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A comparative analysis of meat inspection data as an information source of the health and welfare of broiler chickens based on Finnish data

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ABSTRACT

The comprehensive, reliable, and comparable meat inspection (MI) data of broiler chickens (i.e. broilers) are essential for the monitoring and surveillance of broiler health and welfare at the national and European Union (EU) levels. We compared the condemnation causes issued to broiler carcasses during MI in four large Finnish broiler slaughterhouses (SHs) by investigating the similarities and differences between local MI instructions used in the SHs. The way in which MI condemnations were recorded in the Finnish Food Authority's (FFA's) MI statistics were also explored. We additionally analysed the FFA's official MI data from the 2015–2019 period. The study showed that the MI criteria used in the SHs differed from one another regarding how severe or extensive a broiler defect or disease must be to cause condemnation during MI. In Finland, the annual total condemnation prevalence of whole broilers varied between 2.6% and 4.8% in 2015–2019, and a significant difference was observed between the SHs' monthly total condemnation prevalences, except in two SH pairs. Mistakes in recording the FFA's MI statistics and differences in the SH operators' reasons to reject broilers from the food chain affect the comparability of the condemnation prevalences between the SHs. Only half of the SHs partially condemned broiler carcasses and collected data concerning these condemnations. Cellulitis (0.3–1.0%), ascites (0.3–0.4%), and body cavity disorders (0.2–0.3%) were the most common causes for condemning whole broiler carcasses in 2015–2019. The MI data can be used for monitoring and surveillance purposes only once the differences between the SH data and data reliability are known. Although the harmonization of all condemnation causes is impossible, harmonizing the condemnations of carcasses with diseases that most threaten broiler health and welfare and cause the largest economic losses would be important.

1. Introduction

Recording and evaluating the results of poultry meat inspection (MI) is regulated in the Commission Implementing Regulation (EU) 2019/627 of the European Union (EU). The primary purpose of MI is to ensure that the meat is fit for human consumption. However, the results from MI are also used to monitor zoonoses and zoonotic agents, as regulated in Directive 2003/99/EC, and to evaluate broiler chicken (i.e. broiler) welfare and signs indicating poor welfare conditions such as abnormal levels of dermatitis or systemic illness (EC 2007/43). Broiler producers and slaughterhouse operators (SHOs) can use the MI results when evaluating the reasons behind any problems in the quality and health of broiler flocks (Huneau-Salaün et al., 2015; Stärk et al., 2014). Competent authorities can use the MI data for surveillance purposes, as a measurement of national levels for broiler health and welfare and as a measurement of MI uniformity between broiler slaughterhouses (SHs). Apart from audits, MI data are the only way to evaluate and compare MI in the SHs.

Concerns about broiler health and welfare have arisen because of extreme genetic selection, which aims to increase broiler productivity, and the intensive production systems connected to it (Zuidhof et al., 2014). For example, the vertically transferred avian pathogenic *Escherichia coli* caused increased mortality and morbidity in broiler flocks in the Nordic countries in 2015–2016 (Ronco et al., 2017). In addition, intensive breeding is presumably one reason behind the degenerative muscle diseases observed in broilers in the 2010s (Petracci et al., 2019). Pathological changes in the muscles, such as lipidosis, fibrosis, and myodegeneration of the breast muscles, due to these diseases have

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increased carcass condemnation prevalence and have impaired broiler welfare (Norring et al., 2019; Petracci et al., 2019). More timely and effectual information concerning such problems may be available for utilization by the breeding companies if a comparison between MI condemnation rates and reasons were performed.

Reasons for declaring meat in MI as unfit for human consumption are determined in the Commission (EU) Implementing Regulation 2019/627. Meat inspectors' decisions in the SHs concerning broiler carcasses and visceral organs are based on visual observations, and the following measures are based on instructions issued by the competent authorities and official veterinarians in the SHs. The meat inspectors' decisions may be based on a subjective assessment, leading to differences in MI condemnation decisions (Fries & Kobe, 1993). Condemnation causes in the MI are often not associated with the specific aetiologies of a disease (Huneau-Salaün et al., 2015).

The data from broiler MI can be assumed to be uniform and comparable between the SHs and EU Member States under similar production systems. This is due to both the characteristics of broilers and slaughtering processes and to legislation. Slaughtered broilers are young, and both housing conditions and bird management are guided by the breeding companies (Aviagen, 2019; Cobb, 2021). Irrespective of broiler breed, broiler appearance is quite uniform because of the intensive genetic selection to increase productivity by selecting traits supporting this aim (Zuidhof et al., 2014). EU legislation is common to all EU Member States although some national legislation may coexist. The slaughtering processes are also quite similar (Barbut, 2015).

Studies conducted to date have observed large variation between MI condemnation rates and reasons. The Löhren report (2012) showed condemnation rates at broiler MI to vary between 0.5% and 2.7% among 19 EU Member States. According to the study by Lupo et al. (2008), the condemnation rate in France was 0.9% and emaciation and congestion were the main condemnation reasons, whereas the mean percentage of total carcass rejections among eight SHs in the UK was 1.2% and acute internal pathology was the main condemnation reason (Haslam et al., 2008). The classifications used for the condemnation reasons were not identical in these two studies. Comparing the results of various studies examining condemnation rates and reasons is difficult due to varying sample sizes, population sources, epidemiological units, and differences in presenting condemnation rates (Salines et al., 2017). In addition, the different names given to the MI condemnation reasons caused confusion (Salines et al., 2017). Significant differences have been found between MI condemnation rates of the SHs and in the MI condemnation rates between the broiler production systems (Lupo et al., 2008). However, in-depth studies examining how the various condemnation criteria and differences in MI data collection affect the comparability of the MI data are lacking.

The purpose of our study was to analyse and evaluate the quality of MI data collected by the Finnish Food Authority (FFA). This was done by comparing 1) the MI instructions used in different SHs, 2) how condemnation causes were aggregated into the FFA's MI statistics, and 3) the MI data collected to the FFA's MI statistics. Our purpose was also to investigate what conclusions can be made from the FFA's MI statistics concerning animal health and the welfare of Finnish broilers slaughtered in 2015–2019.

2. Materials and methods

The study data incorporated MI instructions and recordings of MI results from broilers slaughtered in large Finnish broiler SHs (n = 4) in 2015–2019. The FFA gave permission for data use prior to data collection.

2.1. Slaughterhouses

The selected SHs (A–D) slaughtered approximately 370 million broilers in 2015–2019, covering 99.8% of all broilers slaughtered in Finland during that period (FFA, 2015, 2016; 2017a, 2018, & 2019). The two largest SHs, both with a slaughter line speed of over 9000 broilers/hour, collectively slaughtered approximately 4.5 times as many broilers as the two smaller SHs combined. Their slaughter line speeds were under 9000 broilers/hour.

2.2. Slaughtered broilers

The slaughtered broilers in all the SHs were Ross 308 hybrids in 2019. The major broiler brand for 2015–2018 was also Ross, although some Cobb and Hubbard were also slaughtered, depending on the SH. Average slaughter age varied between 30 and 40 days depending on the SH (Finland's Broiler Association, 2021). The mean carcass weight after chilling varied from 1.4 kg to 1.8 kg in 2019 depending on the SH. The broilers were reared conventionally indoors without antibiotics or vaccines. The production chain was strictly guided by the meat companies, which had their own contract farmers and contract hatcheries and which owned the SHs.

2.3. Meat inspection instructions in the slaughterhouses

The FFA organizes MI in Finland, and the FFA's official veterinarians perform and lead the SH MI. The meat inspectors, who perform the activities of the official auxiliaries, are qualified SH staff. The local MI instructions were issued by the official veterinarians to the meat inspectors of each SH, to guide in MI decision-making. The local, written MI instructions and instructions for non-MI condemnations, given to the meat inspectors in each SH, were obtained from the chief official veterinarians. Non-MI condemnation indicates that broiler is withdrawn from the food chain during the slaughtering process by an SHO. An SHO withdrew whole broilers from production if 1) the broilers could not be processed normally due to their very small size or 2) the broilers could not be hung on the shackles of the slaughter line due to an injury or damage to their legs. Non-MI condemnation was also necessary if no reason was found for the MI condemnation of a broiler, but the broiler was nonetheless assumed to 3) very probably cause contamination or cross-contamination, for example if the broiler had feed in its crop before evisceration, or 4) because the partial condemnation of a broiler proved impossible (FFA, 2017b; MAF, 795/2014).

2.4. A comparison of the condemnation causes and criteria in meat inspection and a comparison of condemnation recordings collected into the Finnish Food Authority's official statistics

Guidelines for MI condemnation were established in each SH based on local MI instructions received from the chief official veterinarian of each SH. The similarities and differences between the MI condemnations carried out in the SHs were defined by comparing the local MI instructions. Each chief official veterinarian was asked how condemnations were recorded into the FFA's official statistics if that information could not be concluded from the instructions. Information on how each chief official veterinarian aggregated the condemnation causes into the seven condemnation groups in the FFA's official statistics were obtained in the same manner (Table 1).

2.5. Collection of meat inspection data from the Finnish Food Authority's meat inspection statistics and from the official veterinarians

The MI data were obtained from the FFA for the 2015–2019 period. The FFA's MI statistics did not provide information regarding cellulitis condemnations only, as these were aggregated into one of the condemnation groups. The monthly cellulitis condemnation rates for the same period were therefore obtained from the official veterinarian of each SH. Cellulitis condemnation information was collected because of a colibacillosis epidemic in the Nordic countries in 2014–2016, and the epidemic was presumed to have affected cellulitis prevalence during

Table 1
The categorization of whole and partial condemnations of broiler chicken carcasses into the Finnish Food Authority's (FFA's) condemnation groups and the mean condemnation prevalences in the meat inspection (MI) of four large Finnish broiler slaughterhouses (SHs) in 2019[a].

The FFA's condemnation groups in the official statistics	The mean condemnation prevalence (Min–Max), (%)	Condemnation cause	Proportion of the SHs that includes the condemnation cause in the FFA's condemnation group
1. Ascites	0.43 (0.32–0.56)	Ascites	4/4
2. Body cavity disorders	0.28 (0.16–0.89)	Serious inflammations in the visceral organs, such as peritonitis, pericarditis, airsacculitis, pneumonia, hepatitis	4/4
		Focal hepatic necrosis	4/4
		Yolk sac remnant (yellowish, bad-smelling yolk sac content on the visceral organs and inner surface of the body cavity)	4/4
		Pendulous crop	2/4
		Ascites signs in the liver (without findings in the accompanying carcass)	1/4
3. Emaciated	0.04 (0.00–0.06)	Cachexia	4/4
		Underweight broiler[b]	2/4
4. Dermatitis, cellulitis, phlegmon, abscesses	0.39 (0.26–0.52); (cellulitis 0.28 (0.08–0.43))	Cellulitis	4/4
		Large and/or deep infected wound on carcass	4/4
		Large and/or deep inflammation of the skin	4/4
		Inflammation under skin	4/4
		Squamous cell carcinoma	2/4
		PC[c] of a leg due to a mild infected wound or mild inflammation of the skin (rest of the carcass is accepted)	1/4
5. Bruises, fresh fractures with haemorrhages	0.09 (0.06–0.29)	Large bruises extending over both breast fillets or from the leg to the loin	4/4
		Fresh fractures of a leg or legs with large bruises, which may also be partly green[d]	4/4
		A large bruise on only one breast fillet[e]	2/4
		A leg with a fresh bruise with Ø > 2.6 cm. PC (rest of the carcass is accepted. In the other SH, the rest of the carcass is a non-MI-condemnation, i.e. the carcass is rejected by the SHO)	2/4
		An old, large green bruise	2/4
6. Other reasons	0.22 (0.08–0.32)	A dehydrated broiler; abnormal colour of a broiler; a broiler with deformity or neoplasia	4/4
		Broilers with severe arthritis or tenosynovitis or ruptured Achilles tendons (with or without other disorders like abnormal colour of the broiler)	4/4
		Wooden breast (severe cases)	4/4
		Broilers with clearly detectable arthritis or tenosynovitis or ruptured Achilles tendon with no other disorders[f]	2/4
		PC of a leg due to a mild tenosynovitis (rest of the carcass is accepted)	1/4
		Squamous cell carcinoma	2/4
		An old, large green bruise	2/4
		A pendulous crop	2/4
		Broilers with a severe local necrosis of *M. trapezius* (not recorded PC in the other two SHs)	2/4
7. Processing failures	2.89 (0.21–5.47)	Faecal contamination or other soiling of a carcass; a bile-stained carcass (more than slightly)	4/4
		An uncut broiler; a carcass damaged in the slaughtering process; numerous feathers left on a carcass	4/4
		Overscalding of the carcass	4/4
		Failure in the evisceration process[g]	3/4
		Broilers that went through an interrupted slaughtering process due to a failure in the slaughtering process[b]	3/4

[a] The official meat inspection statistics 2019, Finnish Food Authority.

[b] Non-MI condemnation, i.e. the carcass is rejected by the slaughterhouse operator (SHO) in another SH/other SHs.
[c] PC, partial condemnation.
[d] Variation between SHs about condemnation limits for size, age, and bruise location.
[e] Only PC in the other SH if the muscle is intact under the skin.
[f] PC if arthritis, tenosynovitis, or ruptured Achillon tendon is only in one leg. Rest of the carcass is a non-MI condemnation.
[g] In three SHs this condemnation is performed only if manual evisceration is impossible (the removed carcass is a non-MI condemnation in one of these SHs).

that time (Ronco et al., 2017). The FFA's MI statistics included data regarding the number of broilers brought to each SH and the number of non-MI condemnations; the number and weight of accepted broilers; the number of carcasses with partial condemnations, the number of condemned whole carcasses, the number of ante-mortem condemned carcasses, and the number of broilers dead on arrival (Fig. 1). In addition, the FFA's MI statistics included the numbers of whole- and partial-carcass condemnations in each condemnation group. The data also included the number of carcasses intended for heat treatment (EU 2019/627; MAF 590/2014).

2.6. Statistical analyses

Statistical analyses were performed using SPSS® Statistics Version 26 (IBM Corp., New York, USA). Non-parametric tests were used when the data were not normally distributed. The Shapiro–Wilk test was used to test for normality. The Kruskal–Wallis test and pairwise comparisons with Bonferroni correction were used when we analysed the significances of the differences between the SHs' monthly condemnation prevalences of ascites, cellulitis, and body cavity disorders from 2015 to 2019. The same test was used when the significances of the differences were analysed between the SH prevalences of whole-broiler condemnations, between the seasonal condemnation prevalences of ascites, and between the annual condemnation prevalences of cellulitis in the SHs C and D. The one-way ANOVA test and pairwise comparisons with Bonferroni correction were used when the significances of the differences were analysed between the annual condemnation prevalences of cellulitis in the SHs A and B. The epsilon squared estimate (ϵ^2) was calculated as an effect size estimate after the Kruskal–Wallis test, and the eta-squared (η^2) after the one-way ANOVA test. The differences in condemnation prevalences between the two groups of the SHs pairs were tested using the Mann–Whitney *U* test. Group 1 included the two SHs where carcasses were not condemned partially, while group 2 included the two SHs where both whole and partial condemnations were performed. Correlation coefficient *r* was calculated as an effect size estimate after the Mann–Whiney *U* test. P-values < 0.05 were considered to indicate statistical significance.

3. Results

3.1. Broiler acceptance/condemnation decisions in the slaughterhouses

MI condemnations are performed at several stages during the slaughtering process (Fig. 1). Condemnation data of the visceral organs were not collected in any of the SHs if the accompanying carcasses were accepted. Partial condemnations of carcass defects were performed and recorded in two SHs, and, depending on the SH, the rejected parts were the legs, parts of the breast skin, wings, and an infected part of the thighs, next to the tail.

Non-MI condemnations differed between the SHs and included runts or very small broilers rejected before they were hung on the slaughter line (2/4 SHs), underweight broilers (2/4 SHs), broilers with feed left in their crops (4/4 SHs), mechanical damages without dirtiness (3/4 SHs), and carcasses before chilling after a long disruption of the slaughtering process (1/4 SHs). Non-MI condemnations in Finland, except for runts and very small broilers that were rejected prior to shackling, were in practice performed by the meat inspectors during the post-mortem inspection (PMI) and were controlled by the official veterinarians.

The instructions concerning whole-broiler condemnations that were due to visible serious defects or pathological lesions in the carcasses or visceral organs were similar in the MI of each SH. Ascites, cellulitis, serious inflammation in the visceral organs, focal hepatic necrosis, yolk remnants on a carcass, severe cases of wooden breast, an emaciated or dehydrated broiler, abnormal colour, or serious or large inflammation or a large bruise on a carcass were examples of such condemnation causes. Furthermore, processing failures that caused carcass contamination or that otherwise resulted in carcasses and visceral organs to be unfit for human consumption were reasons for whole-broiler condemnations in

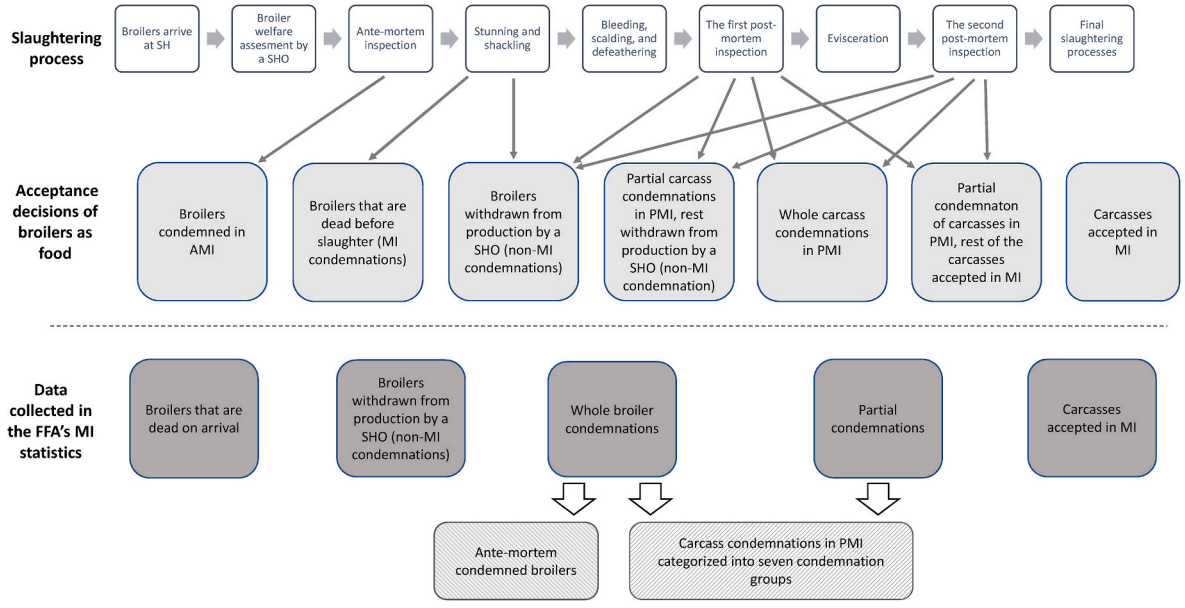

Fig. 1. Description of meat inspection (MI) condemnations, non-MI condemnations, and partial MI condemnations during the slaughtering process. Description of the recordings that are made to the Finnish Food Authority's (FFA's) MI statistics.
SHO = slaughterhouse operator; AMI = ante-mortem inspection; PMI = post-mortem inspection.

all the SHs (Table 1).

Differences in the SH MI instructions concerned limited or mild carcass defects (Table 1). In two SHs, such carcasses were accepted in the MI without any partial condemnation. In two other SHs, depending on the defect, the alternatives for handling such carcasses were: 1) the defect was cut off from the carcass during the PMI and the rest of the carcass was accepted in the MI, 2) the defective part of the carcass was condemned as an MI condemnation and the rest of the carcass was rejected as a non-MI condemnation, or 3) the defective leg or wing was marked for later trimming at the cutting plant and the rest of the carcass was accepted in the MI. Furthermore, the SHs showed differences in the limit values for whole-carcass condemnations (Table 1).

3.2. Meat inspection condemnation recordings in the Finnish Food Authority's meat inspection statistics and the condemnation prevalences

The mean total annual prevalence of whole-broiler condemnations in the MI ranged from 2.6% to 4.8% in Finland in 2015–2019. The prevalence of the total monthly condemnations of whole broilers in the MI varied between the SHs (Kruskal-Wallis test, $P < 0.001$, $\epsilon^2 = 0.291$). Pairwise comparisons showed significant differences in SH pairs AB, AC, AD ($P < 0.001$), and BC ($P = 0.001$), but the difference was not significant in SH pairs DB and DC. One SH had misleading data regarding the non-MI condemnations of runts and very small broilers because they were sometimes recorded as ante-mortem condemnations during 2015–2019. We deduced this from the monthly reports compiled from the official MI data.

Excluding condemnations due to processing failures during the slaughter process, the mean annual total condemnation prevalence of whole broilers varied between 1.4% and 2.2% in Finland in 2015–2019. The highest and lowest total annual condemnation prevalences of whole broilers were recorded during the MI of SH D (Fig. 2.).

The principles for recording partial condemnations varied strongly between the two SHs that partly condemned carcasses and collected data concerning the condemnations. One SH excluded the partial condemnations of the wings and skin from recordings sent to the FFA's MI statistics while the other SH recorded the number of carcasses with partial condemnations. Partial condemnation prevalence was therefore remarkably higher in SH B than in the other SH (Fig. 2.).

In the PMI, condemned whole broilers and condemned legs were aggregated into seven condemnation groups in the FFA's MI statistics based on the condemnation cause (Table 1). Partial condemnations of the skin or condemned wings were excluded from these groups. Leg condemnation recordings were collected into the condemnation groups of "dermatitis, cellulitis, phlegmon, and abscesses", "bruises, fresh fractures with haemorrhages", and "other reasons", depending on the cause (Table 1). The condemnation prevalences in these condemnation groups differed significantly between the SHs without (group 1) and with (group 2) partial condemnations. The Mann–Whitney *U* test showed a significant difference between these two groups regarding condemnation prevalences in the "dermatitis, cellulitis, phlegmon, and abscesses" group ($P < 0.001$, $r = -0{,}662$) and in the "bruises, fresh fractures with haemorrhages" group ($P < 0.001$, $r = -0{,}637$).

The categorization of whole-broiler condemnation causes into seven condemnation groups varied between the SHs regarding certain causes (Table 1). Condemnation causes, such as pendulous crop, squamous cell carcinoma, and old and large, green bruises, were aggregated into different condemnation groups in two SHs compared to the other two SHs. In addition, two SHs rejected underweight broilers as non-MI condemnations, whereas they were recorded into the "emaciated" group by the other two SHs. However, these previous two SHs rejected runts (rejected before being hung on the slaughter line) as ante-mortem condemnations, whereas the latter two SHs rejected them as non-MI condemnations. One SH showed misleading data in the "dermatitis,

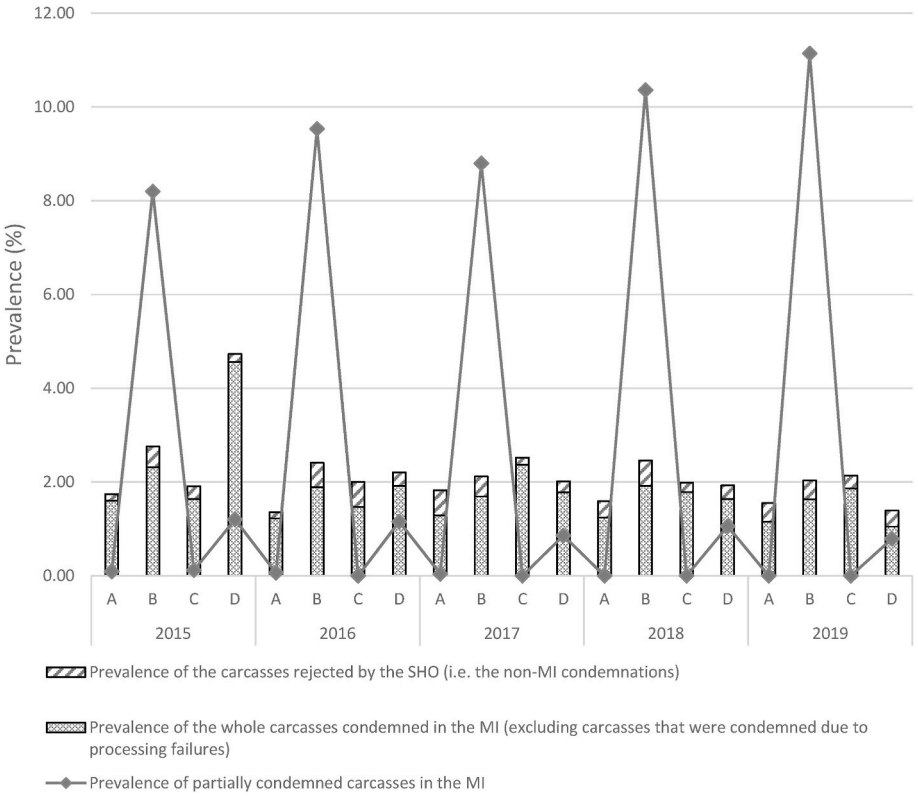

Fig. 2. The recordings from the meat inspection (MI) in the Finnish broiler slaughterhouses (A–D) in the Finnish Food Authority's meat inspection statistics. The prevalence of the partial and whole carcass condemnations in the MI and prevalence of the carcass rejects performed by the slaughterhouse operator (SHO) (i.e. the non-MI condemnations) in 2015–2019.

cellulitis, phlegmon, and abscesses" group; cellulitis condemnation prevalence during a nine-month period was higher than the prevalence of the whole condemnation group.

The number of broilers condemned due to ascites was the most uniformly collected data that was possible to obtain from the FFA's MI statistics (Table 1). Cellulitis was the other uniform condemnation cause. Furthermore, the "body cavity disorders" group was quite a uniform condemnation group (Table 1). During 2015–2019, ascites, cellulitis, and body cavity disorders were the most common condemnation causes of whole carcasses, excluding processing failures.

3.3. Ascites, cellulitis, and body cavity disorders: the most common and most uniformly collected meat inspection condemnation causes

Cellulitis was the most common single condemnation cause for whole-carcass condemnations in 2015–2018. The median and variation of cellulitis prevalence among the SHs decreased from 2015 to 2019 (Fig. 3). During these years, we observed significant differences between years in SHs A and B (one-way ANOVA, $P < 0.001$, $\eta^2 = 0.776$ and $P < 0.001$, $\eta^2 = 0.714$), and C (Kruskal-Wallis test, $P < 0.001$, $\epsilon^2 = 0.861$), and a decreasing trend in monthly cellulitis prevalence was observed in these SHs. Differences between the SHs varied (Table 2).

Ascites was the most common single cause for whole-carcass condemnation in 2019 (Table 1). The average prevalence of ascites remained quite similar during 2015–2019 (Table 2). The monthly prevalence of ascites in SH C was lower than ascites prevalence in the other SHs in 2015–2018. The pairwise test with Bonferroni correction showed significant differences between SH C and the other SHs in 2015–2017 (Table 2). The season affected ascites prevalence (Kruskal-Wallis test, $P < 0.001$, $\epsilon^2 = 0.141$) (Fig. 3). A pairwise test with Bonferroni correction showed a significant difference between summer (June, July, August) and autumn (September, October, November), $P = 0.017$; summer and spring (March, April, May), $P < 0.001$, and summer and winter (December, January, February), $P < 0.001$.

Condemnation prevalences due to body cavity disorders remained low and quite steady in 2015–2019 (Fig. 3). The significant differences in the prevalences of body cavity disorders between the SHs varied depending on the year (Table 2).

4. Discussion

The prerequisites for using MI data are their comprehensiveness, reliability, and comparability. Our study, including the MI data from all Finnish large SHs over a five-year period, showed that the MI data were not collected fully uniformly. Only part of the data could be used for evaluating broiler health and welfare at the national level and for comparing the MI results between different SHs. MI practices and condemnation criteria affected the condemnations of carcasses and their parts in the SHs. The aggregation and recording of these condemnations into the FFA's MI statistics influenced the MI data content. We observed differences in all these issues between the SHs. The same problems with uniformity and a lack of standardized MI data seem to also affect other EU Member States (Fries & Kobe, 1993; Huneau-Salaün et al., 2015; Löhren, 2012; Wall & Jansson, 2019).

This study allowed identifying the most reliable part of the MI data by investigating each stage affecting the MI data content. The prevalences of ascites, cellulitis, and body cavity disorders were the most uniformly collected and recorded MI data. Our findings are important because obtaining information about these prevalences from the farms is impossible in an equally comprehensive manner (Huneau-Salaün et al., 2015). However, when using the condemnation causes as a welfare indicator or an indicator of health problems at the national level, the differences between the SHs in their organization and working conditions during the PMI must be taken into account (Törmä et al., 2021). In addition, the subjective carcass assessments and various interpretations of MI condemnation limits negatively influence MI data uniformity (Bisaillon et al., 1988). Locally within an SH, this could be partly solved by carrying out regular performance tests for the meat inspectors and through written instructions issued by the local official veterinarians, as carried out in the Finnish SHs in our study.

Our results showed that Finnish SHs had fairly, but not completely, uniform principles when performing and recording whole-carcass condemnations. Differences were observed in the non-MI condemnations and some misleading data were found in the monthly reports. If condemnations due to processing failures were not considered the condemnation causes for whole carcasses included reasons that affected broiler health and welfare. In Finland, the mean annual total condemnation prevalence of whole broilers was higher (1.4–2.2% (processing failures excluded)) than in many other EU Member States (14 EU Member States had broiler condemnation rates below 1.4%) (Löhren, 2012). In Sweden, the condemnation prevalence was 1.7% in 2016 and 1.6% in 2017 (Wall & Jansson, 2019). Alfifi et al. (2020) reported a condemnation prevalence of 1.1% in Denmark in 2016–2018, and Salines et al. (2017) a condemnation prevalence of 1.1% among standard broilers in France in 2012–2013. However, these condemnation prevalences only concerned the SHs participating in each study. Comparing the condemnation prevalences between EU Member States includes many uncertainty factors such as differences in broiler ages and production systems, in data content (with or without condemnations due to processing failures), in the study population, and in the study year. The MI systems may also differ, such as the inspection time per broiler (Löhren, 2012; Törmä et al., 2021).

Using the total condemnation prevalence of whole broilers as a welfare indicator seems problematic because determining the limit value for acceptable rates is impossible if data collection is not uniform, as was the case in Finland. However, over 90% of EU Member States have evaluated total rejections as an indicator of broiler welfare, which is required in the Broiler Directive 2007/43/EC (Butterworth et al., 2016). In addition, despite uncertainty, many studies have used condemnation rates when studying factors that adversely affect broiler

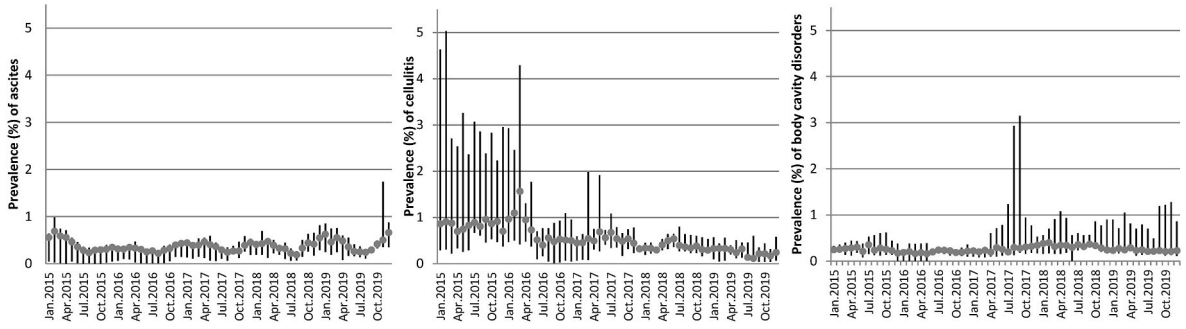

Fig. 3. Prevalence of condemnations due to ascites, cellulitis, and body cavity disorders in Finnish broiler slaughterhouses in 2015–2019. The vertical line indicates maximum and minimum values and • indicates the median value.

Table 2
Monthly prevalences of ascites, cellulitis, and body cavity disorders among slaughtered broiler chickens in Finland in 2015–2019.

Condemnation group[a]	Year	Monthly prevalence (%)			P-values of the pairwise comparisons between the slaughterhouses (A–D)					
		Mean	Median	Min–Max	AB	AC	AD	BC	BD	CD
Ascites	2015	0.41	0.35	0.24–0.71	1.00	**0.001**[b]	1.00	**<0.001**	1.00	**<0.001**
	2016	0.32	0.34	0.22–0.41	1.00	**<0.001**	1.00	**<0.001**	1.00	**0.001**
	2017	0.35	0.38	0.24–0.44	1.00	**0.002**	0.458	**0.002**	0.451	**<0.001**
	2018	0.37	0.39	0.18–0.57	0.079	0.238	0.059	**<0.001**	1.00	**<0.001**
	2019	0.43	0.43	0.23–0.66	0.122	1.00	0.238	**0.001**	1.00	**0.004**
Cellulitis	2015	1.02	1.00	0.89–1.32	**0.036**	1.00	**< 0.001**	**0.002**	0.214	**< 0.001**
	2016	0.63	0.57	0.49–0.88	**0.016**	1.00	**0.002**	0.166	1.00	**0.037**
	2017	0.52	0.51	0.35–0.74	**0.024**	1.00	0.359	0.052	1.00	0.622
	2018	0.41	0.40	0.30–0.51	**0.004**	1.00	0.818	**0.003**	0.358	0.669
	2019	0.28	0.29	0.22–0.32	**0.008**	0.242	0.202	1.00	**< 0.001**	**< 0.001**
Body cavity disorders	2015	0.25	0.25	0.19–0.32	**0.020**	0.979	0.340	0.740	**< 0.001**	**0.006**
	2016	0.20	0.19	0.17–0.22	0.078	0.369	0.184	1.00	**< 0.001**	**< 0.001**
	2017	0.27	0.24	0.16–0.48	0.250	**0.001**	0.185	**< 0.001**	**< 0.001**	0.660
	2018	0.32	0.32	0.28–0.38	0.111	**0.028**	1.00	**< 0.001**	**0.037**	0.087
	2019	0.28	0.28	0.24–0.33	**0.003**	0.192	**0.044**	**< 0.001**	1.00	**< 0.001**

[a] Condemnation groups in the Finnish Food Authority meat inspection statistics.
[b] Significant P-values (Kruskal–Wallis test and pairwise comparisons with Bonferroni correction, $P < 0.05$) have been highlighted in bold.

health or welfare (Alfifi et al., 2020; Averós et al., 2020; Haslam et al., 2008). Securing the reliability and knowledge of the MI data content would therefore be important.

The question of whether partial condemnations should be made during PMI is difficult in the broiler slaughtering process due to the fast line speed and automatic processes where broiler carcasses must hang on the shackle line also after PMI. Removing local defects from carcasses has therefore been organized in various ways in the PMI or has been left as the responsibility of the SHOs. According to our study, only two SHs performed partial carcass condemnations in their PMI, and these condemnations were recorded differently into the FFA's MI statistics. For this reason, the partial condemnation prevalences and the condemnation groups in the FFA's MI statistics, also including the number of partial condemnations, were not comparable. Partial condemnations were included in three condemnation groups: "dermatitis, cellulitis, phlegmon, abscesses"; "bruises and fresh fractures with haemorrhages"; and "other reasons". It is impossible to set national limit values for these condemnation groups or to use the condemnation prevalences of these groups as a measure of broiler health problems or poor welfare conditions, as required in Regulation (EU) 2019/627 and Broiler Directive 2007/43/EC. The low harmonization level of the condemnation causes and criteria in the MI complicates their use as welfare indicators. This has also been observed in Butterworth et al. (2016). However, comparing the MI condemnation prevalences is possible between different years in a single SH.

Ascites, cellulitis, and body cavity disorders were the most common condemnation causes in the Finnish SHs. They are important for broiler production because they weakened broiler welfare in addition to causing economic losses as a result of the large number of broilers rejected due to these reasons. These three reasons were also the most uniformly collected causes, possibly because the lesions caused by these conditions, especially regarding ascites and cellulitis, are characteristic and generally severe, and a condemnation decision is therefore easy to make. According to earlier studies, the most common causes vary slightly between countries. Salines et al. (2017) reported generalized congestion, cachexia, and non-purulent cutaneous lesions as the main condemnation reasons among broilers, whereas acute internal pathology, small/emaciated broilers, ascites, and skin conditions/abscesses were the main condemnation causes in the study by Haslam et al. (2008). According to Buzdugan et al. (2020), ascites and abnormal colour were the most common condemnation causes in one SH in England in 2015–2017. Variation in the classification of the condemnation causes can partly explain these differences (Salines et al., 2017). For example, generalized congestion may be a consequence of cardiac insufficiency, sepsis, or toxaemia and may be categorized into various causes, such as ascites/abnormal colour/other diseases, in the other EU Member States. However, differences in certain causes, e.g. in the condemnation rate of small/emaciated/cachectic broilers, could have been due to differences in the disease situation or on-farm culling practices between EU Member States. These broilers can also be rejected as non-MI condemnations; they are thus rejected during shackling or as underweight broilers. An increased prevalence of these broilers is a sign of weakened welfare of the broiler flock on a farm. That is why observing increased prevalence is important.

Ascites prevalence has remained quite steady. Ascites is a result of a pulmonary hypertension syndrome, which is a consequence of a rapid growth rate, anatomical and physiological characteristics of fast-growing broilers, and of breeding aiming to produce broilers with a high yield of pectoral muscles (Julian, 1993). Ascites is a significant MI condemnation cause in many countries such as Denmark, Sweden, and the UK (Alfifi et al., 2020; Wall & Jansson, 2019; Buzdugan et al., 2021). According to our study, ascites prevalence was significantly lower in summer than in the other seasons. This supports the long-known fact that cold weather increases ascites prevalence (Julian et al., 1989; Sato et al., 2001). The seasonal variation of ascites has also been observed by Part et al. (2016). Ascites prevalence in one SH differed significantly from the others, possibly due to different MI practices or condemnation guidelines in that SH, although the difference could not be revealed from the instructions. As ascites is common in Finnish broilers and it impairs broiler welfare, research is needed on ways to reduce its incidence.

The detected high cellulitis prevalence during 2015–2016 was most probably due to the colibacillosis epidemic, caused by avian pathogenic *E. coli* (APEC) in Nordic broiler production during those years (Ronco et al., 2017). The marked decrease in cellulitis prevalence in 2018–2019 was presumably a sign of the corrective measures taking effect. However, cellulitis remained one of the main condemnation reasons in 2018. Cellulitis was an important condemnation cause also e.g. in Germany, where 25% of the total condemnations were due to cellulitis in 2018 (Schulze Bernd et al., 2020). Cellulitis is usually caused by *E. coli,* which mainly enters under the skin via scratches (Vaillancourt & Barnes, 2008). Both broiler-related factors, such as poor feathering and nervousness, and rearing conditions, such as lighting and litter quality, affect the incidence of scratches and cellulitis (Schulze Bernd et al., 2020; Vaillancourt & Barnes, 2008).

Cellulitis prevalence differed between the SHs, particularly in 2015–2016 when the condemnation rate was highest. Although our results did not offer a clear explanation for these differences, we assume that the MI facilities also affected the cellulitis rate in addition to on-farm management or bird-related issues. Cellulitis is an inflammation under the skin with varying visible gross lesions on the skin, and the

yellow–brown discolouration and increased thickness of the skin are not always present in cellulitis cases (Fallavena et al., 2000; Vaillancourt & Barnes, 2008). Various inspection methods (inspection, incision, palpation) and good lighting are needed to detect cellulitis lesions. Significant differences in lighting conditions at the PMI stations between the SHs (Törmä et al., 2021) can cause variation in detecting cellulitis lesions. St-Hilaire and Sears (2003) found that an SH had the greatest impact on the variation in cellulitis condemnation prevalence in the MI. This supports the view that inspection practices and facilities in the PMI stations should be harmonized (Törmä et al., 2021). However, this SH-related variation was only partly due to a different inspection system (St-Hilaire & Sears, 2003), and otherwise the differences were assumed to be due to different condemnation criteria. In addition, Buzdugan et al. (2020) found differences in cellulitis prevalence between work shifts in their study SH showing different implementation of the condemnation criteria within one SH. Finding cellulitis during MI is important because cellulitis lesions in carcasses adversely affect meat quality due to inflammatory changes in the carcasses. Cellulitis can be part of systemic colibacillosis, such as during an APEC epidemic, and it adversely affects broiler health and welfare. Varying or minor external visible signs of cellulitis in carcasses may complicate the introduction of an automatic computer vision system for the inspection of broiler carcasses.

We found that the "body cavity disorders" group included both inflammation conditions and other defects in the body cavities and visceral organs of carcasses. It is therefore not a uniform group. The prevalence of this group was quite low in Finland, while acute internal pathology was the greatest reason for whole-broiler condemnation in the UK, with a mean prevalence of 0.4% (Haslam et al., 2008). "Acute internal pathology" only included inflammatory diseases in the earlier study. The lower prevalence in that group in our study indicates that body cavity disorders due to inflammation are less frequent than in the study by Haslam et al. (2008).

It is impossible to observe increases in individual diseases or defects in the FFA's MI statistics because many condemnation causes are aggregated into a few condemnation groups. For example, the condemnation group "Other reasons" in the FFA's MI statistics included many condemnation causes (such as arthritis or tenosynovitis) that significantly affect the health and welfare of broilers. Further, it is impossible to obtain information on the wooden breast condition from the official statistics. Data concerning it would have been helpful for revealing problems that rapid growth can cause to broiler welfare (Petracci et al., 2019). In addition, the condemnation group "dermatitis, cellulitis, phlegmon, abscesses" included many important diseases. Condemnations due to these reasons were collected separately into the MI data in each SHs. Methods should be developed that allow for better use of MI data to reveal new or emerging problems related to broiler welfare. Official veterinarians should be encouraged to report exceptional changes in MI condemnation rates or causes. The competent authority should analyse the national MI data instead of only collecting them. Using this information, it may be possible to detect and prevent diseases that threaten broiler health and welfare and cause economic losses at the national level.

5. Conclusion

Uniform MI organization, working conditions, MI condemnation causes and criteria for condemnations, and collection of MI data must be secured to achieve uniform MI data. In particular, condemnation criteria for mild and moderate lesions or defects and differences in determining non-MI condemnations cause differences in the MI data.

Our results showed that the data from the most common condemnations causes, i.e. ascites, cellulitis, and body cavity disorders, were the most uniformly collected. Thus, although the harmonization of all condemnation causes is impossible, it would be important to harmonize the condemnations of carcasses with diseases that most threaten broiler health and welfare and cause the largest economic losses. Additionally, monitoring the development of MI condemnation prevalence in a single SH is useful. When using the MI data for monitoring and surveillance purposes, e.g. as an indicator for broiler welfare, it is important to understand the differences between the data from the SHs and the reliability of the MI data. The analysis of individual condemnation causes in the aggregated MI data is important for monitoring and surveillance purposes and for the detection of new, emerging pathological conditions threatening broilers.

CRediT authorship contribution statement

K. Törmä: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Visualization. **E. Kaukonen:** Writing – review & editing. **J. Lundén:** Writing – review & editing. **M. Fredriksson-Ahomaa:** Writing – review & editing, Supervision. **R. Laukkanen-Ninios:** Writing – review & editing, Visualization, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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