Epidemiology And Infection
August 2015, Volume 143 Issue 11 Pages 2459-2472
http://dx.doi.org/10.1017/S0950268814003379
http://archimer.ifremer.fr/doc/00273/38472/

Contribution of Meat Inspection to the surveillance of poultry health and welfare in the European Union

Huneau-Salaün A. [1, *], Staerk K. D. C. [2, 3], Mateus A. [2, 3], Lupo Coralie [4], Lindberg A. [5], Le Bouquin-Leneveu S. [1]

[1] ANSES, Ploufragan Plouzane Lab, Ploufragan, France.
[2] SAFOSO Inc, Bern, Switzerland.
[3] Royal Vet Coll, Hertford, Herts, England.
[4] IFREMER, LGPMM SG2M, La Tremblade, France.
[5] Natl Vet Inst, S-75007 Uppsala, Sweden.

* Corresponding author : A. Huneau-Salaün, email address : adeline.huneau@anses.fr

Abstract :

In the European Union, Meat Inspection (MI) aims to protect public health by ensuring that minimal hazardous material enters in the food chain. It also contributes to the detection and monitoring of animal diseases and welfare problems but its utility for animal surveillance has been assessed partially for some diseases only. Using the example of poultry production, we propose a complete assessment of MI as a health surveillance system. MI allows a long-term syndromic surveillance of poultry health but its contribution is lowered by a lack of data standardization, analysis and reporting. In addition, the probability of case detection for 20 diseases and welfare conditions was quantified using a scenario tree modelling approach, with input data based on literature and expert opinion. The sensitivity of MI appeared to be very high to detect most of the conditions studied because MI is performed at batch level and applied to a high number of birds per batch.

Keywords : Animal welfare, disease surveillance, Meat Inspection, poultry

1. Introduction : From the past to the current: Why does meat inspection have to evolve?

Meat Inspection (MI) is a control process commonly described as a set of tasks carried out at slaughterhouse and sometimes at farm to ensure that animals entering the food chain comply with the legal hygiene requirements for human consumption. The major aim of MI is therefore to protect the public from hazards, such as infectious agents, that could be transmitted or carried by meat (contamination). The increasing burden of food-borne illnesses and the rapid changes in food production and food exchanges in the world led the Food and Agriculture Organization and the World Health Organization to propose ~~new~~ guidelines for strengthening food control systems. Taking into account this international context, a new European legislation, relying on the White Paper on Food Safety published in 2000, has been developed. It aims to base food control systems on an integrated "farm-to-fork" approach and on a risk analysis process. The White Paper was the stepping stone for the three Hygiene Regulations known as the Hygiene Package, that deal with all foods and that cover the entire food chain (2). In the Hygiene Package, the Regulation 854/2004 lays down specific rules for the organization of official controls on animal products (3).

The first conclusions on the application of this regulation drawn by the Chief Veterinary Officers of the European Member States in 2008 showed that a modernization of sanitary inspection in slaughterhouses was needed to fully exploit benefits from a risk-based approach. Consequently, the European Commission (4) mandated EFSA to evaluate the capacity of the current MI to assess the fitness of meat for human consumption and, if needed, to propose modifications to ensure an appropriate level of Public Health Protection (Mandate 1005) (5); the questions had to be considered separately for the main animal production systems in Europe, including poultry. As the main Public Health hazards in poultry products could not be detected by the current visual MI (6), proposed changes in MI procedures were expected to be important. In addition to the protection of Public Health, MI also contributes to animal health and welfare surveillance by detecting and monitoring disease syndromes and welfare problems that are not reported at farm level. The EFSA panel on Animal Health and Animal Welfare (AHAW) was mandated to assess the potential consequences on animal health and welfare surveillance of the changes in the current MI system proposed by the other EFSA panels.

The objective of our paper was to present findings of this assessment and to demonstrate how this evaluation evolved from an empirical and practical experience to a global and quantitative assessment. This paper focuses only on poultry species but reports on other species have been published on the EFSA website (http://www.efsa.europa.eu, topic Meat Inspection). Firstly, a literature review will describe the past experiences demonstrating the contribution of the current MI procedures to poultry health surveillance. Secondly, the methodology and the main results will be shown. Elements dealing with the impact of the modernization of MI on poultry health surveillance can be found elsewhere (6).

2. Surveillance of animal health and welfare during the current MI procedure

The current MI procedure in the European Union is described for all species in the Annex I of the Regulation 854/2004 (7) with special dispositions for poultry species in Section IV, Chapter V. The epidemiological unit of interest in MI is a batch of poultry i.e. poultry reared on the same holding and sent to slaughter in a single transport. The MI for poultry consists in three inspection tasks carried out under the supervision of the Official Veterinarian (OV). MI tasks can be delegated to official auxiliaries operating under the supervision of the OV

(Annex I, Section III, Chapter III and part A). In poultry and lagomorphs abattoirs, these auxiliaries may be from the slaughterhouse staff provided that the inspection staff acts independently from the production staff and they receive appropriate training provided by the Official Veterinary Authorities.

2.1. The Food Chain Information

The first step of MI is devoted to checking and analyzing Food Chain Information (FCI) i.e. relevant information on animals' identification and on animals' health transmitted from the holding of provenance. Required FCI is described in Annex II Section III of the Regulation 853/2004 (7); most of the Member States collect harmonized FCI at national level via a standardized declaration form. FCI has to be transmitted to the OV at least 24 hours before slaughtering, when the *ante-mortem* inspection is carried out at the abattoir. If the birds have been inspected at the farm of origin, FCI can be provided before unloading the batch in the slaughterhouse. FCI is based on declarations of farmers and Food Business Operators (FBO). The reliability of FCI might be questionable. However Lupo et al. (8) concluded that FCI transmitted to slaughterhouses was concordant with on-farm observations collected by independent investigators. FCI analysis is a direct application of the risk-based approach because results from FCI have to be taken into account to adapt the thoroughness of the inspection process accordingly to the health status of the batch. The study of Lupo et al. (9) showed that FCI was relevant to identify batches of broilers with a high risk of sanitary condemnation, demonstrating the usefulness of FCI for a risk-based MI. Various measures could be taken in response to the estimated risk of condemnation shown by a batch of poultry as slowing down the slaughter line speed to allow in-depth inspection. In France, an experimental program is presently carried out to define a standardized frame of application of the risk-based inspection and to estimate its practicality under commercial conditions (10).

2.2. The *Ante-Mortem* Inspection

The second inspection task is the *ante-mortem* inspection (AMI) which takes place at slaughterhouse in most of the Member States but that can be also carried out at farm for poultry species. AMI mainly aims to detect any sign indicating that animal welfare has been compromised during handling and transport or that animals are affected by conditions likely to adversely affect animal or human health. In particular, stress caused by loading and transport may enhance the expression of clinical signs in animals suffering from a disease at incubation or subclinical stages. There are two to three points of control for AMI (11); inspection in crates, inspection after unloading and inspection after stunning. Only a sample of crates is inspected before unloading but all birds are individually observed during the manual shackling. AMI is the key stage for monitoring welfare conditions relative to handling and transport of poultry (e.g. dead on arrival, thermal comfort during transport) but Regulation 854/2004 also states that special attention should be taken during AMI on the detection of diseases on the list of the OIE (12). For instance, avian botulism can only be detected during the inspection of live birds due to its pathognomonic clinical signs (flaccid paralysis of the neck, wings and/or legs) as no visible lesion can be detected during *Post-mortem* Inspection (PMI).

2.3. The *Post-mortem* Inspection

The third task is the *Post-Mortem* Inspection of the whole plucked carcass, the viscera and the carcass after evisceration (including the body cavity). PMI is designed to detect and withdraw from the food chain carcasses showing grossly identifiable abnormalities that may affect their safety or wholesomeness; special attention should be also put to the detection of zoonotic diseases and of diseases classified in the list of the OIE (12). On the contrary to the previous inspection tasks that are mostly done at batch level, PMI is carried out at individual level implying that all carcasses are to be inspected. PMI leads to condemnation of the carcasses or parts of them that are judged to be unfit for human consumption, based on a visual inspection. Reasons for carcass condemnation are not explicitly described in the Regulation 854/2004 but possible origins of unfit meat are exhaustively listed. Condemnation for poultry carcasses is based on visual macroscopic criteria that are rarely pathognomonic. As an example, the most frequent reasons of condemnations in broiler and turkey broiler batches in France are emaciation and congestion, which are generic terms concordant with a large spectrum of diseases and conditions (13, 14). A few infectious or parasitic diseases may lead to pathognomonic lesions enabling a direct diagnostic during PMI. For instance, histomoniasis (*Histomonas meleagridis*) sometimes leads to characteristic round lesions on liver that could be detected during manual evisceration (15) but birds affected at such an advanced stage of the disease are normally unfit for slaughter. Avian tuberculosis (*Mycobacterium avium*) is a chronic infection with a protracted course that may be unnoticed at farm but typical tubercular granulomata can be easily detected on the spleen and liver during PMI (16). Nevertheless, a reason for condemnation is generally given with no inference on the etiology of the lesions. As an example, in a study on carcasses condemned for skin lesions, Fallavena et al (17) concluded that cutaneous macroscopic changes as observed at PMI were not specific and did not allow accurate identification of skin diseases.

3. Specific contribution of the current MI to poultry health and welfare surveillance

3.1. A two-way information flow: an opportunity for poultry health surveillance

The Regulation 854/2004 requires a transmission of the results from MI to the FBOs and to the primary producer when the detected problems may be related to rearing conditions. This disposition establishes the principle of a two-way information flow: from the farm to the slaughterhouse with the FCI and from the abattoir to the farm with the transmission of MI results. There are some practical examples of benefits from feedback transmission of MI observations. A pilot study reported by Ansong-Danquah et al (18) was carried out in a Canadian abattoir during five years in 1980s, with a systematic feedback of MI results to farmers and to broiler companies. During the first two years, lesions caused by Marek's disease were the primary cause of carcass condemnations, underlining insufficient vaccination coverage of the broiler population. Vaccination programs were therefore reinforced by the broiler companies and condemnations for lesions due to Marek's disease were no more relevant during the last three years of the experiment.

3.2. Integration of welfare surveillance

The recent evolution of the assessment of animal welfare towards the monitoring of animal-based welfare indicators (19) gives a new dimension to PMI. As demonstrated in the Welfare Quality project (20), animal-based welfare-outcome indicators related to body condition in poultry can be more easily and more accurately monitored during PMI than on-farm. This is the case for injuries, hematomas, scratches, foot-pad dermatitis, hock burns and breast blisters, which are more visible on shackled and plucked carcasses. Ascites characterized by an accumulation of liquid in the body cavity is also better detected during PMI than on farm or at AMI. These conditions provide information on welfare during handling and transport but also on welfare during rearing, since most of the indicators are significantly associated with on-farm factors (21, 22). The Swedish Broiler Welfare Program demonstrates that the regulation of broiler density during rearing, based on the prevalence of footpad dermatitis observed during PMI, can reduce the incidence of this problem (23, 24).

The implementation of the Directive 2007/43/EC on broiler protection is going to generalize the use of PMI for collection of animal-based welfare indicators; results from PMI become one of the key indicators to allow derogation to the maximum stocking density during rearing.

3.3. Concrete examples of MI contribution to poultry health surveillance

Despite the fact that the main aim of MI is to protect public health from food-borne hazards, it also allows monitoring animal health and welfare. This system can both contribute to the detection of cases of an emerging or re-emerging animal disease and to the monitoring of the prevalence of endemic diseases and welfare conditions. Although these contributions to animal health surveillance are potentially high, there are few examples in the literature clearly demonstrating the value of MI in this context (Table 1). Most of these studies rely on an in-depth *post-mortem* inspection, sometimes completed by histological and bacteriological analysis. Furthermore, outputs of these studies are rarely analysed in another way than the economical impact of condemnations for producers and FBOs. Discussions proposed by the authors on the contribution of MI to animal health surveillance are summarized in Table 1.
A relevant experience of the MI contribution to poultry health surveillance is the emergence of cellulitis in North America. At the end of 1990s, a sharp increase in carcass condemnations was detected in Canadian poultry abattoirs (25), due to a new kind of skin lesion classified as cellulitis. Examination of condemned carcasses of broilers and turkeys enabled the precise description of this condition, which was not visible on animals at farm nor at AMI as it is a subclinical syndrome (26). A monitoring program of the percentage of carcass condemnations for cellulitis was consequently started in federal abattoirs. This program allowed to quantify the increasing incidence of cellulitis during the following years (27). Observations during PMI were also used to classify batches in accordance to their level of condemnation for cellulitis; this classification was the basis for an analytical epidemiological survey to identify risk factors for cellulitis on poultry farms (28).

4. Assessing the contribution of MI to poultry health and welfare surveillance in Europe

4.1. Qualitative assessment of the contribution of MI to poultry health surveillance

Surveillance is defined as a systematic ongoing collection, aggregation, and analysis of data and the timely transmission of information to the risk manager in order to take mitigation measures (29). MI can be considered as a component of a syndromic surveillance carried out at slaughter level: FCI, clinical signs and gross lesions are used to monitor various health hazards, without further diagnosis. The Table 2 provides a list of criteria to assess the quality of a surveillance system, adapted from Salman et al. (30), and its application to the current MI system in poultry. Most of the quality criteria could be assessed from a complete description of MI procedures, as carried out by Löhren (2012), but estimation of sensitivity and positive predictive value could only be obtained by experiment (31) or by modeling using methods such as latent classes (32, 33) or as decision tree scenarios.

Despite this lack of available data on performance, the quality assessment was used to produce a short SWOT analysis of MI as a surveillance component (Table 3)(34). MI is now a long-standing and well-accepted surveillance component in Europe. One of its major strengths is its high representativeness: mortality rates of poultry during rearing are relatively low in the European Union, implying that most of the birds entering in production are sent to the abattoir and submitted to MI. MI may be considered as an early-warning surveillance as any modification in health state of animals could be timely detected. However emerging or re-emerging diseases are expected to be detected before slaughter (clinical surveillance at farm) and MI is rather the ultimate component of a passive (or reactive) surveillance system, which raises the alarm when the others components fail. The special case of MI in poultry is that the inspection is carried out at both batch and bird levels. The global approach at batch level is of interest in animal health surveillance: warning thresholds could be set up for main health indicators and standardized measures proposed in response to the alerts. The use of the MI system for the surveillance of animal health does not add supplementary costs to the expenses already incurred for public health protection; it is therefore an inexpensive way to monitor animal health. Regarding weaknesses, there are basically several technical factors (for example, speed of the line and lighting) that may interfere with the detection of health problems. The results of MI may also depend on staff experience. A systematic use of AMI observations and condemnation results for health surveillance would need the centralization of results in a harmonized frame of collection and specific staff devoted to results analysis. MI is not an “enhanced passive” surveillance component (29), as there is no general and active supervision of MI results in terms of animal health and welfare. In addition to technical constraints and difficulties in data centralization, flexibility of MI is rather low because its general frame is fixed by European and national regulations: any modification in the procedure needs time, staff formation and sometimes financial resources in order for it to be implemented at a national level. The risk-based approach adopted with the Hygiene Package is an opportunity for the optimization of MI as a surveillance component. However the risk-based surveillance only targets the needs for public health protection: the new dispositions may constitute the main threat to the contribution of MI to animal health surveillance.

4.2. Quantitative assessment of the contribution of MI to poultry health surveillance

4.2.1. Methodology

The assessment of the sensitivity, i.e. the probability to detect cases, remains the key element in evaluating the performance of MI as a health surveillance system (35). We used quantitative decision tree scenario models to evaluate the sensitivity of MI as an animal surveillance system, parameterized with data from literature if available or by expert opinions. The approach is described in more detail by Stärk et al. (34). Briefly, the EFSA AHAW panel defined a list of 20 poultry diseases and welfare conditions to be addressed; the prioritization of diseases took into account the relevance of their surveillance at the slaughterhouse, their epidemiologic characteristics (epizootic or enzootic diseases) and their regulatory and/or economic importance. A bibliographic review was carried out to gather data on the prevalence of diseases and welfare conditions at flock level and at the European level and on risk factors associated with these conditions. The review was completed by elicitation of expert opinions to fill in gaps in knowledge identified. The elicitation was based on a modified Delphi method as described by Stärk et al. (36) and the questionnaires used for elicitation are available from the authors upon request.

For each disease or welfare condition, the most affected poultry (species, age and type of production i.e. egg, meat or breeder) was identified and typical and mild cases described by the experts (Figure). A typical case as seen during MI was defined by a set of symptoms and lesions that are likely to be observed in more than two thirds of birds affected by the given condition and presented for slaughter. A mild case was characterized by more subtle signs than a typical case but was still detectable during MI; it was assumed to be less frequent than a typical case. In a second step of the elicitation, experts were asked to provide estimates on the prevalence of affected batches arriving for slaughter, the proportion of typical and mild cases in an affected batch and the probability of detection of a typical case during each step of the MI procedure. The final outcome of the expert elicitation was an estimate (most likely ± range) of the probability of detection under the current MI procedure of a typical case for each of the 20 diseases or welfare conditions.

Next, the value of MI as a surveillance system was assessed, using two scenario tree-models: the “freedom of disease” approach for epizootic diseases (Highly Pathogen Avian Influenza (HPAI) and Newcastle disease) and the “detection fraction” approach for other enzootic diseases and welfare conditions (37). The “freedom of disease” approach measures the ability of a surveillance system to detect one or more infected birds and/or batch of birds if the frequency of the disease is higher than a designed prevalence in the monitored population (38). This method then evaluates the capacity of a surveillance system to detect an emerging or re-emerging disease and to give an “alert signal”. In the “detection fraction” approach, the value of a surveillance system is assessed by the proportion of cases of the disease detected by the surveillance; this approach is adapted to monitor prevalence of an enzootic disease. In both approaches, the models yield a probability of detection that could be interpreted as the sensitivity of the surveillance system. Consolidated estimates collected during expert elicitation for AMI and PMI were used as input, together with estimates of proportions of case types likely to be presented at the abattoir. The output was estimated by translation of the consolidated estimates into BetaPert distributions, and by using Monte-Carlo simulation (10,000 iterations). Each step of the model represents a node of a tree, and is run in the sequence shown in the figure. The most likely and 5th and 95th percentiles of the output distributions of AMI, PMI and the whole inspection process were derived for each diseases and conditions.

4.2.2. Sensitivity of MI for poultry health and welfare surveillance

The sensitivity of MI for detection of a “typical” case was estimated as high for most of the diseases and conditions studied (Table 4). This high sensitivity has to be examined taking into account some methodological limitations. The methodological development was an on-going process and was not fully consolidated when poultry was considered (one of the first species studied along with pigs). The first limitation was linked to the assumption that the probabilities of detection of abnormalities at each inspection step were independent, leading to a possible underestimation of the detection sensitivity for diseases demonstrating signs detectable at a small number of inspection points, as for botulism or “dead on arrival”. In addition, in a risk-based inspection, each inspection step has to be adapted taking into account the results of the previous steps, implying a dependence of the task results. Nevertheless, the sensitivity estimations given separately for each inspection step by the experts (37) suggested that the evaluation of FCI contributed more than the crate inspection to the detection of abnormalities during AMI. During PMI, visual inspection of organs and, to a lesser extent, of the body cavity were considered the most sensitive tasks for disease detection whereas observation of the whole carcass and the feet contributed the most to the detection of welfare problems. Another methodological difficulty was related to the organization of MI for poultry both at batch level (AMI) and at bird level (PMI). The sensitivity of detection of an affected batch (i.e. a batch with a least one affected bird) depended on the sensitivity of detection at bird level and also on the number of animals submitted to the MI. Since the size of a poultry batch is generally high (several thousands of birds), the sensitivity of detection at batch level was particularly high for all diseases and conditions. It is therefore expected that the inspection of a large number of animals will always be a very effective way of detecting diseases, even though the sensitivity of detection at bird level is low.

4.2.3. Relative contribution of MI to the global animal health surveillance system

In addition to the evaluation of sensitivity of MI to detect diseases and welfare problems, we assessed the relative contribution of MI to animal surveillance in comparison to other surveillance components existing in the European Union. One epizootic disease (Avian Influenza (AI)), three enzootic diseases (Aspergillosis, Colisepticaemia, Infectious Bursal Disease (IBD)) and one welfare problem (Ascites) were considered. For AI, a conventional scenario tree model for freedom of disease was used considering two surveillance components other than MI: clinical surveillance at farm (39) and serological surveillance (40). The estimated sensitivities at batch level (for a common batch size equals to 10,000 birds) were very high and similar for the three surveillance components considered (Table 5). A scenario tree model was already used to assess the sensitivity of AI surveillance system in

Canada (41) and in Catalonia (42). In these studies, MI was not taken into account in the surveillance system thus its sensitivity was not estimated. This omission suggests that MI is not considered as a means of AI detection, despite that surveillance of list A OIE diseases is one of the MI objectives. Our results showed, however, that MI could be as sensitive as other passive or active components of the surveillance system. It might be worth considering it when evaluating the effectiveness of the overall surveillance system. The Spanish study considered clinical surveillance at farm as a component of the surveillance system; the probability to detect a batch of broilers infected by HPAI was as high as we estimated in this project for AI in turkeys, but was considerably lower for Low Pathogenic Avian Influenza. Such a distinction according to AI pathogenicity could not be done in our project because data on epidemiology of HPAI and LPAI are lacking at the European scale.

For the four other enzootic conditions, a tree model based on the "detection fraction" approach was developed including MI and clinical surveillance as surveillance components. The detection fraction for colisepticaemia and IBD was estimated to be very high for a batch of 10,000 birds, both for clinical suspicion and MI (Table 6) because the within flock prevalence at farm was estimated as high by the experts (more than 30% of infected birds) and the farmer and veterinarian's awareness was expected to be also high for these diseases. The benefit of abattoir inspection over farm surveillance was therefore minimal. On the contrary, the incremental benefit of MI surveillance over the clinical surveillance turned out to be high for ascites. Experts estimated the probability of detection by the farmer to be low (less than 50%) for this condition: ascites cases are rare in a flock of broilers, occurring mainly at the end of the rearing period when farmers are not prone to ask for veterinarian visit and the symptoms are usually general and unspecific. The probability of detection of ascites was estimated as very high during PMI, leading to a higher value of MI than clinical surveillance for detecting ascites. For aspergillosis in breeder turkeys, the benefit of MI was also higher than for clinical suspicion but the detected fraction remained very low. This was due to low between- and within- flock prevalences and a high proportion of mild cases, which are more difficult to detect.

5. Conclusion

Surveillance of poultry health during MI is an example of a syndromic surveillance, as in most of the cases, no inference can be made on the etiologic cause based on the clinical signs and lesions observed during slaughter. MI enables to rapidly collect data on any health event but it does not contribute to early-warning surveillance as it takes place at the last step of the production chain; MI is rather the ultimate component of a passive surveillance system. Nevertheless, the increased use of animal-based welfare-indicators in the assessment of poultry welfare confers a new importance on MI, given that these indicators are more easily collected at slaughter than on farm. Despite that there is a common agreement on its interest, concrete and quantified examples of the contribution of MI to poultry health surveillance are lacking because surveillance data generated by MI are not harmonized at European level and they are not systematically collected and analyzed. However some past examples show that the two-way information flow from the farm to the slaughterhouse (FCI) and from the slaughterhouse to the farm (MI information) could be effectively used to monitor and even enhance poultry health and welfare. The models proposed to quantify the sensitivity of the current MI in the surveillance of both enzootic and epizootic diseases provide a tool which allows the assessment of the potential impact of a revised MI procedure on poultry health surveillance in Europe.

Acknowledgements

We acknowledge the contributions of the experts who participated in the expert elicitation exercise. We are also grateful to Mr. Georgiev from the Animal Health and Welfare Unit in EFSA and to members of the working group appointed by EFSA to integrate this work to AHAW scientific opinions, particularly to Prof. More. This work was supported by EFSA (Service Contract No CT/EFSA/AHAW/2010/05).

Declaration of Interest

None.

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Table1 Examples of studies using MI for monitoring health and welfare in poultry in Europe, North America, South America, Middle East and Asia. Classification of the studies according to their objectives: “case report" (description of a new condition), “prevalence” (assessment of condition prevalence and its temporal evolution), “etiology” (identification of the etiology of a condition) and “risk factors” (identification of factors associated with the occurrence of a condition)

Country	Objective	Condition	MI procedure	Discussion on the interest of MI in animal health surveillance	Source
UK	Prevalence	Causes of condemnation	Routine		(43)
UK	Prevalence Risk factors	Causes of condemnation	Routine	Difficulties in classification of causes of condemnation: lack of concordance between abattoirs	(44)
France	Prevalence Risk factors	Causes of condemnation	Routine		(13, 45)
France	Prevalence Risk factors	Causes of condemnation	Routine		(14)
France	Risk factors	Skin lesions	Routine	Broiler welfare during rearing can be assessed based on lesions observed during MI	(22)
Norway	Prevalence Etiology	Hepatic lesions	Routine	Suggest the use of the rate of condemnation for hepatic lesions as an indicator for the surveillance of necrotic enteritis in broilers	(46)
Ireland	Prevalence Risk factors	Bruises	Reinforced		(47)
Denmark	Prevalence Risk factors	Pododermatitis	Routine	Variation between abattoirs due to subjectivity of the inspection	(48)

Denmark	Etiology	Dead on Arrival	Reinforced	Dead on Arrival birds as observed during AMI are an accurate indicator of welfare conditions during pre-slaughter handling	(49)
Netherlands	Case report	Lesions due to *Ornithobacterium*	Routine	MI as an alarm system: increase in condemnations for aerosacculitis. Only mild symptoms at farm, not reported	(50)
Netherlands	Prevalence	Lesions due to Ornithobacterium	Reinforced		(51)
Lithuania	Prevalence	Causes of condemnation	Routine	Insufficient feed-back to farmers provided by MI services: data on carcass condemnations are not used to implement preventive measures at farm level	(52)
Bulgaria	Etiology	Nephropathy	Routine	Condemnations for nephropathies led to the identification of animal feed contamination by mycotoxins	(53)
Poland	Prevalence	Causes of condemnation	Routine		(54)
Canada	Case report	Cellulitis	Routine		(55)
Canada	Prevalence	Cellulitis	Routine	Subjectivity in condemnations, variation between abattoirs in inspection decisions	(56) (27)
Canada	Prevalence	Cellulitis	Routine	Interest on MI in detection of the emerging condition and its subsequent monitoring	(25)
Canada	Prevalence	Ascitis	Routine		(55)
Canada	Prevalence	Causes of condemnation	Routine		(57)
Canada	Prevalence	Causes of	Reinforced		(58)

		condemnation			
Canada	Etiology	Hepatic lesions	Reinforced		(59)
Canada	Risk factors	Cyanosis	Routine		(60)
Canada	Risk factors	Cellulitis	Reinforced		(28)
USA	Prevalence Etiology Risk factors	Squamous cell carcinoma	Routine		(61)
USA	Etiology	Septicemia	Reinforced	Experimental essay to assess the association between macroscopic lesions noticeable during PMI and causative agents	(31)
Brazil	Case report	Dorsal cranial myopathy	Routine	Report of a new form of myopathy on heavy broilers, only detectable at PMI	(62)
Brazil	Prevalence	Ascitis	Routine		(63)
Brazil	Prevalence	Aerosacculites Traumatic lesions	Routine	Suggest the use of data from MI by the industry to evaluate specific programs and identify areas of improvements	(64)
Brazil	Prevalence	Causes of condemnation	Routine		(65, 66)
Brazil	Etiology	Skin lesion syndrome	Reinforced	Macroscopic lesions are not specific, no inference on etiologic cause is possible	(17)
Brazil	Etiology	Aerosacculites	Reinforced		(67)
Saudi Arabia	Case report	Hemorrhages	Routine	MI as an alarm system: increase of condemnation of sub-cutaneous hemorrhages not detected at farm	(68)
Iran	Prevalence	Causes of	Routine		(69)

		condemnation			
Japan	Case report	Endocarditis	Routine	Report of broiler infection by *Streptococcus gallolyticus*: sub-clinical but visible lesions at PMI	(70)

Table 2 Qualitative assessment of MI as a surveillance component for health and welfare surveillance in poultry in the European Union (adapted from Salman *et al.* (30))

Parameter	Definition	Application to MI
Usefulness	Contribution to the prevention and control of diseases	Potentially high. Examples given for poultry
Simplicity	The ease of operating	Need training of operators and technical constraints are high
Flexibility	Ability of the system to adapt to changing information needs of operating conditions	Low: high number of operators. Modification needs to be applied in a harmonized way and may require legislation changes.
Quality of data	Completeness and validity	Potentially high for completeness Validity: harmonization of data collection in the regulations but some subjectivity remains in MI decisions
Acceptability	Willingness of operators to participate	High: MI is mandatory and it is of high economic importance for FBOs to produce meat fit for human consumption
Sensitivity	Ability to detect a case or to detect a change in prevalence	To be evaluated in the present paper
Positive Predictive Value	Proportion of reported cases that are actually related to the event under surveillance	Low in term of identification of etiologic cause High for syndromes despite some subjectivity in the assessment.
Representativeness	Population coverage	Complete for animals fit for transport
Timeliness	The time between steps in surveillance	Short time between detection and report to primary producer (upward flow of information) and/or report to Veterinary Authorities. However, the feed-back is not always done.
Stability	Reliability: ability to collect, manage and provide data without failure Availability: ability to be operational when it is needed	Reliability: potentially high if a data collection system is set up Availability: high because MI system is perennial system

Table 3 Strength-Weakness-Opportunity-Threat (SWOT) analysis of MI as a surveillance system of animal health and welfare surveillance

STRENGTHS	Well-established and well-accepted: FBOs have economic interests in MI
	High coverage of targeted population
	Continuous monitoring: basis to draw reliable trends
	Capacity to detect emerging problems
	Two-way information flows
WEAKNESSES	Animal health and welfare surveillance is not the first objective of MI
	Only suitable for problems leading to macroscopic abnormalities
	Animal are fit for transport: detection of milder cases than in farm surveillance
	No specific case definition
	Lack of standardization despite efforts of harmonization
	High technical constraints
	Lack of flexibility: input-based design, fixed by regulations
	Data are not centralized and analyzed at national or E.U levels
OPPORTUNITIES	Implementation of welfare regulations in EU: abattoir is the best place for assessment of animal-based welfare indicators
	Relying on a risk-based approach enabling optimization of cost/benefice ratio
	Automatisation of MI process
THREATS	Evolution of MI to cover new public health hazards: reallocation of resources
	Delegation of visual MI to FBOs

Table 4. Probabilities of case detection (mode) of *ante* and *post-mortem* inspection procedures at individual bird level (5% and 95% percentiles) for 20 diseases and conditions

	Diseases and conditions	Ante-Mortem inspection	Post-Mortem inspection
Epizootic	Highly Pathogenic Avian Influenza (HPAI)	0.98 (0.95; 0.995)	1.00 (1.00; 1.00)
	Newcastle disease (ND)	0.92 (0.88; 0.96)	1.00 (1.00; 1.00)
Endemic diseases	Coliform celullitis (Gangrenous celullitis)	0.78 (0.55; 0.89)	1.00 (1.00; 1.00)
	Mycoplasma gallisepticum infection	0.92 (0.86; 0.97)	0.98 (0.97; 0.99)
	Colisepticaemia	0.81 (0.53; 0.99)	1.00 (1.00; 1.00)
	Botulism	0.98 (0.96; 0.99)	0.00 (0.00; 0.00)
	Necrotic enteritis and hepatic disease	0.95 (0.89; 1.00)	1.00 (0.99; 1.00)
	Avian tuberculosis	0.92 (0.79; 0.96)	1.00 (1.00; 1.00)
	Egg peritonitis	0.62 (0.47; 0.74)	1.00 (1.00; 1.00)
	Duck plague	0.99 (0.97; 1.00)	1.00 (1.00; 1.00)
	Infectious bursal disease (IBD)	0.91 (0.82; 0.97)	0.80 (0.68; 0.91)
	Aspergillosis	0.79 (0.69; 0.85)	1.00 (0.99; 1.00)
	Histomoniasis	0.96 (0.91; 0.98)	1.00 (1.00; 1.00)
Welfare conditions	Dead on arrival (DOA)	1.00 (0.91; 1.00)	0.00 (0.00; 0.00)
	Thermal discomfort	0.85 (0.76; 0.94)	1.00 (0.98; 1.00)
	Traumatic injuries	0.99 (0.97; 1.00)	1.00 (1.00; 1.00)
	Pododermatitis	0.74 (0.57; 0.82)	0.80 (0.64; 0.87)
	Skin lesions	0.85 (0.74; 0.93)	1.00 (1.00; 1.00)
	Tarsal dermatitis	0.71 (0.56; 0.86)	1.00 (1.00; 1.00)
	Ascites	0.93 (0.85; 0.96)	1.00 (1.00; 1.00)

Table 5. Estimated proportion of turkeys and turkey batches detected as true positives for avian influenza (AI) by different surveillance system components

Surveillance systems component	Proportion of true positives detected (per bird, animal level)	Proportion of true positives detected (per batch, 10.000 birds)**
Abattoir inspection	0.0103	1.0
Clinical suspicion	0.0017	1.0
Serology	0.0245	1.0
Combined*	0.0361	1.0

*The combined value does not consider overlap between surveillance system components

**Assumed between –flock prevalence = 0.096, within flock-prevalence = 0.283

Table 6. Detection fraction at batch level (10,000 birds) of selected endemic diseases/conditions by abattoir inspection and clinical suspicion and comparative detection performance with an assumed coverage of 100%

	Abattoir inspection SSC*1	Clinical suspicion SSC2	Incremental benefit SSC1 over SSC2	Incremental benefit SSC2 over SSC1
ASPERGILLOSIS	0.049	0.001	0.049	0.001
COLISEPTICAEMIA	1.0	1.0	0.0	0.0
IBD	1.0	0.962	0.038	0.0
ASCITES	0.849	0.021	0.831	0.003

*Surveillance System Component

Figure Flow-diagram of the scenario tree model, with the arrows indicating the order that each step occurs i.e. node of the tree is calculated.