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RESEARCH ARTICLE

Additional *post-mortem* inspection procedures and laboratory methods as supplements for visual meat inspection of finishing pigs in Europe—Use and variability

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Abstract

In the EU, a *post-mortem* inspection of finishing pigs comprises visual inspections of the carcass and offal followed by additional examinations, such as palpation and incision of parts, when needed. Moreover, it can include various laboratory tests. Since European meat inspection is regulated by the EU, one may assume that *post-mortem* inspection is performed in the same way in the Member States. However, previous studies showed that variations exist. This article shows the results of a survey performed in September 2020 on how visual meat inspection of finishing pigs is applied in Europe. By using a questionnaire, palpations, incisions and other procedures for 10 gross pathological findings and laboratory methods applied by official veterinarians to evaluate the fitness of meat for human consumption were assessed. We received 44 responses from 26 European countries. Most respondents reported that visual meat inspection was a generally applied inspection method. The main reason for not applying visual meat inspection was export requirements. The most important reasons for applying palpations and incisions in addition to visual inspection were findings detected in *ante-* or *post-mortem* inspection. There was considerable variation in the use of palpations and incisions, other *post-mortem* procedures and laboratory tests to assess meat fitness for human consumption. The respondents mentioned some country-specific practices, but we also observed variations within the responding official veterinarians that could not be explained by country of origin or years of work experience. Additional detailed studies on the variation are needed before harmonisation of meat inspection procedures are attempted.

Keywords Meat inspection · Swine · Veterinarians · Official controls · Legislation

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1 Introduction

Globally, meat inspection is a mandatory food control activity defined by legislation. It is essential for verifying compliance with requirements on consumer protection, animal health and animal welfare (Commission Implementing Regulation (EU) 2019/627). Therefore, uniform practical arrangements have been laid down in the EU for meat inspection in order to ensure high levels of consumer and animal health and welfare protection as well as fair trade (Commission Implementing Regulation (EU) 2019/627; Regulation (EU) 2017/625 of the European Parliament and of the Council).

In the EU, *post-mortem* inspection procedures of domestic pigs are regulated by Commission Implementing Regulation (EU) 2019/627. The Regulation prescribes visual inspection of the carcass and offal, supplemented by additional examinations, such as palpation and incision of parts of the carcass and offal, and laboratory tests when indicated (Article 14 of Commission Implementing Regulation (EU) 2019/627). Article 14 further specifies the purpose of the additional examinations, but it does not specify which laboratory tests should be used. According to Article 14, the additional examinations are should be used to:

(a) diagnose a specific hazard, and detect
(b) animal diseases,
(c) chemical residues or contaminants,
(d) non-compliance with microbiological criteria or the presence of microbiological hazards or,
(e) other factors that may cause the carcass and offal to be deemed unfit for human consumption or cause restrictions for their use.

The additional *post-mortem* inspection (APMI) procedures using palpations and incisions and their indications for domestic pigs are presented in Article 23(2) of the Commission Implementing Regulation (EU) 2019/627): The APMI procedures must be made if, in the opinion of the official veterinarian, a possible risk to human health, animal health or animal welfare is indicated. Indication of such a risk, defined in Article 24, includes:

(a) the checks and analysis of the checks of documents containing food chain information and official certificates and declarations and other relevant information.
(b) the findings of the *ante-mortem* inspection,
(c) the results of the verifications of compliance with animal welfare rules,
(d) the findings of *post-mortem* inspection and
(e) additional epidemiological data or other data from the holding of provenance of the animals.

Meat inspection is regulated at the EU level by EU Regulations, which are automatically binding in the EU member states. In addition, EU Regulations have been adopted in some non-EU-countries, e.g. in countries belonging to the European Economic Area (EEA), or in those applying to become member states or looking to obtain access to the EU market. Visual meat inspection of domestic pigs as a standard has been in force since June 2014 (Commission Regulation (EU) No 219/2014). Therefore, it might be assumed that visual meat inspection would be fairly established, and that meat inspection is performed in the same way in all EU Member States. However, there are reasons for differences, such as export requirements that limit the use of visual meat inspection in export-oriented slaughterhouses (Alban et al. 2021; Laukkanen-Ninios et al. 2020; Riess and Hoelzer 2020). Also, the use of risk-based approaches in meat inspection, which focuses on high-risk hazards and aims to enhance meat safety throughout the food chain (Blagojević et al. 2021), affects how meat inspection is performed. For example, the prevalence of various diseases in different countries affects which palpations and incisions are needed in each country. Recent studies have shown systemic variations in meat inspection between countries (Alban et al. 2022), within countries (Klinger et al. 2021) and at individual inspector level within a slaughterhouse (Arzoomand et al. 2019). Alban et al. (2022) detected differences in the number of available codes, code terminology, and frequency of meat inspection findings in European countries. Klinger et al. (2021) showed differences between and within slaughterhouses on the observed prevalence of meat inspection findings. Within a slaughterhouse, differences between meat inspection decisions of detained carcasses were observed between meat inspection personnel (Arzoomand et al. 2019). Before any attempt to harmonise the way meat inspection is performed in the EU, detailed understanding is needed regarding how meat inspection is performed within European countries.

The aims of this study were to investigate to which degree visual meat inspection is applied in European countries and to determine the indications for APMI procedures applied to supplement visual meat inspection. To address this, we collected information on procedures in relation to 10 selected cases commonly seen in pig meat inspection, and on laboratory methods that official veterinarians use to assess the fitness of meat for human consumption.

Table 1 Country of origin of the 44 survey respondents according to regions defined in the EU Thesaurus EuroVoc

Group	No. of responses	No. of countries	Central and East Europe	North Europe	South Europe	West Europe
EU Member States	34	20	Croatia Poland Slovakia Slovenia	Denmark Estonia Finland Latvia Lithuania Sweden	Greece Italy Portugal Spain	Austria Belgium France Germany Ireland The Netherlands
Other	10	6	Albania Serbia	Iceland Norway		Switzerland United Kingdom
Total	44	26				

2 Material and methods

2.1 Recruitment of respondents

This work was part of a questionnaire study undertaken in the COST Action 18105 RIBMINS,[1] aiming at collecting information on how *post-mortem* inspection of finishing pigs is currently performed in Europe. The questionnaire was distributed in September 2020 via 33 National Contact Points of the COST Action RIBMINS and via members of the European Commission Working Group on Food Hygiene and Controls of Food of Animal Origin of the Standing Committee on Plants, Animals, Food and Feed (SCoPAFF). The National Contact Points and members of the Commission Working Group were instructed to invite one or more official veterinarians with practical experience in pig meat inspection from their country.

2.2 Questionnaire

An electronic questionnaire was prepared using SurveyHero® (enuvoGmbH, Zürich, Switzerland) to collect data on how meat inspection of finishing pigs is currently performed in European countries (Vieira-Pinto et al. 2022). In this paper, we analysed questions on each respondent's background, their application of visual meat inspection, APMI procedures and laboratory tests to support visual meat inspection of finishing pigs (Table S1, Supplementary Material). The use of APMI procedures as described in Article 23(2) (a)–(i) of Commission Implementing Regulation (EU) 2019/627)[2] was explored for 10 gross pathological findings that can be detected during *post-mortem* inspection of finishing pigs and can be responsible for total condemnation (Table S1, Supplementary Material). These 10 gross pathological findings were selected based on data describing the main condemnation causes in seven European countries (Alban et al. 2022). The selected gross pathological findings were abscesses, arthritis, cachexia, erysipelas, icterus, *Mycobacterium*-like lesions, osteomyelitis, peritonitis, pleuritis and pneumonia.

2.3 Data processing and statistical analyses

The data were processed, and figures created using Excel 2016 (Microsoft, Redmond, WA, USA), except for boxplots and scatter plots, which were created by IBM SPSS 27 (IBM Corp. Released 2020, IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY, USA: IBM Corp).

A total response was discarded if the respondent had not marked the questionnaire as finished, and a response to an individual question was discarded if it was clearly non-relevant.

The mean ranks of the most important reasons for the respondents to perform APMI procedures were calculated as an average of the ranks (1–5) given by the respondents, where 1 was the most and 5 the least important reason.

Countries were grouped into regions according to definitions of the EU's thesaurus EuroVoc,[3] to examine regional differences in the number of APMI procedures used to detect the 10 gross pathological findings (Table 1). The groups were compared using Kruskal–Wallis H test in IBM SPSS 27.

The correlation between the respondents' years of work experience and number of APMI procedures was tested using Spearman's Rank Order Correlation in IBM SPSS 27.

3 Results

In total, 44 complete responses were received from 26 European countries (Table 1), with between 1 and 3 responses from each country. Two responses were not verified as completed by the respondents and therefore excluded from the study. Additionally, 2 responses

[1] www.ribmins.com Accessed 20 June 2022.

[2] http://data.europa.eu/eli/reg_impl/2019/627/oj Accessed 20 June 2022.

[3] https://eur-lex.europa.eu/browse/eurovoc.html Accessed 30.06.2022.

Table 2 Reasons for not applying visual meat inspection (n = 11)

Reason	Visual meat inspection		Total
	Not always applied[a] (n = 8)	Not applied (n = 3)	
Export requirements	3 (38%)[b]	2 (67%)	5 (45%)
Legal requirements for additional *post-mortem* procedures	4 (50%)	0	4 (36%)
Disease control[c]	1 (13%)	0	1 (9%)
Epidemiological data[d]	2 (25%)	0	2 (18%)
Not yet implemented	0	1 (33%)	1 (9%)

[a]Two respondents mentioned two different reasons

[b]Includes outdoor-reared pigs in export slaughterhouses

[c]A requirement to incise a proportion of mandibular lymph nodes (*Lnn. mandibulares*, submaxillary lymph nodes in (Article 23 (2) (a) of Commission Implementing Regulation (EU) 2019/627) and to perform subsequent additional *post-mortem* procedures for the batch if lesions are found

[d]*Salmonella* and *Mycobacterium* status of the farm

regarding question (2.2) about the application of visual meat inspection in their daily work were excluded, because the respondents did not perform meat inspection daily (Table S1 Supplementary Material). In addition, one respondent did not answer the questions concerning laboratory methods.

The response rate for the survey could not be calculated since there was no direct list of the recipients. However, we received answers from 25 out of 33 countries (76%), where COST Action RIBMINS identified National Contact Points and one country without a National Contact Point. The answers came from 20 of the 27 EU Member States (74%) (Table 1). The median work experience of the respondents (n = 43) was 10 years and ranged between 1 and 34 years.

3.1 Application of visual meat inspection

Visual meat inspection was applied by 31 respondents (74%), not always applied by 8 respondents (19%), and not applied by 3 respondents (7%). Export requirements was the main reason for not or not always applying visual meat inspection (Table 2). Four respondents specified legal requirements as a reason for not always applying visual inspections, such as findings during *ante-* or *post-mortem* inspections or welfare concerns (Table 2).

3.2 Application of APMI procedures

The most important reasons for the respondents to perform APMI procedures were "findings in *post-mortem* inspection" (mean rank 1.8), followed by "findings in *ante-mortem* inspection" (mean rank 2.1). The ranking of "the checks and analysis of the checks of documents" (mean rank 3.4), "additional epidemiological data or other data from the holding of provenance of the animals" (mean rank 3.7) and "the results of the verifications of compliance with animal welfare rules" (mean rank 3.8) varied considerably between respondents (Fig. 1).

There were 7 responses (16%) describing other data, results or findings used to determine whether APMI procedures are needed. The data specified encompassed food chain information (n = 2), results from *Salmonella* monitoring program (n = 2), comparison of data/ranking of holdings (n = 2), membership of a private quality scheme (n = 1),

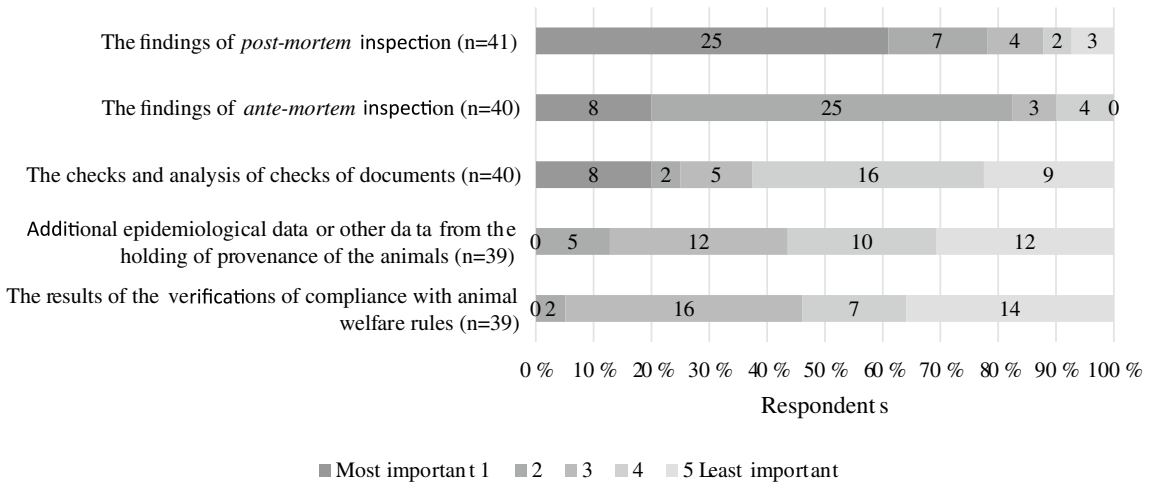

Fig. 1 Ranking of the reasons to perform additional *post-mortem* procedures according to the frequency of use by all respondents (1 = most important; 5 = least important). The data labels indicate the number of respondents

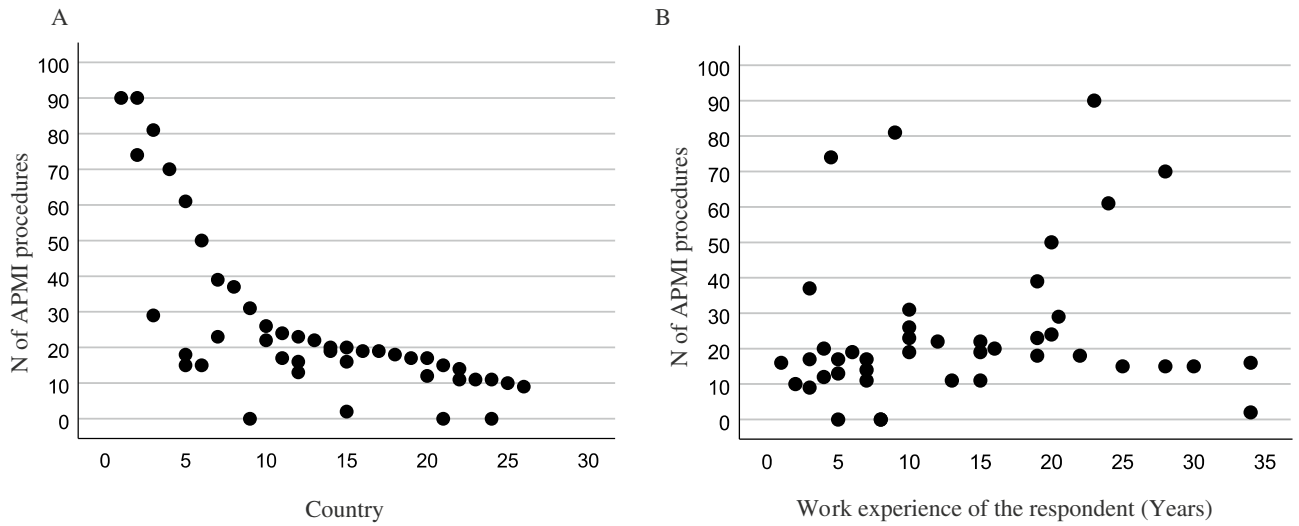

Fig. 2 Scatter chart plotting. **A** Country with descending total number of additional *post-mortem* inspection (APMI) procedures and **B** work experience against sum of (APMI) procedures (Article 23 (2) (a)–(i) of Commission Implementing Regulation (EU) 2019/627). The maximum number of APMI procedures per respondent was 90, enlisted from the 9 different APMI procedures for 10 gross pathological findings combined, which the 44 respondents stated as required

documents (n = 1), results from previous batches (n = 1), and experience (n = 1).

3.3 APMI procedures to determine meat's fitness for human consumption

When evaluating whether meat was fit for human consumption or not, the mode values of APMI procedures were 0 or 1 for 7 of the 10 investigated gross pathological findings (Fig. S1 Supplementary Material). Abscesses and *Mycobacterium*-like lesions varied most in the number of APMI procedures required to evaluate whether meat was fit for consumption or not (Fig. 1 Supplementary Material). The number of APMI procedures varied between the respondents, irrespective of work experience and country of origin (Fig. 2). There was no significant correlation between the years of work experience and total number of applied APMI procedures ($\rho = 0.246$; $p = 0.112$). There was a weak positive correlation between work experience and number of APMI procedures used to detect abscesses ($\rho = 0.381$; $p = 0.012$) and peritonitis ($\rho = 0.324$; $p = 0.034$). There was no significant difference (Kruskal-Wallis H, $p > 0.05$ for all APMI procedures) between geographical regions in the use of APMI procedures (Fig. 3).

Three respondents did not declare any use of APMI procedures to detect the 10 common gross pathological findings, whereas 2 respondents stated they used all 9 APMI procedures given in Commission Implementing Regulation (EU) 2019/627 for all 10 gross pathological findings (Fig. 2; Fig. S1 Supplementary Material).

The most frequently used APMI procedures were palpation of lungs and tracheobronchial (bronchial lymph nodes in Article 23 (2) (b) of Commission Implementing Regulation (EU) 2019/627), and mediastinal lymph nodes together with incision of trachea, bronchi, and lungs. It was particularly used in cases of pleuritis (82% of respondents) and pneumonia (82% of respondents) (Fig. 4). The least used APMI procedure was incision of the supramammary lymph nodes, except for *Mycobacterium*-like lesions, where it was the second least used procedure after those for the umbilical region and joints of young animals (Fig. 4).

Mycobacterium-like lesions required the most APMI procedures (mean 3.6) (Fig. S1 Supplementary Material) and most often (86%) required at least one APMI procedure (Fig. 4). The most commonly used APMI procedures for *Mycobacterium*-like lesions (68%) were incision, examination and palpation of the mandibular lymph nodes (*Lnn. mandibulares*, submaxillary lymph nodes in Article 23 (2) (a) of Commission Implementing Regulation (EU) 2019/627) and if necessary, incision of the gastric and mesenteric lymph nodes (64%). Cachexia (50%) and osteomyelitis (50%) were the gross pathological findings requiring the fewest APMI procedures, followed by icterus (66%) (Fig. 4).

3.4 Other *post-mortem* procedures to evaluate the fitness of meat for human consumption

Altogether, 26 (59%) respondents stated that they used other procedures than those defined in Article 23(2) of

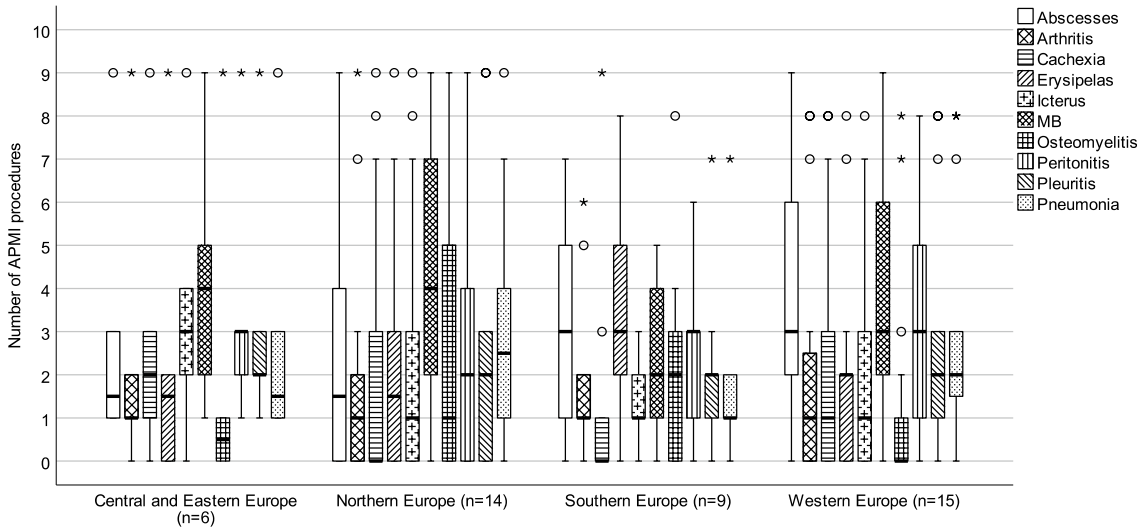

Fig. 3 Boxplot of the number of additional *post-mortem* inspection (APMI) procedures (n = 9) (Article 23(2) (a)–(i) of Commission Implementing Regulation (EU) 2019/627) that 44 respondents stated to be required to determine if pork is fit for human consumption for each of the 10 gross pathological findings according to regions defined in the EU's Thesaurus EuroVoc. The line in the box represents the median. The outliers (circles) are ≥ 1.5 x Interquartile range and (asterisks) ≥ 3 x Interquartile range. MB, *Mycobacterium*-like lesions

Additional *post-mortem* procedure	Cachexia	Osteomyelitis	Icterus	Erysipelas	Arthritis	Abscesses	Peritonitis	Pleuritis	Pneumonia	MB-like lesions[a]	Total[b]
(h) Suppramammary lymph nodes	11	9	9	14	14	20	11	9	7	18	43
(g) Kidney	34	27	27	32	20	32	32	23	23	25	66
(i) Umbilical region and joints of young animals	14	23	7	27	59	30	16	11	9	7	73
(f) Spleen	20	18	39	32	18	23	43	18	20	39	80
(c) Heart	34	34	25	59	39	41	25	61	50	23	82
(d) Liver	27	25	61	27	23	43	57	18	20	59	86
(a) Mandibular lymph nodes[c]	25	16	14	23	14	43	18	27	34	68	86
(e) Gastric and mesenteric lymph nodes	25	18	25	16	14	32	70	16	16	64	89
(b) Lungs	25	25	16	20	18	50	25	82	82	61	89
At least one additional post-mortem procedure	50	50	66	70	73	80	82	84	86	86	93

Fig. 4 The proportion (%) of respondents (n = 44) that consider additional *post-mortem* inspection (APMI) procedures (Article 23 (2) (a)–(i) of Commission Implementing Regulation (EU) 2019/627) are required to determine if meat is fit for human consumption for 10 gross pathological findings. The shade of the colour reflects the magnitude of proportion. [a]*Mycobacterium*-like lesions. [b]Total column depicts the proportion (%) of respondents who consider the APMI procedure is required in at least one of the 10 gross pathological findings. [c]*Lnn. mandibulares*, submaxillary lymph nodes in (Article 23 (2) (a) of Commission Implementing Regulation (EU) 2019/627

Commission Implementing Regulation (EU) 2019/627. In addition, 24 respondents (55%) gave 106 comments on those other procedures to evaluate the meat fitness for human consumption. Six additional procedures were identified in the comments:

(1) Incision of joints and regional lymph nodes in suspected arthritis.
(2) Incision of other lymph nodes than those mentioned in Article 23(2).
(3) Check of the bone marrow for signs of serous atrophy in suspected cachexia.
(4) Incision through the skin in suspected erysipelas.
(5) Check of the intima of the blood vessels or subcutaneous fat and connective tissue in suspected icterus.
(6) The incision of iliopsoas musculature and, if necessary, the shoulder and topside in suspected osteomyelitis/pyaemia.

3.5 Guidelines for meat inspection

Altogether, 15 respondents (34%) stated that at least one of the applied APMI procedures was based on official published guidelines. A total of 27 respondents (61%) gave examples of various literature they consult for guidance in how to perform meat inspection; like national instructions (44%), legislation (22%), scientific publications (22%), books (7%), regional guidelines (7%), internal instructions (3%), EFSA materials (4%), or materials from the US Food

Table 3 Laboratory methods used to support meat inspection decision

Test	Respondents (n = 18)		Examples of gross pathological findings (n = 58)[a]		
	No.	%	No.[b]	%	Description (n)[b]
Boiling test	2	11	4	7	Abscesses with odour (1), Cryptorchidism (1), Lesions in kidneys (1), Sexual odour (1)
Histopathology	5	28	10	17	Tumours (2), Cachexia (1), Icterus (1), Mesothelioma (1), Muscle degeneration (1), *Mycobacterium*-like lesions (1), Petechiae (1)[c], Phlegmons (1)[c], Pityriasis rosea (1), Prolapse (1)[c], Severe grade of tail necrosis (1)[b], Umbilical hernia (1)[c], Wounds (1)[c]
Microbiology	14	78	30	52	*Mycobacterium*-like lesions (5), Pleuritis/purulent pleuritis (4), Arthritis (3), Erysipelas like lesions (3), Abscesses (2), Peritonitis (2), Pneumonia/acute pneumonia (2), Septicaemia (1), Pyaemia (1), Cachexia (1), Heart valve deposits (1), Infectious, thrombotic endocarditis (1), Infectious, thrombotic endophlebitis (1), Inflammation of bowels (1), Inflammation of organs (1), Nephritis (1), Osteomyelitis (1), Petechiae (1), Phlegmons (1), Prolapse (1), Reactive lymph nodes (1), Severe grade of tail necrosis (1), Umbilical hernia (1), Visual changes on skin (1), Wounds (1)
Antimicrobial residue testing	7	39	10	17	Pleuritis (2), Signs of infection (2), Abscesses (1), Cachexia (1), *Mycobacterium*-like lesions (1), Pathological changes in the kidneys and liver (1), Pneumonia (1), Reactive lymph nodes (1)
Parasitology	4	22	4	7	Cysticercosis (3), Cysts (1)
pH measurement	2	11	2	3	Consistency difference (1), Pleuritis (1)
Alcohol/ether test, Quick test	2	11	2	3	Abnormal colour (yellow) (2)

[a]Respondents gave 1−5 examples

[b]Multiple laboratory methods (2–3) were mentioned in 9 examples of gross pathological lesions. In addition, multiple (2–6) gross pathological lesions were described in a single example (n = 6) as reasons for the use of a laboratory method

[c]If proof of animal welfare is needed

Safety and Inspection Service (FSIS) (4%), and the internet (4%).

3.6 Laboratory methods to support meat inspection decision

Altogether, 21 respondents (49%) stated that they used laboratory tests to support meat inspection decisions. One did not specify which methods and when they are used. Two mentioned that laboratory methods were applied for trichinellosis, *Mycobacterium*-like lesions and in suspicion of *Erysipelothrix rhusiopathiae* and African swine fever, but they did not further specify the methods.

According to 10 out of 13 respondents that answered the question about guidelines, the laboratory methods were based on official published guidelines. Seven respondents specified that 5 guidelines were national, 1 regional, and 1 internal. Altogether, 18 respondents gave examples of 8 different types of laboratory methods in support of meat inspection decisions (Table 3). Microbiological methods in different forms were mostly mentioned (30 times by 14 respondents; 78%; Table 3), although it was not clear from the responses which specific methods were used. One respondent stated bacteriological examinations according to official guidelines, but they only used it in bovines and not in pigs due to high testing costs.

4 Discussion

The respondents of the survey had a median of 10 years work experience, and the questionnaire showed good turnout and representation of the EU member states. However, the data is only indicative for the methods used in the participating countries, as 1–3 official veterinarians per country answered the survey.

4.1 Application of visual meat inspection

In the EU, although visual meat inspection of pigs is in force since June 2014 (Commission Regulation (EU) No 219/2014), the application of the method is still not fully implemented. The change of meat inspection from traditional incisions and palpations to visual meat inspection was based on a scientific opinion by EFSA (2011). EFSA's risk assessment concluded that palpations and incisions during meat inspection do not contribute to the detection of meat safety hazards for consumers, but instead may pose a risk of contamination or cross-contamination of carcasses with pathogens such as *Salmonella* spp. and *Yersinia enterocolitica*.

Export requirements were the respondents' main reason for not applying visual meat inspection. The question of export requirements has also been raised in previous studies on visual meat inspection (Alban et al. 2021; Antunović et al. 2021; Bækbo et al. 2015; Laukkanen-Ninios et al. 2020; Riess and Hoelzer 2020). The requirement to conduct traditional inspection on meat destined for export complicates logistics and trade and increases costs, but at the end boils down to whether business is possible or not. From a scientific point of view, the lack of acceptance outside the EU might have been mitigated by using evidence-informed decision making that takes multiple factors into account (FAO 2017; Ruzante et al. 2017) or incorporating other measures, in this case negotiations of the equivalence of *post-mortem* inspection methods by changing legislation. Legal requirements for APMI procedures, like findings during *ante-* or *post-mortem* inspection, epidemiological status, such as occurrence of *Salmonella* spp. on farm and disease control, or incision of mandibular lymph nodes were stated as reasons for not always applying visual meat inspection. It is possible that some respondents understood from the questionnaire that application of visual meat inspection includes only visual inspection without APMI procedures when indicated, or they otherwise wanted to clarify their answer. However, the comments gave examples of situations when APMI procedures are used in addition to visual inspection.

4.2 Application of APMI procedures

The most important reasons to perform APMI procedures were findings in *post-mortem* inspection followed by findings in *ante-mortem* inspection. The responses may reflect the actual evaluation of importance, but also the possibility of obtaining information: The findings after *post-mortem* and *ante-mortem* inspection of an individual animal are probably the easiest sources of information to access, since they are obtainable during meat inspection and require minimal (*ante-mortem*) or no (*post-mortem*) information systems. According to data from various European countries, food chain information requires further development before it can be used to assess the need for APMI procedures (Antunović et al. 2021; Felin et al. 2016; Gomes-Neves et al. 2018; Pattono et al. 2014; Riess and Hoelzer 2020; Windhaus et al. 2007). In addition, adequate information systems needed by official controls for epidemiological and other information from the farms are lacking (Laukkanen-Ninios et al. 2020; Riess and Hoelzer 2020; Windhaus et al. 2007).

Seven respondents used other data, results, or findings to determine whether APMI procedures were needed. These data sourced from food chain information, results from *Salmonella* monitoring programs, comparison of data/ranking of holdings, membership of a quality scheme, documents, results from previous batches and experience. However,

only the latter is not included in the list of Article 24 of Commission Implementing Regulation (EU) 2019/627 as a reason to perform APMI procedures. The responses mainly depict checks and their analysis of documents, and additional epidemiological data or other data from the holding of provenance. The reasons for these answers could be possible ambiguity of the questionnaire, the need to clarify the responses to this question, and/or their unfamiliarity with the (English) terms used in Article 24 of Commission Implementing Regulation (EU) 2019/627. However, the answers depict situations when epidemiological data and food chain information are used to assess the need for APMI procedures in some slaughterhouses.

4.3 APMI procedures to determine if meat is fit for human consumption

In general, only a few APMI procedures were used per gross pathological finding. This is logical, since meat inspection procedures and associated coding systems were created to detect a wide variety of pathological conditions (Alban et al. 2022), and not all procedures are needed for all gross pathological findings.

The number of APMI procedures varied considerably between the respondents. The reason for this variation is uncertain and our data do not contain enough respondents per country to analyse this variation in detail. However, our data indicate that differences might not depend solely on the experience or the country origin of the inspector. Arzoomand et al. (2019) noticed large intra-class variation among meat inspection decisions of detained carcasses made by official veterinarians working in one slaughterhouse in Sweden. Similar variation is possible in our study, although a recent study detected other systemic differences in meat inspection systems in European countries (Alban et al. 2022).

Abscesses had most variation in the number of APMI procedures required to evaluate whether meat was fit for human consumption or not. This may be because in some cases, an abscess can reflect a local condition, but in other cases can be part of a septicaemic complex. Hence, the variation in APMI procedures could reflect the fact that the meat inspection decision is based on whether the condition is generalised or not (Alban et al. 2021). Abscesses can be caused by pyaemia (Huey 1996; Soethout et al. 1981), in which case total condemnation is required (Article 45(f) of Commission Implementing Regulation (EU) 2019/627). In addition, the national procedures to assess whether the condition is generalised at the time of slaughter can differ. For example, Denmark has a targeted inspection procedure to detect abscesses related to prior septicaemia (Alban et al. 2021). However, it is uncertain if, e.g., an aetiological diagnosis of pyaemia will bring decisive information or reduce the risk to public health.

Mycobacterium-like lesions were stated requiring the most APMI procedures and most often required at least one APMI procedure. In addition, *Mycobacterium*-like lesions had the second highest variation in the number of APMI procedures to evaluate whether meat was fit for consumption or not. The reasons for this are not clear. However, *Mycobacterium*-like lesions can be caused by representatives of the *Mycobacterium* (*M.*) *avium*-complex as well as of the *M. tuberculosis*-complex, which could have affected how respondents understood and answered the question, depending on the occurrence of *M. bovis* and *M. avium* in pigs in their respective country. In principle, the decision for total condemnation of a carcass for *M. bovis* (Article 33(2) of Commission Implementing Regulation (EU) 2019/627) and *M. avium* (Article 45 (f) of Commission Implementing Regulation (EU) 2019/627) depends on the generalisation of the infection and therefore, the condemnation of the whole carcass and organs requires inspection of multiple sites. However, the occurrence of *M. bovis* in pigs differs across Europe, as several countries are officially free of bovine tuberculosis (European Food Safety Authority & European Centre for Disease Prevention and Control 2021). In pigs, infections with *M. avium* are more prevalent than with *M. bovis* in most European countries and regions, but is difficult to macroscopically distinguish *Mycobacterium*-like lesions in lymph nodes caused by *M. avium* from those caused by *M. bovis*. Thus, the *M. bovis* status of the country or the region needs to be considered when lymph nodes of finishing pigs with *Mycobacterium*-like lesions are found. There are also different systems to handle *M. bovis* and *M. avium* infections in different countries. In Denmark, which is officially bovine tuberculosis free (OTF), lesions outside the gastrointestinal system are sent for testing for *M. bovis*¸ but lesions in the gastrointestinal system result in only partial condemnation (Hansen et al. 2018). In OTF Germany, the infection risk of *M. bovis* for indoor raised finishing pigs is estimated as negligible, and mainly the lung and gastrointestinal tract have to be inspected to check for generalisation (BfR 2009). In the Netherlands (OTF), a major slaughter company uses serological testing of farms to detect *M. avium* in order to avoid incision and palpation of mandibular and gastrointestinal lymph nodes (van Wagenberg et al. 2013).

In this study, one respondent described a system where mandibular lymph nodes were incised from 10% of pigs in a batch, and if lesions were found, APMI procedures were completed on all pigs from the same batch. The most commonly used APMI procedures for *Mycobacterium*-like lesions were "an incision and examination of the submaxillary [mandibular] lymph nodes (*Lnn. mandibulares*)", and "a palpation and, if necessary, incision of the gastric and mesenteric lymph nodes" (Article 23(2) of Commission

Implementing Regulation (EU) 2019/627). Mandibular, gastric and mesenteric lymph nodes are pathognomonic sites to detect mycobacteria, including *M. tuberculosis*-complex, in domestic pigs (Cardoso-Toset et al. 2015a, 2020; Hibiya et al. 2010).

Cachexia (50%) and osteomyelitis (50%) were the least mentioned conditions requiring APMI procedures (Figs. 3 and 4). Cachexia, manifesting most notably as serous atrophy of fat and also as atrophy of other organs such as muscles and the liver (Herenda et al. 1994), is visible on the carcass and organs and therefore, could also be judged without APMI procedures. However, there might be different practices on when to use the code for cachexia (e.g., for thin animals), which means it is relevant to use APMI procedures. Also, vertebral osteomyelitis is often macroscopically visible in the carcass without APMI procedures (Vieira-Pinto et al. 2020) when carcasses are split for meat inspection, but APMI procedures are important to differentiate localised from systemic cases (Vieira-Pinto et al. 2020).

The least used APMI procedure was incision of the supramammary lymph nodes. This is linked to the inspection of udder of sows and therefore, these lymph nodes were, before the application of visual meat inspection, routinely incised only in sows (Regulation (EC) No 854/2004 of the European Parliament and of the Council, Annex I, Chapter IV, Section IV, B, 1(k)). This suggests that incision of these lymph nodes is not particularly relevant or used in meat inspection of finishing pigs. The "palpation of the umbilical region and joints of young animals and, if necessary, incision of the umbilical region and opening of the joints" (Article 23(2i) of Commission Implementing Regulation (EU) 2019/627) was also rarely used, except in relation to arthritis. The palpation and incision of umbilical region and joints of young animals can reveal umbilical infection and indicate the portal of entry for an ascending infection and subsequent arthritis. However, infection of umbilicus occurs in new-born animals (Constable et al. 2017), and so palpation of umbilical region and joints of young animals is probably most useful for the inspection of piglets and not for finishing pigs. In any case, palpation and, if necessary, incision of joints can be used to detect arthritis in carcasses as an APMI procedure as also mentioned by the respondents in the present study.

4.4 Other *post-mortem* procedures to evaluate if meat is fit for human consumption

Altogether, 59% of the respondents answered that they used other procedures than those defined in Article 23(2) of Commission Implementing Regulation (EU) 2019/627 to evaluate whether meat is fit for human consumption. However, they were actually not other procedures, as comments clarified the use of APMI procedures. Additional examinations, such as other *post-mortem* procedures can be performed according to Article 14(1) of Commission Implementing Regulation (EU) 2019/627. In practice, it is not necessary to separate which article is applied when performing official controls. However, all official controls have to be based on legislation and therefore, the separation between APMI and other *post-mortem* procedures is meaningful.

From the comments, we were able to identify 6 other *post-mortem* procedures. For example, incision of joints and regional lymph nodes are commonly used procedures in meat inspection. However, country-specific methods are also used. In Denmark, findings indicating prior septicaemia result in a targeted investigation covering separation of the iliopsoas muscles from the spine and a deep cut along the shoulder and femur to look for osteomyelitis and pyaemia (Bækbo et al. 2016).

4.5 Guidelines for meat inspection

The respondents described different kinds of literature for guided use of APMI procedures, showing that they seek support for practices in various places. Since this was in addition to legislation, it strongly suggests that legislation alone is not enough and that more instructions are needed. The variety of sources also indicates a lack of clear instructions for the use of APMI procedures and a need for common guidelines on when to use them.

4.6 Laboratory methods to support meat inspection decisions

This study evinced a substantial variation regarding the application of additional laboratory methods and also the kind of methods that are being used. This information was collected by asking the respondents to give up to 5 examples of gross pathological findings requiring laboratory testing in support of meat inspection decisions. Therefore, the results represent a glimpse of the applied methods and indications, rather than a full listing of all methods and their indications or the frequency of their use.

Microbiological methods in different forms were most frequently mentioned. They can be used to detect specific pathogens, such as *Erysipelothrix rhusiopathiae* (Laukkanen-Ninios 2014) or as an indicator of generalised infection (Kogka et al. 2021; Laukkanen-Ninios 2014). Other mentioned methods were antimicrobial residue testing, in some countries often used together with bacteriological examination (Kogka et al. 2021; Laukkanen-Ninios 2014). In the literature, various methods are described either for meat inspection or screening purposes, to detect antimicrobial residues in slaughtered animals (Alban et al. 2018; Pikkemaat 2009). Histopathology can be used to further investigate the nature of a lesion (Maxie

and Miller 2016; Sánchez et al. 2018). Histopathological and microbiological methods were mentioned in association with *Mycobacterium*-like lesions, where histopathology can show typical necrotising granulomatous lesions, Ziehl-Neelsen stain to show acid-fast bacteria, or cultivation or PCR to detect and identify the causative agent (Cardoso-Toset et al. 2015b). Parasitology was mentioned particularly in relation to *Cysticercus*. The boiling test mentioned is used to check for abnormal odours, and the test of pH to check for quality and technical processing characteristics, particularly pale, soft, exudative (PSE) meat in pigs (Laukkanen-Ninios 2014). The use of a quick test or an alcohol/ether test were stated as laboratory methods to detect icterus. These are based on showing bilirubin in the sample, along with other methods (Auer 1968; Robinson 1975). There are also methods in the literature that were not mentioned in the questionnaire, such as water content test of bone marrow to judge emaciation with oedema (Bunčić 2006; Herenda et al. 1994). It may be that these methods are not in active use anymore.

4.7 Study limitations and further studies

Due to the study design with only a few respondents per country, the results are indicative regarding the methods used in Europe and not representative for individual countries. Our data showed considerable variation regarding the use of APMI procedures in relation to 10 common gross pathological findings in finishing pigs. Our data suggest that there are country-specific factors that affect how APMI procedures are used, but we also observed variation between the responding official veterinarians, which could not be explained by country or experience.

There were some factors that affected the quality of data. It was not always clear whether the open answers provided were comments for a previous question or actual answers for the question at hand. To avoid data manipulation, we kept the answers in their places and considered these discrepancies in discussion. For laboratory methods, we asked the respondents to give up to 5 examples of gross pathological findings requiring laboratory testing in support of meat inspection decisions. Therefore, the data are not exhaustive, nor can they be used to show differences in the use of laboratory methods in different countries. However, based on our results, different types of laboratory methods are used in conjunction with visual meat inspection, and there is most likely a variation in the used methods.

Since our results suggest a considerable variation in how meat inspection is performed as well as for the used instructions and guidelines, meat inspection in Europe could benefit from a calibration development as done in New Zealand (NZFSA 2009). In addition, a consensus should be reached on how to perform APMI procedures in the EU, e.g. before EU-level instructions and training on APMI procedures are possible.

5 Conclusions

Based on this study, visual meat inspection for finishing pigs is applied by most but not all participating official veterinarians. The main reason for not applying visual meat inspection was export requirements. The most important reasons to perform APMI procedures were findings in *ante-* and *post-mortem* inspection. There was a wide variation in using additional and other *post-mortem* procedures, as well as for laboratory methods to assess whether meat is fit for human consumption. This could not be explained by the respondents' experience or the country or European region. The reasons and level of variation should be further investigated in order to reach harmonised and risk-based meat inspection systems applied in the EU.

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Declarations

Conflict of interest LA and OA work for organisations that give advice to farmers and meat-producing companies. RLN's employment is partly funded by the Finnish Food Authority. SS works for the Portuguese veterinary authorities. SG, JGL, NL, DM, PM, and MVP declare no conflict of interest.

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