



Food chain information for pigs in Europe: A study on the status quo, the applicability and suggestions for improvements

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ABSTRACT

Food chain information (FCI) as stated in Regulation (EC) No 853/2004 plays a vital role in supporting decision-making and guiding of risk managers at abattoirs by providing valuable insights into inspection methods and intensity. However, the lack of specific guidelines on data collection within FCI presents a challenge. To address this issue, we conducted an online survey among stakeholders in the European pig industry to assess the current state of FCI implementation and identify areas for improvement. Out of the 93 respondents, over 50% reported they had access to data on ante- and post-mortem findings as well as on treatments with withdrawal periods during the fattening period. Additionally, 49% had access to data on veterinary medicinal products (VMPs) administered to the pigs. Despite the mandatory nature of this data according to Regulation (EC) No 853/2004, our findings revealed a lack of legally required information in the transmission of FCI. When evaluating the usefulness of FCI in food safety decision-making, 60% of the respondents found it helpful, while 40% expressed varying levels of dissatisfaction with the currently available FCI. These results highlight the current challenges in the implementation of FCI for pigs in Europe. Furthermore, our study identified a significant correlation between the assessment of FCI usefulness and access to animal health data and additional information on abnormalities. We also identified research gaps in establishing critical thresholds for mortality rate and determining the relevant period for VMP documentation. To enhance the FCI system and improve animal health and food safety, management, comprehensive legislation and technical implementations for data exchange are crucial. Close collaboration among stakeholders, stakeholder training, development of abattoir-specific strategies and integration of harmonised epidemiological indicators into FCI are recommended. In conclusion, clear specifications regarding the necessary data for FCI are vital as FCI plays an integral role in the risk-based meat safety assurance system. Implementing these recommendations will enhance the effectiveness of FCI, improve decision-making processes and strengthen the overall food safety management.

1. Introduction

One of the primary objectives of meat inspection is to determine the fitness of meat for human consumption, alongside optimising animal health and animal welfare (Regulation (EU) 2017/625, Commission Implementing Regulation (EU) 2019/627) (European Commission, 2017, 2019). However, traditional ante-mortem (AM) and post-mortem (PM) inspections have limitations in detecting high-priority meat-borne hazards, such as *Salmonella* or *Yersinia enterocolitica* in pigs (Blagojevic & Antic, 2014; Blagojevic et al., 2021; Fredriksson-Ahomaa, 2014; EFSA

Panel on Biological Hazards, 2011). In fact, handling techniques during PM inspections, like palpation and incision, can potentially contribute to the spread of hazards through cross-contamination (EFSA Panel on Biological Hazards, 2011). Over recent decades, the European Union (EU) has transitioned towards a more risk-based approach to meat inspection (Regulation (EC) No 178/2002, Regulation (EU) 2017/625, Commission Implementing Regulation (EU) 2019/627) (European Commission, 2002, 2017, 2019). This approach incorporates risk assessment, risk management and risk communication (Fredriksson-Ahomaa, 2014), including visual meat inspection and the

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collection of food chain information (FCI) as defined in Regulation (EC) No 853/2004 (European Commission, 2004b). FCI involves collecting information along the food chain for animals intended for slaughter and facilitating the information exchange among stakeholders at different production stages. The successful implementation of a risk-based meat safety assurance system (RB-MSAS) relies on effective longitudinal integration across the entire food chain (Ferri et al., 2023). RB-MSAS is a dynamic and flexible management system that incorporates risk assessment and encompasses measures implemented during both pre-harvest and harvest phases of the meat chain to ensure meat safety (Blagojevic et al., 2021). FCI plays a vital role within RB-MSAS and recent research emphasises the importance of integrating more standardised and advanced FCI, including the utilisation of harmonised epidemiological indicators (HEIs), to continually enhance public health (Blagojevic, 2019; Blagojevic et al., 2021; Bonardi et al., 2021; Buncic et al., 2019; Ferri et al., 2023; Nastasijević et al., 2020; Salines et al., 2023). This integration presents a progressive step towards improving the overall effectiveness and efficiency of meat inspection processes.

The relevant data to be included in FCI are specified in Annex II, Section III of Regulation (EC) No 853/2004 and encompass:

- (a) the animal health status of the holding of provenance or region,
- (b) the animals' health status,
- (c) veterinary medicinal products (VMPs) or other treatments administered within a relevant period and with a withdrawal period greater than zero days,
- (d) the occurrence of diseases that may affect the safety of meat,
- (e) the results of any analysis to diagnose diseases that may affect the safety of meat,
- (f) relevant reports about previous AM and PM inspections of animals from the same holding,
- (g) production data, when this might indicate the presence of disease,
- (h) the name and address of the private veterinarian responsible for the farm.

The content of FCI assists in determining the intensity and procedures of AM and PM inspections at abattoirs, as well as slaughter procedures, depending on the risk associated with incoming herds or individual animals (Fredriksson-Ahomaa, 2014). Moreover, the exchange of FCI enables risk categorisation of farms and feedback on AM and PM findings to support continuous on-farm improvement processes. Nevertheless, the EU Regulation No 853/2004 lacks detailed specifications regarding the specific data to be collected, resulting in variations in FCI implementation at country and abattoir-level. Consequently, heterogeneity exists in the information content of FCI across Europe. The current state of FCI is characterised as underdeveloped and underutilised (Buncic et al., 2019). Blagojevic et al. (2021) highlighted the lack of requirements specifying how FCI should be analysed and utilised. Concerns have been raised by meat inspection professionals regarding the poor quality of FCI (Laukkanen-Ninios et al., 2020). Furthermore, available FCI for pig meat inspection is considered insufficient in practice (Felin et al., 2016). Overall, there is a significant lack in useful FCI that would enable effective risk-based decisions (Antunović et al., 2021).

To evaluate the effectiveness and information content of the FCI systems implemented in Europe, particularly for pigs, we conducted a survey involving various stakeholders within the European pig industry. Our objective was to gather first-hand insights and evaluate the current state of FCI, as well as its practical utility.

2. Materials and methods

2.1. Questionnaire development and design

The questionnaire was developed by Working Group 2 of the

RIBMINS (Risk-based meat inspection and integrated meat safety assurance) COST Action (CA18105). It was created in English and underwent validation by two social scientists from the Agriculture Economics Research Institute (AGRERI) ELGO-DIMITRA in Greece, following positive feedback. To facilitate data collection, the questionnaire was entered into SurveyHero®, a cloud-based software and questionnaire tool (enuvoGmbH, Zurich, Switzerland). The research protocol involving the questionnaire was approved by the Central Ethics Committee of Freie Universität Berlin, Germany (ZEA-Nr. 2022-008). To ensure respondents' anonymity, we refrained from collecting personal identifiers like names, contact information and identifying details like IP addresses. The questionnaire comprised various question formats, including single-choice, multiple-choice (allowing multiple answers) and open-ended questions. In total, it consisted of 23 questions divided into two sections (Supplement S1). The first section gathered general information about the respondents, including their professional role, the country and the size of the abattoir they worked in (estimated average number of pigs slaughtered per week). The main section comprised 20 questions focused on assessing the current state of FCI. These questions explored topics like the type of information collected and transmitted, the respondents' evaluation of FCI usability, improvement proposals and potential consequences resulting from information transmitted via FCI. Within this section, there were seven higher-level questions that revealed sub-questions when respondents selected "yes" as their answer, allowing for further investigation into specific aspects related to FCI.

2.2. Questionnaire distribution and data collection

The RIBMINS science communication manager coordinated the online survey by distributing the weblink. The manager instructed the 33 RIBMINS national contact points (NCPs) at that time, located in various European countries, to recruit suitable respondents. Although FCI, as defined in Regulation (EC) No 853/2004, holds legal jurisdiction within EU member states (MSs), its influence extends to non-EU countries and those within the European Economic Area (EEA) due to import and export regulations along with ongoing EU membership applications. Each NCP had the autonomy to decide on the number of respondents they would invite to participate. They were asked to create a representative sample that reflects the structural aspects of their respective country, ensuring participation from small, medium and large-sized abattoirs, accurately representing their specific pig abattoir structure. Additionally, they were instructed to include at least one meat inspection officer, such as an official veterinarian (further referred to as OV), and one food business operator or quality assurance manager (further referred to as FBO). The questionnaire's target group also encompassed industry professionals involved in meat safety assurance systems at farm or abattoir-level. To address language barriers, the NCPs were asked to translate the questionnaire into their native language and translate the answers back into English. The response period was initially set between November and December 2020, with a reopening from September to November 2022.

2.3. Data analysis

The data analysis was conducted using Microsoft Excel® (Version 2211) for descriptive statistics. For chi-square tests, calculation of the phi coefficient and determining correlations between variables, IBM® SPSS Statistics (Version 29) was used. The Fisher's exact test was used to calculate p-values for cases with cell frequencies below five. For anonymity, countries were grouped into three categories: EU MSs, EEA countries and non-EU MSs. The United Kingdom (UK) was categorised as EU MSs due to the ongoing Brexit transition phase and the country's continued adherence to EU rules during the survey period. To ensure a high level of confidentiality, responses categorised as "other" were carefully examined. When compatible, these responses were classified and counted alongside the existing answer options.

3. Results and discussion

3.1. General information

In the initial round, we received 53 responses and the second round generated 40 additional responses. The second round aimed to provide a more comprehensive and representative dataset, addressing the non-response of important pig-producing countries in Europe like Belgium and Spain. In total, there were 93 respondents from 24 different countries. Among them, 69 respondents worked in 17 EU MSs, including Belgium, Croatia, Denmark, France, Germany, Greece, Ireland, Italy, Latvia, the Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden and the UK. Four respondents worked in two EEA countries, Iceland and Norway. The remaining 19 respondents worked in five non-EU countries, including Albania, Bosnia and Herzegovina, North Macedonia, Serbia and Switzerland (the first four being EU candidate countries). Altogether, we received responses from all eight major pig-producing countries in Europe (Spain, Germany, France, Poland, the Netherlands, Denmark, Italy, Belgium) (European Commission, 2023), indicating the representativeness of the results. A total of 60% (56/93), and thus the majority of respondents, were OV's (Table 1). FBOs comprised 30% of the respondents (28/93). Nine respondents (10%) classified themselves as "other", including professionals working in the meat safety sector as academics or advisors associated with farms or abattoirs.

3.2. Status quo of the information content and assessment of FCI's usefulness

3.2.1. Overall access to information

The respondents were queried about their access to various types of data, including the mortality rate during the fattening period, treatments with withdrawal periods, veterinary medicinal product usage apart from antibiotics, animal health status, pregnancy data, cleanliness and AM and PM inspection results from animals from previous slaughter batches. Fig. 1 presents the distribution of respondent percentages based on their access to information received through FCI. Legally, Regulation

Table 1
Distribution of respondents' professional roles, country status and abattoir sizes (n = 93).

Professional Role	Country Status	Abattoir Size	Total	Percentage	
OV	EU MS	Small	14	15.0%	
		Medium	13	14.0%	
		Medium-large	12	12.9%	
	EEA	Large	1	1.1%	
		Non-EU	Small	2	2.2%
			Small	11	11.8%
FBO	EU MS	Medium	3	3.2%	
		Small	7	7.5%	
		Medium	5	5.4%	
	EEA	Medium-large	11	11.8%	
		Large	1	1.1%	
		Small	1	1.1%	
Other	EU MS	Small	3	3.2%	
		Small	1	1.1%	
		Medium	1	1.1%	
	Non-EU	Medium-large	3	3.2%	
		Medium	1	1.1%	
		Small	2	2.2%	
		Medium-large	1	1.1%	

OV = official veterinarian; FBO = food business operator; Other = respondent classified in the category "other"; EU MS = member state of the European Union; EEA = member state of the European Economic Area; non-EU = European country that is not a member state of the European Union; Small = < 1000 pigs slaughtered per week; Medium = 1000 to 10,000 pigs slaughtered per week; Medium-large = 10,001 to 100,000 pigs slaughtered per week; Large = > 100,000 pigs slaughtered per week.

(EC) No 853/2004 (European Commission, 2004b) mandates the collection of AM and PM findings, treatment data, veterinary medicinal product usage and animal health status. However, data on the mortality rate, pregnancy and cleanliness are not specified in the legislation and are therefore not legally mandated. When considering only the EU MSs, which must adhere to EU regulation, 71% of respondents (49/69) reported having access to AM findings data, 70% (48/69) to PM findings data, 58% (40/69) to treatment data, 52% (36/69) to veterinary medicinal product usage data and 45% (31/69) to data on the animal health status. Our analysis showed no correlation between the respondents' roles (OVs vs. FBOs) and the information they had access to. Another study revealed challenges surrounding incomplete or inaccurate mandatory data transmission and reception as well. According to Gomes-Neves et al. (2018) farmers can be unfamiliar with the regulatory requirements or hold misconceptions about what information should be provided. Additionally, non-compliance with legal requirements (Mensah & Julien, 2011; Yapp & Fairman, 2006) could be another contributing factor. Existing research suggests that FCI often fall short in providing meaningful and comprehensive data (Antunović et al., 2021; Bonardi et al., 2021; Buncic et al., 2019; Laukkanen-Ninios et al., 2020), resulting in a lack of essential information or inaccuracies within the transmitted data (Felin et al., 2016; Gomes-Neves et al., 2018; O'Sullivan et al., 2015; Pattono et al., 2014; Ranucci et al., 2021). However, since our survey did not explore the specific reasons behind missing information further research, especially targeted interviews, is essential to gain deeper insights. These investigations can help uncover the specific factors contributing to respondents reporting a lack of mandatory information regulated by EU legislation and identify potential gaps or challenges in the implementation and communication of mandatory information requirements as well as reasons for non-compliance.

Annex II Section III Point 4. (a) of Regulation (EC) No 853/2004 (European Commission, 2004b) specifies exceptions for the reporting of certain data through FCI. These exceptions apply if (i) the abattoir already possesses this information or (ii) if the farmer declares no relevant information to report. While respondents were allowed to add notes for each question, none of them addressed that a lack of access indicated that no relevant information was to report, according to subitem (ii). Furthermore, the questions focused on access rather than transmission to minimise the influence of subitem (i). The information specified in subitem (i) remains essential for the FBO at the abattoir, necessitating they have access to it.

Our statistical analysis revealed several significant correlations (Table 2). Notably, a correlation emerged between the access to PM findings and the size of the abattoir, specifically in small- or medium-sized abattoirs. The chi-square tests' contingency table frequencies imply that medium-sized abattoirs had access to PM findings more frequently than expected, while small-sized abattoirs displayed the opposite, having access to PM findings less frequently than anticipated. Conversely, small-sized abattoirs exhibited significantly more frequent access to pregnancy-related data. It is worth noting that the direction of association cannot generally be determined for nominal data with only two categories. Medium-sized abattoirs showed further significant correlations related to access to additional data in case of abnormalities while medium to large-sized abattoirs exhibited significant correlations regarding data on VMPs and the animal health status (Table 2). For VMPs and the animal health status, the chi-square tests' contingency table analysis imply that medium to large-sized abattoirs were expected to receive data more often, but the observed frequencies indicated otherwise, warranting further investigation. The country's EU membership was also identified as a significant factor influencing the receipt of information, particularly AM and PM findings (Table 2). As expected, EU MSs received significantly more AM and PM findings, which aligns with the mandatory nature of FCI legislation for EU MSs. However, it is surprising that this correlation was observed for only two out of the five mandatory data. It is also important to remember that correlations found in the chi-square test do not imply causation and there can be other

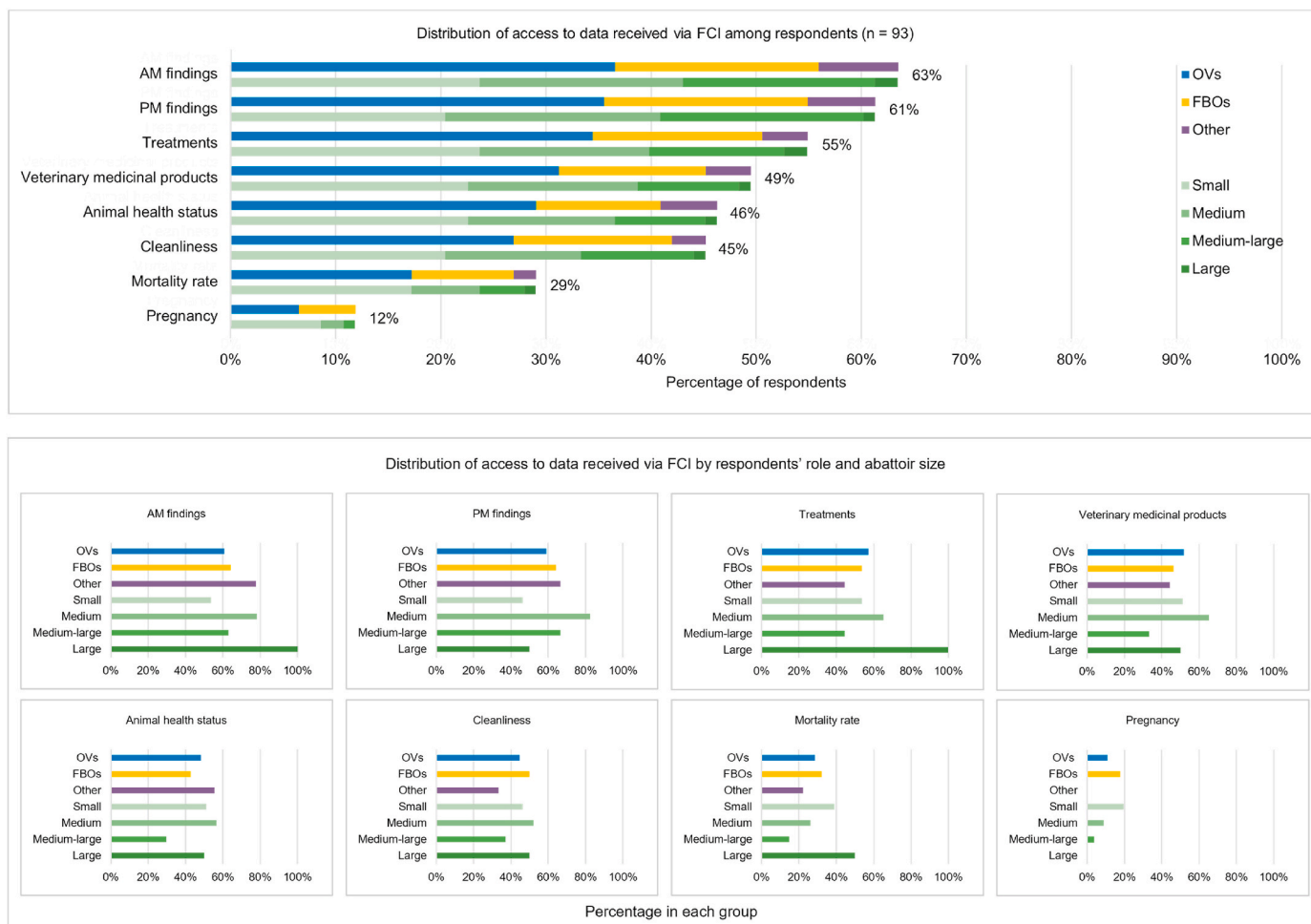


Fig. 1. Distribution of access to data received via FCI among all respondents (n = 93) and by respondents' role (official veterinarians (OVs), n = 56; food business operators (FBOs), n = 28; other respondents (Other), n = 9) and abattoir size (Small (< 1000 pigs slaughtered per week), n = 41; Medium (1000 to 10,000 pigs slaughtered per week), n = 23; Medium-large (10,001 to 100,000 pigs slaughtered per week), n = 27; Large (> 100,000 pigs slaughtered per week), n = 2).

factors influencing these associations.

3.2.1.1. Regular contact with practitioners. The respondents were also asked about their regular contact with private veterinarians responsible for the farms and if they have access to supplementary information in the case of abnormalities. A significant correlation was found between small-sized abattoirs and regular contact with private veterinarians (Table 2). Moreover, medium-sized abattoirs demonstrated a reliance on private veterinarians in cases of abnormalities and when additional information was needed. Regular contact between abattoirs and private veterinarians is instrumental in sharing information and promptly addressing emerging issues related to animal health and food safety. The Federation of Veterinarians of Europe underscores this, stating that “FCI as defined in the legislation is a two way process linking the veterinary practitioner with the Official Veterinarian at the slaughterhouse” (O’Sullivan et al., 2015). This highlights the essential involvement of private veterinarians on farms within the context of the RB-MSAS (Ferri et al., 2023).

3.2.2. Assessment of FCI’s usefulness

Furthermore, the respondents were asked to assess the extent to which FCI helps them in making decisions regarding food safety. In total, 60% of the respondents (56/93) assessed FCI as useful for decision-making regarding food safety. Significant correlations emerged when examining the roles of the respondents as OVs and FBOs (Table 2) with fewer OVs perceiving FCI as helpful compared to FBOs. This discrepancy

could reflect varying perspectives and needs in utilising FCI for decision-making between the two groups. OVs, responsible for regulatory compliance and conducting inspections, likely possess a thorough understanding of the limitations of the FCI system and the broader regulatory obligations they must meet. Therefore, their assessment of FCI could be influenced by the need for comprehensive and detailed information to fulfil their regulatory responsibilities effectively. Conversely, FBOs, who primarily focus on the operational aspects of food production, evaluate FCI based on its practical benefits in their day-to-day operations. Addressing these varying perspectives is essential to enhance the effectiveness of the FCI system. Improvements should aim to provide comprehensive and relevant information that meets the regulatory requirements of OVs and the operational needs of FBOs.

While a majority of respondents assessed FCI as useful, a significant portion (40%, 37/93) expressed dissatisfaction, describing it as rarely (35%, 32/93) or not useful (5%, 5/93). These findings emphasise the need for improvement in the current FCI system, as previously highlighted by various authors (Antunović et al., 2021; Blagojevic et al., 2021; Bonardi et al., 2021; Buncic et al., 2019; Felin et al., 2016; Gomes-Neves et al., 2018; O’Sullivan et al., 2015; Ranucci et al., 2021). In exploring the reasons behind this dissatisfaction, one respondent provided insights. They emphasised that FCI is primarily important for accessing data on administered treatments and ensuring compliance with withdrawal periods. However, they felt that FCI lacks additional valuable information and reported that FCI does not provide any significant information beyond the treatment data. These explanations

Table 2

Summary of significant results (chi-square test; n = 93; degrees of freedom = 1) for dichotomous variables A and B.

Variable A	Variable B	Chi-Square	p-Value	Phi Coefficient
Abattoir size: small	Data access: PM findings	6.907	0.009	-0.273
Abattoir size: medium	Data access: PM findings	5.853	0.016	0.251
Abattoir size: small	Data access: pregnancy-related	4.152	0.042	0.211
Abattoir size: medium	Data access: additional data in case of abnormalities	6.134	0.013	0.257
Abattoir size: medium-large	Data access: veterinary medicinal products	3.959	0.047	-0.206
Abattoir size: medium-large	Data access: animal health status	4.221	0.040	-0.213
Country status: EU MS	Data access: AM findings	6.612	0.010	-0.267
Country status: EU MS	Data access: PM findings	7.717	0.005	-0.288
Abattoir size: small	Contact with private veterinarians on farms	4.550	0.033	0.221
Role: OVs	Assessment: FCI's helpfulness	8.462	0.004	-0.302
Role: FBOs	Assessment: FCI's helpfulness	5.635	0.018	0.246
Assessment: FCI's helpfulness	Data access: animal health status	9.121	0.003	0.313
Assessment: FCI's helpfulness	Data access: additional data in case of abnormalities	8.532	0.003	0.303
Assessment: FCI's helpfulness	Data access: pregnancy-related	8.243	0.004	0.298
Assessment: FCI's helpfulness	Data access: veterinary medicinal products	5.046	0.025	0.233
Assessment: FCI's helpfulness	Contact with private veterinarians on farms	5.003	0.025	0.232
Assessment: FCI's helpfulness	Data access: AM findings	3.872	0.049	0.204
Abattoir size: small	Transmission: paper-based	21.500	<0.001	-0.543
Abattoir size: small	Transmission: electronic	10.071	0.002	0.329
Abattoir size: medium	Transmission: electronic	4.966	0.026	-0.231
Assessment: transmission's practicability	Transmission: paper-based	29.885	<0.001	-0.354

highlight the perceived limitations of the current FCI system for pigs and the need to address these shortcomings to meet the information needs of the data receivers in the future.

To identify the valuable information, we conducted an analysis to determine the factors associated with the perceived usefulness of FCI among respondents who assessed it as helpful. Our findings revealed significant correlations between usefulness and access to various types of information (Table 2), suggesting that respondents with access to this information were more likely to perceive FCI as useful. Therefore, providing comprehensive and relevant data in these areas could significantly improve the perceived value and effectiveness of FCI for decision-making regarding food safety.

3.2.3. Animal health status of the herd

Notably in our survey, access to data on the animal health status demonstrated the highest correlation with usefulness in assessing food safety (Table 2). Among the 43 respondents who had access to this data (Fig. 1), the majority of respondents reported having access to information on treatments during the fattening period (67%, 29/43), specific diseases reported to food safety authorities (60%, 26/43) and the mortality rate during the fattening period (51%, 22/43). Furthermore, four respondents (9%) mentioned collecting data on the on-farm *Salmonella* status. Interestingly, these four respondents were FBOs working in the same EU MS with no national *Salmonella* monitoring on farm-level. According to Bonardi et al. (2021), the *Salmonella* status of pig farms is included in the FCI in countries where farm-level monitoring is conducted, which in the EU is a minority. This information enables risk managers at abattoirs, OVs as well as FBOs, to organise slaughter operations and implement hygienic measures for high-risk pigs, as practiced in Denmark (Alban et al., 2012). The inclusion of HEIs in the FCI supports decision-making and targeted risk management during the slaughter process (EFSA, 2011; Li et al., 2023). HEIs for pigs have been introduced by the European Food Safety Authority (EFSA) to be utilised as part of the risk-based meat inspection within the meat safety assurance framework over a decade ago (EFSA, 2011) and still, their application and implementation seem to be lacking (Bonardi et al., 2021; Ferri et al., 2023; Salines et al., 2023). As part of this questionnaire study, we have conducted a survey on the implementation of HEIs for pigs in Europe and the results are presented in a separate publication by Li, Meemken, Antunovic, Nesbakken, & Langforth, 2024. The results indicate that HEIs for pigs are underutilised across Europe failing to harness the full potential of a RB-MSAS and missing the opportunity to add valuable data to the FCI.

The assessment of animal health relies heavily on treatment data, including indications and the use of VMPS. However, the mortality rate during fattening, calculated as the proportion of deceased and euthanised pigs relative to the initial number of animals, also holds particular importance. It serves as a suitable metric due to its numerical nature, making it easily calculable and devoid of subjective interpretation. The mortality rate provides a clear distinction between living and deceased animals. Numerous studies have demonstrated the value of the mortality rate as an indicator for assessing animal health (Dickhaus et al., 2009; Grosse-Kleimann, Plate, et al., 2021; Grosse-Kleimann, Wegner, et al., 2021; Nienhaus et al., 2020). Belgium, for instance, has established an animal health barometer comprising 13 indicators, including the mortality rate for pigs (FASFC, 2016). In our study, we investigated the optimal critical threshold for the mortality rate associated with visible lesions during meat inspection, with the premise that an increase in mortality rate is correlated with a rise in visible lesions at meat inspection. The respondents reported both thresholds <1% and 2–5% almost equally (33%, 31/93; 34%, 32/93). As the study's findings are inconclusive regarding the determination of an optimal threshold for the mortality rate linked to pathological findings, we cannot provide a clear recommendation. Further research is necessary, particularly considering the limited existing research on this particular threshold. Most existing research focuses on average on-farm mortality rates in fattening pigs (Depoorter et al., 2015; Grosse-Kleimann, Plate, et al., 2021; Grosse-Kleimann, Wegner, et al., 2021), which require monitoring and evaluation to assess improvements in overall animal health. Thomann et al. (2023) identified that the optimal mortality threshold for ensuring good animal health should be <1.5%, while values exceeding 3% are considered alarming. Regarding the use of the mortality rate as an indicator for meat inspection in the current herd, the threshold appears to fall within a similar range of < 1–5% according to our results.

3.2.4. Animal health status of holdings in the region

The data derived from the holding of origin of the animals are important for facilitating the organisation of slaughter operations for FBOs and assisting OVs in determining appropriate inspection procedures (Bonardi et al., 2021). The majority of respondents (72%, 67/93) reported that they obtain information about recent outbreaks of notifiable diseases in their region from the regional veterinary service. National disease databases were accessed by 55% of the respondents (51/93) and 34% (32/93) mentioned the World Organisation for Animal Health. In addition, 19% of the respondents (18/93) suggested other sources such as national networks and media publications. Notifiable

diseases can significantly impact animal health as well as transportation and export activities, potentially leading to abattoir closure in severe cases (European Commission, 2016).

3.2.5. Treatment data and documentation obligation

The utilisation of antibiotics has been and continues to be a matter of great significance, both for animal health and food safety. Administration of VMPs within a relevant period before slaughter serves as an indicator of the animal's health status and aids in predicting findings during meat inspection. When VMPs are administered within the relevant period, it indicates prior treatment for disease or infection. In the case of broilers, a study by Junghans et al., (2022) found that a higher rate of antibiotic usage increases the likelihood of abnormalities during meat inspection and condemnation due to pathological lesions. Our study investigated the relevant period before slaughter in different countries. However, we encountered challenges as respondents from the same country provided different time specifications, ranging from zero days to the entire fattening period, even in countries with nationally regulated relevant periods (Li et al., 2024). This inconsistency hindered our ability to evaluate the question effectively. It appears that there are difficulties in understanding the concept of the “relevant period”, resulting in data transmitted through FCI that is not comprehended by its recipients, and thus failing to serve its intended purpose. Similar findings regarding the lack of understanding of the relevant period were also reported by Popp et al. (2017).

We also asked respondents for their opinions on the most meaningful period for documentation obligation of VMPs (Fig. 2). The results revealed a lack of consensus among the respondents, underscoring the challenge in determining a meaningful time frame for the relevant period found in this study and previously (Li et al., 2024). Previous research by Popp et al. (2017) has already highlighted the difficulty in establishing a correlation between the usage of VMPs and the occurrence of pathologic findings at meat inspection. Further research is necessary to gain a deeper understanding of this issue.

The access to data on VMPs other than antibiotics covered a range of categories, including antiparasitic medicines (42%, 39/93), vaccines (37%, 34/93), feed additives (30%, 28/93) and anti-inflammatory drugs (33%, 7/93). It is important to note that some of these non-antibiotic VMPs also have specific withdrawal periods. The use of vaccines and antiparasitic medicines holds particular importance as they can provide valuable insights into the presence or absence of specific abnormalities. A study by Felin et al. (2016) revealed that pigs treated with VMPs within three months prior to slaughter had a lower incidence of condemned livers. Similarly, Alban et al. (2013) observed that an increased

pneumonia vaccines use correlated with a decrease in the prevalence of chronic pneumonia. These findings emphasise the potential benefits of considering treatment data, including information on VMP usage, indications and types, when evaluating animal health and aiming to enhance meat inspection outcomes.

3.2.6. Reports from previous AM and PM inspections

A total of 63% of the respondents (59/93) had access to reports from previous AM inspections, while 61% (57/93) received PM findings from the same farm of origin within the FCI (Fig. 1). These data are of importance due to the profound implications they hold. When examining previous AM findings, respondents were able to access a wide range of data concerning animals from the same holding, including clinical signs of disease (86%, 51/59), visible lesions caused by injury (83%, 49/59), dead-on-arrival rate (81%, 48/59) and animal welfare problems (3%, 2/59). Similarly, for previous PM findings, the respondents had access to diverse data regarding animals from the same holding, including total condemnation (82%, 47/57), partial condemnation (72%, 41/57), organ lesions (58%, 33/57) such as milk spots, abscesses, tail necrosis, pleurisy and others, low carcass quality (42%, 24/57) and disease implying lesions (42%, 24/57) such as mycobacteria-like lesions, erysipelas lesions, hydatid cysts and others. The study by Felin et al. (2016) revealed several statistically significant correlations between the meat inspection results of previously slaughtered pigs and the findings of the current batch, including partial and organ condemnations from the same holding. That study (Felin et al., 2016) demonstrated that the meat inspection results of the current batch can be effectively predicted by considering the previous meat inspection results of pigs from the same holding. To enhance the FCI system, Felin et al. (2016) proposed a simple scoring system for incoming slaughter batches, suggesting that implementing this scoring system could lead to improvements in the FCI system, potentially at EU level. Notably, the study concluded with the recognition that the scoring system's effectiveness could be enhanced once the FCI data were reliable and uniform. The challenge of making the FCI system valuable and reliable, however, continues to this day (Antunović et al., 2021; Bonardi et al., 2021; Buncic et al., 2019; Gomes-Neves et al., 2018; Ranucci et al., 2021).

3.2.7. Pregnancy-related data

Our investigation into the access to pregnancy-related data aimed to explore its relevance to animal welfare and its potential impact on meat inspection outcomes. EFSA's opinion on animal welfare considerations related to the slaughter or killing of pregnant livestock animals emphasises the need to ascertain the pregnancy status of animals to avoid

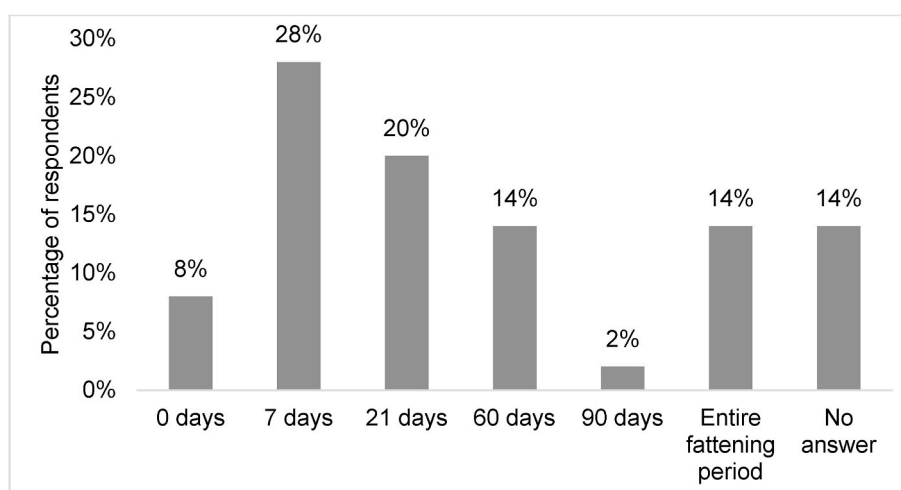


Fig. 2. Proposed time frame for obligatory documentation of the relevant period before slaughter for veterinary medicinal products with a withdrawal period (n = 93).

their slaughter during the last third of gestation (EFSA Panel on Animal Health and Animal Welfare, 2017). Additionally, EFSA recommends the inclusion of information about insemination and pregnancy diagnosis in the documentation accompanying animals at the time. The results from our study revealed a significant association between pregnancy-related data and the assessment of FCI's usefulness (Table 2), indicating its importance in the evaluation process. Access to this information allows data recipients to understand the reasons for sending a sow to slaughter, enabling a more targeted and detailed assessment. A majority of the respondents 82% (9/11) reported to have access to specific pregnancy-related data such as information on the insemination date, providing valuable insights into the reproductive history of the sows. Additionally, 55% (6/11) reported to have access to ultrasound results and 36% (4/11) to have access to palpation findings, providing additional information obtained through physical examination. Although the direct impact of pregnancy data on meat safety may be limited, the inclusion of such information in the FCI holds significance in comprehensively understanding animal health and animal welfare aspects. This, in turn, aids OVs and FBOs in determining appropriate inspection procedures and ensuring the overall well-being of the animals throughout the entire slaughter process. The correlation between pregnancy-related data and the perception of the FCI as useful highlights its relevance in enhancing the effectiveness of the system. However, it is important to acknowledge that the calculation is based on a small sample size of only 11 out of 93 respondents, which diminishes the reliability of this assessment's significance.

3.2.8. Data on cleanliness

Almost half of the respondents (45%, 42/93) reported to have access to data on the cleanliness of incoming pigs for slaughter (Fig. 1). This information serves as an indicator for both animal health and welfare as well as food hygiene and safety. Pigs that arrive at the abattoir in a soiled condition present a potential risk of cross-contamination to other pigs and the produced meat as well as to the abattoir staff and equipment. Only clean animals are permitted to be received at the abattoir and it is the FBOs' responsibility to ensure the cleanliness of animals upon arrival (European Commission, 2004a; 2004b). OVs inspect and verify the cleanliness of animals as part of the AM inspection. If a batch of pigs is delivered in a dirty condition, additional measures such as logistic slaughter or cleaning of the slaughter line should be implemented to mitigate the risk of contamination. Furthermore, it is important to provide feedback on cleanliness data to the farms and, possibly, the responsible practitioners. Increased findings at PM inspection could be indicative of poor management practices and hygiene issues. Consequently, this information is valuable for farms to improve their management processes to enhance animal health and welfare.

3.2.9. Data on additional information

Of all the respondents, 29% (27/93) requested additional information beyond the legally required FCI. These supplementary information covered various aspects, including the official farm number (93%, 25/27), farm location (63%, 17/27), production system (conventional vs. organic; 44%, 12/27), husbandry system (indoor vs. outdoor; 44%, 12/27), herd size (41%, 11/27), quality assurance system (37%, 10/27) and information on heat treatment of the feed (11%, 3/27). Additionally, one respondent mentioned specific information regarding immunocastration, which underscores the growing focus on this topic due to evolving national legislations. Otherwise, details related to immunocastration would typically be included within the treatment and vaccination data. Incorporating information related to the production and husbandry systems can provide valuable insights into the presence of diseases, especially in outdoor and organic farms where the risk of hazards such as *Trichinella* is higher (Gamble, 2022). By considering these factors, stakeholders involved in meat inspection can gain a more comprehensive understanding of the potential risks associated with specific production and husbandry practices. This knowledge helps in

the implementation of appropriate inspection procedures and the adoption of preventive measures to ensure food safety, as it is understood in the framework of RB-MSAS (Buncic et al., 2019; Ferri et al., 2023). Moreover, knowledge about the production and husbandry systems aids FBOs to effectively organise slaughter operations. For instance, organic pigs need to be slaughtered separately from conventional pigs (European Commission, 2007) and transitioning from slaughtering of outdoor to indoor reared pigs requires intermediate cleaning.

3.3. Transmission procedure

To evaluate the transmission procedure of FCI, we surveyed the respondents regarding their access to FCI and their perception of its practicality. Out of the total respondents, 57% (53/93) received FCI in paper-based format, 14% (13/93) had electronic access and 28% (26/93) had both paper-based and electronic access. One respondent did not provide a response. Regarding the practicality of FCI transmission, 68% of the respondents (63/93) assessed it as practical, while 32% (30/93) did not. In the statistical analysis, we identified a significant correlation between the abattoir size and the transmission procedure (Table 2). Small-sized abattoirs received significantly less paper-based FCI and significantly more electronic FCI. Interestingly, medium-sized abattoirs received FCI significantly less frequently via electronic transmission. Despite the assumption that the transmission procedure is heavily influenced by the degree of integration within each country's supply system, considering unique geographical and structural factors that shape abattoir size classifications as well, the observed trend remains surprising. This is particularly notable since larger abattoirs typically exhibit higher integration levels, implying a greater inclination to adopt digital methods. In terms of the assessment of the transmission procedure, a significant correlation was found with paper-based transmission (Table 2). The paper-based transmission was considered less practical. Conversely, the electronic or combined transmission method would be preferred. Similar findings were already observed in a previous study focusing on broilers (Langforth et al., 2023). However, the use of an electronic database rather than just electronic transmission as proposed by Jacobs et al. (2023) and Windhaus et al. (2007) and the feasibility of an electronic database highlighted by Laukkanen-Ninios et al. (2020), Li et al. (2024) and Ranucci et al. (2021) would further enhance the transmission process, ensuring the transfer of all necessary data and enabling risk managers to extract essential information.

3.4. Consequences of FCI

The respondents were asked about the potential consequences and actions they would take based on the information transmitted via FCI as well as their preferences for additional data to be included in the FCI, which could be a measure of the usefulness or relevance of the information. Fig. 3 displays the measures and outcomes reported by the respondents upon receiving specific data through FCI. Among the various data categories, PM and AM findings, treatment and mortality data, information from private veterinarians and clean livestock policy were identified as the most influential factors leading to substantial measures with notable time and resource implications. These measures included reducing the line speed and intensifying meat inspection necessitating the involvement of additional personnel (indicated in red). Ensuring the effective transmission of these data through FCI is essential. Regarding PM findings, respondents reported implementing various subsequent measures, such as intensifying meat inspection through conducting supplementary tests (46/93), raising awareness (42/93) and intensifying meat inspection through the allocation of additional personnel (35/93). When it came to knowledge about treatment data, the most employed measure among the respondents was residue testing (57/93). In contrast, respondents showed limited actions in response to information related to the production system, quality assurance system,

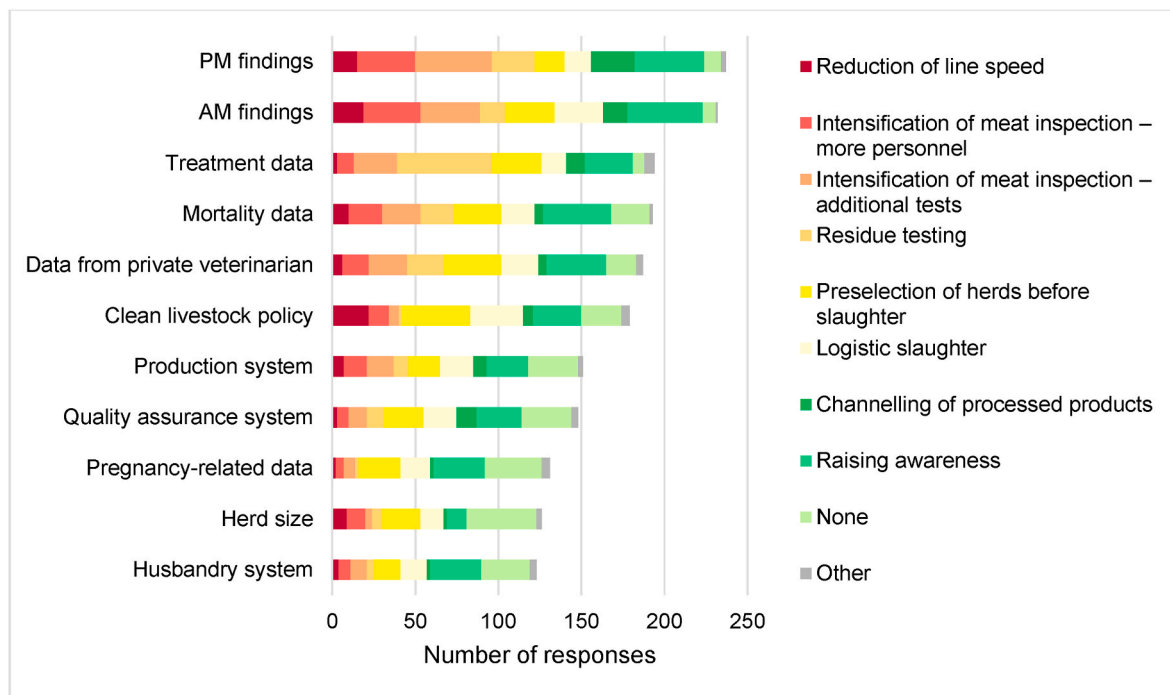


Fig. 3. Consequent measures at abattoir-level in response to specific information transmitted via FCI ($n = 93$, multiple answers possible), ranked by their impact on the slaughter process, ranging from dark red (high impact in terms of time and effort) to green (low impact in terms of time and effort).

pregnancy-related data, herd size and husbandry system. These factors were selected the least overall and were associated with minimal consequences (indicated in light green). This observation aligns with previous findings in broiler production (Langforth et al., 2023). Besides pregnancy-related data, especially general and production data were mentioned. These data contain important information for organisational purposes but are mostly, with exception of production and husbandry systems, of little relevance for risk categorisation, which is the actual intention of having FCI in the framework of RB-MSAS (Blagojevic et al., 2021; Buncic et al., 2019; Ferri et al., 2023).

3.5. Feedback of information to farmers

Effective feedback of information to farmers is a crucial aspect of FCI and the RB-MSAS as a whole (Ferri et al., 2023). It enables farmers to receive valuable insights and data related to their operations, allowing them to make informed decisions and take appropriate actions. Per Regulation (EU) 2019/627, the OV is tasked with providing feedback on relevant information from meat inspection to both the FBOs at abattoir and farm as well as to the private veterinarian responsible for the farm (European Commission, 2019). In practice, the transmission usually takes place within the abattoir's internal processes, while the information relayed to the farm is often facilitated by the abattoir operator along with other accounting documents. In our study, we found that 15% of the respondents (14/93) reported providing no feedback on specific information to the farmers. This indicates a potential gap in the communication process between the abattoirs and farms, highlighting the need for improved feedback mechanisms. Among the respondents, 56% (52/93) mentioned providing feedback on AM findings. This feedback can offer farmers important information about the health condition of the animals before slaughter, enabling them to address any potential issues and improve animal welfare (Ghidini et al., 2021). The majority of the respondents (82%, 76/93) reported providing feedback on PM findings. This feedback is particularly valuable as it provides farmers with insights into the health, conditions and any abnormalities found during the slaughter process (Vecerek et al., 2020). In addition to health-related feedback, four respondents (4%) mentioned providing

feedback on animal welfare-related matters, indicating the importance of monitoring and addressing animal welfare concerns as well. Furthermore, two respondents (2%) mentioned providing feedback on cleanliness. Farmers bear an undeniable responsibility for maintaining good animal health and welfare, which includes ensuring the proper cleanliness of their animals (European Commission, 1998). However, the reality can diverge from this ideal and, as discovered by Kosola et al. (2022), minor non-compliances that may not immediately jeopardise food safety can escalate into more severe breaches over time. To effectively convey the significance of compliance with food safety standards to FBOs, including those involved in primary production, official controls have proven to be impactful (Kettunen et al., 2017; Nevas et al., 2013). Official controls should not solely be perceived as a punitive one-way process; instead, they can serve as a platform for delivering effective feedback. Efforts should be made to improve the feedback process and ensure that farmers receive comprehensive and timely information related to their operations. This can contribute to the continuous improvement of farming practices, better animal welfare and ultimately enhance the overall quality and safety of the meat production process (Blagojevic et al., 2021). Without an effective feedback process, the purpose of FCI let alone the risk-based approach of meat inspection is ineffectual.

3.6. Overall discussion and suggestions for improvement

FCI is pivotal in facilitating decision-making processes related to food safety. Our survey findings show that 60% of the respondents considered FCI to be a valuable tool for decision-making regarding food safety. This recognition underscores its potential in supporting informed decision-making processes. However, it is noteworthy that 40% of the respondents expressed dissatisfaction, indicating room for improvement in the current FCI system. Respondents highlighted limitations in the current FCI system, emphasising the need for additional valuable information on VMPs beyond administered treatments and compliance with withdrawal periods. Addressing these limitations is necessary to enhance the effectiveness of the FCI system and ensure its value in supporting risk-based decision-making processes. Previous research has

also echoed these concerns, describing FCI as underdeveloped and underutilised (Buncic et al., 2019), lacking specified requirements for analysis and utilisation (Blagojevic et al., 2021) and questioning the quality of FCI data and continued reliance on traditional inspection methods (Laukkanen-Ninios et al., 2020). Furthermore, the inadequacy of available FCI for pig inspection highlights the need for useful and comprehensive information to enable effective risk-based decisions (Antunović et al., 2021; Felin et al., 2016; Gomes-Neves et al., 2018; O'Sullivan et al., 2015; Pattono et al., 2014; Ranucci et al., 2021).

To improve the FCI system, respondents provided several recommendations. These primarily revolved around improving mortality data by including the detailed causes of death, enhancing husbandry system specifics, providing more comprehensive treatment data, including indications and refining PM findings. It is also essential to address the current flaws in the transmission of specific FCI data. Research has shown that pig slaughter batches with nothing to declare in the FCI had statistically higher condemnation rates of livers (Felin et al., 2016), contradicting the purpose of FCI and risk-based decision-making. The current accuracy of FCI is insufficient and farmers require clearer guidance and standardised reporting procedures. Farmers often provide inaccurate information in FCI (Felin et al., 2016; Gomes-Neves et al., 2018), possibly due to a lack of understanding of its purpose. Another study has highlighted the difficulties faced by stakeholders in receiving accurate FCI (Luukkanen et al., 2015), which aligns with our own results. In order to obtain adequate data, education and training, along with additional guidance on the required information, are necessary. Adequate training for FBOs, including farmers, OVAs and competent authorities is important to achieving these improvements (Blagojevic et al., 2021; Ferri et al., 2023; Gomes-Neves et al., 2018; Ranucci et al., 2021). The feedback process also requires advancement, establishing a seamless system of upstream (farm-to-abattoir) and downstream (abattoir-to-farm) exchange of information (Salines et al., 2023). In the framework of the RB-MSAS, the FCI system should be flexible to accommodate improvements, ensuring that the feedback process serves as an opportunity for enhancement rather than a punitive measure. To enhance the FCI system, it is crucial to include monitoring and surveillance of the defined high-priority hazards and HEIs for pigs (EFSA, 2011; EFSA Panel on Biological Hazards, 2011). A comprehensive system that utilises data from FCI and HEIs to identify risks and propose subsequent measures is essential for the full implementation of RB-MSAS (Blagojevic et al., 2021; Buncic et al., 2019; Ferri et al., 2023).

4. Conclusion

FCI is a key component of EFSA's risk categorisation model and the RB-MSAS. However, there are limitations within the FCI system for pigs that need to be addressed to enhance its effectiveness. Currently, the implementation of FCI in Europe for pigs falls short of expectations, with 45% of respondents lacking legally required data and 40% finding FCI of little or no help in food safety decision-making. Notably, there were no significant differences observed between OVAs and FBOs regarding the receipt of FCI. However, when assessing the usefulness of FCI, a significantly lower proportion of OVAs found it helpful compared to FBOs. Moreover, our study revealed a significant correlation between respondents' assessment of FCI's usefulness and their access to data on animal health status and to additional information in the case of abnormalities. The study identified research gaps in establishing critical thresholds for the mortality rate and determining the relevant period for obligatory documentation of VMPs. Closing these research gaps is vital to help accurately assess animal health status in a more objective and standardised manner. Additionally, comprehensive research efforts are needed to fully understand the relationship between VMP usage and the occurrence of pathological findings. To enhance the effectiveness of the FCI system and improve the management of animal health and food safety in Europe, various improvements are necessary. Comprehensive legislation mandating the harmonised transmission of FCI data is

essential for ensuring meaningful and reliable information exchange. Technical implementations enabling easy bidirectional, electronic exchange of FCI data between farmers, FBOs and OVAs, along with access to a shared database, are essential. Close collaboration between operators and decision-makers is vital for accurately interpreting and applying FCI. Adequate training for stakeholders is necessary to maximise the benefits of FCI by ensuring a clear understanding of its meaning and application. Additionally, the development of abattoir-specific strategies is recommended to implement targeted subsequent measures based on the information received through the FCI. Lastly, HEIs for the main foodborne biological hazards associated with pigs and pork should be integrated into FCI. By addressing these recommendations, we can enhance the effectiveness of the FCI system, improve decision-making processes and ultimately strengthen our ability to manage animal health and ensure food safety effectively.

CRedit authorship contribution statement

Ting-Ting Li: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Susann Langforth:** Investigation, Writing – review & editing. **Rudi Isbrandt:** Investigation. **Nina Langkabel:** Investigation, Writing – review & editing. **Smaragda Sotiraki:** Conceptualization, Methodology. **Sofia Anastasiadou:** Methodology, Writing – review & editing. **Truls Nesbakken:** Conceptualization, Methodology, Writing – review & editing. **Diana Meemken:** Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

All authors declare that they do not have any conflict of competing interest.

Data availability

The data that has been used is confidential.

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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.2023.110174>.

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