respecting the national epidemiological situation, the local food safety culture, and the trade agreements in force.

1. Introduction

1.1. Background

Continuous improvement of the meat inspection system in force is on the agenda worldwide (Blagojevic et al., 2021; Buncic et al., 2019; Riess & Hoelzer, 2020). With the assistance of academia, the competent authorities (CAs) and food business operators (FBOs) aim to establish a system that can detect and remove meat and organs with abnormalities possibly associated with food safety hazards and help improve animal health and welfare, all in a cost-efficient way. The recent introduction of visual-only inspection (VOI) of pigs in the European Union (EU) is an

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attempt to meet the need for modernisation. However, more could be done regarding prioritisation of hazards and methods of surveying and handling data. To address this, the RIBMINS EU COST Action Network (CA18105) was established in 2019. The aim of RIBMINS is to combine and strengthen Europe-wide research efforts to develop modern meat safety control systems for different animal species (https://ribmins.com).

In the EU, the CAs, involving official veterinarians (OVs) and official auxiliaries (OAs), mostly perform meat inspection, although an independent third party not employed by the authorities can also be involved. The EU Food Inspection Regulation 2019/627 applies in all EU Member States (EU Commission, 2019). Article 45 in this Regulation contains a list of 21 reasons for declaring meat unfit for human consumption (Table S1). Twenty of these reasons are applicable to pigs, as one reason (reason "q") refers to specified risk material due to bovine spongiform encephalopathy (BSE), so it is not applicable to pigs.

The EU list uses letters from "a" to "u". To address these reasons for declaring meat unfit for human consumption, many European countries have set up a code system to register findings observed during meat inspection. Based on the codes registered and the detailed condemnation criteria in force in the country, a decision is made regarding whether a slaughtered animal is fit for human consumption or not, and if not, which specific actions, such as a total or partial condemnation, are needed.

Although meat inspection was originally developed with a focus on food safety and hygiene, modern meat inspection also needs to detect non-compliance with animal welfare rules as reflected in Article 44 in the EU Food Inspection Regulation 2019/627. However, specific reasons for identification of non-compliance have not been listed in the Regulation. As the abattoir is the bottle neck of farming animals for consumption, many diseases and conditions can be detected at ante- and post-mortem inspection. It seems, therefore, convenient to ask OVs and OAs to register relevant findings. This implies that codes for animal welfare should be part of the meat inspection code system. Some national systems already have codes for specific animal welfare issues additional to those in Article 45 that cover meat fitness for human consumption. The old EU Meat Inspection Regulation 854/2004 has been implemented by EU Member States and countries in the European Economic Area (EEA), with updates due to the new EU Food Inspection Regulation 2019/627. Moreover, other countries are aligning their legislation because they export to the EU or intend to do so. Each Member State can have its own code system, reflecting the size and the epidemiological status of the national herd, the animal/disease history, and the food safety culture.

Modernisation and some degree of harmonisation of the meat inspection code systems would be beneficial, not just for the cost-effectiveness, but also to enable improvements in public health, animal health and animal welfare. Development of an ontology (Noy & McGuinness, 2001) with common names for the codes describing the findings during inspection could be beneficial. Nonetheless, full harmonisation may not allow the countries to have a flexible inspection system targeted to their needs, e.g., with respect to their epidemiological situation. On the other hand, if the systems differ too much, no meaningful comparisons can be made. Additionally, some systems could be objectively better than others, and therefore, one could learn from the other. The search for a balance between flexibility and harmonisation is also seen in other areas of importance to food safety, e.g., regarding residue surveillance, where EU Directive 96/23/EC has been repealed and replaced by Regulation 2017/625, with the additional current development of documents taking into account technological possibilities that did not exist at the time the former Directive came into force (Alban et al., 2020).

1.2. Objectives

The overall goal was to help optimise and standardise the pig meat inspection system. To do so, mapping of the current practices was undertaken, through the following three objectives:

1. Compare different national meat inspection code systems;
2. Compare findings related to total and partial condemnations;
3. Compare post-mortem reasons for unfitness of meat given in the EU Food Inspection Regulation (EU) 2019/627 with different national code lists.

2. Materials and methods

2.1. Selection of countries

The work group 4 (WG4) members of RIBMINS representing Denmark, Finland, Germany, Italy, Norway, Portugal and Spain provided information about the meat inspection coding systems in force in 2019 in these seven countries. These countries represent a broad spectrum of pig production in Europe: Germany is the largest producer of pig meat in the EU, Spain the second-largest, Denmark comes in as number five, Italy as number six, Portugal as number 13, Finland as number 17 and Norway as number 18 (Danish Agriculture & Food Council, 2020; Ridder, 2020). Geographically speaking, Denmark, Finland, Germany and Norway represent Northern Europe, whereas Italy, Portugal and Spain represent Southern Europe. Meat inspection is performed by personnel employed by the CA in all seven countries. Pig meat inspection data were collected from all seven countries. The data covered finishing pigs, slaughtered and inspected in 2019, and mainly raised indoors. For Italy, the data included heavy finishing pigs slaughtered at >9 months of age and weighing >160 kg. For some countries, data for all pigs inspected were obtained, whereas for others, only data from one or more major pig abattoirs could be collected. Table 1 contains a brief description of the data provided by each country.

2.2. Methods

To address Objective 1, each national code system was studied to determine whether it consisted of a few, summarised codes or many detailed codes. This was done by allocating the codes into six groups following the approach in the Danish guidance on meat inspection (Danish Ministry of Environment and Food, 2020):

1) decisions on carcass acceptance such as fully accepted, accepted after de-boning or freezing, accepted for processing only or total condemnation,
2) general findings such as dead on arrival, cachexia and pyaemia,
3) topographic lesions occurring in specific body parts (e.g. heart, respiratory or gastrointestinal organs, skeleton and skin); these lesions include pericarditis, pneumonia and abscesses,
4) lesions induced by specific parasites, bacteria, viruses, mycotoxins or neoplasia and inducing aetiological conditions such as *Actinobacillus pleuropneumoniae*, tuberculosis, *Salmonella*-positive, erysipelas, porcine nephropathy or parasite-induced lesions in the liver,
5) errors related to the slaughter or inspection process and to contamination due to ingesta, faeces, bile, scalding water, oil or pus, and,
6) suspicion of the presence of residues of authorised medicinal or prohibited substances in animal/carcass.

Moreover, strengths (S), weaknesses (W), opportunities (O), and threats (T) of the different code systems were qualitatively analysed (SWOT-like analysis). This is a qualitative approach, developed to evaluate in a structured manner the planning and functioning of a business (Dyson, 2004). Such analysis is usually undertaken through brainstorming (Dyson, 2004). WG4 decided to undertake SWOT-like brainstorming by country, so WG4 members asked one or more experts regarding the views of the CA or the OV and one or more experts regarding the views of the FBO about their views on the national meat inspection code system. To qualify as an expert, a minimum of 10 years of working experience with meat inspection was required. The following four open questions were used as a simplified SWOT analysis, focusing

Table 1
Description of meat inspection data sets from seven European countries used to analyse coding systems, based on data covering 2019.

Question	Denmark	Finland	Germany	Italy	Norway	Portugal	Spain
Total no. of pigs slaughtered in country	16.6 M	1.8 M	53.6 M	11.5 M	1.6 M	4.2 M	53.0 M
No. of abattoirs in dataset	1 (the largest abattoir)	All pig abattoirs	All pig abattoirs	3	1	All pig abattoirs in mainland Portugal	2
No. of pigs in dataset	3,968,106	1,788,400	53,561,424	952,224	196,773	4,219,242	3,460,187
Pig sub-population covered	Finishing pigs	Finishing pigs	Finishing pigs	Indoor raised finishing pigs (heavy pigs >160 kg and >9 months old	Finishing pigs, sows, and boars	Finishing pigs, sows, and boars raised in- or outdoors	Indoor raised finishing pigs

on S, W and T: 1) one thing that others and I like about the system, 2) things that others and I struggle with, 3) things that people should be aware of, 4) things that this system is not good at covering. When referring to "others", the interviewer explained that this referred to colleagues working within the CA or the FBO. This approach has been used to collect information about surveillance systems for antimicrobial use and resistance (Nielsen et al., 2020; Sandberg et al., 2021).

For Objective 2, the distribution of codes associated with total and partial condemnation in each of the countries was inspected. This allowed the percentage of totally condemned pigs in the different countries to be compared statistically using a Chi-square test. Subsequently, the most common causes of total and partial condemnation were identified by country using the names from the national code systems. For the six countries that contributed detailed data on total condemnation, the most commonly used codes for total condemnation with comparable meanings were grouped by marking them with the same colour in a table. This allowed us to rank the aggregated codes by country, based on the frequencies recorded. Hereby, similarities and variations in the most common types of findings leading to total condemnation were identified. Possible reasons for the observed variations were discussed by the WG4 members. For partial condemnation, data from only six countries were available. To compare partial condemnations in these countries, it was decided to use the seven codes from Finland that reflect the most common pathologies observed in pigs: abscesses, arthritis, ascariasis (milk spot liver), pericarditis, pleuritis, pneumonia and tail biting.

Finally, for Objective 3, the official EU list of reasons meat is considered unfit for human consumption (Reg. (EU) 2019/627, Art. 45) was compared with the official national code lists in force for post-mortem findings applicable for pigs in the seven European countries. For each national code list, all codes available were included, irrespective of whether the code was related to total or partial condemnation. To see differences between countries, each national code was allocated to the respective EU reason for unfitness. Then, frequency calculations and 2-by-2-tables were performed using SPSS statistics software. From the seven countries, all 664 available codes with similar meanings were grouped and compared. The intention was to identify the minimum number of codes needed to describe relevant findings in pigs in a way that would be meaningful to the pig producers and, hence, not be too summarised.

3. Results

3.1. Short description of the meat inspection systems in force in the seven countries

Denmark has a code system described in the Meat Inspection Guidance. For each code, the action to take is specified, which depends on whether the finding reflects an acute or chronic stage of disease, whether it is generalised or local, and whether complications are observed or not. The code system is updated regularly, and a slightly revised system came into force in late 2020. Both lists can be found in the document published by the Danish Ministry of Environment and Food (2020). The official code system in meat inspection applies to all pigs, and a total of 89 codes was available in the system in force in 2019. The local abattoirs have additional codes, which they use for steering the carcass and parts thereof. The high number of codes enables differentiation between findings. A tail bite characterised by local infection only will result in partial condemnation. In contrast, a tail bite with lesions indicating generalised infection will result in total or partial condemnation depending on the outcome of a detailed investigation for pyaemia, wherein predilection sites for pyaemia are inspected in the rework area (Alban et al., 2021). Up to four codes can be registered per pig. The meat inspectors focus on the findings for which a corrective action is required, such as total or partial condemnation. This means mild abnormalities, e.g. catarrhal bronchopneumonia, are not necessarily recorded into the database (Alban et al., 2021).

Finland has a national list of recommended codes, generic for all red meat species (Finnish Food Authority, 2013). Moreover, the large abattoirs each have their own code systems. Data are recorded into the abattoir database using the abattoir's coding system, and from there, data are transferred to the national database by the OV. The national list of recommended codes defines the necessary action for each code. As in Denmark, the specific action depends on the stage of the finding, the spread and the level of complications. Total and partial condemnation data are collected from all abattoirs. The national code list has just been revised, and the new list will come into force from 2022 (Finnish Food Authority, 2020). In addition, seven findings reflecting the most common pathologies important for production or economic reasons, or serving as welfare indicators for finishing pigs (abscesses, arthritis, ascariasis, pericarditis, pleuritis, pneumonia, and tail biting), are used to assess pig morbidity. Data for these seven codes are collected from all abattoirs (MAF, 2012). These data for seven codes are recorded irrespective of meat inspection decisions and are not linked to total or partial condemnations. For sows, data on shoulder wounds are collected (MAF, 2012).

Germany has a national code system for total and partial condemnations. Additionally, several abattoir-specific codes are used in the different abattoirs. These additional codes include further information, e.g., regarding the topographic localisation of the finding. Depending on the abattoir, the OV enters the data electronically via a touch-pad terminal or manually in a paper-based solution, using the abattoir-specific code system. These data are transcribed into the national system, and from there, the data are regularly transferred into the national statistics on meat inspection at the Federal Statistical Office, called DESTATIS (DESTATIS, 2020). For total condemnation of pigs, there are 22 official codes covering generalised conditions such as cachexia, specific infections like erysipelas and other pathological findings, such as multiple abscesses. Some of the 22 codes subsume technical defects during slaughter or insufficient or missing meat inspection. Regarding partial condemnation, the German code system consists of two parts, one focusing on findings in organs, the other elucidating findings on carcasses. The first part consists of 12 official codes that describe findings in the lungs, pleura, pericardium, heart, liver, gastrointestinal tract and kidneys. The second part consists of eight codes that describe any alteration in other carcass parts, e.g., bleeding in the skin and single abscesses. More than one code can be registered per pig.

Italy does not have an official set of codes in force. A first attempt to produce a future national list was made when visual inspection was compared with traditional inspection (Ghidini et al., 2018). The only national list of codes currently used to record findings during meat inspection is contained in the Classyfarm system (Classyfarm, 2020) used to risk-rank the farms. Classyfarm was designed so that both the CA and the FBO can introduce data into the system. Antimicrobial consumption was the first issue considered in Classyfarm, followed by animal welfare and biosecurity. This risk ranking of farms then led to the development of a set of codes to be used at meat inspection and that mainly reflect the clinical evaluation of the animals. That set of codes is now also used for total and partial condemnations. More than one code can be registered per pig. The data used in the current work were collected during a pilot trial of the system by contracted veterinarians.

Norway has one list of codes, generic for all red meat species (Norwegian Food Safety Authority, 2019). In the system from 2019, three ante-mortem and 43 post-mortem codes were available for pigs. The codes are decision-oriented and harmonised with legislative demands in Regulation (EC) No. 854/2004. For each code, there is a description of what the necessary action should be (Norwegian Food Safety Authority, 2019). As in Denmark and Finland, the specific action depends on the stage of the finding, its spread and the level of complications. Among the 46 codes, 28 can result in either total or partial condemnation. The code system is currently being updated to harmonise with Article 45 of Regulation (EU) 2019/627. The meat inspection personnel also perform detailed inspection of slaughtered animals to make diagnoses of clinical importance. These data are entered in a separate register system, called USR, which has been in force since the 1970s. USR for pigs has eight codes: 1) abscesses and infected wounds, 2) arthritis and joint lesions, 3) pericarditis and pleuritis, 4) pneumonia, 5) ascariasis, 6) healed tail lesions and short tails, 7) open tail wounds, and 8) shoulder wounds in sows (Norwegian Food Safety Authority, 2018). USR data are transferred to the abattoir and forwarded with the carcass grading information to central databases administered by Animalia (the Norwegian Meat and Poultry Research Centre). For total condemnation, more than one code can be registered per pig.

Portugal has a national database, called SIPACE, with restricted access, for recording the results of official controls carried out in food and feed establishments (http://srvbamid.dgv.min-agricultura.pt/portal/page/portal/DGV/genericos?generico=14800780&cboui=14800780). It contains records of the causes of total and partial condemnation of all animal species slaughtered for human consumption. The OVs enter the information about findings at inspection into the database, whereby this information becomes automatically available to all OVs as well as the regional and central veterinary services of the national CA. The terminology used for recording condemnation causes is harmonised at national level, which facilitates data processing and comparison of results between abattoirs. For total condemnation of pigs, 138 codes are available from the 207 codes for all ungulates. For total condemnation, only one code can be registered per pig. In that case, the OV must select the code that best reflects the reason for condemnation. There are 56 codes for partial condemnation of pigs, which can be used for several organs/carcass parts. For partial condemnation, more than one code can be registered per pig. It is mandatory to register partial condemnation findings only if the proportion of condemnations is above 5% of the slaughtered pigs in the same batch. Information about tail biting lesions, castration and tail docking is registered in SIPACE for every batch.

Spain has a common code list at regional level, but it is not harmonised at the national level. Larger abattoirs develop additional code lists adapted to their own requirements and demands. A clear separation between total and partial condemnation is not always evident in the code list, and the decision depends on the finding or condemnation cause itself, or the judgment of the OV. More than one code can be registered per pig. The number of codes in each list fluctuates among regions and abattoirs from 10 to >30 codes. Total and partial condemnations are always registered by the OV by manual or electronic means according to the abattoir facilities. Then, the CA at regional level registers condemnations, and the data are made available for the CA's official reports.

Table 2 provides an overview of the different systems in force in the seven countries.

Table 2
Description of the pig meat inspection coding systems in force in seven European countries. Slaughtered animals are subjected to total condemnation (TC), partial condemnation (PC) or other adequate treatment. AM: Ante-mortem, PM: post-mortem.

Question	Denmark	Finland	Germany[c]	Italy	Norway	Portugal[c]	Spain
National meat inspection code system in place?	Yes	Yes[b]	Yes	Yes, but not official	Yes	Yes	No, only at regional level
Total no. of codes in the system - including AM and PM	89	141	TC: 22 PC Carcass: 8 PC Organ: 12	44	49	TC: 138 PC: 56	36
No. of codes that can be used to describe one pig	4	Depends on the slaughterhouse	No limit	TC: 1 PC: No limit	No limit	TC: 1 PC: several	No limit
No. of codes reflecting an action taken or to be taken such as TC, PC, accepted for processing only, for freezing, or for de-boning etc	6	13	0	1	3	0	0
No. of codes describing general findings/condition such as dead on arrival, cachectic	6 AM codes and 6 PM codes	7 AM codes and 21 PM codes	7	11	13	4 AM codes and 18 PM codes	2 AM codes and 11 p.m. codes
No. of codes describing topographic conditions (e.g. in heart, respiratory or gastro-intestinal organs, skeleton or skin) including abscesses	55	63	20	11	14	72	14
No. of codes describing etiological condition (e.g. lesions induced by specific parasites, bacteria, viruses, neoplasia, or mycotoxines	6	33	7	20	5	33	3
Dirty or bloody carcass and errors related to the slaughter or inspection process[a] and contamination due to ingesta, faeces, bile, scalding water, oil, and pus	8	2	4	1	7	6	6
Suspicion of presence of residues of legal medicinals or prohibited substances in animal/carcass	2	2	4	0	7	5	0

[a] Includes no animal traceability, animal slaughtered without AM inspection and similar events.
[b] However, large abattoirs have their own code lists.
[c] The country has separate code lists for PM and AM.

3.2. SWOT-like analysis

Condensed results of the SWOT-like analysis are presented in Table 3a (local meat inspectors' views) and Table 3b (FBOs' views). The detailed results, including the number of experts interviewed per country (N = 2 to 8), are presented in the Supplementary materials in Tables S2–S7. For Finland, no data were included because the large abattoirs each use their own meat inspection code lists. Hence, the national coding list is only in use at small Finnish abattoirs. Tables 3a and 3b shows that a national code system with precise terminology allows people involved in meat inspection to feel competent when using the system. Such a system helps adequate judgement to be made and allows feedback of useful data to the producer. This view was irrespective of whether the responder was the OV, CA or FBO. Italy was an exception to this, because it does not have any official meat inspection code system. Another general comment was that training of all personnel involved in meat inspection is required to ensure the system is fully functional. In general, the local meat inspectors were more focused on challenges related to functional aspects of the systems, such as how to fill in data correctly at high slaughter speeds or during breakdown. In contrast, the FBOs were focused on how to improve the value-for-money associated delivered by meat inspection.

3.3. Comparison of findings related to total condemnation in 2019

In Denmark, 0.15% of 4.0 million finishing pigs slaughtered in the largest abattoir were totally condemned. Among the pigs that were totally condemned, an average of 2.2 findings were registered per pig. The most frequent cause of total condemnation was "circulatory disorders", which in the newest version of the code list has been renamed and regrouped to "complications", . This was registered for 43.3% of the condemned pigs. This was followed by "osteomyelitis including related soft abscesses" (11.6%), "acute pleuritis" (10.9%), "icterus" (10.4%), "gastric ulcer" (8.3%), "rectal stricture" (6.9%), "dead on arrival" (6.0%), "acute erysipelas" (5.6%), "acute peritonitis" (4.6%) and "septicaemia (embolic pneumonia, splenitis, nephritis)" (4.2%). Each of the remaining causes constituted <4% of the totally condemned pigs.

In Finland, 0.51% of 1.8 million finishing pigs were totally condemned. The number of codes registered per condemned pig and causes for total condemnation are not collected in Finland.

In Germany, 0.20% of 53.6 million slaughtered finishing pigs were totally condemned according to DESTATIS, having one (0.19%) or more (0.02%) post-mortem findings. The most frequent cause of total condemnation was "multiple abscesses" (31.9%) followed by "organoleptic changes" (17.2%) and "errors due to slaughter process" (11.1%). When the prevalences of "errors due to slaughter process" and "other errors due to slaughter process" were combined, these errors were ascribed to 20.4% of the total condemnations, making slaughter errors the second most common reason for total condemnation.

In Italy, 0.21% of 11.5 million heavy finishing pigs were totally condemned. Only one cause of total condemnation per pig is allowed. The most frequent cause of total condemnation was "contamination with faeces or bile" (19.7%), which are two kinds of slaughter errors. Registration of "abscesses" is done by location in the carcass using three different codes: spinal, neck and thigh. When the prevalences of spinal, neck and thigh abscesses were combined, they were ascribed to 21.6% of the total condemnations. "Erysipelas" caused 12.9% of the total condemnations, more than "pleuritis" and "peritonitis" combined, which were ascribed to only 11.9% of the total condemnations.

In Norway, 0.25% of 1.6 million finishing pigs were totally condemned according to data obtained from the national carcass grading database. In the abattoir that provided detailed data for the present study, 508 of 196,773 slaughtered pigs (0.26%) were totally condemned, and on average, there were 2.1 findings per condemned animal. The most frequent cause of total condemnation was "systemic disease", consisting of "sepsis, pyaemia, toxaemia or viraemia". These findings occurred in 57.3% of the total condemnations. "Abscesses" and "phlegmons" were present in 33.3% of the total condemnations, followed by "peritonitis" (26.6%), "pericarditis/pleuritis" (19.7%), "gastrointestinal diseases" (13.2%), "abnormal colour" (7.5%), "arthritis" (6.3%), "pneumonia" (5.5%), "urinary tract diseases" (5.1%), and "skin diseases" (4.7%). Condemnations related to "slaughter process errors" constituted 0.4%, and "technical data errors" constituted 3.3% of the total condemnations.

In Portugal, 0.38% of 4.2 million pigs were totally condemned. These totally condemned pigs covered all abattoirs from mainland Portugal.

Table 3a
Condensed answers of a SWOT-like analysis of local meat inspectors' views in six countries participating in a study about meat inspection code systems, 2020.

Things that I really like about the code system in place	Things that I struggle with when using the code system	Things that people should be aware of when using the system	Things that the system is not covering or not good at covering
A common system with codes covering all relevant conditions enables an adequate judgement (DE + DK + ES + IT + NO + PT) Full control of carcasses and organs results in valuable findings of relevance for food safety, animal and herd health, where the latter is useful for the farmer (DE + ES + IT + NO) Electronical registration increases the quality of the data registered and facilitates its use (DK + NO + PT)	Summary codes are in place, so meat inspectors need to be familiar with all codes to ensure proper recordings (DK + NO) Use of codes is not uniform across the country (DE + NO) Some findings have limited or no significance (IT) Difficult to fill data at slaughtering line speed. No guidelines for code assignment (IT) No need for benchmarking small abattoirs or small farms (DE) One unique code list for all ungulates can generate confusion and lead to errors in data registration (PT) Registration of findings leading to partial condemnation can take time, if there are many (PT) Complicated to adjust a coding system; if it is short, there are unquantified processes, if it is long, doubts may arise (ES)	Not all codes are relevant for food safety (DE) Smaller size infected/abscessed bursitis should be recorded (DE) Focus mainly on carcass – recording of findings on plucks and intestines vary between plants (DK) The same finding may be recorded using two different codes (DK) In some abattoirs difficult to find a spot where to place tablet to fill the data (IT) If registration terminals break down, back-up is recording on paper (DK + NO) Meat inspectors need training to be fully able to use the system (DE + DK + IT + NO + PT) Calibrations are needed (NO) Data registration must be done with utmost attention to avoid errors that can lead to the impracticability of using the data (PT) Effectiveness of OV regarding communication of results is essential to avoid loss of information (ES)	System not focused on food safety impact, but mainly on quality issues (DK + NO) Weak reproducibility of lung lesions (DE) Visual-only inspection makes it difficult to detect some findings (DK + IT + NO) Foodborne hazards are generally not detected (DK + IT + NO) Registration of causes of partial condemnation are not recorded individually making it impossible to calculate percentage of animals without any findings (PT) System only allows entering one cause of total condemnation (PT) System is not used to order actions, only to record results (PT) Difficult to implement a system that covers both total and partial condemnation (ES) Benchmarking of relevant findings not undertaken (DE) Evaluation of consumer protection, animal health and welfare should focus on visible findings as well as monitoring programmes (DE)

Country codes used: DE = Germany, DK = Denmark, ES = Spain, IT = Italy, NO = Norway, PT = Portugal.

Table 3b
Condensed answers of a SWOT-like analysis of food business operators' views (FBO) in six countries participating in a study about meat inspection code systems, 2020.

Things that I really like about the code system in place	Things that I struggle with when using the code system	Things that people should be aware of when using the system	Things that the system is not covering or not good at covering
The meaning of the codes is well-known and cover in practise all conditions that may arise (DK + ES + NO + PT) Valuable findings: liver with milk spots, medium + high grade pneumonia, pericarditis, pleuritis, and abscesses (DE) When paying the producer, transparent, useful, and detailed information/ documentation can be provided (DE + DK + ES + NO + PT) The codes describe well the herd/batch status, which can be used as an alert system for further investigations by the farmer (DE + IT + NO) Registration has become simpler and all use same system (NO) Steering codes are convenient to direct carcasses/cuts to adequate usage (DK) Data can be used for follow-up, control and research (DK + NO + PT) As the same terminology is used in all abattoirs, it is easy to compare meat inspection results (PT)	Variation in how code system is used between abattoir plants (DK + NO) Some findings have limited or no significance (DE) Although condemnation criteria are clear in the instruction, the interpretation leads to different judgement which creates insecurity for the abattoirs (ES) Scarcer availability of official staff for PM, so private-sector organisation of meat inspection will probably come (DE) Use of system is still occasional and not applied all over the country - at least non in every abattoir (IT) Small abattoirs have less interest in using data from inspection (DK) Meat inspection costs are perceived as high and with questionable value-for-money (DK) Weak explanation of how recordings address targeted intentions (NO) Data exchange system is still in an experimental phase and needs adjustments (PT)	Abattoir workers need to be trained to support CA in their work (DK) Large variability between OV and OA regarding detection of findings (DE) FBO must find adequate place for the system (IT) OV may be assisted by external personnel to perform task (further cost) (IT) In case of breakdown: Abattoir worker needs to register manually (DK) Knowledge of data flow is required to ensure meaningful interpretation (DK + PT) Training sessions should be held between CA/OV and FBO to unify criteria and make decisions of CA more understandable (DE + ES) Condemnation criteria associated with food safety and poor slaughtering process are of high interest to FBO (ES) Greater integration of modern, cost-effective laboratory diagnostics should be considered for large-scale screenings (DE) Despite of significant improvements, need for continuous system development and maintenance (NO) Adequate internet connection and a computer for the exclusive use of the OV are needed (PT)	System not focused on food safety impact, but mainly on quality issues, and foodborne hazards are not detected (DK) System is not focusing on herd health issues of interest to the pig producer (DK + IT) More attention should be paid to animal welfare codes and to comparability of detection and recording (DE). Regular performance reports are lacking disabling improvement in performance (NO) Not yet possible to register condemnations directly on the line and system is not used to order actions, but to record results (PT) Partial condemnations are not registered individually for each animal (PT) Absence of supporting laboratory tools may result in unnecessary condemnations (ES)

Country codes used: DE = Germany, DK = Denmark, ES = Spain, IT=Italy, NO=Norway, PT=Portugal.

The pigs consisted of finishing pigs and breeding pigs, raised indoors or outdoors. The most frequent cause of total condemnation was "osteitis" (36.3%), followed by "polyarthritis and arthritis" (10.3%), "multiple abscesses" (8.5%), "peritonitis" (7.1%), "pneumonia" (7.2%), "pleuro-pneumonia" (6.9%), "cachexia" (5.9%), "multiple lung or pleural abscesses" (2.4%), "traumatised, bloody or organoleptic changed meat" (1.8%) and "slaughter process deficiencies" (1.8%).

In Spain, two large abattoirs provided data. Overall, 0.11% (Abattoir A: 0.06%; Abattoir B 0.14%) of the 3.5 million pigs slaughtered at these two abattoirs were totally condemned. The most frequent cause of total condemnation was the presence of "abscesses or multiple abscesses" (28.5%), followed by "icterus" (20.5%) and "suppurative osteitis" (17.8%). Other causes of total condemnation were "erysipelas" (4.4%), "cachexia" (4.0%), "septicaemia" (2.6%), "polyarthritis" (2.5%), "delayed evisceration" (1.9%), "organoleptic alterations" (1.7%) and "over-scalding" (1.7%). Each of the remaining causes constituted <1.7% of the totally condemned pigs.

3.4. Comparison of findings related to partial condemnation in 2019

The percentage of pigs, carcasses or plucks subjected to partial condemnation is presented by country. Registration of more than one finding related to partial condemnation per pig was allowed in all seven countries' meat inspection systems. The codes that most frequently resulted in partial condemnation were listed. For each of these codes, the percentage of pigs out of the number of partially condemned pigs is indicated. For Finland, the percentage of partially condemned pigs out of the total number of slaughtered pigs is indicated.

In Denmark, no findings were registered at all for 54% of the pigs. For the remaining 46% of the pigs, 1.4 findings were registered per pig, on average. The most frequent cause of partial condemnation was "chronic pleuritis" (26.7%), followed by "mechanical errors related to slaughter" (24.3%), "contamination with bile" (8.5%) and "scar/contusion/bursitis" (5.7%). The remaining causes were found only infrequently, with a relative proportion of <5% each.

In Finland, regarding carcasses, 9.0% were officially subjected to partial condemnation. The data from the national monitoring system of pig health (explained in Section 3.1) showed "pleuritis" was the most frequent finding, observed in 22.5% of the pigs at slaughter, followed by "ascariasis" (5.0%), "pericarditis" (4.3%), "abscess/abscesses" (3.0%), "arthritis" (2.8%), "pneumonia" (2.7%) and "tail biting" (1.0%).

In Germany, the frequency of partial condemnations for carcass findings was 2.8% of all slaughtered finishing pigs. A total of 30.4% pigs had findings in their organs that led to partial condemnation. Among the organ alterations, the most frequent observations were in lungs (41.3%) and pleura (21.9%). Hence, 63.2% of all organ alterations in finishing pigs were observed in respiratory tract organs, corresponding to a total of 19.2% of all slaughtered finishing pigs. This was followed by parasite infection in the liver ("ascariasis") observed in 27.4% of all partial organ condemnations, "alterations of the kidney" (13.9%) and "pericarditis" (11.8%). Other registered organ alterations were "inflammations" or other alterations of the gastrointestinal tract, the liver or the heart (three codes).

In Italy, codes related to respiratory diseases were the most frequently registered, with "pleuritis", "enzootic pneumonia" and "pleuropneumonia" (first, second and fifth most common, respectively) together accounting for 38.0% of the total registrations. "Faecal or bile contamination" was detected in 5.5% of the inspected animals, "ascariasis" in 4.5%.

In Norway, partial condemnations are not required to be registered in the CA's register if the condemnation constitutes less than 10% of the carcass weight. However, as described above, in the USR system, some of the partial condemnations are registered for monitoring purposes. For example, the prevalence of "tail wounds/short tail" recorded in USR was 0.065%, corresponding to 2/3 of the animals with registered abnormalities. Moreover, parasites were registered as the cause of partial

condemnation of 0.06% of pig livers.

In Portugal, it is mandatory to register partial condemnation findings only if the proportion of condemnations is above 5% in the batch of slaughtered pigs, so some of the partial condemnations are not registered. On average, partial condemnations were recorded for 8.7% of the pigs slaughtered. The most frequent causes of partial condemnation were "liver-parasitism" (34.0%), "lung-emphysema" (18.7%), "lung-pneumonia, pleuritis, pleuropneumonia" (12.9%), "liver-degeneration" (7.5%), "stomach/intestines-enteritis" (5.8%), "lung-slaughter bleeding" (4.3%), "liver-hepatitis" (3.0%), "stomach/intestines-parasitism" (2.6%), "lung–congestion" (1.4%), "claws–arthritis" (1.2%) and "heart-uncomplicated infectious pericarditis" (1.2%).

In Spain, the two abattoirs contributing to the present study did not record partial condemnations, so the situation here cannot be compared with those in the other countries.

3.5. The most common codes for total and partial condemnation using grouped data

The most common codes resulting in total condemnation were grouped by similarity for six countries individually. For Finland, data for total condemnation were not available. Firstly, a frequency list for each country was created. Some countries had a plethora of up to 20 codes, whereas other countries used fewer codes. As a result, 10 aggregated codes were identified after grouping individual national codes with similar meanings (Table 4). The prevalences for some of these codes were missing for individual countries when a code contributing to the aggregated code did not exist in the national system. The absolute prevalences for the codes differed between the six countries. For Denmark, the most common code was complications called "circulatory disorder", whereas for Germany and Spain it was "abscesses", for Italy "slaughter process deficiencies", for Norway "generalised disease" and for Portugal "osteomyelitis/tail biting".

To compare partial condemnation causes, data from six countries were used. Partial condemnation data were not available for Spain. For Finland, only data for seven codes reflecting the most common pathologies were available: abscesses, arthritis, ascariasis, pericarditis, pleuritis, pneumonia, and tail biting. These seven codes usually result in partial condemnation, and they were used for a comparison between the countries. Compared to total condemnation data, there was a higher consistency between the absolute prevalences of causes of partial condemnation in the six countries. Again, it was impossible to identify one common most frequent code for all countries. "Pleuritis" was the most frequent code resulting in partial condemnation in three (Denmark, Finland, and Italy) of the six countries, whereas "pneumonia" and "milk spot livers" occurred more frequently in Finland, Germany, and Italy. In Norway, the low prevalences of the seven codes reflect the fact that partial condemnations are not mandatorily recorded in the CA's register, if the condemnation constitutes less than 10% of the carcass weight (Table 5).

3.6. Comparison of reasons for unfitness of meat

All seven countries included in this study have their own code system to register findings during meat inspection. Portugal and Finland have the most detailed systems, with 194 and 188 different codes, respectively, for total or partial condemnation. In contrast, Germany and Spain have 43 and 36 codes, respectively. In total, 664 national codes exist for all seven countries included in the study. Each of these codes was allocated to one of the 20 specific EU reasons for condemnation of pig meat, irrespective of whether the code would lead to total or partial condemnation of the carcass or organs. In total, 428 national codes were used to describe "pathological or organoleptic changes" (reason "o"). The second largest group consisted of 77 codes covering different aspects of generalised disease, such as "generalised septicaemia, pyaemia, toxaemia or viraemia" (reason "f"). A total of 26 codes were included in reason "o", specifying findings visible at post-mortem and with pathological changes, although the aetiological cause of a finding was a

Table 4
Top-10 list of aggregated meat inspection codes related to total condemnation for six European countries with absolute prevalences (%) observed at meat inspection of pigs, based on data covering 2019. More than one code can be used per pig in all countries except Portugal.

Aggregated code	Included codes	Absolute prevalence (%)					
		Denmark	Germany	Italy	Norway	Portugal	Spain
Abscesses	All codes that mention abscess	0.013	0.065[a]	0.022	0.086	0.033	0.027[a]
Arthritis	Polyarthritis/Arthritis	0.001	0.013	0.022	0.016	0.039	0.005
Cachexia/Thin	All codes associated with emaciation: cachexia, thin, malnutrition	0.006	0.006	0.002	0.002	0.022	0.006
Colour alteration/Icterus	Icterus, changes in colour	0.015	0.008	0.009	0.020	0.007	0.023
Erysipelas	Acute or chronic	0.008	0.004	0.027	0.012	<0.001	0.012
Generalised disease (septicaemia, infection)	All codes associated with generalised disease or condition: septicaemia, bacterial infection, generalised disease	0.006	0.024	0.001	0.159[a]	0.009	0.002
Circulatory disorders	Circulatory disorders, insufficient bleeding, anaemic, bloody meat	0.063[a]	0.001	<0.001	0.001	0.007	0.001
Osteomyelitis/Tail biting	Osteomyelitis, osteitis, tail biting, all codes which can lead to osteomyelitis or result in abscesses in the vertebral column	0.022	0.006	0.025	not recorded	0.139[a c]	<0.001[d]
Peritonitis	Acute or chronic	0.007	not recorded[b]	0.016	0.071	0.027	0.006
Slaughter process deficiencies	All possible findings due to process errors and contamination	0.009	0.042	0.041[a]	0.001	0.007	0.002

[a] The aggregated code which was most common in the country.
[b] In Germany, peritonitis is not recorded separately, but as part of the partial condemnation codes "inflammation in skin, muscle or other tissues" or "other pathophysiological lesions".
[c] In Portugal, the post-mortem finding "tail biting" is not a code for total condemnation, and thus, the aggregated code "osteomyelitis/tail biting" includes "osteomyelitis", "purulent osteitis" and "other osteitis".
[d] In Spain, the post-mortem finding "osteomyelitis/tail biting" does not exist, but the code "osteitis" exists as does the code "abscesses".

Table 5
The absolute prevalences (%) of seven findings at meat inspection – in general leading to partial condemnation – observed in pigs in each of six European countries, based on data from 2019. More than one code can be used per pig in all countries.

Meat inspection code	Absolute prevalence (%)					
	Denmark	Finland	Germany	Italy	Norway	Portugal
Abscess/Phlegmon	3.96	2.99	0.89	0.98	0.09[a]	0.04
Arthritis	0.18	2.82	0.46	1.06	0.02	0.18
Ascariosis/Milk spot liver	0.07	4.99	8.33	4.78	0.06[b]	2.94[a]
Pericarditis	0.05	4.34	3.58	6.15	0.05[c]	0.04
Pleuritis	16.84[a]	22.47[a]	6.64	10.37		1.18[c]
Pneumonia (all types)	0.18	2.66	10.07[a]	12.88[a]	0.02	
Tail biting	0.47	1.02	0.47	0.94	0.07[b]	<0.01

[d] In Portugal, the post-mortem findings pleuritis and pneumonia are counted within one of two codes "lung - pneumonia, pleuritis, pleuropneumonia" or "spareribs - pneumonia, pleuritis, pleuropneumonia".
[a] The aggregated code with the highest prevalence in the individual country.
[b] Obtained from the Norwegian USR data collection.
[c] In Norway, the post-mortem findings pericarditis and pleuritis are counted within one code "pericarditis/pleuritis".

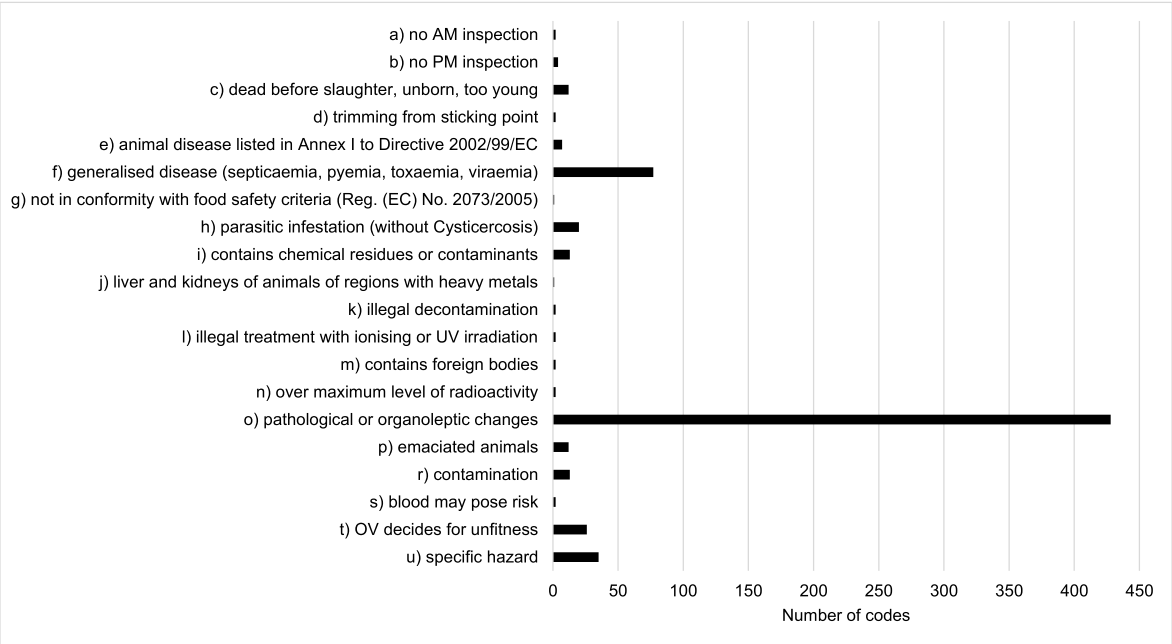

Fig. 1. Distribution of meat inspection codes (N = 664) in all seven countries' code systems according to the EU Food Inspection Regulation 2019/627 list of 20 reasons for pig meat to be considered as unfit for human consumption. (Reason "o" includes 26 national codes that could not be linked clearly to reasons "o" or "f".) AM: ante-mortem, PM: post-mortem.

generalised disease like pyaemia or septicaemia, i.e., polyarthritis, pyelonephritis or multiple abscesses (Fig. 1).

Furthermore, our intention was to identify the necessary number of codes needed to describe relevant findings in pigs in a way that would be informative for the pig producers, while also covering the 20 reasons for unfitness listed in the EU Food Inspection Regulation (EU Commission, 2019). The list of the aggregated codes identified was based on combining the seven countries' national codes, where they had similar meanings or possible associations to a pathology. Here, the wording in the 20 reasons for condemnation of the EU Regulation was maintained and additional findings were added. This resulted in the definition of 40 new aggregated codes, which include the reasons for unfitness as listed in the EU Regulation, specifications for some of these reasons, and typical post-mortem findings for pigs as shown in the present study. In this list, specific animal welfare codes were not identified.

The EU reason "o" meaning "pathological or organoleptic changes" was divided into two groups: 1) pathological findings and 2) organoleptic changes. For each of these two categories, new definitions, and hence codes, were suggested, reflecting different pathological findings that can appear in different organs. Twelve codes were associated with findings in different organs, such as liver lesion, kidney lesion and pneumonia. Icterus as an important organoleptic change was defined as one code.

For 101 codes on the national lists, no grouping or leaving them as individual codes seemed useful. They were associated with the EU reasons "generalised disease", "pathological or organoleptic findings" and "OV decides for unfitness". Therefore, these national codes were allocated to a new code named "other reasons for condemnation". An overview of the suggested new aggregated codes is given in Table 6.

Table 6
Suggested new, aggregated codes covering the 20 reasons for condemning fresh pig meat as unfit for human consumption, as given in EU Food Inspection Regulation 2019/627.

Aggregated code	Additional codes included	EU reason of condemnation
No ante-mortem inspection		No ante-mortem inspection
No post-mortem inspection		No post-mortem inspection
Dead before slaughter	Rejected from slaughter/euthanised	Dead before slaughter, unborn, too young
Emergency slaughter		
Unborn/too young		
Trimmings from sticking point		Trimmings from sticking point
Animal disease listed in Annex I to Directive 2002/99/EC		Animal disease listed in Annex I to Directive 2002/99/EC
Generalised disease/infection/toxaemia	Bacteria, viral, other infections leading to generalised infection, notifiable diseases	Generalised disease like septicaemia, pyaemia, toxaemia, viraemia
Not in conformity with food safety criteria of Reg. (EC) No. 2073/2005		Not in conformity with food safety criteria of EU Regulation 2073/2005
Parasitic infection/infestation (without cysticercosis and trichinellosis)	All parasitic diseases other than cysticercosis and trichinellosis	Parasitic infestation (without cysticercosis or trichinellosis)
Meat contains chemical residues or contaminants		Meat contains chemical residues or contaminants
Liver and kidney from animals in regions with heavy metals		Liver and kidneys from animals out of regions with heavy metals
Illegal decontamination		Illegal decontamination
Illegal treatment with ionising or UV irradiation		Illegal treatment with ionising or UV irradiation
Meat contains foreign bodies		Meat contains foreign bodies
Over maximum level of accepted radioactivity		Over maximum level of radioactivity
Icterus	Icterus, jaundice	Pathological or organoleptic changes (boar taint, abnormal colour)
Organoleptic changes	Abnormal odour, abnormal taste, abnormal texture	
Insufficient bleeding	Insufficient bleeding, bloody carcass	
PSE/DFD		
Abscess	All types of abscesses irrespective of the localisation	
Arthritis/polyarthritis		
Erysipelas	All types of erysipelas with localised or generalised lesions	
Pneumonia	All types of pneumonia	
Pleuritis	All types of pleuritis	
Peritonitis	All types of peritonitis	
Tail biting	Tail biting, abscess around the tail	
Osteomyelitis/osteitis	Osteomyelitis, osteitis	
Organ lesion	Fractures, gastritis/enteritis, heart lesions (endocarditis, pericarditis, myocarditis), kidney lesions (nephritis, cysts), liver lesions (hepatitis, perihepatitis, milk spots), lung lesions, muscle lesions, skin lesions	
Hernia/prolapse	All types of hernia, rectal prolapse	
Ascites		
Cachexia/thin/malnutrition	Thin, lean, malnutrition, cachexia	Emaciated animals
Contamination	Any contamination of the carcass and organs	Contamination
Blood may pose a health risk		Blood may pose a health risk
Slaughter process deficiencies	Any slaughter error leading to contamination	OV decides for unfitness
Lack of organs		
Bites	All signs of biting ante-mortem	
Marking	Over-tattooing, wrong marking, identification problems	
Late post-mortem inspection		
Specific hazard(s)	Brucellosis, cysticercosis, salmonellosis, trichinellosis, tuberculosis	Specific Hazard
Other reasons for condemnation	All types of post-mortem findings that could not be grouped in another suggested, new aggregated code	

4. Discussion

4.1. Key results

Meat inspection systems are undergoing continuous revision and reform by the CAs, and currently, there is pressure from the FBOs for lower costs and greater effectiveness (Blagojevic et al., 2021; Buncic et al., 2019; Riess & Hoelzer, 2020). However, before changing the system, it is important to study the impact of proposed changes and alternatives. Moreover, some degree of harmonisation would make sense from both public health and animal health perspective. Consequently, it is scientifically appropriate to begin by analysing the systems in force, including the code systems for registering the findings during meat inspection, to identify to what extent the systems differ. The focus in this study was on European pigs, but similar challenges are expected for other livestock species. In the EU, alternative and simplified inspection of young bovines, sheep, and goats with no eruption of permanent incisors and non-grey horses is now allowed (EU Commission, 2019), so this topic is of some urgency. Moreover, a cost-effective meat inspection system is not just a European issue, but is equally relevant for other parts of the world, including developing countries, in their attempts to produce safe meat for their own populations and to enable export of meat. To address this issue, the Food and Agriculture Organization of the United Nations (FAO) has led the development of a guidance document regarding risk-based meat inspection. The objective of the document is to strengthen capacities in designing and implementing national policies, strategies and regulatory frameworks within meat inspection (FAO, 2019).

Overall, substantial differences were found between the code systems in force in the seven countries. The diversity in these code systems reflects their individual modification over time, with gradual changes fulfilling country-specific needs. Such unscientific development means it

could be necessary to completely rethink the system. Some countries had separate sets of total condemnation and partial condemnation codes. Other countries listed all codes in one list only. In Portugal and Italy, only one code is allowed to totally condemn a pig. In contrast, four codes are allowed in Denmark, and the other countries do not limit numbers of codes. Each approach has its own advantages and disadvantages, but when interpreting and comparing data from different national databases, the differences regarding data recording structure must be known. Our finding is in line with Stärk et al. (2014), who found that although the legal basis is the same, the way meat inspection is undertaken differs between countries.

The number of codes available also varied greatly. It may be argued that a system with many codes will make it possible to give a detailed description of the findings during inspection and that these findings will be of value to the livestock producers. However, the question is whether a very high number of codes is needed for routine meat inspection of pigs. Also, the decision to assign a code to a specific condition could be unnecessarily laborious with a higher number of codes. A balance should, therefore, be found between the need to know the aetiology and simplicity, while remembering to focus on determining the necessary corrective actions related to each specific finding.

The experts participating in the SWOT-like analysis pointed to the value of continued education for meat inspection personnel to ensure proper functioning of the system (Tables 3a and 3b). The universities in collaboration with the FBO and the CA should be encouraged to organise such training. Moreover, within the COST Action RIBMMINS, training schools are organised, with free access to training materials (https://ribmins.com/training-school-on-future-meat-safety/).

Substantial differences in the percentage of pigs being condemned in each country were detected; from 0.11% in Spain to 0.51% in Finland ($P < 0.0001$). There are several reasons for this variation, but there is also some selection bias in the data, which will be discussed in Section 4.2. Still, the variation in percentage is remarkable, and it can, to some extent, be explained by different criteria regarding carcass condemnations. For example, in Portugal, osteomyelitis in carcasses has, until very recently, mostly resulted in total condemnation, as explained by Vieira-Pinto et al. (2020), whereas in Denmark, carcasses with osteomyelitis are subjected to a so-called pyaemia investigation focusing first on assessing whether the condition is generalised. If this is not the case, the inspection is targeted to the predilection sites for abscesses, and hence, the result is mostly partial condemnation (Alban et al., 2021). This distinction between generalised and local is in accordance with footnote 2, in Section 3 to Annex I in the EU Food Inspection Regulation 2019/627, which states that the coding system can include a subdivision for mild, generalised disease and more severe disease (EU Commission, 2019). In Norway, the condemnation rate has steadily declined since 2002, when 0.81% of pig carcasses were totally condemned (Animalia, 2020). During this period in Norway, interpretation of the EU regulations has changed, calibration exercises related to meat inspections have been undertaken, the code system has been revised, and the animals' genetic constitution and housing has improved. The issue of condemnation criteria warrants further investigation and is currently being investigated by WG4.

Moreover, when the most common aggregated codes leading to total and partial condemnations were compared, large variations in code prevalences were seen, such that it was impossible to identify one aggregated code as the most frequent in all six countries (Tables 4 and 5). These differences could reflect true differences in animal health caused by different types of production or herd sizes. As an example, pigs in Northern Italy are generally slaughtered at >9 months old and weighing >160 kg (Ghidini et al., 2018). This is much older than in the six other countries, where finishing pigs are slaughtered when 5.5–6 months old. The greater age could explain the different importance of erysipelas, which plays a more prominent role in total condemnation in Italy than in the other countries. However, the difference observed could also be ascribed to different ways of handling erysipelas cases; in Denmark, Finland, Norway and Portugal, only acute cases are condemned, while chronic cases are partially condemned. In Italy, the distinction between acute and chronic cannot be used in relation to this condition, leading to more total condemnations. It was also found that quite different codes can be used to record similar findings. For example, a case of total condemnation due to osteomyelitis can be registered using this designation in one country, but in another country, the codes septicaemia or abscesses can be used. This type of variation occurs between OV and OA in one abattoir (Schleicher et al., 2013) and between abattoirs (Steinmann et al., 2018). Moreover, there was great variation regarding the underlying reasons for recording a finding; in Denmark, the focus is on recording findings where an action is required, whereas in Portugal the focus is more on recording abnormalities irrespective of action (Table 2). Finally, in Norway, findings requiring partial condemnation are not registered systematically, leading to low apparent prevalences as noted in Table 5. The variation in when and how to register a finding made statistical testing of apparent differences meaningless in the current study. To further elucidate whether the observed differences are due to animal health, it could be of interest to consider data on veterinary treatment, including antimicrobial use. However, reductions in antimicrobial use can result in an increase in some meat inspection findings, as was found in Denmark after the introduction of the so-called Yellow Card scheme that limits the use of antimicrobials in Danish pigs (Alban et al., 2013).

Our comparison of the national code systems with the EU list of reasons for declaring meat unfit for consumption showed that only the Norwegian national code system included all EU reasons together with additional country-specific and more detailed codes. In all other countries, a plethora of codes existed, but they did not cover all the 20 reasons relevant for pigs as the EU Regulation specifies (Tables S1 and S8). For a total of 26 national codes, it was difficult to ascribe them to one EU reason solely, as they reflected both a systemic condition, and hence "generalised disease" (reason "f") and a "pathological change" (reason "o" "pathological or organoleptic changes"). We suggested dividing reason "o" into two codes: "pathological changes" and "organoleptic changes like abnormal smell, colour or taste".

Overall, the EU list of reasons sufficiently describes when to condemn meat due to food safety and hygiene concerns, whereas it does not cover directly animal welfare issues. Animal welfare is addressed in Article 44 of the EU Food Regulation 2019/627. This might reflect the development of modern meat inspection laws (Blagojevic et al., 2021; Buncic et al., 2019; Stärk et al., 2014). Increasingly, the aspect of animal welfare is playing a more important role in Western societies. Hence, animal welfare is not seen as part of meat hygiene but as a parallel topic, for which codes are needed that would enable the OV and OA to collect relevant data in a uniform way. Still, pathological changes resulting from non-compliance with animal welfare rules can be recorded according to the current system using reasons "f", "o" or "p". Moreover, reason "o" covering pathological or organoleptic changes is too broad, so several new codes are suggested to ensure the data recorded during meat inspection are informative for all parties involved; the livestock producer, the CA, and the FBO. Some of the EU reasons are not equally relevant or applicable in all Member States, e.g. "n", referring to meat exceeding maximum permitted radioactivity levels. Also, not all EU reasons are applicable to finishing pigs, e.g. reason "j" is applied to animals over 2 years old. For other reasons, a procedure is in force instead of a code, e.g. for EU reason "g", dealing with the food safety criteria, where an FBO's own check programme involving sampling after cooling could be in place.

4.2. Limitations

In general, it was difficult to access the relevant information about the code systems in force and meat inspection data. Therefore, when national data were unavailable, data from one or two large abattoirs were used. This means that an additional source of bias was introduced;

the Danish data included a high number of slaughtered pigs from one plant only, which belonged to the largest abattoir company, Danish Crown, slaughtering 75% of the pigs in Denmark, making the data representative overall (Danish Agriculture & Food Council, 2020). In Finland, the national database available for the study contains the prevalences of total condemnations, partial condemnations and certain findings, but the findings are recorded separately and cannot be linked with the total or partial condemnations. The German data included all finishing pigs slaughtered in the country. In Italy, there is no official meat inspection code system, and therefore, the Classyfarm system developed by the Experimental Zooprophylactic Institute of Lombardy and Emilia Romagna (IZSLER) and owned by the Italian Ministry of Health (Classyfarm, 2020) was used. The Norwegian data describing causes of condemnation were from one abattoir only. The Portuguese data covered all pigs slaughtered in mainland Portugal, including sows and boars, indoor- and outdoor-raised. The Spanish data originated from two large abattoirs slaughtering indoor finishing pigs. This variation in the data origins should be kept in mind when interpreting the results. The challenge related to retrieving data from meat inspection was also experienced by Stärk et al. (2014), who chose to use expert opinion in their work for EFSA. Still, the data obtained allowed us to analyse the issue of bias in the registration of meat inspection findings and to reach the conclusion that the variation in code systems is substantial, hampering an easy comparison of data. The bias found was higher for the findings leading to partial condemnation than for those leading to total condemnation.

In several of the seven countries, the way data were recorded disabled some simple analyses, e.g., the percentage of pigs with no findings at all. Furthermore, when multiple codes could be assigned to one pig, the summary data contained the number of times a code was used, but it did not indicate whether one slaughtered pig had received several codes. Moreover, for some countries allowing multiple codes for total condemnation, it was unknown whether the assignment of a specific code had led to partial or total condemnation, as another code also found on the carcass could have determined the outcome. No statistical testing of differences in observed prevalences between countries was performed, except for the condemnation prevalences. This was partly because of the issues described immediately above, and partly because when datasets are very large, even minute differences in prevalences become statistically significant. In that case, attention should be directed to the overall differences observed in the prevalences.

The SWOT-like analyses were based upon comprehensive discussions with two to eight experts per country. Four open questions phrased in simple language were posed, encouraging the interviewees to provide detailed and comprehensive answers. Such a qualitative approach is well-known, and the value lies, among other things, in the production of extremely relevant data (Dyson, 2004; Léger et al., 2019). Moreover, such open questions have been used recently with success (Nielsen et al., 2020; Sandberg et al., 2021). Our experts all had more than 10 years of experience related to meat inspection, which adds credence to their answers. However, it should be borne in mind that slightly different answers could have been provided if other experts had been interviewed.

4.3. Perspectives and recommendations

Meat inspection should detect conditions relevant to public health and decide on fitness of meat for human consumption, and therefore, on the basis of the current study, a new list consisting of 40 aggregated codes is suggested. However, inspection should also detect animal health issues and non-compliance with animal welfare rules, and therefore, relevant codes for animal welfare should be identified and added, as these are not sufficiently covered in the existing code lists. The CA and the FBO have an interest in showing compliance with requirements given by national legislation and/or important trade partners, and hence, be decision oriented. The pig producers could be interested not just in knowing the outcomes (condemnation or not, total or partial), but also receiving data on their pigs' health status. The challenge will be to handle the different requirements listed above in a cost-effective way.

Development and use of clear guidelines and associated training are needed regarding how to register the findings observed in a pig. Calibration is expected to lead to more harmonisation, which will enable meaningful comparison of data from the different abattoirs within a country or region and between countries. Such harmonisation will also be appreciated by pig producers sending comparable groups of pigs to different abattoirs or plants and wondering why the health recordings of the groups vary considerably, as shown by Denwood et al. (2015). Variations in post-mortem assessment between OVs and OAs and also between different abattoirs exist, as shown previously (Arzoomand et al., 2019; Steinmann et al., 2018). Harmonisation is also needed before an FBO can implement an incentive system involving reduced payment for pigs that need extra handling due to findings requiring partial condemnation. Such a system was attempted by one large Danish FBO with several plants, but it was discarded due to the large differences in codes used by the different plants (data not shown). If prevalences of conditions causing condemnations reflect true differences in animal health, then the CAs and FBOs should use this information to plan and introduce relevant targeted actions to improve public health as well as animal health and welfare. Here, statistical analyses of causes of condemnation using the inspection data would be useful to identify specific areas where improvements are needed. Such a study on meat inspection codes related to broilers was recently published (Alfifi et al., 2020). Developments in big data analytical techniques and large computer capacity should be useful to further analyse reasons for partial or total condemnations. Moreover, use of prior information about the health status of pigs from one farm could be used to predict the health status of the next batch. Such predictions would be used to plan deliveries and ensure adequate numbers of OVs and OAs are present.

Development of clear and common definitions of the findings observed during meat inspection is suggested – maybe in the form of an ontology. Based on this, a consistent code list could be created to make post-mortem findings in the EU more comparable and the recorded data more useful. Our current study – including the suggested list of 40 aggregated codes – could act as the basis for development of an adequate code system, while not forgetting animal welfare, for which suitable codes need to be established.

5. Conclusion

Comparison of the meat inspection code systems in seven European countries showed the systems vary considerably regarding terminology, number of codes available, the allowed number of codes assigned per pig, and the way the codes in the list can be categorised, e.g. by species or by having one list for total condemnation and another for partial condemnation. Moreover, in one country, there is no official coding system at national level, but only at regional level, and in another country, there is no official code system at all.

The prevalence of total condemnations varies substantially between the seven countries. Although there was some bias in the collected data, the variation was most likely related to the way the condemnation criteria are defined and being used. Total and partial condemnation

findings varied extensively, making it impossible to identify one most common finding. The variation may be related not just to true differences in animal health but also to the way the code systems are set up and interpreted.

Comparison of the 20 reasons for unfitness of pig meat given in the EU Food Inspection Regulation (EU) 2019/627 with the national code lists showed not all countries cover all 20 EU reasons. Not all codes could be linked easily to one specific EU reason. The EU list focuses only on unfitness of meat for human consumption, but animal welfare, another reason for undertaking meat inspection, and which in some cases can also lead to condemnations, is not included. This indicates more codes are needed for a fully functional system.

Finally, a list of 40 new, aggregated codes is proposed in the current study. These aggregated codes should be considered in a future discussion about more harmonised meat inspection. The adoption of aggregated, applicable codes would result in meaningful data for the pig producers and would allow comparisons between abattoirs.

Declaration of interest

LA and OA work for organisations that give advice to farmers and meat-producing companies. SG, DM, PM, NL, and MVP declare no conflict of interest. RLN's employment is partly funded by the Finnish Food Authority. SS works for the Portuguese veterinary authorities. JGL is supported by a "Ramón y Cajal" contract from the Spanish Ministry of Economy and Competitiveness (RYC-2014-16735).

CRediT authorship contribution statement

Lis Alban: planned the work and took lead in all parts of the study, from the conception to the writing of the manuscript. **Patric Maurer:** was responsible for the work related to combining different meat inspection codes with a similar meaning. **Nina Langkabel:** planned the work and took lead in all parts of the study, from the conception to the writing of the manuscript, and was responsible for the work related to combining different meat inspection codes with a similar meaning as well as creating the summary codes. All authors contributed with data and descriptions of their national systems and interpretation of the results as well as read and approved the final version of the manuscript.

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Appendix A. Supplementary data

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