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Remote ante mortem inspection – Possibilities for improved sustainability in low-capacity slaughter

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ABSTRACT

Official compulsory meat inspections (MI) are performed by official veterinarian (OV) on-site at abattoir. Scarce official control staff and travelling needs in low-capacity enterprises may be challenging and lead to negative effects for food business operators and competent authorities. Technical solutions could contribute to solve some problems and improve environmental sustainability, logistics resilience and working conditions. This study examined the feasibility of remote ante mortem inspection (AMI) in low-capacity abattoir using digital devices and commercial software (FaceTime) and measure the effects on control costs and emission of CO_2. A comparison of AMI results performed on-site and remotely, of 1177 animals (786 sheep, 234 cattle, 90 pigs, and 67 goats) during 38 slaughter days 2022 was carried out. In total about 1.8% of the animals had non-compliances at AMI and mostly in cattle (16/234) followed by sheep (4/786) while all included goats and pigs were without non-compliances. All animals were declared fit for slaughter. On-site OVs recorded in total nine of the 20 non-compliances consistent with remote results. Overall agreement was 99.1%, Cohen's kappa 0.617 (0.391, 0.842) and prevalence and bias adjusted kappa (PABAK) 0.981 (0.967, 0.991). The remote veterinarian recorded more non-compliances than OV on-site (McNemar's test, p-value = 0.003). A reduction in driving by control staff reduced the costs and emissions of CO_2; 93% and 89%; respectively.

The overall agreement between remote and on-site AMI results was good. Inter-rater variability was obviously caused by subjective judgements for certain non-compliances, however food safety and animal health and welfare were not compromised by remote AMI. The use of digital devices to increase the sustainability of MI in low-capacity slaughter located in geographically remote areas can be an important part of the future risk-based meat safety assurance system when supported by a strong food safety culture and trust between competent authorities and food business operators.

1. Introduction

Official meat inspections (MI) at commercial abattoirs consist of two mandatory activities: ante mortem inspection (AMI) of live animals and post mortem inspection (PMI) of carcasses and organs. The AMI is defined as the verification of human and animal health, and animal welfare requirements, (EU, 2017, article 17). Official veterinarians (OVs) are in charge of the MI and AMI which is to be carried out by OV in person on-site at the abattoir or where the animals are at emergency slaughter or slaughter in the holding of provenance (EU, 2019a). The documented shortage of OVs at abattoirs reflects the overall shortage of veterinarians in Sweden today (SOU, 2022). OVs consider this part of control as an important task and do not give less attention to AMI in case of shortage of OV staff (Luukkanen et al., 2017).

MI at the abattoir level is an vital source of information concerning the state of the primary production premises, i.e. at farm level (Losada-Espinosa et al., 2021) and the MI is a key activity to ensure good animal health (Alban et al., 2011) and welfare (Stärk et al., 2014). This is also the case for food safety where the hazards and risks concerning human health should be mitigated at the pre-harvest level before entering the food chain (WHO, 2001). Principles of risk analysis, accompanied by proportionality and precaution, are implemented in AMI while being the first phase of the control process of the harvest. (EU, 2002).

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Technical development of official control can help member states of the European Union (EU) to achieve the goals of impartiality, quality, consistency and effectiveness. Moreover, the European Commission is obliged to take into account experience gained, as well as technical and scientific developments when adopting new legislation (EU, 2017).

Sweden is a relatively small meat-producing country in the world (Atlasbig, 2023), and a vast majority of abattoirs are low-capacity (<1000 livestock units and 3% of total red meat production per year) and are often located at a considerable distance from official control staff offices (Kautto & Comin, 2023) resulting in long distance travelling by car. The possible positive environmental sustainability effects of slaughter animals (e.g., free ranging, near to abattoir), are somewhat contradicted by the emissions of CO_2 from official control. Driving conditions can be stressful for OVs and extreme weather, staff shortage and technical problems can hamper or delay MI, causing logistics problems and economical losses for the food business operators (FBOs). These problems could be addressed by a user-friendly, secure, reliable and economically sustainable, digital system for remote MI to guarantee the main goals of MI, namely food safety, animal health and animal welfare.

In 2019, the Swedish Food Agency (SFA) initiated a research project at the Swedish University of Agricultural Sciences (SLU) concerning remote PMI as a feasible alternative to performing PMI on pigs in well-defined conditions (Almqvist, 2021). Further studies have been carried out at abattoirs, where the possibility of relying on digital devices to perform PMI remotely has been tested (Kautto & Comin, 2023).

To our knowledge, there are no studies published concerning remote AMI of domestic or farmed animals using technical devices. The objective of this study was to investigate the feasibility and reliability of remote AMI in the slaughter of sheep, goats, cattle and finishing pigs slaughtered at low-capacity abattoirs using non-expensive digital shelfware without compromising food safety, animal health or animal welfare. The CO_2 emissions were compared between routine control and remote AMI.

2. Material and methods

2.1. Study site

The abattoir was a low-capacity abattoir (EU, 2019b) for cattle, accommodating calves (221 units per year), sheep and lambs (135 units), pigs including sows and boars (48 units), and goats (10 units) and is located away from the official control office. Livestock Units (LU) are as follows: (a) adult bovine animal is equal to one LU, (b) other bovine animals: 0.50 LU, (c) pigs with a live weight of over 100 kg: 0.20 LU, (d) other pigs: 0.15 LU, (e) sheep and goats: 0.10 LU, and (f) lambs, kids and piglets of less than 15 kg live weight: 0.05 LU (EU, 2009).

Animals were transported by farmers on approved animal transport means, nearby (under 100 km), and with a very few exceptions of about 300 km away. Primary producers were all small-scale farmers with one exception, a conventional dairy production establishment with robotic milking. Written Food Chain Information (FCI) documents accompanied the animals (EU, 2004b) were checked at the lairage during AMI.

2.2. Data collection

The study period consisted of 38 slaughter days between March and December 2022, excluding some days due to summer or sick leave of the on-site technical support person (TSP, sender). The single TSP in the project was a professional butcher with 30-year experience in rearing, handling and slaughtering of domestic animals and wild game employed by the abattoir company. The TSP at the abattoir lairage contacted the remote project OV (receiver, pOV) at the remote location using smartphones and a commercially available software (FaceTime). Every AMI occasion used Internet 100 MB fibre with routers on-site at the lairage and at the office of the pOV. On two AMI occasions, the receiver used a 4G/5G mobile network with good communication signals and quality equal to the contact's 100 MB fibre.

The unit of interest, the individual animal, was inspected individually according to a defined procedure following the standard AMI routine at SFA. The TSP filmed the animal at a distance between 0.5 and 1 m to check the general body condition, contours, and cleanliness. The closer control checked especially tattoo marking, earmarks, head region (eyes, mouth, and nostrils), skin, hoofs, joints, udder, anus region and testicles. More detailed controls were performed in case of extra information, for example, in cases of longer transportation.

Sheep and pigs were inspected as a group, paying special attention to individuals with abnormal behavior, and thereafter individually in order to detect any clinical signs of infections (e.g., watery eyes, nostrils, mouth, diarrhoea) or other disorders (e.g., traumata) in the same manner as performed for cattle. This procedure should discover whether the animals had a disease or a condition that may adversely affect human or animal health, or animal welfare. The on-site OV inspected the same animals inspected remotely. No communication took place between the pOV (the same person throughout the project) and the on-site OVs (nine in total). Four of the on-site OVs inspected 81% of the slaughter days (31/38 slaughter days).

The average cost for a car used was 3.5 SEK per km and for driving time 950 SEK (velocity 60 km/h) (2022). The amount of km the ordinary OVs were travelling in 38 slaughter days was calculated from the internal database at SFA, as well as the number of animals with a Total Condemnation (TC, carcass and offal not fit for human consumption) decision. Emissions of CO_2 from a middle size car used by OV staff was calculated using the independent on-line calculator by a non-profit organisation (utsläppsrätt.se).

2.3. Data processing

The AMI results of the pOV and the on-site OV on the very same animals in the SFA database were compared and all the AMI results, as well as any TCs in this low-capacity abattoir were compared to the data covering all abattoirs in Sweden during 2022.

Descriptive statistics, overall agreement, Cohen's kappa (Cohen, 1960) and prevalence and bias adjusted kappa (PABAK) (Byrt et al., 1993), as well as McNemar's test with continuity correction (McNemar, 1947) were used to present and analyse the data. The used software was R (R Core Team, 2022) and package epiR (Stevenson et al., 2023).

The definition of the non-compliances from the AMI were classified according to the guidelines used in routine MI at SFA (Livsmedelsverket, 2022). Incoming animals recorded as clean or dirty were graded according to the system of the Swedish Meat Companies Association (Köttföretagen, 2022) where 0-animal is clean or has slight impurities and only on a small extents on critical skin areas, 1-animal has a tangible presence of manure on critical skin areas.

3. Results

Total slaughter at the study abattoir during 2022 was 1456 sheep (17,292 kg, including lambs), 326 cattle (56,160 kg), 214 pigs (6840 kg, including two sows and six boars), and 133 goats (871 kg). In this study, AMI of 1177 animals (786 sheep, 234 cattle, 90 pigs, 67 goats), i.e., 81% of the 2022 slaughter, were included. Animal types, classifications, weights and AMI non-compliances recorded are listed in Table 1. AMI results documented by pOV and on-site OV are presented in Table 2. The infrastructure of slaughter and the AMI results at the national level (2022) can be found in the Supplementary Material.

In our study, about 1.8% (20 out of 1177) of the slaughtered animals had some type of non-compliances at AMI. Allocated to the different animal types, the most findings were in cattle (16/234 cattle, 6.8%) followed by sheep (4/786 sheep, 0.5%). In total, 67 goats were slaughtered, and no non-compliance was found, nor in the 90 pigs (including two sows) checked. All animals were declared fit for

Table 1
Animal type, EUROP-classification (EEC, 1981) and fat class, weight and type of non-compliance in AMI by pOV. Those in bold noted by both pOV and the OV on site.

Animal type	EUROP	Fat	Weight kg	AMI finding
Cattle	P+	3+	215	**Abscess**
Cattle	O+	4+	341	**Abscess**
Cattle	R-	3	254	**Actinosis**[a]
Cattle	P-	2-	167	Lean, thin
Cattle	P-	2+	116	Lean, thin
Cattle	P-	2	166	Lean, thin
Cattle	P-	2+	153	Long hooved
Cattle	P	3-	111	Dirty
Cattle	P	3-	123	Dirty
Cattle	P+	3-	135	Dirty
Cattle	P	3-	141	Dirty
Cattle	P	3+	204	Dirty
Cattle	P+	3	180	Dirty
Cattle	O-	3+	203	Dirty
Cattle	P-	2+	185	**Trauma**
Cattle	P+	3	274	**Swollen elbow joint area**
Sheep	U	3+	22	**Rectal prolapse**
Sheep	E-	2+	32	**Long hooved**
Sheep	E	2+	30	**Long hooved**
Sheep	U+	4-	28	**ID lacking**

[a] *Actinobacillus ligniersii (only soft tissues affected) or A. bovis (osteomyelitis), final diagnosis in PMI.*

Table 2
Summary of the non-compliances documented by remote project OV (pOV +) and OV on-site (OV+) and number of animals without any non-compliances according pOV (POV-) and OV on-site (OV-).

	pOV +	pOV-	Sum
OV +	9	0	9
OV -	11	1157	1168
Sum	20	1157	1177

slaughter in AMI. Overall agreement between pOV OV and on-site OV was 99.1%, Cohen's kappa 0.617 (0.391, 0.842) and Bapak 0.981 (0.967, 0.991). McNemar's chi-squared test with continuity correction showed statistical difference, pOV recording more non-compliances than OV on-site (Chi $^2 = 9.091$, p = value 0.00257, df = 1) (Table 2).

The control time for the OV performing the AMI on mobile devices did not differ from the on-site AMI. According to the SFA control-fee calculator, the AMI control time is 1.5 min/10 goats/sheep/pigs and 6 min/10 cattle/sows/boars in low-capacity slaughter. No extra time beyond normal reception check was needed for the abattoir employed TSP supporting the pOV including FCI control. The streaming quality of the video with sound was evaluated as "good" by both sender and receiver on all occasions.

The total cost for the on-site OV visits in 38 slaughter days was 2.08 SEK/kg (See Supplementary material, 168,752 SEK/81,163 kg of slaughter weight) covering AMI and PMI. If the carcass is declared TC, according to the SFA protocol an OV has to be on-site to make this decision. Two cases were TC in PMI and amounted to a total 542 km, equivalent 1897 SEK for km cost, and 9 h, equivalent 8582 SEK for OV time used for driving. Consequently, the total of 10,479 SEK for travel, giving 0.13 SEK/kg slaughter weight (minus 93% compared to 2.08 SEK) would have been the cost of using remote AMI and PMI. Calculated emission of CO_2 for on-site OV travel by car for 5127 km was 0.976 ton and for travels only for 542 km for TC decisions was 0.103 ton (minus 89%).

4. Discussion

In MI it is necessary to deal with sustainability concerning environmental effects, resilience of food production, food security, economic costs and good working environment for both FBO and OV staff without compromising with food safety, animal health and welfare.

The first comprehensive EU food legislation package ("Hygiene Package") was implemented in 2006 and focused on the ability to fulfil objective criteria (EU, 2002; EU, 2004a; EU, 2004b; EU, 2004c). Subsequently, this legislation has become more detailed. According to Nagel-Alne et al. (2022), normative regulations can create obstacles to innovation and there is a mutual dependency between risk-based legislation and conditional flexibility, as well as between functional demands and control activities targeted at measurable objective criteria.

Even if OVs can get assistance in performing the controls, the final responsibility lies with the OVs (article 18.5, EU, 2017). To improve the efficiency and leverage the use of scarce OV resources, there is a need for new technical tools such as MI on remote devices. This is consistent with the obligations set by the EU Commission when adopting delegated and implementing acts for control in the food chain which must take into account the experience gained as well as technical and scientific developments (EU, 2017).

The study on the low-capacity abattoir was on remote distance and slaughtering animals mainly raised in the vicinity. Non-compliances recorded in AMI are few, giving a high level of overall agreement and even an almost perfect PABAK, reflecting the same observations made by Almqvist et al. (2021). The sample size is limited but sufficient to reflect the circumstances in AMI. The subjectivity in judgement of cleanliness, long hooves and thinness of the animals can be seen in the inter-rater variability between pOV and on-site OV. Inter-rater variability is known even in PMI and some non-compliances are more consistent than others (Comin et al., 2023; Kautto & Comin, 2023). According to other studies (Almqvist et al., 2021, 2023; Kautto & Comin, 2023), the use of digital devices in remote PMI does not negatively affect the inter-rater reliability. We assume that the same should apply to AMI. Sources of differences in professional judgements are both bias (i.e., the average error in judgments) and noise (i.e., the variability of error in judgements). The grade of objectivity is directly connected to the level of noise (Kahneman et al., 2021). Many activities (e.g., training) are needed to reach more precise decisions. Digital devices can be used as technical tools in strive for better "decision hygiene" according to the strategies by Kahneman et al. (2021). An OV performing remote AMI or PMI could easily get a second opinion from another remote online OV, who is working in another part of the country. Better "decision hygiene" contributes to consistency and effectiveness of MI. MI documentation systems vary greatly across the EU and should benefit from their harmonization in regard to various national epidemiological situations (Alban et al., 2022). Regardless of whether the MI is done remotely or on-site, it is of great importance that inter-rater variability is minimized and kept on the level where hazards are mitigated to an acceptable level of protection. We conclude that a pOV with smartphones is at least as capable as an on-site OV to detect non-compliances in animals. In some cases, even better; indeed, a parasite in new host animal has been found in PMI thanks to remote devices (Kautto et al., 2022).

The physical circumstances for OVs using digital remote devices have to be adequate, including good lighting and Wi-Fi or mobile net at the abattoir. The TSP on-site has to be trained to film the animals. Communication and vocal signals from the animals are also important. The time taken to perform AMI in our study was the same as it would be on-site. Vigilance that is the capability to be sensitive to potential changes in one's environment – in our case non-compliances in animals going to slaughter – is a level of alertness above the threshold for a certain period of time (Schie et al., 2021). The time per occasions for AMI in low-capacity slaughter are, in our opinion, so short, both on-site and remote, that the vigilance can be kept high enough.

In general, if MI is to be improved, it is crucial to mitigate the information asymmetry from the pre-harvest stage to slaughter by better FCI. According to Felin et al. (2016), the incoming FCI is not good enough because most of the zoonoses relevant to pig meat safety appear as latent infections with asymptomatic incoming animals. Thus for example pre-scoring serological monitoring, could improve the FCI system and should be applicable at the EU level.

An effective risk-based MI can be reached with clearly defined positions and roles for FBOs and CA along the food chain giving minimum administrative burden, trusting relationships, and more effective and equal control with competence-based cooperation (Salines et al., 2018). This could be a firm foundation for the meat safety assurance system (MSAS, Ferri et al., 2023). The final model for the remote MI, including remote TC decisions, should be well defined and based on risk assessments taking in to account, for example, the type and volume of slaughter or game handling, animal health status of the region, risk category of the farm, as well as abattoir or game handling establishment (GHE), the latest results in AMI, PMI and from control of FBO. High competence level of OVs, as well as a strong food safety culture within FBOs are important for the trust needed for effective co-operation along the food chain when new technical devices become a part of the future MSAS.

Many low-capacity abattoirs, creates higher CO_2 emissions due to the inspectors' travels by car and unsustainable burdens for the FBOs and CAs with high costs. In our case, the travelling costs could be reduced by 93% in SEK/kg slaughter weight, if both the AMI and PMI could be performed remotely with only the TC checked on-site, as demanded today. The AMI and PMI in large abattoirs have zero emission of CO_2 from driving and the lowest cost per slaughter weight, with average costs of 0.32 SEK/kg slaughter weight (in total 191 abattoirs during 2022, Livsmedelsverket, 2023), while the slaughter of reindeers is one of the costliest, 0.53 SEK/kg slaughter weight (Kautto et al., 2017) with large emissions of CO_2 from OV staff travels in concordance with our study abattoir. Sweden is the 63rd most polluting country of 184 countries globally with regard to CO_2 emissions (Country economy, 2023). MI is a mandatory activity and should diminish CO_2 emissions according to the international goals (UN, 2023; EU, 2023) and be part of the decreasing trend in the country (Country economy, 2023).

The remote MI method, with non-expensive smartphones, should be implemented in the future EU legislation as an enhanced flexibility option. Direct positive effects could be gained if remote AMI is performed in control times of high pressure, establishments in geographically constrained areas, in slaughter on the holding of provenance and in emergency slaughter creating independency from scarce OV resources, bad weather and other hampering conditions. Remote AMI is undoubtedly an important factor for the sustainability and resilience of operations for low-capacity slaughter and GHE located in geographically remote areas.

5. Conclusions

The inter-rater variability in AMI needs to be mitigated for better decision hygiene in general.

The use of digital devices in remote AMI does not compromise food safety, animal health or welfare.

Remote AMI could reduce the emissions of CO_2 from official control while helping improved working conditions for control staff and FBOs.

New technical devices can play an important role in the future risk-based meat safety assurance system.

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Arja Helena Kautto: Conceptualization, Formal analysis, Project administration, Investigation, Methodology, Software, Writing - original draft, Writing - review & editing. **Ingrid Medin:** project planning, writing -review & editing, **Viktor Almqvist:** Wrtiting - review & editing, **Sofia Boqvist:** Writing - review & editing, **Ivar Vågsholm:** Conceptualization, project planning, writing - review & editing.

Declaration of competing interest

None.

Data availability

Data is presented in the article

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Appendix A. Supplementary data

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