

Modernising meat inspection using risk-based approaches

Output from a workshop held at the SafePork Conference 2023

A workshop at the SafePork Conference in 2023 delved deeply into the concepts and practicalities of risk-based meat inspection. Such approaches could significantly improve food safety while making the process more efficient and cost-effective.

By Lis Alban et al.

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 by developing 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 in 2023. This covered risk categorisation of farms and abattoirs, meat inspection condemnation criteria, and problem detection using cameras. The specific challenges related to RB-MSAS for the Global South were also 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 the 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 implementing RB-MSAS. Moreover, training of relevant personnel, including primary producers, abattoir workers and competent authorities, is required.

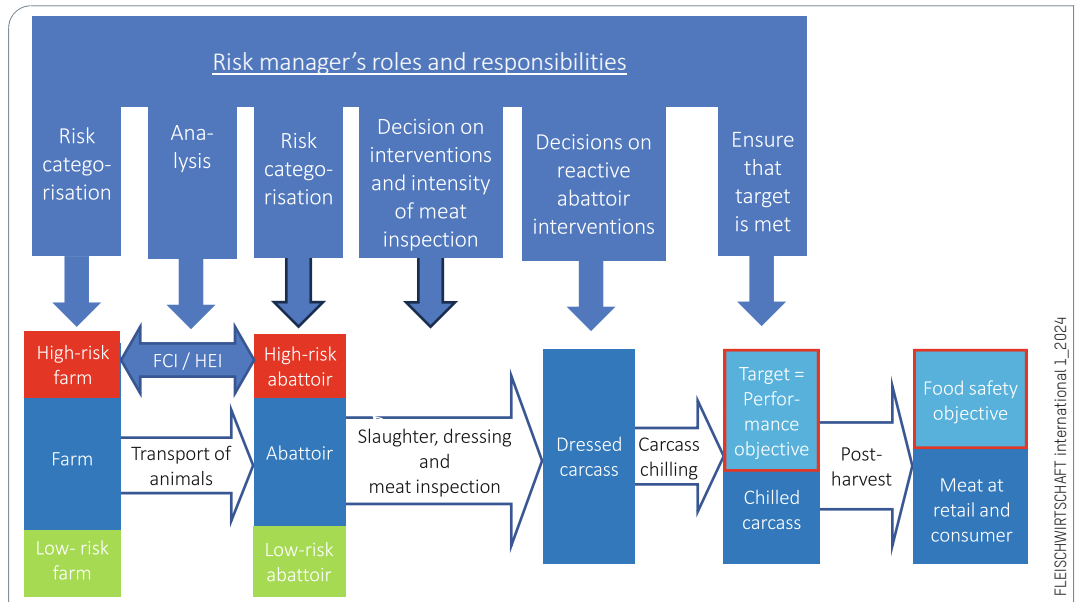


Fig. 1: Graphical description of the principles behind risk-based meat safety assurance systems (RB-MSAS) highlighting the connection between the risk associated with the animals delivered for slaughter and the abattoir's capacity to handle this risk to ensure safe meat for the consumers. SOURCE: ALBAN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

How can food inspection be done cost-effectively?

Safe, affordable food is a requirement for the sustainable development of societies, as its 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 and 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? Are there technologies in the pipeline that could improve food safety

without implying cost increases? RIBMINS has been working from 2019 to 2023 to address 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.

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 to ensure 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 gener-

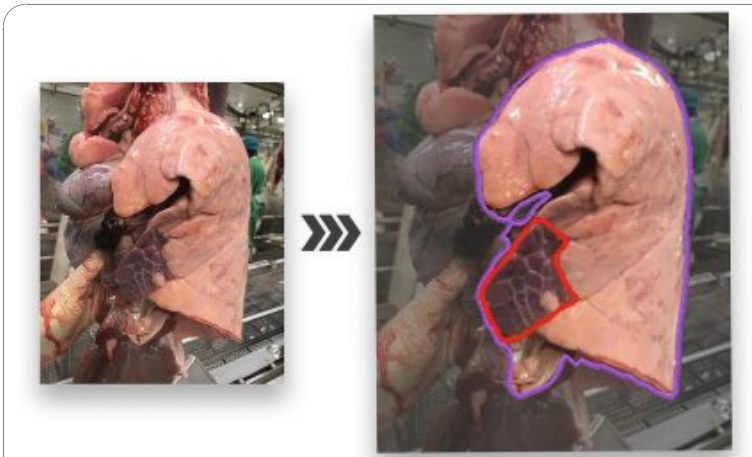


Fig. 2: Segmentation of a pig lung image using the ADAL technology, highlighting anatomical sections and identifying pneumonia lesions (in red) Photo: Farm4Trade

ate 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. The 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 (e.g., European Food Safety Authority, 2011). Harmonised epidemiological indicators are either direct measurements of a specific hazard somewhere in the supply chain or 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, respec-

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Fig. 3: Showing the cell phone setup, which was used in a study on remote meat inspection.

Photo: Arja Helena Kautto



Fig. 4: Anne Klottrup from the Danish Veterinary and Food Administration and member of the Expert Group on Food Hygiene and Control of Food of Animal Origin under the European Commission. Photo: Lis Alban

tively). Suggestions for improving FCI include, for example, 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, the RIBMINS network carried out three systematic literature reviews. 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 Epi-

demiological 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 achieving the food safety objective, as shown in Figure 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 into 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 among 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 the PM inspection of finishing pigs, a European online survey was undertaken by the RIBMINS network in 2021-22. The focus was on criteria regarding ten important PM inspection findings: abscesses, arthritis, cachexia, erysipelas, icterus, *Mycobacterium*-like lesions, osteomyelitis, peritonitis, pleuritis and pneumonia. A total of 44 com-

pleted 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 technologies

The next presentation dealt with a field trial undertaken in Norway, using Artificial Intelligence (AI)-based technology called Automatic Detection of Abattoir Lesions (ADAL), which uses deep learning algorithms and image processing to automatically score lung lesions and pleurisy in slaughtered pigs. Figure 2 shows how the lung tissue is segmented into normal and abnormal tissue. This innovative technology represents a pivotal approach to

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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 the initiation of vaccination. Hence, the role of the official veterinarian and the private practitioner could be positively transformed by the use of this technology.

The development of this AI method 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 to 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 of camera-based vision systems for use in meat safety, please see SANDBERG et al. (2023).

Ante-mortem inspection from a distance

The EU Regulation 853/2004 was updated in September 2021, 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 to 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 follows a checklist that was developed to ensure uniform inspection. Next, the AM inspection is performed physically on the farm, where the official veterinarian describes relevant findings that are 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 in the video, and there is an agreement among 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 could be compensated over time through growing 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.

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 (Figure 3). 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 carcasses inspected by the remotely located official veterinarian. A total of 221

carcasses (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 baseline 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).

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 more difficult (HONKA et al., 2023). The use of new technology as an integral part of meat inspection should help resolve this problem and contribute to freeing official veterinarians/auxiliaries to perform other tasks. However,

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according to Anne Klottrup from the Danish Veterinary and Food Administration (Figure 4), 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.

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 Alimentar-

ius, 2005). The deadline for Brazilian abattoirs to join the RBIS is December 2028.

The RBIS is exclusively applicable under the following conditions:

- 1) Intensive industrial swine production (raised exclusively indoors),
- 2) Pigs under six 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 the identification and prioritisation of relevant hazards. Next, a statistical study determined the prevalence 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 the 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).

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 using traditional methods, as noted in Figure 5. 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



Fig. 5: Pig slaughter in Nagaland, North-east India, by spearing – a relatively quick and humane method Photo: Delia Grace

slaughter slabs, AM inspection is mostly neglected, and visual inspection of carcasses 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). Animals killed in ritual slaughter or as bushmeat are never inspected, an additional challenge 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 meat safety assurance approaches that have yet to be adopted on a 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 on hazard analysis and critical control points (HACCP) that cover the entire supply chain. To do this, scientific knowledge of 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 the 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 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 a lack of agreement on how to undertake meat inspection could easily result in trade barriers. Finally, capacity-

building of primary producers, abattoir workers and 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 <https://ribmins.com/category/training-schools/>. 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 the development of risk-based meat safety assurance systems that are now ready to be taken forward to widespread implementation in Europe and beyond.

The reference list can be obtained upon contact to Lis Alban.

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