Development of a harmonized and risk-based code system for post-mortem inspection of broilers

Michał Majewski [a,b,*], Lis Alban [c,d], Désirée S. Jansson [e], Thomai Lazou [f], Nina Langkabel [g], Dragan Antic [j], Eija Kaukonen [h], Helena Wall [i], Madalena Vieira Pinto [k], Laila Østergaard [l], Ole Gyvelgaard Nielsen [l], Sergio Ghidini [m], Marianne Sandberg [a]

[a] National Food Institute, Technical University of Denmark, Kgs. Lyngby, Denmark
[b] Department of Animal Breeding and Product Quality Assessment, Poznan University of Life Sciences, Poznań, Poland
[c] Department for Food Safety, Veterinary Issues and Risk Analysis, Danish Agriculture & Food Council, Aarhus N, Denmark
[d] Department of Veterinary and Animal Sciences, University of Copenhagen, Frederiksberg, Denmark
[e] Department of Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden
[f] Department of Animal Food Products Hygiene and Technology, School of Veterinary Medicine, Aristotle University of Thessaloniki, Thessaloniki, Greece
[g] Institute of Food Safety and Food Hygiene, School of Veterinary Medicine, Freie Universität Berlin, Berlin, Germany
[h] Department of Food Hygiene and Environmental Health, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland
[i] Department of Applied Animal Science and Welfare, Swedish University of Agricultural Sciences, Uppsala, Sweden
[j] Institute of Infection, Veterinary and Ecological Sciences, University of Liverpool, Liverpool, UK
[k] Animal and Veterinary Research Center (CECAV), University of Trás-os-Montes e Alto Douro, Vila Real, Portugal
[l] Ministry of Food, Agriculture and Fisheries, Danish Veterinary and Food Administration, Copenhagen, Denmark
[m] Department of Veterinary Medicine and Animal Sciences, Milan University, Lodi, Italy

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ABSTRACT

In most European countries, findings detected at post-mortem inspection (PMI) of broilers at slaughter are registered using national or regional code systems. The aim of this study was to map and compare existing national broiler PMI code systems in Europe and to suggest a new harmonized and risk-based code set intended to be interpreted in the same way in all countries. Information about the code systems, condemnation criteria, and the proportion of unfit broiler carcasses in 2022, as well as reasons justifying condemnation, were collected from nine European countries through an online survey. The reasons for declaring meat as unfit for human consumption were divided into food safety, meat quality, broiler health, or broiler welfare. The data were analyzed, and a risk-based code set consisting of 13 codes was developed. Ten of these new codes cover 80% of all condemnations listed in the data retrieved from the countries in the study. The remaining three codes are indicators of broiler welfare. The results were presented in the form of spider diagrams, indicating massive differences between the countries. Harmonization of the code list and the associated decision criteria will allow PMI to be conducted in the same way in different abattoirs and countries. This standardization of the PMI of broilers will enable detailed analysis of PMI results for further use in risk-based meat safety assurance systems and the implementation of computer-based vision systems at PMI in the future.

1. Introduction

Poultry is currently the most widely consumed meat worldwide and the consumption is increasing (FAO, 2023; Mottet & Tempio, 2017; USDA, 2023). Ensuring food safety is one of the main pillars of the European Union (EU) (EC, 2002) and is achieved through multifaceted measures designed to prevent or control hazards and risks at various stages of the food chain. In poultry meat production, this encompasses the inspection of the food chain information (FCI) from the primary producer, followed by ante-mortem inspection (AMI) and post-mortem inspection (PMI) of poultry carcasses (EU, 2019b). Moreover, in the EU, it is mandatory to have national surveillance programs in live chickens and broiler meat for *Salmonella*, *Campylobacter*, and bacteria carrying extended-spectrum β-lactamase and/or AmpC β-lactamase

(ESBL/AmpC) genes (EC, 2003; EC, 2020; EFSA, 2012b).

Apart from food safety, animal health and welfare are of importance for meeting the requirements related to animal production. Based on the FCI, the local competent authorities (CA) determine whether there are any indications that 1) the health and welfare of the birds have been compromised, 2) the meat of the birds contains residues of veterinary medicinal products, prohibited substances, or environmental contaminants, or 3) the meat constitutes a source of zoonoses or infectious animal diseases. The AMI includes the control of the FCI documents and an inspection of the flock before slaughter. The aim of AMI is to monitor and record any incidents, related to health and welfare, which could have occurred on the farm and during transport. In PMI, the detection of lesions/abnormalities as well as visible contaminations on the surface of the carcasses are recorded. As a result, the unfit parts or the whole carcasses are removed from the food chain (EU, 2019b; Huneau-Salaün et al., 2015). In most abattoirs in the EU member states (MSs), the carcasses and viscera of poultry are subjected to visual PMI directly after evisceration. In some broiler abattoirs, there is an additional PMI station before evisceration to remove unfit carcasses earlier and prevent contamination of the slaughter line during subsequent operations. Yet another complementary PMI station can be present at the end of the processing line to detect slaughter processing defects in eviscerated carcasses (EFSA, 2012b; Törmä et al., 2021). The findings detected at PMI can be classified as having implications for food safety, meat quality, animal health, and animal welfare. PMI findings commonly observed in broilers are skin lesions, ascites, discoloration, arthritis, polyserositis, and the presence of fibrin in various organs indicating systemic infection, cachexia or mortality before slaughter, contamination of the carcass with crop or intestinal/cloacal contents, or other slaughter process-related defects (Alfifi et al., 2020; Koutsianos et al., 2021).

As stated above, the main goal of PMI is to withdraw unfit carcasses from the food chain, but information about the reasons for condemnation is valuable for various stakeholders. Knowledge of the reasons for the condemnations could be used to improve the health and welfare of future broiler flocks, but PMI is currently underused for this purpose (Langforth et al., 2023). Moreover, the PMI procedure is not harmonized in the EU. Therefore, relevant data cannot be used for benchmarking between MSs. Nor is PMI fully consistent between abattoirs within the same country (Törmä et al., 2021). Uniformity would benefit all stakeholders, because carcasses would be subjected to PMI based on the same codes and condemnation criteria and would, for example, enhance equal treatment of broilers regardless of the abattoir to which the producers deliver their birds.

Computer vision systems (CVS) based on artificial intelligence have been developed over several years to serve as PMI tools, though their efficient application remains currently challenging for PMI (Sandberg et al., 2023). As regards broiler abattoirs, a harmonized code system is a prerequisite for efficient performance of CVSs since its development and validation for individual abattoirs or MSs with different sets of condemnation codes would be challenging, laborious, and remarkably expensive. Therefore, a harmonized system with a common list of codes and associated condemnation criteria (defined as the threshold for when to condemn according to the severity of the lesion related to the different codes) is required.

Article 45 of the Commission Implementing Regulation (EU) 2019/627 quotes 18 reasons for declaring poultry meat unfit for human consumption (EU, 2019b). In many MSs, broiler carcasses deemed unfit for human consumption at PMI are registered using national or regional code systems, based on the reasons listed in the Regulation (EC) 2019/627. However, the findings might be named and interpreted in different ways in the MSs, largely reflecting the tradition in each MS when national condemnation criteria were developed. In some MSs, national guidelines are available, providing precise instructions aiming at standardizing PMI at country level. These guidelines can describe the responsibility of the official veterinarian (OV) and official auxiliary (OA)

in defining when a carcass is unfit for human consumption. The variation in carcass assessment could be higher in the absence of documented guidelines or working instructions (EFSA, 2012b).

Due to the variety of possible findings, including their range of severity and different ways of carcass handling between abattoirs and countries, it is challenging to establish a uniform procedure for PMI. First, a set of harmonized codes is required. However, the MSs sometimes use different names for the same findings. Alban et al. (2022) revealed that in MSs with a high number of available codes for PMI of pigs, some codes were infrequently used. Therefore, the MSs' code lists could probably be updated to a simpler and risk-based system consisting of fewer codes. In the same context, the codes should reflect the relevance of findings at AMI and PMI to food safety, meat quality, animal health, and animal welfare. Furthermore, for comprehensive harmonization, the condemnation criteria and associated handling of carcasses should be identified for each code.

The aim of this paper was to develop a proposal for a harmonized code set for broiler PMI findings, which can adequately describe food safety, meat quality, broiler health, and broiler welfare. This goal was achieved through the following objectives.

1. Map and compare existing national broiler chicken PMI code systems in Europe,
2. Determine the number of codes most frequently used in broiler PMI in Europe,
3. Classify the codes in terms of association with food safety, meat quality, broiler health, or broiler welfare,
4. Propose a new harmonized risk-based code set (RBCS) for Europe,
5. Suggest how to visualize broiler PMI outputs to ensure utility for different kinds of stakeholders.

2. Materials and methods

2.1. Study characteristics

The countries included in the study were MSs of Denmark, Finland, Germany, Greece, Italy, Poland, Portugal, Sweden, and a non-MS, the United Kingdom (UK), which represent all regions of Europe (Northern, Central and Eastern, Southern and Western) according to the United Nation's geoscheme (https://unstats.un.org/unsd/methodology/m49/).

Data from the European Commission (https://agridata.ec.europa.eu) were used to calculate the production and export volume in 2022 for the selected MSs. Moreover, data from the Statista platform (https://www.statista.com/topics/6102/poultry-in-the-united-kingdom/#topicOverview) were used to calculate the production and export volume in the UK.

To collect relevant data from the different MSs and the UK (hereafter called countries), an online survey was prepared using Microsoft Forms application from Microsoft Office package (Redmond, USA). The online survey was completed by the authors of the study, whereby information about the different code systems and condemnation criteria used in PMI was collected. Furthermore, the proportion (prevalence) of each of the different PMI findings in broilers recorded in the different countries in 2022 were retrieved. If data from 2022 were not available, data from an earlier year were obtained. If data representing the entire country could not be obtained, data were provided for a representative region or large-capacity abattoirs. The survey was mostly based on multiple-choice as well as a few open-answer questions regarding the code systems and associated condemnation criteria in place. The data were collected by the authors of the study from official national annual reports and publicly available databases provided by CA. The exception was Denmark, for which data describing the findings were obtained electronically from the KIK database system used by the abattoirs to register daily PMI data. All survey questions are available in the supplementary materials.

2.2. Assessment methodology and collected data

2.2.1. Code sets for PMI findings in different countries

In the survey, the following data was collected per country.

- The number of codes available and used for the official/national registration of PMI findings,
- Whether the option existed of recording partial condemnation (PC) and total condemnation (TC) or only TCs consequential to PMI findings,
- The proportion of carcasses deemed unfit for human consumption in 2022.

2.2.2. Analysis of the code sets from the different countries

To assess whether some codes were used more frequently than others, they were initially sorted by their frequency of use in the countries included in this study. Next, the number of codes ascribed to 80%, 90%, 95%, and 99% of all PMI findings were identified by country.

Then, the codes were also classified according to the listed points in Article 45 of Commission Implementing Regulation (EU) 2019/627 (EU, 2019b) for declaring fresh meat unfit for human consumption. The grouping was based upon the authors' perceived associations of each code with food safety, meat quality, broiler health, and broiler welfare, and a code could be ascribed to more than one category.

A new European PMI code set was developed, based on the most commonly used codes in the countries, broiler welfare indicators, and the harmonized epidemiological indicators (HEIs) described in EFSA's scientific opinion for broiler chicken meat inspection (EFSA, 2012a, Grilli et al., 2015). For this, only the necessary codes were included while considering the need to describe relevant broiler PMI findings in a way that would provide valuable information to the CA, the abattoirs, and the broiler producers. Finally, Microsoft Excel software was utilized to generate spider diagrams to present grouped reasons for condemnation of broilers based on PMI findings from the different countries.

2.2.3. Development of a new RBCS for Europe

The most prevalent causes covering 80% of condemnations in the study period were considered to develop the RBCS. Moreover, the national code sets from the countries included in the study were analyzed in terms of matching the 18 reasons for rejections applicable to poultry as described in Article 45 of the Commission Implementing Regulation (EU) 2019/627 (EU, 2019b). Among these, three condemnation reasons that cannot be objectively detected/decided at PMI were not included: i – chemical residues in meat; h – parasitic infestation, and; t – in the opinion of the OV may constitute a risk to human or animal health or is for any other reason not suitable for human consumption (unspecific meaning, likely subjective).

On this basis, the most frequently used causes for condemnation of poultry carcasses were selected and included in a new harmonized RBCS. Furthermore, the impacts of the findings at PMI on food safety, meat quality, broiler health, and broiler welfare were considered to ensure all of them were covered by the RBCS. Other post-mortem assessments conducted in the broiler abattoir (e.g., hanging of the birds in the shackles, scoring of footpad lesions), which reflected food safety, meat quality, broiler health, and broiler welfare, were also considered in the RBCS development. Finally, additional literature was used to assess to which category the different codes should be assigned.

3. Results

The completed questionnaires of the online survey provided data from nine countries: Denmark, Finland, Germany, Greece, Italy, Poland, Portugal, Sweden, and the United Kingdom. The size of the broiler production including the export value for each of the included countries is listed in Table 1.

Table 1

Size of broiler production and export in each of the nine European countries in different European regions included in the study of post-mortem inspection systems in 2022.

Region of Europe	Country	Size of poultry meat production in million heads[a]	Size of export value in million €[a]
Northern	Denmark	98	0.4
	Finland	82	0.1
	Sweden	113	10
	United Kingdom[b]	1100	256
Eastern	Poland	1276	915
Southern	Greece	148	12
	Italy	569	42
	Portugal	233	10
Western	Germany	701	66

[a] Source of data for the MSs: European Commission.
[b] Source of data for the United Kingdom: https://www.statista.com/.

3.1. Number of available codes

All countries except Italy had a national code system implemented for broiler PMI. A summary of the national code systems is presented in Table 2. The numbers of predefined codes in the code sets from the eight countries with a code system in place differed. Finland (n = 7), Greece (n = 7), and Denmark (n = 11) had the lowest number of codes, while the UK (n = 22), Germany (n = 29), and Portugal (n = 30) had the highest number of codes (Table 2).

3.2. Description of the code sets

All carcasses deemed unfit for human consumption are registered, and the reason for condemnation is provided for each carcass. The results of PMI are communicated in most countries in one way or another to the broiler producers.

However, in some countries there are certain exceptions. In Germany, the recording system is not harmonized at the national level, but at regional level. The reporting of condemned carcasses is mandatory, whereas it is not mandatory to report the causes of condemnation and not all codes from the national set are available at all abattoirs. Codes to describe findings in offal exist, but are not used for broilers. Additionally, more than one code can be used per carcass, although this was infrequently applied in 2022 (0.04% of all condemnations).

In Greece, PMI findings are grouped into two categories: "macroscopic findings" consisting of four codes and "animal protection"

Table 2

Characteristics of national systems for recording broiler PMI findings in the eight European countries with a national code system in place.

Country	Number of available codes	National system allows registration of[a]	Maximum number of codes used per carcass
Denmark	11	TC	1
Finland	7	TC, PC	1
Germany	29 (19)[b]	TC, PC	Unlimited
Greece	7[c]	TC, PC	Unlimited
Poland	17	TC	1
Portugal	30	TC	1
Sweden	19	TC	1
United Kingdom	22 (20)[d]	TC, PC	1

[a] TC – total condemnation, PC – partial condemnation.
[b] The value before the bracket applies to codes used for carcasses and offal. The value in brackets only applies to codes used for carcasses.
[c] There are seven predefined codes, but an unlimited number of additional descriptive codes.
[d] Two codes, "dead on arrival" and "ante-mortem rejects" are included in the UK code system, but they are registered before slaughter and carcasses are removed from the processing line before PMI.

consisting of three codes. In both categories, there is an additional code called "other" allowing for the registration of an unlimited number of descriptive findings by the OV. Again, more than one code can be attributed to one carcass. In Sweden, codes are grouped into two categories: those pertaining to diseases, lesions, and abnormalities and those describing processing failures.

Only Italy did not have an official code system in place, and each Italian region follows its own procedure. However, the data are not collected or reported at the national or regional levels. Some data related to quality, processing failures, or welfare issues are collected by the FBO's quality control teams at the abattoir level and are used to evaluate the broiler producers and the operation at slaughter. For example, a large production abattoir in the Emilia Romagna region uses an internal system with codes for processing-related defects and broiler welfare indicators. In 2022, this abattoir reported the following: crusts (1%), hematomas (5%), foot injuries (45%), hock scabs (2%), chest scabs (0.1%), hematomas in wings (2.5%), and ascites (0.15%).

3.3. Differences in names and meaning of the most commonly used codes

The names of different PMI codes in eight countries are in the Supplementary Tables S1 and S2. Major differences between code names used to describe skin lesions and generalized disease were detected among the participating countries (Fig. 1).

Meat quality defects were also described with different codes among countries. In Germany, meat quality defects were divided into four subcategories: organoleptic, color, smell, or consistency disorders. In the national code sets of Portugal, Sweden, and the UK, there were separate codes for myopathies. On the other hand, no code related to meat quality was available in the Polish national code set.

3.4. Proportions of the codes used

Available data at a national level for 2022 were collected from Denmark, Finland, Germany, Greece, Poland, Sweden, and the UK. In Portugal, only data from 2019 were available. Danish PMI data were collected from two large abattoirs, representing the vast majority of national broiler meat production. In the UK, the data originated from England and Wales and represented the majority of the slaughtered broilers in the UK.

Total condemnation results are presented in Table 3. In the eight countries from which data were available, the proportion of carcasses unfit for human consumption varied from 0.02 to 2.47%. The highest proportions of carcass condemnation were observed in Sweden (2.47%), Germany (1.97%), Finland (1.54%), and the UK (1.89%). The lowest proportions were observed in Greece (0.02%), Poland (0.54%), Denmark (0.90%), and Portugal (1.07%). Data were not available from Italy. Detailed data on all code sets and proportions are in the Supplementary Tables S1 and S2.

Table 3
Total broiler condemnation figures in eight European countries in 2022.

Country	Proportion of condemned broiler carcasses (%)
Denmark	0.90
Finland	1.54
Germany	1.97
Greece	0.02
Poland	0.54
Portugal[a]	1.07
Sweden	2.47
United Kingdom	1.89

[a] Year 2019.
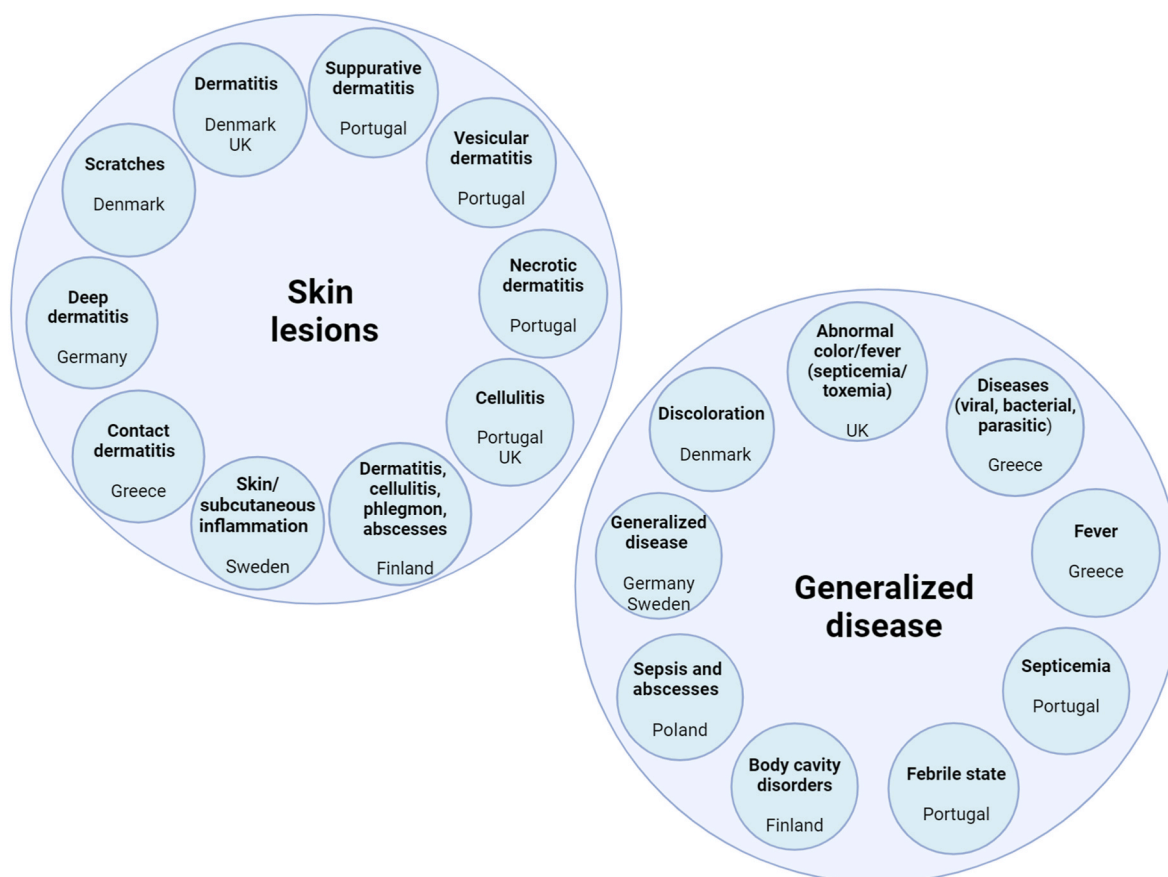
Fig. 1. Differences in names of the codes describing skin lesions and generalized disease in eight European countries. The figure was created with BioRender.com.

3.5. Frequencies of the codes used

Several available PMI codes were never or rarely used in practice in some countries (Table 4). The number of the broiler PMI codes that covered the majority of all the registered condemnations in the countries included in this study are presented in Table 4. The complete list of the codes covering 80%, 90%, 95%, and 99% of all condemnations in nine European countries is also available in Table S5 of the supplementary materials.

3.6. Guidelines for the codes and condemnation criteria of broiler PMI

National guidelines for the performance of broiler PMI are available in Denmark, Finland, Portugal, Sweden, and the UK. All the guidelines have a separate chapter for poultry meat that indicates which findings to look for during broiler PMI. In all national guidelines except for those in Finland and Sweden, findings are illustrated with pictures and descriptive criteria including severity of the finding for declaring broiler meat unfit for consumption (Table 5).

3.7. Proposal for a risk-based code set (RBCS)

The PMI codes most commonly used for broilers and the relative frequency of selected causes for total condemnation of a broiler in each country are presented in Table 6. Detailed data assigning the relative frequency of the used codes are presented in Tables S1 and S2 of the supplementary materials.

The correspondence between the existing broiler PMI codes available in the different countries and the reasons listed in the Article 45 of the Commission Implementing Regulation (EU) 2019/627 is shown in Table 7. Notably, the existing national PMI specific codes are far from covering the 19 reasons for condemnation applicable for poultry. Remaining reasons can be covered by the code "others". Detailed data assigning each code to the appropriate legislation-based reason are presented Table S3 of the supplementary materials.

Considering 80% of all reasons for declaring meat unfit for consumption in the eight countries and those listed in Article 45 of the Commission Implementing Regulation (EU) 2019/627, a new set of codes was developed. The proposed set consists of 13 specific codes that

Table 4
Number of post-mortem inspection codes covering 80%, 90%, 95%, and 99% of all registered condemnations of broilers in the eight European countries with a national code system in place in 2022.

	Number of available codes	Number of codes covering condemnations in			
		80%	90%	95%	99%
Denmark	11	4	5	6	7
Finland	7[a]	4	4	6	6
Germany	29[b]	5	6	6	7
Greece	7[c]	3	3	4	5
Poland	17	4	5	5	6
Portugal[d]	48	10	14	17	24
Sweden	19	5	6	10	19
United Kingdom	22 (20)[e]	9	11	14	18

[a] Nationally, condemnations are classified under seven used codes, but the publicly available data only shows the numbers and percents of six codes. The code "processing failures" had previously been merged with the code "other reasons", so processing failures were unable to be included in the Finnish data supplied to us.
[b] A total of 19 codes are available for carcasses, and 10 additional codes are for offal.
[c] Seven codes are predefined, but an unlimited number of additional descriptive codes can be used.
[d] Year 2019.
[e] In the UK data, "dead on arrival" and "ante-mortem rejects" codes were excluded by us from the calculations.

correspond to the existing national codes and to five legislation-based reasons.

We stress that "acute arthritis", "chronic arthritis", and "footpad lesions" codes did not appear in the most-used codes list that we prepared and that covers 80% of condemnations. However, these three codes do reflect broiler health and broiler welfare, so they have been included by us in the proposed harmonized and risk-based code set (Fig. 2).

The reasons for declaring meat unfit for human consumption in the European countries, considering the potential relationships with food safety, meat quality, broiler health, and broiler welfare aspects, are available in Table S4 of the supplementary materials.

Considering the correlation of lesions/abnormalities to broiler welfare, broiler health, food safety, or meat quality (Fig. 2) and using the codes covering 80% of all condemnations in the study period, the PMI results are illustrated as spider charts in Fig. 3. All the countries used codes related to "broiler welfare", ranging from 20.0% of registrations in the UK to 59.0% in Greece. The "broiler health" codes covered almost three quarters of all findings in Greece (73.9% of condemnations), about half in Denmark (62.7%), Portugal (50.6%), and in Finland (49.3%). The detection and registration of processing failures and meat quality issues most frequently occurred in Germany (35.9%) and Sweden (34.6%), less so in Greece (18.4%), and in Portugal (12.5%). In other countries they were rarely registered or were included in the "other", like in Denmark, Finland, and Poland. The food safety code "meat contamination" was registered in Poland (18.9%) and the UK (10.8%).

4. Discussion

Information related to the national condemnation code systems in nine European countries was collected and analyzed in this study. Only Italy did not implement any kind of national code set. Among the remaining countries, differences in the number and names of the available codes and in the frequency of reasons for condemnation were identified. The collected data revealed a lack of harmonization and a new updated risk-based code set was, thus, developed.

4.1. Harmonization

The scientific opinions for the modernization of meat inspection of the European Food Safety Authority (EFSA) have ranked the hazards of interest for different food producing animals. The opinion for poultry provided direction for a risk-based meat inspection in Europe, while acknowledging that harmonization is still lacking (EFSA, 2012b). The Cost Action 18105 Risk-Based Meat Inspection and Integrated Meat Safety Assurance (RIBMINS) (2019–2023) has conducted in-depth work on several aspects of modernization of meat inspection, and among this, on how to harmonize PMI in different species (Antunović et al., 2021). The results revealed that PMI of pigs, bovines, and poultry is still not harmonized in the MSs (Alban et al., 2022; Collineau et al., 2022; Salines et al., 2017).

The harmonization of what to record during broiler PMI as well as how to reach associated decisions would allow for detailed analysis of the results for further use in risk-based meat safety assurance systems (RB-MSAS) within and between countries (Collineau et al., 2022; Ferri et al., 2023). All valuable data will then be used to ensure the highest level of public health protection (Blagojevic et al., 2021). More than a decade ago, the EFSA scientific opinion for poultry meat inspection suggested updating the PMI codes to better reflect animal health, animal welfare, food safety, and meat quality (EFSA, 2012b).

Collecting and analyzing data to provide feedback to all stakeholders throughout the supply chain is important in contemporary risk management systems (Salines et al., 2018). Langforth et al. (2023) found that 75% of the OVs in Europe utilized FCI in their decision-making. Allain et al. (2018) designed an innovative warning system to support meat inspection in poultry abattoirs in France. An important element of the system was the provision of feedback to all stakeholders in a

Table 5
Characteristics of national guidelines of broiler PMI in nine European countries.

Country	Is a national PMI guideline in force?	Does the national guideline describe the criteria for declaring broiler meat unfit for consumption?	Does the national guideline include photos showing broiler PMI codes?
Denmark	Yes	Yes	Yes
Finland	Yes	Yes	No
Germany	No		
Greece	No		
Italy	No		
Poland	No		
Portugal	Yes	Yes	Yes
Sweden	Yes	Yes	No
United Kingdom	Yes	Yes	Yes

Table 6
Relative frequencies of the five most common reasons for condemnation of broilers in eight European countries during 2022.

Country	Common code name[1]					Sum of the five most common reasons
	Skin lesions (dermatitis/cellulitis)[1]	Ascites/oedema	Cachexia	Generalized disease	Lesions to internal organs (e.g. hepatitis, pericarditis)	
Denmark	19.9	15.2	4.2	10.3	9.8	59.4
Finland	36.4	30.2	2.2	NA[b]	NA[b]	68.8
Germany	34.1	16.8	2.7	9.0	NA	62.6
Greece	NA	0.0	59.0	14.9	NA	73.9
Poland	NA	NA	23.2	17.2	NA	40.4
Portugal[a]	8.9	5.1	22.0	13.9	5.64	55.5
Sweden	26.4	11.9	1.5	9.1	2.1	51.0
United Kingdom	17.6	14.4	1.5	12.1	18.4[c]	59.0

[1] A diversity of code names is used for the same finding. A common code name was chosen to allow comparison of data from the different countries.
NA – Not available due to the lack of a code corresponding to the specific finding.
[1] Scratches not included.
[a] Year 2019.
[b] In Finland, the codes "body cavity disorders" and "others" contain diverse types of lesions, and it was impossible for us to assign them correctly to the categories included in this table.
[c] Sum of the relative frequencies for the codes related to hepatitis, pericarditis, perihepatic, peritonitis, and salpingitis.

Table 7
Summary of the reasons for declaring broiler meat unfit for human consumption listed in Article 45 of the Commission Implementing Regulation (EU) 2019/627 (EC, 2019b) and covered by specific predefined codes in the national code sets in eight European countries.
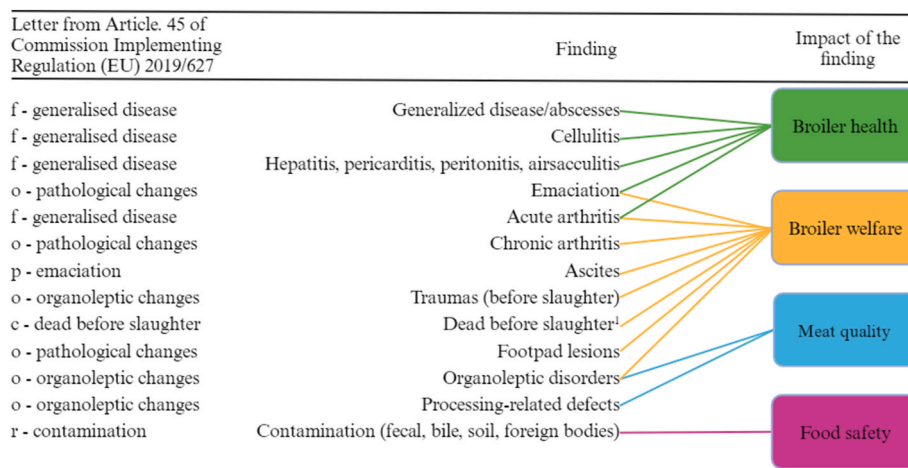
Country	Reasons listed in Article 45 of the Commission Implementing Regulation (EU) 2019/627											Total
	a	b	c	f	h	i	m	o	p	r	u	
Denmark				•				•	•			3
Finland				•				•	•	•		4
Germany	•	•		•	•			•	•			6
Greece				•	•		•	•				4
Poland				•	•	•		•	•	•	•	7
Portugal				•		•		•	•	•		5
Sweden		•		•		•		•	•	•		6
United Kingdom			•	•				•	•	•		5
Total	1	2	1	8	3	3	1	8	7	5	1	

a – derives from animals that have not undergone AMI; b – derives from animals whose offal has not undergone PMI; c – derives from animals that are dead before slaughter; f – generalized disease; h – exhibits parasitic infestation; i – chemical residues or contaminants in meat; m – contains foreign bodies; o – organoleptic and pathological changes; p – derives from emaciated animals; r – shows soiling; fecal or other contamination; u – gives rise to specific hazards (*Salmonella, Campylobacter* in broiler).

standardized way, such as the spider charts presented in Fig. 3. To achieve this, the codes, PMI guidelines, correct interpretations, and harmonization of all of these are needed to obtain more accurate results. For example, in Poland, the code "other" was used for 25% of the reasons for condemnation. This high proportion could be attributed to the lack of national guidelines regarding the interpretation of PMI findings in broiler carcasses, but further analyses are needed to determine this. In Denmark, Portugal, and the UK, guidelines are available with pictures of findings (codes) and their different severities (criteria). Such guidelines with pictures will most likely contribute to harmonized assessments but

are lacking in several countries. Among the countries that have national guidelines, only the Finnish guideline does not contain photos showing the finding. However, the Finnish abattoirs provide OVs with additional instructions with photos.

The reasons for PMI condemnations mainly reflect gross findings instead of etiologic diagnoses (Fallavena et al., 2000). Criteria including the severity of the lesions must also be considered when making decisions regarding when to register a finding and when to condemn a broiler carcass, partially or totally. Some subjectivity is observed in PMI of other livestock species and reflects the fact that the inspectors are

Letter from Article. 45 of Commission Implementing Regulation (EU) 2019/627	Finding	Impact of the finding
f - generalised disease	Generalized disease/abscesses	
f - generalised disease	Cellulitis	Broiler health
f - generalised disease	Hepatitis, pericarditis, peritonitis, airsacculitis	
o - pathological changes	Emaciation	
f - generalised disease	Acute arthritis	Broiler welfare
o - pathological changes	Chronic arthritis	
p - emaciation	Ascites	
o - organoleptic changes	Traumas (before slaughter)	
c - dead before slaughter	Dead before slaughter[1]	Meat quality
o - pathological changes	Footpad lesions	
o - organoleptic changes	Organoleptic disorders	
o - organoleptic changes	Processing-related defects	
r - contamination	Contamination (fecal, bile, soil, foreign bodies)	Food safety

Fig. 2. Reasons for declaring broiler meat as unfit for human consumption in European countries, considering the potential impact on food safety, meat quality, broiler health, and broiler welfare, based on the data from eight European countries and covering 80% of all condemned carcasses. The alphanumeric characters correspond to the reasons listed in Article 45 of Commission Implementing Regulation (EU) 2019/627 (EU, 2019b).
[1] Refers to poultry that died during transport to the abattoir and were accidently hung on the shackles, processed on the slaughter line and presented for PMI.

individuals, who interpret the Commission Implementing Regulation (EU) 2019/627 and guidelines differently based on their competence and experience. In the case of pig carcasses, the harmonization of basic principles for evidence-based judgement of post-mortem findings would help avoid unnecessary condemnation in a safe manner (Vieira-Pinto et al., 2022).

4.2. Codes related to broiler health or broiler welfare

According to EFSA, PMI of poultry allows, to some extent, detection of findings related to the birds' health and welfare (EFSA, 2012b). Animal diseases can be divided into notifiable diseases and those related to production (Stärk et al., 2014). Notifiable diseases in poultry are difficult to detect at PMI due to limited possibilities of confirmation on site, because these diagnoses usually require laboratory molecular analyses. Flocks suffering from transmissible animal diseases should preferably be detected before they are sent to the abattoir (EU, 2019b). However, PMI can play an important role in "back-up" surveillance when previous means of detection have failed (Stärk et al., 2014).

On the other hand, production diseases (e.g., skin diseases, generalized disease) usually do not affect the entire flock and can be detected at the PMI of individual carcasses. This is the last chance to remove unfit meat from the food chain before placing it on the market. PMI results can also be used to assess the effectiveness of production disease control measures, such as the efficiency of vaccinations (Stärk et al., 2014).

Cellulitis, in the European code systems often called either "dermatitis" or "cellulitis", is one of the most frequent lesions in broiler carcasses in Europe (EFSA, 2012b). In some countries, some codes likely include cellulitis, e.g., "scratches" and "dermatitis" in Denmark, but their names are generic and cannot be used to assess the true proportion of this lesion. In this country, the OV can register one of the codes referring to skin diseases, choosing between "dermatitis" and "cellulitis". In Poland, there is no specific code to which cellulitis can be assigned directly. If it occurs in the form of systemic disease, it could be recorded with the "sepsis and abscess" code, but mild lesions leave room for various interpretations regarding when to register and what action should be taken.

A new code system would require a name and assessment criteria of the lesion severity, specifying when the lesion is so aggravated that it calls for total and not just partial condemnation of the carcasses. We recommend that "scratches" be deleted from the code system, and that "traumas" is used instead. Generalized infections of broilers (e.g., colisepticemia) are production diseases that are detected frequently at PMI

(EFSA, 2012b). Again, code names relevant to generalized disease differ between the countries, leaving some room for different interpretations.

Traumatic injuries, hematomas, ascites, scratches, breast blisters, footpad dermatitis, and hock burns reflect the house conditions and quality of handling of the live birds on the farm and during transport to the abattoir. These conditions can be used as a reliable indicator of broiler welfare (Allain et al., 2009; Valkova et al., 2021). Scratches and footpad dermatitis can be the entry port for microorganisms that can inflict systemic infections, and the code classification of the lesion will depend on its severity (Alfifi et al., 2020). Accurate information about the lesions related to broiler welfare can provide very valuable feedback to the stakeholders. For this reason, half of the codes from RBCS are related to some extent to broiler welfare issues. The "acute joint infections", "ascites", "traumas (before slaughter)", "dead before slaughter", "footpad lesions", and "organoleptic disorders" codes are directly related to lesions in broiler flocks with poor welfare and are detectable at the PMI of carcasses or offal.

Carcasses of broilers that are dead before slaughter should be detected and removed from the food chain before shackling (EU, 2019b). The "dead before slaughter" code refers just to those carcasses accidently shackled, processed, and subjected to PMI on the slaughter line, and so represents only a small part of the broiler corpses present in transport vehicles. The final PMI inspection report needs to contain full data, including for all birds dead before slaughter. We note that in the national code system in the UK, dead birds are detected before slaughter, but are reported in PMI results.

The background of "cachexia" is also complex (Alfifi et al., 2020). Cachexia in broilers is mostly related to welfare issues, but it can also be a symptom of disease. Starved birds should be euthanized on farm to avoid additional suffering and must not be sent for slaughter (EFSA, 2012b, Nery et al., 2017).

Due to the fast growth of commercial broiler chickens and delayed development of their skeletons, some diseases in the bones and joints can occur and be detected after slaughter (Santos et al., 2022). These disorders can be caused by infectious or noninfectious factors or a combination thereof (Liu et al., 2023). Therefore, bone lesions and joint lesions could be important broiler health or broiler welfare indicators at PMI. The main cause of leg diseases in broilers is their rapid growth, leading to chronic overload of bones, joints, tendons, and ligaments (Shim et al., 2012). On the other hand, bacterial and viral diseases lead to acute lesions manifested by lameness, synovitis, purulent arthritis, fever, paralysis, and paresis (Oh et al., 2010; Robbins et al., 2012; Szafraniec et al., 2020). The detection of arthritis at PMI does not provide a
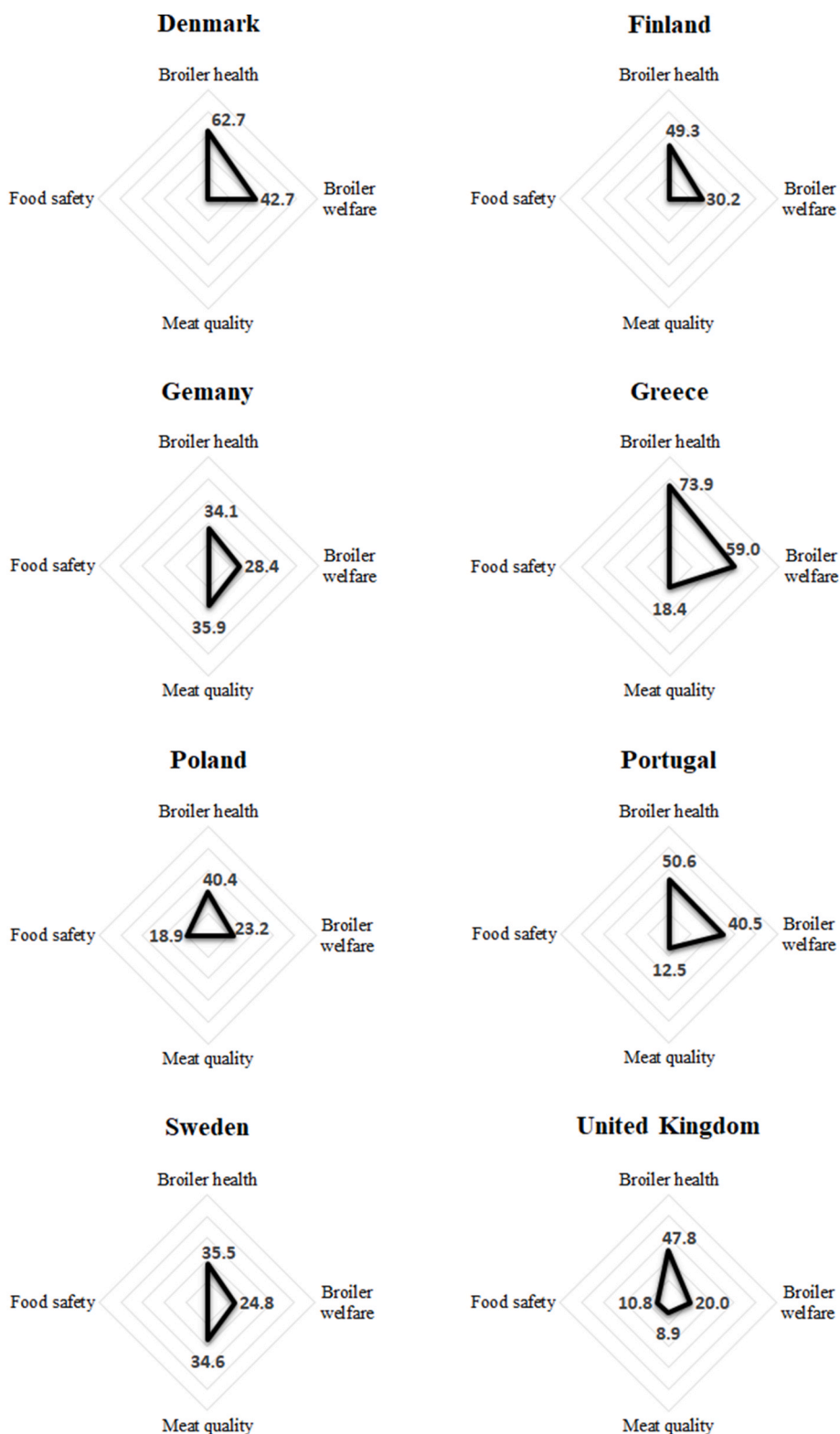
Fig. 3. Spider charts presenting the relative distribution (as % of total broiler condemnations) of PMI findings in view of their relevance to broiler health, broiler welfare, meat quality, and food safety in eight European countries in 2022[1].
[1] Year 2019.

precise answer as to the cause of the lesion, but it draws attention to the existing problem.

Footpad dermatitis in poultry is characterized by inflammation and necrotic lesions on the surface of the footpads and toes (Greene et al., 1985). It is an indicator of broiler welfare and is widely used in European countries (Louton et al., 2022). The occurrence of footpad dermatitis is detected in most European countries according to procedures conducted at a special PMI station set up specifically for this condition. However, in some countries it is reported along with other PMI findings operating standard PMI systems. Currently, in most European countries, a

representative number of feet is assessed, and on this basis, the level of welfare is determined. In some large abattoirs, CVSs are used to assess all broiler feet for meat quality purposes. The new RBCS should be comprehensive and consist of all relevant PMI items; clearly, footpad dermatitis assessment needs to be included. Therefore, the "footpad lesions" code has been included in the RBCS.

4.3. Food safety related codes

The lesions detected during PMI in broilers are regarded of limited importance for food safety, whereas the detection of fecal contamination on carcasses and offal resulting from post-mortem processing is important (EFSA, 2012b; Wessels et al., 2021). In 2012, EFSA suggested the use of HEIs to control hazards in poultry (EFSA, 2012a). The HEIs currently used for broilers in Europe are still considered appropriate, since salmonellosis and campylobacteriosis in humans are often ascribed to poultry and remain at high rates in some countries in Europe (EFSA and ECDC, 2022; Langkabel et al., 2023). *Salmonella* and *Campylobacter* can be carried in the digestive tract of clinically healthy broilers. The pathogens on the surface of broiler meat originate mostly from broiler intestines, but the number of pathogens depends on the combination of pre- and post-harvest interventions, where slaughter hygiene and the removal of contaminated carcasses from the food chain are of major importance. However, the detection of feces or other gastrointestinal content can be difficult to recognize with the naked eye, especially when contamination occurs on parts out of the inspector's visual field or is scattered in the form of very small spots (Gorji et al., 2022; Törmä et al., 2024). Moreover, due to the high speed of the broiler slaughter lines, body cavities are usually inspected by tilting individual carcasses only if soiling or damage to the viscera is suspected (Törmä et al., 2021). For this reason, human pathogens, such as *Salmonella*, *Campylobacter*, and bacteria carrying ESBL/AmpC genes, can only be detected indirectly and inefficiently during routine visual PMI. The presence of these bacteria is monitored according to the established EU microbiological criteria for foodstuffs (EC, 2005; EFSA, 2012b).

Many lesions detected at PMI, such as cellulitis and airsacculitis, can be caused by an extra-intestinal avian pathogenic *Escherichia coli* (APEC), which has also been suggested as a potential human pathogen (Dho-Moulin & Fairbrother, 1999). APEC occurs in the intestines of healthy broilers and can occasionally cause extraintestinal infections, being the primary pathogen or complicating viral infections. However, it does not seem justifiable to put codes that can be related to lesions caused by APEC (dermatitis, cellulitis, and systemic infections) in the 'food safety' category, since the direct transmission of APEC from food to human is not observed (Mellata, 2013, Manges, 2016). For these reasons, in PMI of broilers, only the "meat contamination" code can be classified as being relevant to food safety.

4.4. Meat quality and processing failure-related codes

In the RBCS, we suggest the use of only two codes that cover a broad spectrum of abnormalities. "Organoleptic disorders" code was described in most countries in different ways, including organoleptic defects and myopathies. The "processing defects" code is related to all abnormalities caused by machine damage post slaughter (e.g., overscalding, errors during evisceration, muscle damage during processing). The detection and recording of these findings provide important information to FBOs regarding meat quality.

4.5. PMI of broilers in the new risk-based context

A modernized meat safety system is risk-based (RB-MSAS), longitudinally integrated (providing multiple interventions or measures in the whole production chain), flexible, and dynamic (Blagojevic et al., 2021). Broiler PMI is usually carried out by an OV, or by OA or trained abattoir staff under the supervision of the OV. Appropriate training of the OV and the OA is a long process (EU, 2019a). The knowledge and skills acquired during this training far exceed visual PMI and allow for a comprehensive approach to the supervision of slaughter and other meat production stages (EU, 2019b). The CA can decide that only a representative sample of carcasses from each flock undergoes PMI if the FBO has a system in place that allows the detection and the separation of birds with abnormalities, contamination, or defects.

4.6. Computer vision systems (CVS)

The above-mentioned regulations and the RB-MSAS approaches allow the implementation of CVSs, which can increase the sensitivity of PMI (Yang et al., 2009). Article 6 of Commission Implementing Regulation (EC) 2019/627 and Article 16 of Regulation (EC) 2017/625 indicate openness to scientific and technological development (EC, 2017; EU, 2019b). CVSs for broilers have been developed over several years and are currently reaching their final stage (Sandberg et al., 2023). An important idea in the context of RB-MSAS is the effective use of new technologies that can improve the quality of the PMI and enable the exchange of information among CA, FBO, and broiler producer (Ferri et al., 2023). The information needed for such a system could be collected using CVS (Antunović et al., 2021; Blagojevic et al., 2021). However, for the abattoir to be able to implement vision devices, other systems for reducing the risk related to specific hazards present in meat should be implemented. Sandberg et al. (2023) noted that for CVS-based inspection to be effective, the PMI code set must be standardized. Törmä et al. (2021) emphasizes that, even in one country, differences related to PMI conditions, including lighting, inspection duration, the number of meat inspectors, and inspection methods affect the PMI outcomes in different abattoirs.

In most of the countries participating in the study, only one code is allowed to be used for one carcass, which results from internal instructions in force in these countries. Only the Greek and German systems allow for registration of an unlimited number of codes for one carcass, so likely, this option is not commonly utilized in Europe. CVS will allow more than one code per carcass, and hence, a more precise description for each individual broiler will be provided. The criteria for condemnation will be able to be regulated up or down according to the national preferences.

4.7. Conclusions

The study showed the differences in code systems in European countries. The condemnation rate of broiler carcasses differs between and within countries and is influenced by many factors related to the performance of PMI. Based on information from nine European countries, a harmonized code list for use in PMI of broilers is suggested. This list will be a prerequisite for harmonized PMI and will also be eminently suitable for use in CVSs that enable automated PMI. Correlating different codes with the four defined surveillance objectives, namely food safety, meat quality, broiler health, and broiler welfare, is a step forward for deciding the necessary sensitivity and specificity that would be required from the CVS. The food safety surveillance objective, which requires detection of fecal and intestinal material on carcasses, will require high sensitivity at the individual carcass level. The three other objectives will likely only require high flock sensitivity, since the purpose is to document the prevalence at that level to guide improvements in broiler meat quality and in live broiler health and welfare.

CRediT authorship contribution statement

Michał Majewski: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Lis Alban:** Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Désirée S. Jansson:** Investigation, Writing – review & editing. **Thomai Lazou:** Investigation, Writing – review & editing. **Nina Langkabel:** Investigation, Writing – review & editing. **Dragan Antic:** Investigation, Writing – review & editing. **Eija Kaukonen:** Investigation, Writing – review & editing. **Helena Wall:** Investigation, Writing – review & editing. **Madalena Vieira Pinto:** Investigation, Writing – review & editing. **Laila Østergaard:** Investigation, Writing – review & editing. **Ole Gyvelgaard Nielsen:** Investigation, Writing – review & editing. **Sergio Ghidini:** Investigation, Writing – review & editing. **Marianne Sandberg:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data on national coding systems is available upon request, but in some countries we have not obtained permission to distribute the guidelines.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi. org/10.1016/j.foodcont.2024.110665.

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