Modernising meat inspection using risk-based approaches – output from a workshop held in relation to the SafePork Conference 2023

L. Alban[1,2], E.R. Albuquerque[3], A. Capobianco-Dondona[4], A.H. Kautto[5], A. Klottrup[6], D. Meemken[7], D. Oorburg[8], M.K. Poulsen[1], D. Grace[9,10], M. Vieira-Pinto[11], B. Blagojevic[12]

[1]: Dept. of Food Safety and Veterinary Issues, Danish Agriculture & Food Council, Copenhagen, Denmark

[2]: Dept. of Veterinary and Animal Sciences, University of Copenhagen, Frederiksberg, Denmark

[3]: Dept. of Inspection of Animal Products (DIPOA), Ministry of Agriculture and Livestock, Brazil

[4]: Farm4Trade s.r.l., Atessa, Italy,

[5]: Dept. Biomedical Sciences and Veterinary Public Health (BVF), SLU, Uppsala, Sweden,

[6]: Danish Veterinary and Food Administration, Glostrup, Denmark,

[7]: Institute of Food Safety and Food Hygiene, Working Group Meat Hygiene, Freie Universität Berlin, Berlin, Germany

[8]: Vion Food Group, Boxtel, The Netherlands,

[9]: Natural Resources Institute, University of Greenwich, UK,

[10]: International Livestock Research Institute, Nairobi, Kenya,

[11]: Veterinary and Animal Research Centre, University of Trás-os-Montes and Alto Douro, Portugal,

[12]: Dept. of Veterinary Medicine, University of Novi Sad, Novi Sad, Serbia.

* Corresponding author lia@lf.dk (Lis Alban)

Abstract

Many resources are dedicated to ensuring meat safety at the different phases of meat production, from stable to table or field to finger. Given the high cost of current control systems, there is interest in making safety assurance more cost-effective. An international network called RIBMINS has been working on this through the development of risk-based meat safety assurance systems (RB-MSAS). The latest approaches within RB-MSAS were presented and discussed at a workshop at the SafePork Conference, 2023. This covered risk categorisation of farms and abattoirs, meat inspection condemnation criteria, and problem detection using cameras. Additionally, the specific challenges related to RB-MSAS for the Global South were presented. Finally, the views of the competent authorities and the food business operators regarding RB-MSAS were discussed. One take-home message was that there are new cost-effective technical approaches with potential for widespread use. Moreover, modernised meat inspection is in the interest of all stakeholders because food safety can be maintained, while food losses, environmental effects and costs are kept low. To ensure progress, a joint effort is required involving evidence-based documentation of the impact of the suggested changes. Evidence can be used to update current legislation, which in several cases is acting as a barrier to the implementation of RB-MSAS. Moreover, training of relevant personnel including primary producers, abattoir workers and competent authorities is required.

How can food inspection be done cost-effectively?

Safe, affordable food is a requirement for sustainable development of societies, as it's provision affects public health, the economy (including trade and tourism) and the environment. Moreover, the growing global population puts pressure on the food system, leading to intensification and industrialisation of livestock production as well as to an increase in international trade. This has implications, both positive and negative, for food safety and security. While in traditional, informal systems, most meat is not inspected (Jabbar & Grace, 2012), both modern meat production and trade require safety-assured meat. As a result, many human and financial resources are needed to ensure meat safety – either during the pre-harvest phase, at harvest or during post-harvest. However, could all this be done in a more cost-effective way than the current? And are there technologies in the pipeline that could improve food safety without implying cost increases? An international COST Action network called RIBMINS has been working from 2019 to 2023 on addressing these questions through the development of risk-based meat safety assurance systems (RB-MSAS), primarily in Europe, but also with overseas partners. For more information about RIBMINS, please see: https://ribmins.com/.

The main results of RIBMINS were presented at a workshop held on 15 May 2023 at the SafePork Conference, which took place in New Orleans, USA. At the workshop, the basic principles of RB-MSAS were discussed along with a presentation of case studies using new camera-based vision technologies. Moreover, different representatives from both sides of the Atlantic Ocean provided feedback and critiques on the feasibility of the whole concept, while also giving the status of modernised meat inspection in their country, including the way this issue is treated.

This paper reports the main take-home messages from the workshop. Each presentation can be found on the RIBMINS website: RIBMINS at SafePork 2023 – Ribmins

MSAS definition and implementation

The RB-MSAS concept is to have a flexible, dynamic and longitudinally integrated system comprising all preventive and control measures applied at farm and abattoir nodes of the meat chain, to achieve specific targets set for chilled carcasses (Blagojevic et al., 2021). The main components of the system are to:

1) categorise the farms according to their risk,
2) categorise the abattoirs according to their risk,
3) use Food Chain Information (FCI) and Harmonised Epidemiological Indicators,
4) apply risk-based meat inspection,
5) make use of food safety management systems assuring abattoir process hygiene, and
6) have risk managers who coordinate the system.

The risk managers' role is to choose and balance which control options will be applied to ensure the hazard-based targets for chilled carcasses are achieved and to generate the overall most cost-effective contribution to public health (Figure 1). The RB-MSAS is still in the early phases of its implementation in Europe. The full development and implementation of the system are expected in the future, but it is foreseen that it will be a slow and careful process. Numerous challenges and opportunities of the system have been identified so far (Antunovic et al., 2021). Intensive research, training of the participants and close collaboration among all stakeholders are crucial pre-conditions for implementing RB-MSAS. Use of new digital technologies can facilitate implementation. Moreover, sharing the European experiences in meat safety assurance systems with overseas countries is required to ensure understanding and mutual recognition of the systems in place. In addition, European innovations could be relevant for other regions, especially where resources are scarce.

Farm risk categorisation and pre-harvest strategies

Within RB-MSAS, the risk category of the farm, the nature of the current batch of slaughter animals, and ante-mortem (AM) inspection results together allow the risk manager to decide how intense the meat inspection

needs to be. The key components for the categorisation are in the FCI, which is specified by Regulation (EC) No. 853/2004, as well as in the Harmonised Epidemiological Indicators as proposed by the European Food Safety Authority (see e.g., European Food Safety Authority, 2011). Harmonised Epidemiological Indicators are either direct measurements of a specific hazard somewhere in the supply chain or are audits of farm biosecurity as an indirect way of assessing the risk of the hazard. Recently conducted Europe-wide online surveys (Langforth et al. 2023, Li et al. 2024a,b) have shown that the FCI currently available to the official veterinarians and the food business operators was barely helpful or was not at all helpful for food safety decision-making for many respondents (25% of poultry respondents, 40% of pig and 52% of cattle respondents, respectively). Suggestions for improving FCI are, for example, to include the mortality rate, the treatment index and indications of the treatments. The surveys also revealed that knowledge of Harmonised Epidemiological Indicators and their use is low throughout Europe (Langkabel et al., 2023; Li et al., 2023).

Regarding pre-harvest food safety strategies, three systematic literature reviews were carried out by the RIBMINS network. The focus was on the effectiveness of on-farm measures to control the main food safety hazards identified by the European Food Safety Authority in cattle, pigs and broilers (Pessoa et al., 2021; Rodrigues da Costa et al., 2021, 2023). The reviews concluded that, overall, high health status coupled with good management and biosecurity are effective means to control most foodborne pathogens**.** However, some foodborne pathogens are evidently best controlled at the post-harvest level.

Abattoir risk categorisation and harvest strategies

After categorising farms with respect to their risk, the next step is to categorise abattoirs. This should be based on the ability of the abattoir to cope with the risk associated with the animals that are being received. Here, an essential component of the RB-MSAS is to focus on the performance of the food safety management system as well as the abattoir's use of Harmonised Epidemiological Indicators. The risk manager's decisions include establishing which abattoirs should receive animals from which farms and whether additional risk mitigation measures are needed. Such measures could consist of slaughtering the animals with the lowest risk first (logistic slaughter), reducing slaughter-line speed, or applying additional/reactive interventions, including decontamination treatments, on dressed carcasses. Hence, the conjoined use of farm and abattoir risk categories enables risk managers to balance the level of risk represented by the slaughter animals and the risk-reducing capacity of the abattoir to achieve the set carcass targets. Together, these two risk categorisations help to reach the performance objectives, which will contribute to achieve the appropriate level of protection as shown in Fig. 1. Abattoir risk categorisation could also help identify abattoirs requiring more stringent auditing and/or technology improvements. Currently, the EU Process Hygiene Criteria (Anon., 2005) helps to group abattoirs in three risk categories based on the microbiological status of dressed carcasses: acceptable, marginal or unacceptable. A recent study across European abattoirs found that a variety of methods of assessing the process hygiene and risk categorisation of abattoirs are used in different countries (Salines et al., 2023). However, no European country has yet formally included Harmonised Epidemiological Indicators in abattoir risk categorisation, and no country is currently combining farm and abattoir risk categorisation systems.

Risk-based meat inspection

During the post-mortem (PM) inspection, official veterinarians register gross pathology and contaminations on the carcasses. To do so, they need a list of codes, and for each of these, a judgement criterion to apply that allows them to decide whether or not the meat is fit for human consumption. However, although the EU Food Inspection Regulation 2019/627 sets out a list of 21 reasons for judging meat as unfit for consumption (EU Commission, 2019), the code lists in force vary substantially between the EU Member States, while some do not have an official code list (Alban et al., 2022). Moreover, the judgement criteria listed by the EU are mostly generic, favouring subjectivity (Vieira-Pinto et al., 2022). To address the degree of variation in total

condemnation criteria applied during PM inspection of finishing pigs, a European online survey was undertaken by the RIBMINS network in 2021-22. The focus was on criteria regarding 10 important PM inspection findings: abscesses, arthritis, cachexia, erysipelas, icterus, *Mycobacterium*-like lesions, osteomyelitis, peritonitis, pleuritis and pneumonia. A total of 44 completed questionnaires were obtained from 26 European countries. The results showed a substantial variation in the criteria in place in the participating countries. For example, answers related to *Mycobacterium*-like lesions revealed that 16% of the respondents totally condemned all cases, whereas the remaining respondents only did so in cases of generalised disease. Variability was also seen regarding the macroscopic indicators used to define a generalised condition related to the 10 PM inspection findings addressed, as fully described in Vieira-Pinto et al. (2022). The variety in code lists and condemnation criteria points to the need for at least some harmonisation to improve decision-making, to permit comparative analysis beneficial for risk-based meat inspection and to enable future use of camera-based vision systems.

New camera-based vision-based technologies

The next presentation dealt with a field trial, undertaken in Norway, using an Artificial Intelligence (AI)-based technology, called Automatic Detection of Abattoir Lesions (ADAL), which uses deep learning algorithms and image processing to automatically score pleurisy in slaughtered pigs. This innovative technology represents a pivotal approach to advancing animal health and meat safety. In the field trial, 19,029 pig chest-wall images were analysed, revealing a 10.2% incidence of pleurisy. The ADAL technology promises a fast, cost-effective means to systematically record and score lesions. This information can be fed back to the individual pig producers in the form of FCI. The pig producers and their veterinary practitioners can then identify relevant disease control strategies to enhance on-farm health and productivity, e.g., through initiation of vaccination. Hence, the role of the official veterinarian and the private practitioner could be positively transformed by the use of this technology.

This AI method's development marks a considerable step towards automated, real-time analysis of health, production and welfare parameters in abattoirs. Its ability to improve disease detection and reduce human error in manual scoring would be revolutionary for the livestock industry, providing invaluable support to stakeholders, including the producers and their veterinarians. There are no legislative barriers for using this AI system to obtain automated scorings of pleurisy, as it would not replace the existing PM inspection, but it could replace the tedious, manual scoring done upon request and at the expense of the pig producer. The manual scoring system actually limits the number of animals scored and the frequency of monitoring respiratory health. For a systematic review on camera-based vision systems for use in meat safety, please see Sandberg et al. (2023).

Post-mortem inspection from a distance

The future RB-MSAS should make use of practical options that will contribute to a high level of safety, feasibility, resilience and sustainability in many senses. One of those practical options could be remote meat inspection using hardware and software at reasonable prices. A project has recently been undertaken at a medium-sized pig abattoir in Sweden, where the purpose was to study the feasibility of remote PM inspection. The PM inspection was done using smartphones on-site at the abattoir, and hence, the system requires an internet connection on the slaughter-line and a remote personal computer as a receiver. At the abattoir, a technical support person filmed the slaughtered pig carcasses and organs in real time, while PM inspection was done by an official veterinarian on a remote personal computer. Open-source software was customised for this purpose. In total, 1009 pigs were inspected during the project.

Findings in remote PM inspection were detected on 243 carcases inspected by the remotely located official veterinarian. A total of 221 carcases (91%) had only one diagnosis and 22 (9%) had two diagnoses. These results were compared to the results from the routine PM inspection done on-site on the very same carcasses.

There were also base-line measurements, where two official veterinarians inspected the same carcasses on-site without communicating with each other during one working day. Inter-rater variability was present between the official veterinarians in both systems. Hence, the remote location of the inspector did not affect the inter-rater reliability negatively. Some findings were more consistently detected than others. This was also expected and has been seen in other inspection data from slaughter and game handling.

Official veterinarians are professionals who are required to make decisions based on their own training and experience, and this logically creates some bias and noise. However, garnering a second opinion is not feasible for the existing slaughter-line inspection due to practical hurdles. The use of the remote system could improve the precision of decisions, while the remote veterinarian can also communicate, if needed, with other veterinarians in their office. This kind of technical development in meat inspection would be more objective and less dependent on the idiosyncrasies of any one professional. Still, there is a list of prerequisites for implementation to become a success, as highlighted by Hunka et al. (2023).

Ante-mortem inspection from a distance

The EU Regulation 853/2004 was updated in February 2023, and it now requires official veterinarians to conduct AM inspection of cattle that are emergency slaughtered on a farm (EU Commission, 2004). The official veterinarian might have a long way to drive, implying an extended time before the animal can be inspected, which will decrease animal welfare. A pilot project is currently taking place in Denmark, testing the hypothesis that an online AM inspection using video consultation is comparable with a physical AM inspection. The project will also investigate whether stunning and bleeding can be documented sufficiently by video. The AM inspection is first performed online and following a check list that was developed to ensure uniform inspection. Next, the AM inspection is performed physically on the farm, where the official veterinarian describes relevant findings not possible to register on video. Moreover, the video is assessed by another official veterinarian for validation. So far, 35 useful videos of emergency slaughtered bovines have been made, and another 15 will be collected. The preliminary results show that the animal's symptoms are obvious on the video, and there is agreement between the official veterinarians seeing the same videos. Initially, the official veterinarians missed the "sense" of the animal when seeing it only on video, but this was compensated for over time by experience with the new system. The project report will be presented to the EU Commission with a request to allow virtual AM in cases of emergency slaughter, and this will require an amendment of the current EU legislation.

Status of RB-MSAS in Brazil

In Brazil, AM inspection is still carried out by an official veterinarian for all delivered batches, due to concern regarding the presence of notifiable animal diseases with a negative economic impact on society. Brazilian abattoirs will be able to adopt a risk-based PM inspection system (RBIS) following the international recommendations of Codex Alimentarius in its Code of Hygienic Practice for Meat (Codex Alimentarius, 2005). The deadline for Brazilians abattoirs to join the RBIS is December 2028.

The RIBS is exclusively applicable under the following conditions: 1) Intensive industrial swine production (raised exclusively indoors), 2) Pigs under 6 months of age, and 3) Herds under an integrated production system or another capable of showing full control of the animal origin, feed, veterinary assistance and traceability. The FCI must be standardised and implemented in the herd by the pig producer, and it must be available for evaluation by the official veterinarian 24 hours before slaughter.

Prior to allowing traditional meat inspection to be replaced with RBIS, a study was undertaken in Brazil, where the aim was to understand which findings at PM inspection are associated with a food safety risk. The first step was to collect data and information, which led to identification and prioritisation of relevant hazards. Next, a statistical study determined the prevalences of all findings made by traditional inspection in Brazil. Among the most frequently detected findings, those that were associated with the prioritised hazards were then

ascertained. If a finding was not associated with risks to public health, it was decided that the inspection procedures could be transferred to the companies, if carried out under supervision of a private veterinarian. The role of the competent authority will be to undertake audits in a systematic way. For information about the final rule please see Anonymous (2019), while the Scientific Opinion and the final recommendations can be found in Kich et al. (2021).

Barriers to implementing new technology

A shortage of personnel for official meat inspection is ongoing in many European countries, as many of the official veterinarians/auxiliaries are retiring, while recruitment is becoming still more difficult (Honka et al., 2023). The use of new technology as a part of meat inspection should help resolve this problem and contribute to freeing official veterinarians/auxiliaries for other tasks. However, according to Anne Klottrup from the Danish Veterinary and Food Administration (Fig. 2), AI cannot replace official veterinarians/auxiliaries in official controls under the current EU legislation. The AM inspection must be carried out by an official veterinarian, and the PM inspection is to be carried out by an official veterinarian, or by an official auxiliary working under the supervision of the official veterinarian or, where sufficient guarantees are in place, under the responsibility of the official veterinarian. The only exemption from this is that the competent authorities are permitted to decide that only a representative sample of poultry from each flock undergoes PM inspection, if the food business operator has a system in place to the satisfaction of the official veterinarian, and which allows the detection and the separation of birds with abnormalities, contamination or defects. This implies that for now, the new technology cannot replace traditional meat inspection, but it can be used as a supporting tool in the slaughter process. To change this, the legislation must be changed. To make this possible, it is important to develop and present new technologies that utilise AI – such as camera-based vision technologies – to the Expert Group on Food Hygiene and Control of Food of Animal Origin under the European Commission and to the 27 member states in the EU. In fact, pilot projects to investigate the possible implementation of new technology are mandated according to EU Regulation 625/2017, Article 18.9 (The European Parliament and the Council, 2017). Still, the world is larger than the EU, so for further development of new technologies and their uptakes in the meat industry, there must be cooperation on these matters with the rest of the world.

Views on RB-MSAS from low- and middle-income countries

Low- and middle-income countries face several challenges in assuring the quality of meat. Firstly, many animals do not undergo any inspection before or after slaughter. Poultry, small ruminants and pigs are typically slaughtered informally by households or food establishments and by using traditional methods. In Kampala, Uganda, for example, there is only one official abattoir for pigs, and at least half of the pigs in this capital city are slaughtered informally (Atherstone et al., 2019). Secondly, while most cattle and buffaloes are slaughtered in official abattoirs or slaughter slabs, AM inspection is mostly neglected, and visual inspection of carcases is not very effective at detecting gross lesions. For example, one study in Ethiopia found current inspection techniques failed to detect 70% of carcasses with grossly visible lesions of tuberculosis (Biffa et al., 2010). Ritual slaughter and huge consumption of bushmeat are additional challenges to meat safety assurance in low- and middle-income countries.

Given these challenges and the lack of human and financial resources, better and more cost-effective ways of assuring meat safety are urgently required. Africa has more than a billion mobile phones, but hardly any landlines – could RB-MSAS be a similar “leapfrog” technology? There are some promising approaches that have yet to be adopted at the larger scale. Risk maps have been developed for many diseases, including foodborne diseases (Akoko et al., 2023); these could be used to identify animals from high-risk areas for additional attention. In Kenya, a mobile phone-based meat inspection form was piloted and found to facilitate data reporting and analysis (Falzon et al., 2021). While the RB-MSAS as used in Europe is likely to be too expensive and complex for most low- and middle-income countries, the concept is highly relevant and could

help shift countries from the unobtainable goal of modern meat inspection for every animal slaughtered to a more effective and efficient risk-based approach.

A food business operator's point of view

In the EU, the General Food Law places responsibilities for food safety on all producers in a food chain (The European Parliament and the Council, 2002). Food business operators, therefore, need to develop integrated quality assurance systems based upon hazard analysis and critical control points (HACCP) and that cover the entire supply chain. To do this, scientific knowledge on the transmission routes of relevant hazards must be utilised.

The Dutch risk-based Integrated Supply Chain Meat Inspection System (ISCMIS) has been in use since 2006. ISCMIS is an example of how the principles of RB-MSAS can be used effectively in a joint effort by the food business operator and the competent authority to control food safety in a transparent and efficient way. ISCMIS uses the principles of farm categorisation through FCI and serological monitoring as Harmonised Epidemiological Indicators to control relevant hazards in the pork supply chain. These can be known hazards, such as *Toxoplasma gondii*, or emerging hazards, such as Hepatitis E virus. Furthermore, the principles behind abattoir categorisation are used to control *Salmonella* at slaughter. By continuously reporting performance indicators that show the level of process and product control, each food business operator fulfils their risk manager role. Furthermore, data arising from ISMIS now support the competent authority in its supervisory role, as laid down in the EU hygiene package.

The way ahead

As noted at the 2023 SafePork workshop and demonstrated in this paper, many countries throughout the world are moving towards a more risk-based meat inspection, which along with innovative technologies such as camera-based vision AI tools, could make safety assurance more cost-effective.

The work of the RIBMINS network shows how categorising farms according to the risk of animals delivered for slaughter, and similarly, categorising the receiving abattoirs' capacity to handle risk animals, could both be combined to better ensure food safety. In addition, clear lesion code systems and condemnation criteria based on evidence are needed to ensure that not only meat on the market is fit for human consumption, but that food is not lost unnecessarily, thus minimising negative environmental effects, maximising nutritional benefits and keeping costs low. Although much of the work done by RIBMINS seems most relevant for the developed world, the principles and approach are very relevant to low- and middle-income countries, which have a much higher burden of meat-associated disease and even greater resource constraints.

The exchange of evidence, experience and perception is needed to ensure joint progress between the different regions in the world as well as between food business operators and the competent authorities at the local, national and international levels. Academia must be involved too, as generators of evidence that provide the scientific basis for the suggested changes. This could include the establishment of common validation procedures for new technologies. Such a multi-stakeholder collaboration has previously been recommended by Alban et al. as a constructive way of working (Alban et al., 2023). Limitations in the legislation deserve special attention and can require additional platforms or approaches. Again, only a joint effort can bring about the conditions for change, as lack of agreement on how to undertake meat inspection could easily result in trade barriers. Finally, capacity-building of primary producers, abattoir workers and the competent authorities is needed. A series of training schools focusing on the different elements of RB-MSAS were organised as part of RIBMINS. Free access to these materials can be found on Training Schools – Ribmins. Additionally, as part of the RIBMINS activities, Ferri et al. (2023) and Gomes-Neves et al. (2023) have explored the needs of the official veterinarians regarding RB-MSAS. In conclusion, recent years have seen major advances in

development of risk-based meat safety assurance systems that are now ready to be taken forward to widespread implementation in Europe and beyond.

References

1. Akoko, J.M., Mwatondo, A., Muturi, M., Wambua, L., Abkallo, H.M., Nyamota, R., Bosire, C., Oloo, S., Limbaso, K.S., Gakuya, F., Nthiwa, D., Bartlow, A., Middlebrook, E., Fair, J., Oguto, J.O, Gachohi J., Njenga, K., Bett, B. (2023): Mapping brucellosis risk in Kenya and its implications for control strategies in sub-Saharan Africa. Sci. Rep. *13*, Article 20192. https://doi.org/10.1038/s41598-023-47628-1
2. Alban, L., Vieira-Pinto, M., Meemken, D., Maurer, P., Ghidini, S., Santos, S., Gómez Laguna, J., Laukkanen-Ninios, R., Alvseike, O., Langkabel, N. (2022): Differences in terminology and frequency of findings in meat inspection of finishing pigs in seven European countries. Food Control, *132,* Article 1988394. https://doi.org/10.1016/j.foodcont.2021.108394
3. Alban, L., Brookes, V.J., Dórea, F., Sauter-Louis, C., Dürr, S. (2023): Editorial: Bridging science and policy for animal health surveillance: ICAHS4 2022. Front. Vet. Sci. *10*, Article 1285992. https://doi.org/10.3389/fvets.2023.1285992
4. Anonymous (2005): Commission Regulation (EC) 2073/2005. *CL2005R2073EN0090010.0001_cp 1..1 (europa.eu)*
5. Anonymous (2019): Final Rule (IN 79/2018), WTO communication (in Portuguese). *https://www.in.gov.br/materia/-/asset_publisher/Kujrw0TZC2Mb/content/id/55444279/do1-2018-12-17-instrucao-normativa-n-79-de-14-de-dezembro-de-2018-55444116*
6. Antunovic B., Blagojevic B., Johler S., Guldimann C., Vieira-Pinto M., Vågsholm I., Meemken D., Alvseike O., Georgiev M., Alban L. (2021): Challenges and opportunities in the implementation of new meat inspection systems in Europe. Trends Food Sci. Technol. *116*, 460-467. https://doi.org/10.1016/j.tifs.2021.08.002
7. Atherstone, C., Galiwango, R.G., Grace, D., Alonso, S., Dhand, N.K., Ward, M.P., More, S.M. (2019): Analysis of pig trading networks and practices in Uganda. Trop Anim Health Prod. *51*(1):137-147. https://doi.org/10.1007/s11250-018-1668-6
8. Biffa, D., Bogale, A., Skjerve, E. (2010): Diagnostic efficiency of abattoir meat inspection service in Ethiopia to detect carcasses infected with *Mycobacterium bovis*: Implications for public health. BMC Publ. Health *10*, 462. https://doi.org/10.1186/1471-2458-10-462
9. Blagojevic B., Nesbakken T., Alvseike O., Vågsholm I., Antic D., Johler S., Houf K., Meemken D., Nastasijevic I., Vieira-Pinto M., Antunovic B., Georgiev M., Alban L. (2021): Drivers, opportunities, and challenges of the European risk-based meat safety assurance system. Food Control *124*, Article 107870. https://doi.org/10.1016/j.foodcont.2021.107870
10. Codex Alimentarius (2005): Code of hygienic practice for meat - CAC/RCP 58-2005, Annex I – Risk-based evaluation of organoleptic post-mortem inspection procedures for meat. *Code of Hygienic Practice for Meat (fao.org)*
11. EU Commission (2004): Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. Current consolidated version from 15 February 2023. *CL2004R0853EN0240010.0001_cp 1..2 (europa.eu)*
12. EU Commission (2019): Regulation (EU) 2019/627. *http://data.europa.eu/eli/reg_impl/2019/627/oj*
13. European Food Safety Authority (2011): Scientific Report on Technical specifications on harmonised epidemiological indicators for public health hazards to be covered by meat inspection of swine. EFSA Journal 9(10):2371. https://doi:10.2903/j.efsa.2011.2371
14. European Parliament and the Council (2002): Regulation (EU) 178/2002 - The General Food Law. *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02002R0178-20220701&qid=1701172920342*
15. European Parliament and the Council (2017): Regulation (EU) 2017/625. *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0625&from=EN*
16. Falzon, L.C., Ogola, J.G., Odinga, C.O., Naboyshchikov, L., Fèvre, E.M., Berezowski, J. (2021): Electronic data collection to enhance disease surveillance at the slaughterhouse in a smallholder production system. Sci. Rep. *11*, Article 19447. https://doi.org/10.1038/s41598-021-98495-7
17. Ferri, M., Blagojevic, B., Maurer, P., Hengl, B., Guldimann, C., Mojsova, S., Sakaridis, I., Antunovic, B., Gomes-Neves, E., Zdolec, N., Vieira-Pinto, M., Johler, S. (2023): Risk based meat safety assurance system - an introduction to key concepts for future training of Official Veterinarian. Food Control, *146*, Article 109552. https://doi.org/10.1016/j.foodcont.2022.109552

18. Gomes-Neves, E., Cardoso, M. F., Lazou, T., Hengl, B., Bonardi, S., Blagojevic, B., Guldiman, C., Johler, S. (2023): Official veterinarians in Europe: Questionnaire based insights into demographics, work and training. Food Control, *153*, Article 109947. https://doi.org/10.1016/j.foodcont.2023.109947
19. Hunka, A., Vanacore, E., Medin, I., Gjona, E., Kautto, A.H. (2023): Official control in slaughter and game handling: expectations and prerequisites for implementation of remote meat inspection in Sweden, J. Food Protect. Pre-proof, Article 100196. https://doi.org/10.1016/j.jfp.2023.100196
20. Jabbar, M.A., Grace, D., 2012. Regulations for safety of animal source foods in selected Sub-Saharan African countries: Current status and their implications. Res. Rep. 181867. International Livestock Research Institute. doi:10.22004/ag.econ.181867
21. Kich, J.D., Coldebella, A., Albuquerque, E.R., Cardoso, M.R.I., Corbellini, L.G., Costa, E.F. (2021): Modernization of swine slaughter inspection in swine slaughter establishments - risk-based inspection. Scientific opinion 219. Embrapa Suínos e Aves. https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1131118/1/final9663.pdf
22. Langforth, S., Oswaldi, V., Isbrandt, R., Sotiraki, S., Anastasiadou, S., Nesbakken, T., Meemken, D., Langkabel, N. (2023): Food chain information for broilers: Results of a Europe-wide survey on status quo, usability and suggestions for improvement. Food Control, *152*, Article 109844. https://doi.org/10.1016/j.foodcont.2023.109844
23. Langkabel, N., Meemken, D., Li, T.-T., Sotiraki, S., Anastasiadou, S., Nesbakken, T., Langforth, S. (2023): Use of harmonised epidemiological indicators (HEIs) for broilers in Europe. Food Control, *154*, Article 110020. https://doi.org/10.1016/j.foodcont.2023.110020
24. Li, T.-T., Langforth, S., Langkabel, N., Sotiraki, S., Anastasiadou, S., Nesbakken, T., Meemken, D. (2023): Implementation of harmonised epidemiological indicators (HEIs) for pigs – a Europe-wide online survey. Food Control, *153*, Article 109954. https://doi.org/10.1016/j.foodcont.2023.109954
25. Li, T.-T., Langforth, S., Isbrandt, R., Langkabel, N., Sotiraki, S., Anastasiadou, S., Nesbakken, T., & Meemken, D. (2024b): Food chain information for pigs in Europe: A study on the status quo, the applicability and suggestions for improvements. Food Control, *157*, Article 110174. https://doi.org/10.1016/j.foodcont.2023.110174
26. Li, T.-T., Meemken, D., Antunovic, B., Nesbakken, T., & Langforth, S. (2024a): Food chain information for broilers, pigs and bovines in Europe: Comparison of report forms and definitions of the relevant period for reporting treatments with veterinary medicinal products with withdrawal periods. Food Control, *155*, Article 110054. https://doi.org/10.1016/j.foodcont.2023.110054
27. Pessoa, J., Rodrigues da Costa, M., Nesbakken, T., Meemken, D. (2021): Assessment of the effectiveness of pre-harvest meat safety interventions to control foodborne pathogens in broilers: A systematic review. Curr. Clin. Micro. Rpt. *8*, 21–30. https://doi.org/10.1007/s40588-021-00161-z
28. Rodrigues da Costa, M., Pessoa, J., Meemken, D., Nesbakken, T. (2021): A systematic review on the effectiveness of pre-harvest meat safety interventions in pig herds to control *Salmonella* and other foodborne pathogens. Microorg. *9*, Article 1825. https://www.mdpi.com/2076-2607/9/9/1825
29. Rodrigues da Costa, M., Pessoa, J., Nesbakken, T., Meemken, D. (2023): A systematic review to assess the effectiveness of pre-harvest meat safety interventions to control foodborne pathogens in beef. Food Control, *153*, Article 109944. https://doi.org/10.1016/j.foodcont.2023.109944
30. Salines, M., Lazou, T., Gomez-Luengo, J., Holthe, J., Nastasijevic, I., Bouwknegt, M., Dadios, N., Houf, K., Blagojevic, B., Antic, D. (2023): Risk categorisation of abattoirs in Europe: Current state of play. Food Control, *152*, Article 109863. https://doi.org/10.1016/j.foodcont.2023.109863
31. Sandberg, M., Ghidini, S., Alban, L., Dondona, A.C., Blagojevic, B., Bouwknegt, M., Lipman, L., Dam, J.S., Nastasijevic, I., Antic, D. (2023). Applications of computer vision systems for meat safety assurance in abattoirs: A systematic review. Food Control *150*, Article 109768 https://doi.org/10.1016/j.foodcont.2023.109768
32. Vieira-Pinto, M., Langkabel, N., Santos, S., Alban, L., Laguna, J.G., Blagojevic, B., Meemken, D., Bonardi, S., Antunović, B., Ghidini, S., Maurer, P., Alvseike, O., Laukkanen-Ninios, R. (2022): A European survey on post-mortem inspection of finishing pigs: Total condemnation criteria to declare meat unfit for human consumption. Res. Vet. Sci. *152*, 72-82. https://doi.org/10.1016/j.rvsc.2022.07.013

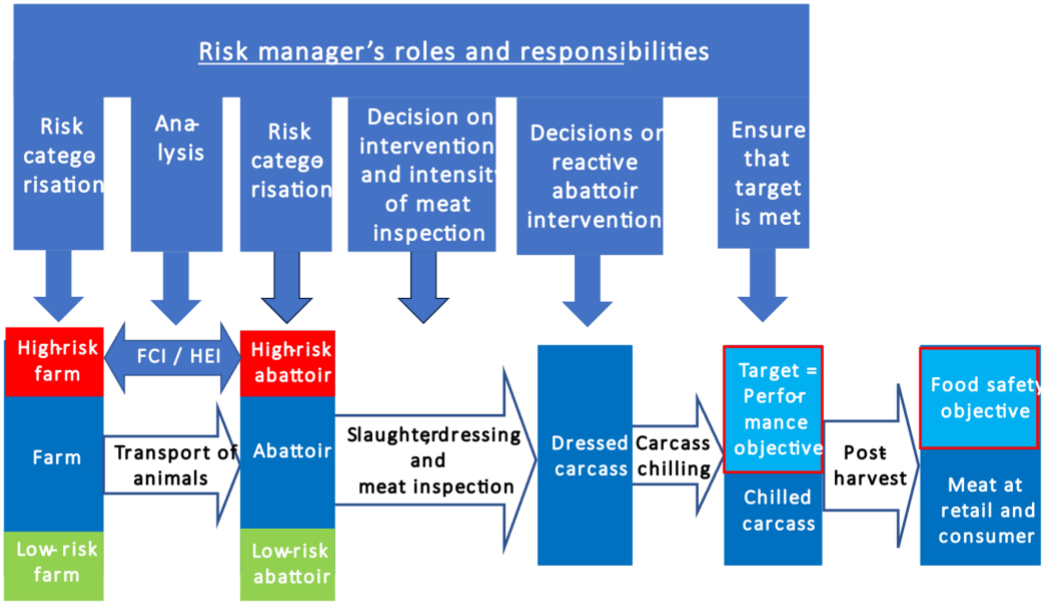

Figure 1. Graphical description of the principles behind risk-based meat safety assurance systems (RB-MSAS) highlighting the connection between the risk associated with the animals delivered for slaughter and the abattoir's capacity to handle this risk to ensure safe meat for the consumers.

Figure 2. Anne Klottrup form the Danish Veterinary and Food Administration, member of the Expert Group on Food Hygiene and Control of Food of Animal Origin under the European Commission