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Risk categorisation of abattoirs in Europe: Current state of play

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ABSTRACT

In the last decades, a risk-based approach has been identified as a step forward in modernising meat safety system in Europe. Risk categorisation of abattoirs based on their process hygiene and the appropriate use of harmonised epidemiological indicators (HEIs) has been suggested as one essential component of the risk-based meat safety assurance system. However, to date, only a limited number of papers have investigated abattoir risk categorisation. Therefore, the objectives of this study were to (i) provide an overview of the use of risk categorisation systems in poultry, pig, cattle and small ruminant abattoirs in Europe and (ii) explore the criteria, relevance and applicability of risk categorisation systems for competent authorities (CAs). To that aim, a questionnaire was designed and sent to representatives of 35 European CAs. Of the 18/35 respondents (51%), 14 (78%) indicated that abattoirs in their country are categorised according to their food safety risk in a systematic way, whilst four countries (22%) do not categorise abattoirs according to their food safety risk. The main reported purpose of categorising abattoirs is to adapt the frequency of official controls. Major differences in the described categorisation systems were found between countries, particularly in their complexity and the criteria used. The number of included criteria ranged from 1 to 10, the main ones being the outcomes of the CA's official audits (78% of the 14 countries), the size of abattoirs (64%), the relevance and credibility of HACCP plans (57%) and export agreements of abattoirs (43%). Less than a third of the surveyed countries indicated they utilise results of microbiological testing as a basis for risk categorisation of abattoirs, and no country has formally included HEIs in its risk categorisation system. The effectiveness of the implemented risk categorisation systems was assessed in five countries only (36%), but with the use of unclear methodology and assessment criteria. More than 80% of respondents expressed their wish to be provided with a practical method for categorising abattoirs according to their pertained food safety risks. In conclusion, the results of this study demonstrate the need to develop a fit-for-purpose and science-based framework for risk categorisation of abattoirs in Europe.

1. Introduction

The protection of public health has always been the uppermost priority of meat inspection, but the contribution of the traditional meat inspection system to food safety has been questioned in recent decades. Indeed, the relevant biological hazards – either by incidence or disease severity – causing the top-four most commonly reported meat borne human diseases in the European Union (EU), namely *Campylobacter* spp., *Salmonella enterica*, Shiga toxin-producing *Escherichia coli* (STEC) and *Yersinia enterocolitica*, are 'invisible' hazards present in the intestinal

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tract and/or on the hide/skin of healthy slaughter animals. These hazards are undetectable by traditional ante- and post-mortem inspection because they do not lead to macroscopic abnormalities and/or gross lesions (EFSA/ECDC, 2021a & 2021b; Blagojevic & Antic, 2014). Therefore, meat safety depends to a great degree on the initial bacterial load of the incoming animals for slaughter and/or the prevention and reduction of cross-contamination incidences during slaughter and carcass dressing (Blagojevic & Antic, 2014; Blagojevic et al., 2021; Buncic, 2014; Buncic et al., 2019). Over the last two decades, this has been addressed by specific EU legislative requirements for food business operators (FBOs), such as the implementation of good manufacturing and hygiene practice procedures (GMP/GHP, i.e., abattoir process hygiene) and hazard analysis and critical control point (HACCP) measures. These are complemented by indicative laboratory analyses of carcass contamination with respect to process hygiene criteria (PHC) and specific sampling schemes, i.e., own-check plans (Anon, 2004a, b; 2005). In addition, it is well recognised that the microbiological status of carcasses can differ widely between abattoirs due to differences in their infrastructure and degree of compliance with food safety requirements (Anon, 2004a; Buncic et al., 2019; Blagojevic et al., 2021).

In this context, calls have been triggered in the European scientific community for meat controls to be revised and more fit-for-purpose (Blagojevic et al., 2021). Ongoing developments and improvements in the traditional approach to meat safety have also been a focus of international organisations. In 2005, the Codex Alimentarius Commission issued the Code of Hygienic Practice for Meat (CAC, 2005) that recommended an integrated and risk-based approach to achieve meat safety. In 2009, the European Food Safety Authority (EFSA) received a mandate from the European Commission to assess the impact of revising the meat inspection system in the EU (EFSA, 2011a; 2012a; 2013a; 2013b). Apart from recommending hazard prioritisation and revealing the flaws and virtues of the traditional meat inspection system, EFSA proposed a generic framework for a new, risk-based meat safety assurance system (RB-MSAS) that incorporates official meat inspection with food safety management systems (FSMS) operated by FBOs (Blagojevic et al., 2021; Nastasijevic et al., 2020). Similarly, the Food and Agriculture Organisation (FAO) has recently issued technical guidance specifying principles and application of risk-based meat inspection (FAO, 2019) that should be part of the integrated approach to the food chain, including upstream (farm-to-abattoir) and downstream (abattoir-to--farm) exchange of information. In addition, the World Organisation for Animal Health (WOAH, founded as OIE) recommends that meat inspection protocols be risk-based and FSMS be developed in accordance with international standards and cover the major hazards of significance for both animal and public health (OIE, 2019).

A comprehensive and coordinated RB-MSAS should incorporate a range of preventive measures and relevant controls, both applied at the farm and abattoir levels in a longitudinally integrated approach (EFSA, 2013a). The main control strategies and tools assembled and utilised in such a RB-MSAS can be summarised as follows: (i) identification and traceability of both animals and meat; (ii) food chain information (FCI) including data on risk-reduction interventions at farm and abattoir levels; (iii) risk categorisation of farms and abattoirs and combination of both risk categorisation systems, based on farm's/abattoir's characteristics, performances and the monitoring of appropriate harmonised epidemiological indicators (HEIs) that can be addressed within MSAS (Supplementary File 1), an epidemiological indicator being defined as the prevalence or incidence of the hazard at a certain stage of the food chain or an indirect measure of the hazard that correlates to the human health risk caused by the hazard (EFSA, 2011b; 2012b; 2013c; 2013d); (iv) GMP/GHP- or HACCP-based measures applied at individual points during abattoir operations and; (v) meat inspection *per se* (Buncic, 2014).

Although these concepts were introduced by EFSA more than ten years ago, risk categorisation of abattoirs and the role of all relevant components necessary for it have not been researched widely and developed further. A targeted database search from 2012 onwards identified only four relevant published studies investigating abattoir risk categorisation (Alvseike et al., 2019; Cegar et al., 2022; Hauge et al., 2023; Nastasijevic et al., 2016). Abattoir process hygiene assessment in cattle and pig (Nastasijevic et al., 2016) and cattle and sheep abattoirs (Alvseike et al., 2019) was carried out with the aim to risk-categorise the investigated abattoirs using a two-fold approach: (i) auditing based on the scoring systems used in the UK (hygiene assessment system, HAS), in Australia (meat hygiene assessment, MHA) and Norway (hygiene performance rating, HPR) and (ii) results of PHC testing. Nastasijevic et al. (2016) found the abattoirs that were assessed as having better hygiene levels according to HAS and MHA audits also reported lower levels of PHC indicator organisms [aerobic colony count (ACC) and Enterobacteriaceae count (EBC)]. Similarly, Alvseike et al. (2019) found that HPR findings were supported by microbiological results and exhibited a linear relationship, i.e., for each percentage of poorer HPR-score, EBC and generic *E. coli* (ECC) contamination of carcasses increased by 0.1 log CFU/cm^2. Furthermore, Cegar et al. (2022) investigated the usefulness of testing for pathogens (*Campylobacter* count and *Salmonella* presence, current PHC) and indicator microorganisms (ACC and EBC in red meat abattoirs, and ECC in poultry abattoirs) in abattoir risk categorisation. The findings from two large-scale and two small-scale poultry abattoirs, which had different technological characteristics, showed conflicting results when the abattoirs were risk-categorised based on test results for either current PHC (pathogens) or the suggested indicator microorganisms (ACC, EBC, ECC). Following the same approach to categorise two poultry abattoirs based on compliance with the legislative limits set for PHC and for indicator bacteria, Hauge et al. (2023) categorised both investigated poultry abattoirs in their study as low-risk. Therefore, the results from these four studies confirm that a multifactorial approach to abattoir risk categorisation is needed, rather than one that is based on risk categorisation components used separately. However, none of these studies proposed a holistic and practical framework to categorise abattoirs.

Given the limited available information in this area, the aim of this study was to contribute to the development of risk categorisation of abattoirs in Europe and discuss a science-based approach for this risk categorisation by: (i) providing an overview of the use of risk categorisation systems in abattoirs and; (ii) discussing the criteria, relevance and applicability of risk categorisation systems for competent authorities (CAs).

2. Materials and methods

2.1. Survey design

A questionnaire was developed to: (i) investigate the extent of the use of risk categorisation systems for abattoirs in Europe (or proposals for their development, if no such system has been implemented) and; (ii) explore the relevance and the applicability of risk categorisation approaches by CAs. The survey concerned poultry, pig, cattle and small ruminant abattoirs. The target respondents were CAs in European countries (one representative per CA).

The questionnaire was composed of 36 questions and the estimated time to fill in the form was 20 min (see Supplementary File 2). A short introduction explained the context of the survey and defined the risk as a function of the probability of an adverse health effect on the consumer and the severity of that effect, consequential to the presence of a hazard in meat. Most of the questions were formulated as closed questions in order to increase the comparability of the respondents' answers. The first section aimed to collect general information and to determine whether abattoirs were, or intended to be, categorised according to their food safety risk in a systematic way, i.e., using a method that includes data collection, processing, storage, and that involves respective actions by the CAs. Depending on their answers, respondents were directed to different sections. The second section was specifically dedicated to those

countries in which abattoirs are already categorised according to the risk they pose for meat consumers. The risk categorisation system and its purpose were addressed in this section. Similar questions were included in the third section which was dedicated to countries that do not have implemented abattoir risk categorisation systems, but plan to develop them in the future. Finally, the last parts of the questionnaire were designed to collect information about data availability for CAs at central level and the need for methodological developments. A single final question was open-ended to allow respondents to express their comments, questions and/or concerns. Respondents were also encouraged to provide detailed material about the system they use for risk categorisation of abattoirs.

2.2. Data collection and analysis

The questionnaire was developed as an online survey using Google Forms software (https://docs.google.com/forms). The survey was e-mailed to the network of National Contact Points from the RIBMINS COST Action,[1] representing 35 European countries. Data were collected between 28th April and June 5, 2022.

Respondents' answers were quantitatively analysed depending on the type of animal species and whether the country had implemented risk categorisation of abattoirs or not. When they were provided, the systems used for risk categorisation are described below.

3. Results

3.1. Study sample

The questionnaire was completed by 18 out of 35 representatives of the CAs that originally received it, resulting in a response rate of 51%. The responding countries were Albania, Belgium, Bosnia and Herzegovina, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Norway, Poland, Portugal, Serbia, Spain, Switzerland and the United Kingdom.

3.2. Level of implementation of abattoir risk categorisation

Of the 18 respondents, 14 (78%) indicated that abattoirs in their country are categorised according to their food safety risk in a systematic way, i.e., using a method that includes data collection, processing, storage and that involves respective actions by the CA. In these 14 countries, abattoirs processing cattle, poultry, pigs and small ruminants are included in a specific risk categorisation system. In addition, three countries indicated that abattoirs slaughtering farmed game, solipeds, ratites and lagomorphs are also among those categorised based on risk. Among these 14 countries, the risk categorisation system is applied countrywide in 11, whereas in the other three, the method varies depending on the province/region. Moreover, in one country, the application of the risk categorisation system is not mandatory for all provinces.

Of the four countries that do not categorise abattoirs according to the corresponding food safety risk, all respondents indicated willingness to implement risk categorisation in the future in their country. In two countries, the risk categorisation system is expected to initially include only poultry abattoirs, in one country all species are expected to be covered by the upcoming risk categorisation system, and in one country the project to develop a risk categorisation system for abattoirs is not yet concrete due to the lack of expertise in this area.

3.3. Criteria considered for risk categorisation of abattoirs

Results show that in countries where risk categorisation of abattoirs is already implemented, the number of criteria included in risk categorisation systems ranges from 1 to 10 (median: 3.5) (Fig. 1 and Supplementary File 3). In these countries, the main criteria considered for the categorisation system are the outcomes of the official audits performed by the CAs (78% of the 14 countries, all species considered), the size of the abattoirs, i.e., their production figures (64%), the relevance and the credibility of the HACCP plan including monitoring and control procedures (57%), the export agreements of the abattoirs (43%), the history of food safety alerts and product withdrawals (36%) and the results of microbiological testing performed either by the FBOs or by the CAs (29% and 36%, respectively). Testing covers ACC (for pigs, cattle and small ruminants), EBC (for pigs, cattle and small ruminants), *Campylobacter* enumeration (for poultry), *Salmonella* detection (all species) and *Trichinella* detection (for pigs, farmed game and solipeds – when applicable). The following criteria were also cited by respondents as aspects to be considered in the abattoir categorisation system: (i) whether the abattoir is combined with a meat processing plant serving at-risk consumers; (ii) the type of products being marketed; (iii) the number of employees working in the abattoir; (iv) compliance with animal welfare regulations; (v) potential deficiencies in the documentation related to the registration and/or authorisation of the establishment and; (vi) willingness of the company to collaborate with the CAs' employees performing the official controls. All 14 countries reported the absence of combining farm and abattoir risk categorisation systems, either because farms are not categorised, or due to the complexity of linking farm- and abattoir-level risks.

In the four countries where risk categorisation of abattoirs is planned to be implemented, the number of criteria that would be included in future risk categorisation systems ranged from 10 to 17 (median: 14). In particular, the main criteria considered for the future categorisation system are: the production figures of the abattoirs; the outcomes of audits from official controls; the results of microbiological testing performed either by the FBOs or by the CAs; the consistency between the results of FBO and CA microbiological testing; the outcomes of internal audits or third-party audits for the voluntary implementation of international FSMS schemes; the relevance and credibility of the HACCP plan; the history of food safety alerts and product withdrawals; the staff turnover and/or training level; the degree of confidence in FBO professionalism; and the export agreements. The respondent from one country also mentioned the abattoir and chilling room storage capacity, usage of facility capacity and qualification of employees as three aspects to be considered in the categorisation system. Regarding microbiological and parasitological testing, ACC, EBC, *Campylobacter*, *Salmonella*, and *Trichinella spiralis* were indicated as important as in countries where risk categorisation is already in place. Generic *Escherichia coli*, ESBL *Escherichia coli*, STEC, *Yersinia enterocolitica*, *Toxoplasma gondii*, *Taenia saginata* cysticercus and *Mycobacterium bovis* were additionally indicated as criteria of importance. Carcass dressing and animal selection methods were cited as important criteria for abattoir risk categorisation only in countries where such categorisation is not currently implemented. To that end, some proposed criteria were animal cleanliness scoring (poultry, cattle and small ruminant abattoirs), pre-slaughter cleaning (poultry, cattle and small ruminant abattoirs), skinning/dehiding/defeathering methods (cattle, small ruminant and poultry abattoirs), scalding and singeing methods (pig abattoirs), evisceration methods (all abattoirs), carcass splitting methods (pig, cattle, small ruminant abattoirs), removal of the head (cattle, small ruminant and poultry abattoirs), removal of the lymph nodes (cattle abattoirs), removal of specified risk materials (SRM) (cattle and small ruminant abattoirs), decontamination of carcasses (pig and cattle abattoirs) and type of chilling (all abattoirs).

[1] The RIBMINS EU COST Action Network (CA18105) was established in 2019. The aim of RIBMINS ("Risk-based meat inspection and integrated food safety assurance") is to combine and strengthen Europe-wide research efforts to develop modern meat safety control systems for different animal species https://ribmins.com.

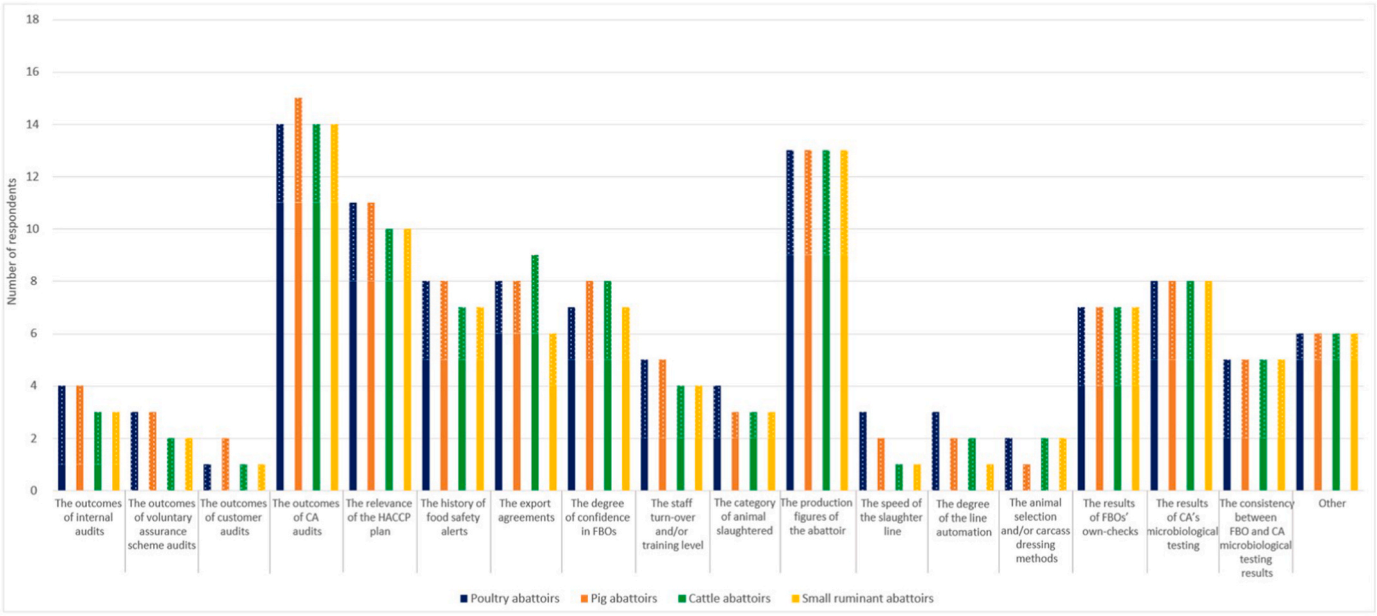

Fig. 1. Criteria included or likely to be included in risk categorisation of abattoirs
Plain areas correspond to countries in which risk categorisation of abattoirs is already implemented (n = 14). Dotted areas correspond to countries in which risk categorisation of abattoirs is planned to be developed (n = 4). FBO: Food Business Operator. CA: Competent Authority.

3.4. Examples of applied abattoir risk categorisation systems

Five respondents provided additional details regarding the way selected criteria are combined to form an abattoir risk categorisation system in their countries (Supplementary File 3).

Case 1. In country J, the method used for risk categorisation of approved food establishments, including abattoirs and cutting plants, comprises two criteria:

- the establishment size, based on the number of employees and the electricity consumption. The risk associated with establishment size (Rs) is assigned on a linear numeric scale of 1–4, with 1 being the lowest and 4 being the highest attributed risk.
- the meat production activity, with each such activity being classified in terms of the type of prepared foodstuff(s), type of processing and the degree of handling to which the foodstuff(s) are subjected. The risk associated with the meat production activity (Ra) is assigned on a linear numeric scale of 1–10, with 1 being the lowest and 10 being the highest attributed risk. The Ra assigned to ungulate abattoirs is 7 and the Ra assigned to poultry abattoirs is 4.

The two risk scores, Rs and Ra, are then added to produce the total risk score. If the sum ranges between 2 and 4, the total risk score (R) is 1; if Rs + Ra = 5 to 6, R = 2; if Rs + Ra = 7 to 8, R = 3; if Rs + Ra = 9 to10, R = 4; and if Rs + Ra = 11 to 14, R = 5. Considering this risk assignment method, the total risk attributed to ungulate abattoirs can range between 3 and 5, whereas the total risk attributed to poultry abattoirs can range between 2 and 3. The frequency of official controls (audits) is then based on the total risk and ranges from 12 to 24 months and from 24 to 30 months for ungulate and poultry abattoirs, respectively.

Case 2. The system in place in country C to risk-categorise abattoirs is rather simple, as the frequency of official controls depends primarily on the results of the previous controls, with all abattoirs being audited four times per year (baseline). This frequency, however, increases with elevated numbers of detected non-compliances as well as with the existence of export agreements. If no major non-compliances are detected during four successive audits, the baseline frequency of audits can be consecutively decreased, to three audits per year and then to two audits per year if compliance is again confirmed during the following year. This adaptation of the frequency of official controls thus resembles more a bonus-malus system than an actual risk categorisation approach.

Case 3. In country G, several score-weighted criteria are included to form a total risk score that is used to risk-categorise the abattoirs:

- size of establishment (i.e., number of employees), accounting for 5% of the total risk score;
- type of establishment (15%);
- type of processing (10%);
- results of checklists for compliance of the establishment (25%);
- results of checklists for compliance with regard to the HACCP system (25%);
- administrative measures over the past three years (10%);
- compliance with the recommendations provided by the CA over the past three years (10%).

Case 4. In country K, the method used for the risk categorisation of approved food establishments, including abattoirs and cutting plants, contains 9 criteria grouped into 3 risk indicators:

- the risk associated with the severity of the consequences (Rs), classified in terms of the establishment size and capacity, food type/category, type of processing, the degree of handling and the probable number of consumers at risk (local, national, international). This risk indicator can range from 0 to 120.
- the risk associated with the level of compliance with regulation (Rc), classified in terms of the food hygiene and safety procedures, covering the layout of the facility, internal organisation and food handling procedures as well as equipment, temperature control, lighting and ventilation. This risk indicator can range from 0 to 130.
- the risk associated with confidence in management and control procedures (Rm) and their focus on the effective control of the identified hazards. This risk indicator can range from 0 to 30.

The three individual risk scores [Rs + Rc + Rm] are then summed and, according to the total risk score, the abattoir is categorised in one of the following risk levels: low-risk, 0–45 score; medium-risk, 46–100

score; and high-risk, 101–180 score. The frequency of official controls is based on the risk level and ranges from 6 to 24 months (low-risk – once in 24 months; medium-risk – once in 12 months; high-risk – once in 6 months or even more often).

Case 5. In country L, a risk categorisation system was introduced in 2021 for all food premises. For non-retail establishments, two types of criteria are considered, those deemed generic and associated with the type of establishment, and those that are specific risks associated with each establishment. The generic criteria are the type of food and its intended use, the establishment activity (e.g., manufacturing, packaging, storage), the target market (local or beyond local area) and the business size as determined by the number of staff (micro, medium or large, with less than 10 employees, 10–100 or more than 100, respectively). The establishment-specific criteria are registration and authorisation (i.e., whether there are shortcomings in the registration and/or authorisation documentation and whether the establishment carries out activities for which it is not authorised), the results of the previous official controls (inspection or audit) and compliance history/corrective actions taken for major non-compliances. Each of the above has subcriteria with their associated weightings, with low scores denoting little or no risk. Thus, for example, products of animal origin attain a score of 5, whilst for non-animal origin products the score is 0; non-ready-to-eat foods attain a score of 0, whilst ready-to-eat foods that allow the growth of Listeria monocytogenes attain a score of 20. Absence of non-compliances attains a score of 0, whilst major and critical non-compliances attain a score of 20 and 40, respectively. The total risk score is calculated by adding all the individual scores of the criteria, having considered all the activities carried out at the establishment. In practice, those activities that present the highest risk scores largely determine the abattoir's final risk categorisation, which in turn defines the minimum frequency of the official controls. Four categories of score-based risk are applicable as follows: 1 – high risk (score >150) requires official audits at least every 6 months; 2 – medium risk (score 101–150), requires official audits at least every 18 months; 3 – low risk (score 50–100), requires official audits every 36 months and; 4 – very low risk (<50), requires official audits every 60 months.

3.5. *Purpose for development and assessment of the effectiveness of risk categorisation of abattoirs*

The main purpose of categorising or planning to categorise abattoirs according to their pertained risks for public health was reported to be to adapt the frequency of official controls (93% of countries already categorising abattoirs and 100% of countries planning to categorise abattoirs) (Fig. 2). Secondary objectives are to adapt official control points (0% and 75%, respectively), to adapt slaughter methods and/or line speed (7% and 25%, respectively), to allow and/or facilitate export (29% and 25%, respectively), to adapt slaughter logistics (7% and 0%, respectively) and to inform consumers about the risk inherent to abattoirs (7 and 0%, respectively). In one country, risk categorisation is also used to adapt official control fees for FBOs.

Among the 14 countries that have adopted a system to risk-categorise the abattoirs, the effectiveness of such a risk-based system has been assessed in five (36%), with assessment results being reported by our survey respondents as satisfactory. The evaluations are conducted internally during audits, either by the staff performing the official controls at the abattoirs, the central CAs, third countries or the European Commission (DG SANTE).

3.6. *Data accessibility*

Data accessibility to CAs at central level varied depending on the criteria that were or could be included in the risk categorisation systems (Fig. 3). The data most commonly available to central CAs are the outcomes of official controls, indicated by 72% of respondents as available on a central computerised database and by 22% of respondents as available upon request to local authorities. Similarly, respondents reported the following data are easily available, either centrally or locally by food safety authorities: the history of food safety alerts and product withdrawals (56% on a central computerised database and 17% upon request to local authorities), export agreements (56% and 28%, respectively), the category of animal slaughtered (72% and 17%, respectively), the production figures of the abattoirs (67% and 22%, respectively) and the results of microbiological testing performed by the CA (61% and 33%, respectively). On the contrary, other data are not available to CAs or are only made available upon request to the FBOs. These are data related to the process itself, i.e., the speed of the slaughter line (not available in 28% of the responding countries, available upon request to FBOs in 33% of the responding countries), the degree of line automation (33% and 33%), the animal selection and carcass dressing methods (39% and 22%), or the outcomes of internal audits (50% and 33%), customer audits (61% and 22%) and third-party audits for the voluntary implementation of international FSMS schemes (50% and 33%).

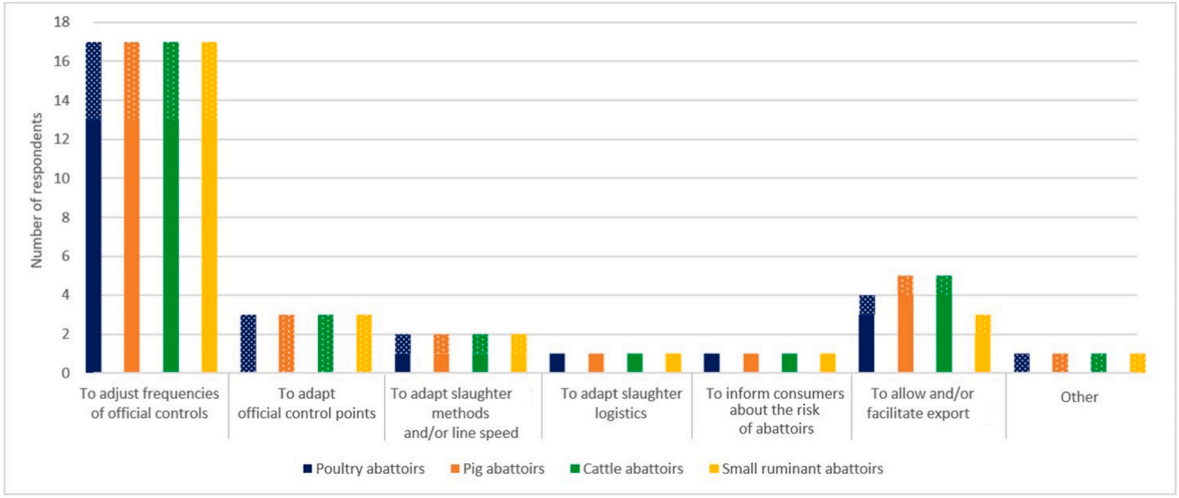

Fig. 2. Purposes of categorising or planning to categorise abattoirs according to their level of risk for public health
Plain areas correspond to countries in which risk categorisation of abattoirs is already implemented (n = 14). Dotted areas correspond to countries in which risk categorisation of abattoirs is planned to be developed (n = 4).

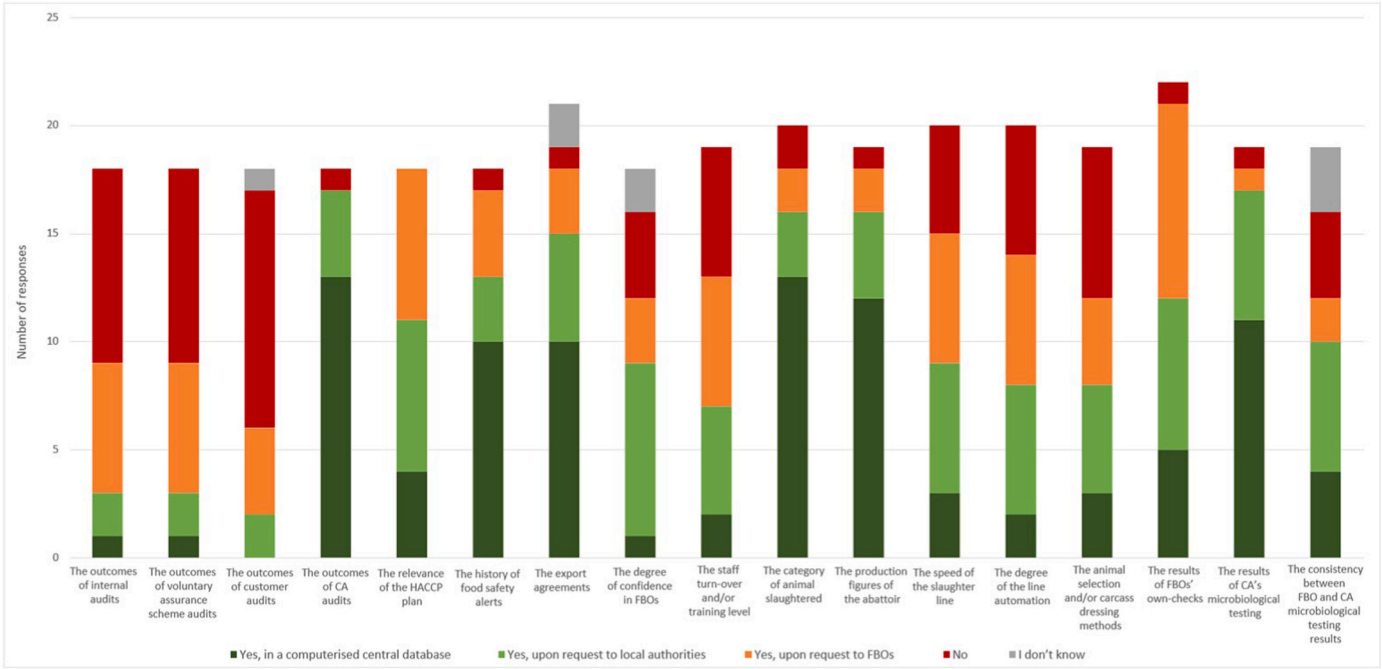

Fig. 3. Level of accessibility by the competent authority to criteria that could be included in risk categorisation of abattoirs.

3.7. Needs for methodological development of risk categorisation systems

Respondents from 15 countries (83%) expressed their wish to be provided with a practical method for categorising abattoirs according to pertained risks to public health. The majority preferred this approach to be flexible enough in order to adapt it to their own context (67% of the 15 countries) and/or to be common to all European countries (60%). Only two respondents (13%) mentioned they would like the system to be directly applicable in their country. Respondents from four countries (27%) would like the system to incorporate as few criteria as possible, whereas the representative from another country (7%) reported that as many criteria as possible should be included in the future system.

Finally, six respondents mentioned that risk categorisation is also used in fields other than food safety in their country. Five of them reported that abattoirs are categorised according to the risk they pose to animal welfare, while one stated that abattoirs are categorised according to the risk they pose regarding animal by-product regulations, environmental aspects, animal health and international trade.

4. Discussion

A risk-based approach has been identified as a step forward in modernising meat inspection in the European Union (Blagojevic et al., 2021). Risk categorisation of abattoirs based on their process hygiene and HEIs has been suggested as one of the essential components of the RB-MSAS (EFSA, 2011a; 2012a; 2013a; 2013b). Given the lack of published knowledge in this area and, overall, the unclear picture of the implementation of risk categorisation of abattoirs in European countries, this study attempted to investigate the current situation using a survey-based approach.

The questionnaire was distributed through a large professional network to European CAs, resulting in a very good response rate of approximately 51%, which was even more valuable considering that the responses came from various geographical areas in Europe. The closed questions allowed for comparability of responses and reliable data analysis, but the drawback was the risk of not gathering detailed information. Since published data on the risk categorisation of abattoirs are limited, the questionnaire-based survey in this study focused primarily on the general outline of risk categorisation approaches in different European countries instead of targeting detailed differences among them. The open-ended final question allowed respondents to elaborate on their responses and provide more detailed material regarding the method used for the risk categorisation of abattoirs in their respective country.

This study identified that among the countries that responded to the survey, the majority have already implemented some form of abattoir risk categorisation, and those that have not intend to do so. Among the respondents, adapting the frequency of official controls performed by the CA is the main driver for the risk categorisation of abattoirs. Risk categorisation of abattoirs can enable the detection of premises requiring more stringent auditing practice(s) and technology improvements. Consequently, such a system would be complementary to the traditional meat inspection procedures and would increase the cost-efficiency of official controls to safeguard public health (Blagojevic et al., 2021; EFSA, 2011a; Nastasijevic et al., 2020). This approach is also consistent with the requirements of European regulations according to which "competent authorities shall perform official controls on all operators regularly, on a risk basis and with appropriate frequency" (regulation (EU) No. 2017/625, art. 9) (Anon, 2017) and "the nature and frequency of auditing tasks in respect of individual establishments shall depend on the assessed risk" (regulation (EU) No 2019/627, art. 4) (Anon, 2019).

However, the results of the survey indicate that the way in which abattoir risk categorisation is conducted differs widely, both in terms of the type and number of criteria considered to determine the risk level and in the resulting frequency at which the controls are to be delivered. Since the current main reason for using abattoir risk categorisation is to determine the frequency of official controls, it is probably not surprising that most countries use, as one of their key criteria, the results of the previous official controls and/or the interventions (corrective actions) applied at the abattoirs in cases of non-compliances. These provide objective evidence, although this is dependent on the level of competence of the person(s) who carried out those controls; therefore, assurance systems that determine whether such controls are indeed effective are required in this context.

The production volume is also used by many countries to determine

the risk pertained to the abattoir. This is also not unexpected, since the larger the throughput of chilled meat, the greater the level of consumer exposure to associated risks of foodborne hazards if the FBO is not applying their FSMS effectively. However, this larger throughput is also usually associated with abattoirs that supply major retail chains and/or export their produced meat to other countries. These abattoirs, therefore, are likely to be subjected to a high level of scrutiny from their customers through private standards (second-party audits performed directly by retailers or third-party audits performed by certification bodies), in addition to the official controls performed by the CA (third-party audits). Usually, the adherence to such private standards require high-level performance of FSMS. It is also likely that the larger abattoirs have quality assurance departments with a number of highly skilled people hired to ensure food safety and hygiene and can perform internal controls in a way that smaller abattoirs cannot afford. Thus, the effective application of HACCP-based FSMS, another key criterion used by most countries for the risk categorisation of abattoirs, can be influenced by the size of the abattoir (where higher production volume is associated with a higher compliance level). It is of note, nevertheless, that the size of the abattoir is not necessarily determined by the number of slaughtered animals, or not exclusively by this, but by other criteria, such as the number of staff employed or the amount of electric power consumed; data for both these criteria could be more easily available.

Only one third of the respondents also indicated that the results of microbiological testing performed either by the FBO or by the CA were utilised in determining the risk category of abattoirs. We speculate that the use of some microbiological testing data could be insufficient, considering that most foodborne outbreaks are associated with pathogenic bacteria. Apart from *Salmonella* detection (all species) and *Campylobacter* enumeration (poultry), no other foodborne pathogens were reported to be included as criteria for the risk categorisation of abattoirs, although they have been proposed by EFSA as HEIs to be monitored on carcasses (e.g., STEC in small ruminants). Indeed, there is a conspicuous absence of the development and use of HEIs to determine the abattoir risk level, even ten years after they were originally proposed by EFSA. This may be related to the fact that the use of HEIs in risk categorisation have not been incorporated into European legislation to date. More effort is needed in the future to use HEIs where of added value as one of the main components of RB-MSAS.

In addition, in some cases, the determined risk categories were somewhat surprising from a science-based perspective: for example, in some countries, poultry abattoirs are deemed low risk compared to red meat abattoirs, even though consumption of poultry meat and poultry products is more frequently associated with human food poisoning (Buncic et al., 2017). This is perhaps because it is anticipated that poultry meat will be fully cooked before consumption, whilst for red meat that may not always be the case. Nevertheless, a high number of foodborne outbreaks (e.g., campylobacteriosis) is often attributed to cross contamination in consumers' kitchen. In addition, despite high levels of automation, poultry abattoirs are usually associated with significantly higher levels of cross contamination of carcasses than red meat abattoirs are. This is due to the poultry abattoirs having high densities of birds in conveyor lines and to the type of technology applied, some of which causes splashes and aerosols, e.g., scalding, defeathering, evisceration practices and inside-out carcass washing.

Interestingly, GHP- and hazard-based interventions are not currently considered as criteria in the currently implemented systems for the risk categorisation of abattoirs, but in countries wishing to implement such categorisation in the future, they are important elements to be considered. In particular, carcass dressing and animal selection methods were cited as important criteria for future risk categorisation only by those countries not currently using abattoir risk categorisation; the proposed examples were animal cleanliness scoring, skinning/dehiding/defeathering methods, evisceration and carcass splitting methods. However, such GMP- and GHP-based procedures are considered in all cases as prerequisites to hazard-based interventions, the proper implementation of the HACCP plan and the overall FSMS efficiency in addressing food safety risks. For example, a range of GHP- and hazard-based skin and carcass interventions in cattle and pig abattoirs, which primarily aim at microbe removal, immobilisation or elimination, were previously reported to provide demonstrable and quantifiable reductions in microbial loads of both bacterial pathogens and indicators (Antic et al., 2021; Zdolec et al., 2022).

All respondents reported the absence of combining farm and abattoir risk categorisation systems, either because farms are not categorised or because of to the complexity of linking farm and abattoir risk levels. This is unfortunate, since RB-MSAS is supposed to be a holistic system comprising all control measures applied at pre-harvest and harvest phases of the meat chain that contribute to the performance objectives (prevalence or concentration of selected hazards or indicators) set for chilled carcasses (Blagojevic et al., 2021). In particular, to properly tailor to the given situations, comprehensive and systematically applied upstream (farm-to-abattoir) and downstream (abattoir-to-farm) exchange of FCI is a prerequisite for optimum meat safety-related decision making by the risk managers. For example, a low-risk animal batch (defined as such on the basis of predetermined HEIs) can be slaughtered in an abattoir where GMP/GHP- and HACCP-based control measures are sufficient for attaining pre-defined targets on chilled carcasses. Conversely, slaughtering a high-risk animal batch requires additional risk-reduction interventions to be applied (i.e., carcass decontamination treatments for targeted bacterial hazards and inactivation treatments for targeted parasitic hazards) (Blagojevic et al., 2021; Buncic, 2014); this high-risk batch should, therefore, be sent to a specific abattoir with high risk-reduction performances. In this way, by combining farm and abattoir categorisation, the final meat borne risk-reduction with respect to priority hazards (both bacterial and parasitic) will exceed the risk-reduction achieved by any individual control strategy (Buncic, 2014; Buncic et al., 2019). Nevertheless, when considering combining farm and abattoir risk categorisation, one should also take the financial viability and practical feasibility into account. Having specific abattoirs slaughtering only high-risk animal batches may not be feasible in every situation, for instance in cases where the distribution of abattoirs across the country is uneven or when the farm-to-abattoir distance is long. The model of directing animals to different abattoirs may be sustainable only in areas where both abattoirs and a multitude of farms are close together. Such combined system including pre-harvest measures may also be too expensive for a certain number of abattoirs and the added value likely needs to be considered through a cost-benefit analysis.

Only a small number of the countries that already carry out risk categorisation of abattoirs (36%) reported that the effectiveness of that categorisation has been assessed, and the result in all cases was reported as satisfactory. The applied methodology reported for this assessment differs, but is mostly based on audits performed by the CA either via staff delivering official controls at the abattoir or by the central CA, although in some cases, it is based on external audits performed by DG SANTE. However, for such assessments, the methodology and criteria remain unclear, i.e., what the differences are in terms of official controls and effectiveness in the current system for protecting food safety and public health compared to the situation before the introduction of the risk categorisation system.

A large majority of the surveyed countries expressed their wish to be provided with a practical method for categorising abattoirs according to their pertained risks to public health. The scientific community could usefully contribute to the development of such a framework to assist the CAs in their transition to a more science-based categorisation system of abattoirs.

A fit-for-purpose risk categorisation of abattoirs first needs an established definition of the risk that is being prioritised. To that end, we recommend a focus on the risk to public health resulting from practices related to an abattoir. Aspects considered in the assessment should subsequently be linked mechanistically to this risk and, thus, be science-based. Opinionated or subjective criteria should be ignored. Abattoir

risk categorisation criteria can be divided into *external* or *passive*, in which the abattoir has no or very little control in practice (size, throughput, location, co-located cutting plants, etc.) and *internal* or *active*, which are under the direct control of the abattoir and form part of the applied FSMS. Ultimately, the assigned risk category will be based on a combination of these two categories of criteria. The first set of criteria can be easily characterised objectively, while assessment of the performance of an abattoir FSMS is more challenging, as this includes all activities and procedures that are directly and indirectly implicated in meat safety, and no objective measurements are available for many of these activities, e.g., microbiological results, robustness of sampling plans, appropriateness of HACCP plans, use of relevant FCI, level of control of faecal contamination, etc. Nevertheless, it is crucial to be able to base the performance assessment of an abattoir FSMS on science-based criteria. Once all relevant criteria have been identified, and data availability has been checked, an evaluation framework, such as that used in multicriteria decision analysis (MCDA), can be employed to serve the risk categorisation of abattoirs (Belton & Stewart, 2002). In MCDA, the relevant criteria are broken down into multiple ordinal levels in terms of effectiveness against the hazards of interest, from the least to the most important level for the risk in focus. Abattoirs are subsequently scored according to these criteria, and a final risk score is produced. The relative importance of certain criteria over others can be included with criteria-weights, if desired. The final score can be used to rank the abattoirs based on the risk of the hazard of interest, or it can be used to define classes of abattoirs according to a set threshold (such as low-, medium- and high-risk). Finally, since the requirement for risk categorisation appears relevant for all food production phases, this method proposed for risk categorisation of abattoirs may be applicable to other types of food business operators.

5. Conclusions

The present study found that the majority of the countries that participated in the survey have an abattoir risk categorisation system in place. However, the science-based evidence that underpins their chosen method to design the reported risk categorisation systems remains unclear. Indeed, this study highlights that the methods already applied for the risk categorisation of abattoirs deviate from EFSA's recommendations. They sometimes differ to a great extent between them, and very often there is no clear scientific and risk-based basis for the implemented risk categorisation system. For example, HEIs – which form a cornerstone of EFSA's risk categorisation models – have not been introduced in any of the 18 countries participating in this survey, at least not in a formalised way. The main driver for risk categorisation of abattoirs appears to be the organisation of future official controls, although those risk categorisation methods are mostly based on historical official control data. The effectiveness of the implemented abattoir risk categorisation methods has largely not been assessed, and although it was reported as satisfactory by some countries, it is difficult to accept those reports at face value due to the absence of any formal assessment methodology. In conclusion, further work is needed on the development of a science-based risk categorisation framework, that can be used by FBOs and CAs across Europe in a harmonised way, to optimise food safety controls and further reduce risks for consumers, while allowing sufficient flexibility for adaptation at national level.

Credit author statement

MS: Conceptualisation; Methodology; Data curation; Formal analysis; Writing – original draft; Writing – review & editing. TL: Methodology; Writing – review & editing. JGL: Methodology; Writing – original draft; Writing – review & editing. JH: Methodology; Writing – original draft; Writing – review & editing. IN: Methodology; Writing – original draft; Writing – review & editing. MB: Methodology; Writing – original draft; Writing – review & editing. ND: Methodology; Writing – original draft; Writing – review & editing. KH: Project administration; Conceptualisation; Methodology; Supervision; Writing – original draft; Writing – review & editing. BB: Project administration; Conceptualisation; Funding acquisition; Supervision; Writing – review & editing. DA: Project administration; Conceptualisation; Methodology; Supervision; Writing – original draft; Writing – review & editing.

Ethical statement

The authors have no ethical statement to declare.

Declaration of competing interest

The authors have no competing interests to declare.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

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