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Current food chain information provides insufficient information for modern meat inspection of pigs

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ABSTRACT

Meat inspection now incorporates a more risk-based approach for protecting human health against meat-borne biological hazards. Official *post-mortem* meat inspection of pigs has shifted to visual meat inspection. The official veterinarian decides on additional *post-mortem* inspection procedures, such as incisions and palpations. The decision is based on declarations in the food chain information (FCI), *ante-mortem* inspection and *post-mortem* inspection. However, a smooth slaughter and inspection process is essential. Therefore, one should be able to assess prior to slaughter which pigs are suitable for visual meat inspection only, and which need more profound inspection procedures. This study evaluates the usability of the FCI provided by pig producers and considered the possibility for risk ranking of incoming slaughter batches according to the previous meat inspection data and the current FCI. Eighty-five slaughter batches comprising 8954 fattening pigs were randomly selected at a slaughterhouse that receives animals from across Finland. The mortality rate, the FCI and the meat inspection results for each batch were obtained. The current FCI alone provided insufficient and inaccurate information for risk ranking purposes for meat inspection. The partial condemnation rate for a batch was best predicted by the partial condemnation rate calculated for all the pigs sent for slaughter from the same holding in the previous year ($p<0.001$) and by prior information on cough declared in the current FCI ($p=0.02$) statement. Training and information to producers are needed to make the FCI reporting procedures more accurate. Historical meat inspection data on pigs slaughtered from the same holdings and well-chosen symptoms/signs for reporting, should be included in the FCI to facilitate the allocation of pigs for visual inspection. The introduced simple scoring system can be easily used for additional information for directing batches to appropriate meat inspection procedures. To control the main biological public health hazards related to pork, serological

surveillance should be done and the information obtained from analyses should be used as part of the FCI.

Keywords: food chain information; meat inspection; pig; food safety; sensitivity; specificity

1. INTRODUCTION

Meat inspection has four major objectives: public health, animal health, animal welfare and organoleptic meat quality (European Parliament and Council, 2004). Besides public health and animal health issues, meat is to be declared unfit for human consumption also if it indicates patho-physiological changes, anomalies in consistency or organoleptic anomalies (European Parliament and Council, 2004). If the change is local, partial condemnation is done and the abnormal tissue is removed by incision.

Meat inspection has been developed to incorporate a more risk-assessment based approach for protecting human health against meat-borne biological hazards. In regards to the most relevant pork-borne biological hazards of pig meat (*Salmonella* spp., *Yersinia enterocolitica*, *Trichinella* spp. and *Toxoplasma gondii*), only *Trichinella* spp. are detectable within the current post-mortem inspection (EFSA, 2011). A comprehensive pork carcass safety assurance system from 'farm to fork' is needed to ensure the effective control of meat-borne public health hazards, with the primary production stage playing an essential role in managing these risks (EFSA, 2011).

Moreover, the official *post-mortem* meat inspection of pigs shifted to visual meat inspection in EU (European Commission, 2014) in 2014. Techniques such as routine palpations and incisions are omitted from inspection procedures. This is because the risk of microbial cross-

contamination is higher than the risk associated with any potential reduction in detection of conditions by not using these techniques. Current regulations allow the official veterinarian (OV) to decide on any additional *post-mortem* inspection procedures such as incisions and palpations. The decision can be based on one or any combination of the food chain information (FCI), *ante-mortem* inspection (including verification of animal welfare), *post-mortem* inspection or any other data regarding the animal that might in the OV`s opinion indicate a possible risk to public health, animal health or animal welfare. Visual meat inspection is aimed to detect any observable abnormalities in carcasses. Palpation and incision procedures are carried out to fully inspect abnormal carcasses and offal to achieve a preliminary diagnosis and to decide on condemnations or if laboratory analysis are needed. The main deficiency, in these techniques, is that only conditions associated with gross lesions are detected while the most important pork-borne public health hazards are neglected (EFSA, 2011).

Slaughter batches of pigs with high frequency of lesions are not suitable for visual meat inspection. One should be able to identify which batches of slaughter pigs are suitable for visual meat inspection only, and which need more profound inspection procedures to ensure a more efficient slaughter and meat inspection process. To optimize procedures, meat inspectors should be able to focus on the examination of carcasses in which adverse conditions are suspected. Batches of pigs with high frequency of lesions should be slaughtered separately as they need a slower line speed and adequate human resources at trimming line. However, when based on *ante-mortem* inspection, such measures are often too late considering the practical arrangements at the slaughterhouse. On the day of slaughter it is possible, but laborious and impractical to change the slaughter order. In practice, the slaughter

batches of pigs with high frequency of lesions should be recognized beforehand upon reliable and comprehensive FCI reporting.

EU-Regulation (EC) No. 853/2004 stipulates that adequate FCI must be presented to the slaughterhouse operator and to the OV no less than 24 hours before the arrival of the animals at the slaughterhouse. In Finland, all the largest slaughterhouses use a uniform FCI–form, which is used by the pig producers to make the declarations, which include the following:

1) any relevant health status data regarding the holding or the animals in question (for example salmonellosis, trichinellosis, erysipelas, anthrax etc.),
2) any restrictions on the holding imposed by the authorities,
3) any drug residues or unauthorized substances detected in animals or at the holding during the last year,
4) any pigs in the slaughter batch that have been treated with veterinary medicinal products that have a withdrawal period within the three months prior to slaughter,
5) certain symptoms and signs detected in the slaughter batch (in detail in Table 1),
6) anything else relevant considering slaughter,
7) contact information of the veterinary practitioner for the holding.

In Finland, the FCI forms are usually sent to the slaughterhouses electronically, and they do not routinely include any *ante*- and *post-mortem* inspection data on previous batches of animals that had originated from the same holding. Typically the slaughterhouses keep such historical information in their own records, available to the OV (personal communication, Elias Jukola). Farmers have access to the meat inspection data concerning their farm via Sikava (Stakeholders health and welfare register for pig herds in Finland, www.sikava.fi).

The aims of this study were to assess the usability of the FCI provided by the pig holdings that sent the animals for slaughter and to evaluate the possibility of risk ranking of incoming slaughter batches according to the previous meat inspection data and the current FCI statements. As the risk of condemnation is mostly related to animal health and meat quality issues, serological testing were also included to emphasize the most relevant pork-borne public health hazards. The associations between the current and the historical meat inspection results, the FCI and the results from serological tests of slaughter batches of finishing pigs, were analyzed.

2. MATERIALS AND METHODS

2.1 Data

Eighty five slaughter batches of fattening pigs comprising 8954 animals were randomly selected at a slaughterhouse that receives animals from across Finland during the November 2012 to February 2013 period. Approximately 30% of the finishing pigs in Finland are slaughtered in this slaughterhouse. The slaughter batch sizes ranged from 20 to 271 pigs (a median of 87 pigs / batch). The mortality rate for each slaughter batch during last three months of finishing was provided by Sikava (Stakeholders health and welfare register for pig herds in Finland). The FCI, provided by the respective pig producers, and the meat inspection results were provided by the slaughterhouse. The holding of the pigs was traced by their slap marks. A total of 80 pig-production holdings were identified, that in all produce over 10% of the fattening pigs slaughtered annually in Finland. The meat inspection data that was used for the analyses concerned the slaughter batches that were sent from the same holdings during the previous year and covered more than 280 000 pigs. (Approximately 2 100 000 fattening pigs are slaughtered annually in Finland (http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/).)

The meat inspection results collected from the slaughterhouse generally correspond well with the national meat inspection statistics for the same year (Table 1, C). The only variation was observed for pleuritis rates as they were high in this particular slaughterhouse due to even the smallest lesions being reported, though those might not lead to condemnations.

For the purpose of this study, meat juice samples were collected from all the selected 85 slaughter batches (3-10 samples/batch). The meat juice was screened for antibodies for *Salmonella* spp., pathogenic *Yersinia* spp., *Trichinella* spp. and *Toxoplasma gondii* by using the appropriate commercial enzyme linked immunosorbent assay (ELISA) kits. A batch was considered positive when antibodies were detected in one or more of the samples. The serological analyses are described in detail in another publication by the authors (Felin et al., 2015). Table 1 describes in detail the data collected on the selected slaughter batches.

TABLE 1 Data collected on randomly selected 85 slaughter batches of finishing pigs

None of the holdings declared salmonellosis, trichinellosis or any restrictions imposed by the authorities, and erysipelas was notified by only three holdings (Table 1) therefore this information was excluded from the analysis. The declaration on the occurrence of constant coughing during the three months prior to slaughter was coded for statistical analysis as the following: not declared = 0, a bit = 1, a lot=2. None of the holdings declared a lot of constant coughing.

Statistical analysis and assumptions

Associations between the variables derived from the collected data were analyzed using Pearson correlation coefficients (r). Differences between mean values of groups were tested using independent sample t-tests. The values of the t-tests were transformed using the arcus

sine of the square root transformation to achieve homogeneous variances and approximately normal distributions. P-values <0.05 were considered to indicate statistical significance. Linear regression analysis with different stepwise selection algorithms of previous meat inspection reports and of current FCI that may indicate high condemnation rates in forthcoming slaughter batches were used to reveal predictive factors. As batches with high frequency of lesions need more profound inspection procedures, the partial condemnation rate was assumed to be the best indicator in our study to reveal retrospectively, whether or not a slaughter batch could have been suitable for visual meat inspection. The response variables in the regression analyses were the partial condemnation rate, the organ condemnation rate and the sum of the partial and total condemnation rate. Responses were transformed by using the arcus sine of the square root transformation. The residuals had approximately a normal distribution and homogenous variance due to this transformation. Regression models were also estimated for untransformed responses using the regressors found in the stepwise procedures. Analyses were computed using the analytical software package SPSS® Statistics Version 22 (IBM Corp., New York, USA). The results from the scoring system and current meat inspection were classified into a two-by-two contingency table. Sensitivity, specificity and accuracy were calculated as corresponding descriptive test parameters.

3. RESULTS

3.1 Associations between FCI regarding the batch, mortality during fattening and meat inspection results

Slaughter batches were divided into two groups according to the FCI reports: a group of batches with nothing to declare in FCI (n=22) and a group of batches with something to declare (n=63). Slaughter batches with “nothing to declare” in the FCI had statistically higher condemnation rates of livers than the batches with something to declare (16.0% and 6.6%,

199 $p<0.01$). The organ condemnation rate was also higher for the batches with nothing to declare,
200 but this difference was not statistically significant (2.9% and 1.1 %, $p=0.13$).
201
202 Constant coughing was declared in only four batches during the three months prior to
203 slaughter (Table 1, B), which lowers the generality of the results. These four batches had
204 higher mean arthritis prevalences (6.4% and 1.5 %, $p<0.01$), partial (8.8% and 4.8%, $p=0.05$)
205 and total (0.8% and 0.2%, $p=0.07$) condemnation rates than the other batches. The difference
206 between the partial and the total condemnation rate was not statistically significant. In
207 contrast, pneumonia and pleuritis rates observed at meat inspection were not prominent for
208 batches for which coughing was declared in the FCI.
209
210 Batches with a FCI declaration on pigs medicated within last three months prior to slaughter
211 had lower mean condemnation rates for livers (6.3% and 12.2%, $p<0.01$).
212
213 Those batches with declarations on lameness had statistically significantly higher mean
214 prevalences of pleuritis (45.3% and 33.1%, $p=0.04$) at meat inspection. No other statistically
215 significant differences were found.
216
217 The FCI declaration rates, i.e. the percentages of pigs in the batch declared to have a
218 symptom/sign for one of the following: hernias, abscesses/lumps, and lameness correlated
219 with higher pleuritis rates at meat inspection ($r=0.24$, 0.26, 0.31 and $p=0.03$, $p=0.02$, $p<0.01$
220 respectively). The FCI declaration rate for bitten tails correlates with higher pneumonia rates
221 ($r=0.25$, $p=0.02$) at meat inspection. The FCI declaration rate for lameness correlates with
222 more observations on bitten tails ($r=0.26$, $p=0.02$) at meat inspection. The two last mentioned
223 results were based on data regarding only a single batch for each result i.e. two separate

batches. One batch with 29% pneumonia found at meat inspection and another batch with 7% of lameness declared in FCI. When these batches were discarded from the analysis, no correlations were found.

The percentage of bitten tails declared in the FCIs correlated with the observations on bitten tails at meat inspection, but this correlation was not statistically significant ($r=0.20$, $p=0.06$, Figure 1). However, when the zero-values are discarded, the correlation is clear ($r=0.56$, $p<0.01$) (Figure 1).

FIGURE 1 The correlation between the food chain information and meat inspection reports on bitten tails of finishing pigs from 85 slaughter batches

There were no statistically significant correlations between the rate for batch mortality during fattening and any of the meat inspection results. A positive, but non-significant correlation was found between batch mortality rate and pneumonia rate detected at meat inspection ($r=0.19$, $p=0.09$). On the other hand, the correlation was statistically significant when only those batches with pneumonia detected at meat inspection were analyzed ($r=0.26$, $p=0.04$).

There were clear positive correlations ($r=0.49$-0.71, $p<0.001$) between FCI declaration rates for hernias, abscesses/lumps, abnormalities in gait and bitten tails.

Associations between the prior information for a particular batch that declared something in the FCI and meat inspection results of the same batch were analyzed (n=63). This was done because it was suspected that some of the FCIs with “nothing to declare” were not reliable. No new associations were found.

The prior information on the batches declared in the FCI were analyzed by one declaration category at a time, including only those batches with positive declarations (Table 1, B). A positive correlation was found between the declared percentage of pigs with hernias and the total condemnation rate ($r=0.38$, $p=0.04$). Again, the result was determined by one batch with high total condemnation rate of 2.8%. When that batch was excluded from the analysis, no correlation ($r=0.01$, $p=0.92$) was found. No other new associations were found by this analysis.

3.2 Associations between meat inspection results of current and previous batches from the same holding

Several statistically significant ($p<0.05$) correlations between the meat inspection results of all pigs sent for slaughter the previous year and the meat inspection findings from the currently slaughtered batch were found at the holding level (Table 2). No correlations were found for total condemnation, pneumonia and arthritis.

TABLE 2 Statistically significant correlations ($p<0.05$) between meat inspection results for the currently slaughtered batch (n=85) and between meat inspection results for pigs sent from the same holding for slaughter the previous year

3.3 Correlations between serology and meat inspection results

There were no statistically significant correlations found between any of the tested seroprevalences and current meat inspection findings at the slaughter batch level. A negative correlation was found between the seroprevalence within a batch of a pathogenic *Yersinia* spp. and the number of pigs in that batch ($r=-0.33$, $p<0.01$). A positive correlation was found

between the current seroprevalence of *Salmonella* and the prevalence of pneumonia (r=0.28, p<0.01) and also pleuritis (r=0.24, p=0.02) in the previous year findings of the meat inspection.

3.4 Linear regression predicting the meat inspection results

Several variables for condemnation (partial condemnation rate, organ condemnation rate and the sum of the partial and total condemnation rate) derived from the meat inspection data were analyzed to determine the most suitable predictors to ascertain whether the current batch would have been suitable for visual meat inspection. Total condemnations in the current batches were so rare that it was not considered relevant as a factor.

Figure 2 The partial condemnation rates of 85 slaughter batches of finishing pigs and the batches from the same holding during the previous year

While analyzing the predictors for the current partial condemnation rate, an extreme value (Figure 2, previous year´s partial condemnation rate 24%) for one of the batches was discarded from the analyzed data since it would have resulted in illogical models. All the variables of previous meat inspection reports and the information on the batch declared in the FCI, were tested as the explanatory variables. The two exceptions to this were the previous year´s organ condemnation rate and previous year´s rate of bitten tails, both of which had 54 missing values.

The partial condemnation rate of the previous year was revealed as the most important variable for predicting whether or not the current batch would have been suitable for visual meat inspection. The regression analyses revealed the best predictors for the partial

condemnation rate of the batch were the partial condemnation rate of the previous year ($p<0.001$) and the declared cough in the current FCI ($p=0.02$). Total condemnations were so rare, that the predictors were also the same for the sum of the total and partial condemnation rate. When the untransformed partial condemnation rate was predicted by the two best predictors, the adjusted R^2 was 0.31, the regression coefficient of the partial condemnation rate of the last year was 0.93 and the coefficient of the declared cough in the FCI was 4.5. This means that for every additional percent in partial condemnation rate of the last year the partial condemnation rate of the current batch increased by an average of 0.93 percent units and that the predicted partial condemnation rate increased by 4.5 percent units if coughing was reported in the slaughter batch.

The best predictor for the organ condemnation rate of the current batch was the organ condemnation rate of the previous year ($n=31$, $p=0.03$). When the untransformed organ condemnation rate was predicted by the best predictor, the adjusted R^2 was 0.15, regression coefficient of the organ condemnation rate of the last year was 0.19.

3.5 Scoring

Two threshold limits were set to delineate categories, namely: "suitable for visual meat inspection" and to "need additional inspection procedures", which was to ease decision-making for the allocation of the slaughter batches in advance. The statistically significant factors were the previous year´s partial condemnation rate (%) and the FCI regarding the current slaughter batch declaring on occurrence of constant coughing during the three months prior to slaughter. Threshold limits for scoring was calculated by using the 10- and 90 -deciles from the previous year´s condemnation rates: 0 points for below the 10-decile, 1 point for 10-

to 90-decile, and 2 points above the 90–decile. The declaration for a constant cough added another two points.

TABLE 3 Scoring of 85 batches of slaughter pigs according to food chain information provided

Note that, only for four batches were declared to have had constant coughing within the three months prior to slaughter (Table 1, B), which compromises the results. There was a significant positive correlation ($r=0.32$, $p<0.01$) between declarations on constant coughing and current partial condemnation rates even when only the batches with last year´s partial condemnation rate $\leq 8\%$ (n=76) were considered.

Eight batches (Table 3) were given a score of zero points, which indicated that they would have been suitable for visual meat inspection. Analysis of the meat inspection reports for these batches show that they were actually suitable for visual meat inspection (partial condemnation rate 1.4-3.8%, organ condemnation rate 0.0-3.5 %.

A total of 64 batches (Table 3) were scored with one point. An analysis of the meat inspection reports of these batches show that the majority of these batches were suitable for visual meat inspection. However, five of the batches could not be regarded as only suitable for visual meat inspection because of a high rate of partial condemnations (9-13%), and these could not have been detected beforehand with the suggested scoring system. The FCI on these five batches revealed that in only two the pigs had been treated with veterinary medicinal products within the three months prior to slaughter, and their historical meat inspection data and mortality rates during fattening did not markedly differ from the mean. The result indicates

348 that the available prior information was insufficient to discriminate all the relevant batches
349 beforehand.
350
351 Thirteen batches (Table 3) were considered to qualify for additional inspection procedures as
352 they had scores of two points or more (9 batches with last year's partial condemnation rate
353 over 8% and 4 batches with FCI on constant cough). However, seven of these batches had
354 current partial condemnation rates of less than 9% and therefore could have been suitable for
355 visual meat inspection only. Nevertheless, the high condemnation rates for the previous year
356 or reporting cough in FCI for the current slaughter batches indicated that it would have been
357 appropriate to carry out additional inspection procedures.
358
359 We suggest that batches with two points or more (last year's partial condemnation rate over
360 8% or FCI declarations for constant coughing in the current slaughter batches) should be
361 indications for additional meat inspection procedures. Sensitivity and specificity of the
362 scoring method were calculated (Table 4). Current batches with high partial condemnation
363 rates (>9%) were classified as not to have been suitable for visual meat inspection only. With
364 this classification, the worst eighth of the batches were classified as unsuitable for visual meat
365 inspection alone.
366
367 **TABLE 4 Sensitivity and specificity of the scoring system to find slaughter batches of**
368 **pigs unsuitable for visual meat inspection**
369
370 The sensitivity of the scoring system to identify the batches that were unsuitable for visual
371 meat inspection was 55% (95 % confidence interval: 28-79 %). Specificity to identify batches

suitable for visual meat inspection was 91% (CI95: 82-95 %). The accuracy of identifying the batches unsuitable for visual meat inspection was 86% (CI95: 77-92 %).

4. DISCUSSION

The main purpose of the FCI is that the pig producer declares that there are no restrictions to normal slaughter regarding public health, animal health or animal welfare issues. By the FCI form, certain disease symptoms must be declared to provide potentially important and useful information to the OV who might then decide on additional inspection procedures and also to the slaughterhouse that processes the pigs. At present, the information obtained in the Finnish FCIs is not accurate enough for its purpose and more guidance for farmers is needed to improve and unify their reporting procedures. For instance, the farmers report some inaccurate information due to the time-lag between sending the FCI form and the delivery of pigs for slaughter. This is because some farmers submit the FCI form at the same time as they announce their intention to send pigs for slaughter and they usually do not review the FCI before the actual delivery of pigs (Nieminen, 2015). The farmers also found it difficult to assess the number of animals in the finishing batch with specific symptoms (Nieminen, 2015). Such information is essential for conditions as abscesses or tail biting. Another recent study in which a questionnaire was sent to the OVs, official auxiliaries, slaughterhouse representatives and the central authorities in Finland, found that the respondents experienced serious problems in receiving accurate FCIs (Luukkanen et al., 2015). Nonetheless, the Finnish farmers seem to regard FCI with high motivation. In response to a recent non-peer reviewed questionnaire, Finnish farmers (n=153) opined that the currently used FCI improves food safety and prevents animal diseases (Nieminen, 2015).

In this study we explored the prior information given currently by the Finnish FCI, associated it with meat inspection results, and studied their potential as valuable information at the time of slaughter. As a result, well-chosen signs such as cough, with proper guidelines for reporting were shown as a useful contribution to the FCI in order to allocate pigs for visual meat inspection. In addition, the FCI could be used to assess the likelihood of condemnation in meat inspection.

We expected to find differences between those pig-batches for which some FCI information was declared compared to those pig-batches for which nothing was declared on. Surprisingly, batches with "nothing to declare" had poorer meat inspection results than the batches that did declare. However, information in FCIs about constant coughing during the three months prior to slaughter seems to be an important predictor, as those batches with declared cough had higher partial condemnation and arthritis rates. Condemnations had not resulted from higher pneumonia rates as one might assume. Pleuritis rates were slightly, but not significantly higher for batches with declared cough. It should be noted that coughing was rare among the studied batches, which might have overall affected the result. In Finland, *Actinobacillus pleuropneumoniae* (APP) is a significant cause of respiratory infections in growing pigs (Finnish Food Safety Authority Evira, 2014). This quite common pathogen is not a pork-borne hazard for the consumer. Chronic APP-cases have a cough accompanied by pleural adhesions and abscesses (Gottschalk, 2012). Consequently, the partial condemnations in the present study might be due to more severe pleuritis and pleural abscesses. Declarations on constant coughing always need additional inspection procedures, as they seem to predict higher frequency of meat inspection findings.

Significant correlations between the FCI reporting and the subsequent findings of bitten tails might also have been expected, but that was not the case. One explanation for the lack of correlation could be the high number of false reports regarding bitten tails. This suggests that proper guidelines, information and training about the FCI system are needed in order that the producers will provide more useful and reliable information on the animals that are about to be slaughtered. More reliable reporting for bitten tails in the FCI could be especially valuable, as findings of bitten tails positively correlate with the partial condemnation rate and with abscesses. Consequently, this study demonstrates that FCI could indicate when additional inspection procedure is appropriate.

The batches of medicated pigs had fewer condemned livers, which is logical because some of the declared medications were probably ascaris deworming treatments. This has been also found in previous studies (Harbers et al., 1992).

Most of the condemnations are not food safety issues (EFSA, 2011). Meat is judged "not fit for human consumption" usually because of meat quality aspects and to prevent animal diseases and occupational hazards (EFSA, 2011). Meat inspection is also a key component of the overall surveillance system for pig health and welfare and therefore, additional inspection procedures should be done whenever relevant abnormalities are seen or suspected (EFSA, 2011).

Besides data on the pigs that are about to be slaughtered and given by the FCI, in this study the usefulness of historical data regarding post mortem meat inspection findings of pigs produced on the same holding was considered. Vial et al. (2015) proposed a risk based animal health surveillance system, aimed at farms with reoccurring health problems, i.e. a history of

above average condemnation rate. Harbers et al. (1991) concluded that previous *post-mortem* meat inspection findings cannot be used as predictor, partly because of great variation between individual shipments, but it could play a role signaling farms that are likely to deliver pigs with higher level of abnormalities. In this study, we explored the possibility to overcome the problem of unexpected variation between individual shipments with reliable FCI and prior historical data, and created a simple scoring system of slaughter batches to facilitate the current visual meat inspection system. As a result, we found that a simple scoring system of batches according to thresholds obtained from previous meat inspection results and the FCI could be useful. The batches could be sorted in advance according to likelihood of condemnations before their arrival at the slaughterhouse, and then at the time of slaughter to facilitate the OV in deciding the need for any additional inspections.

Using FCI to predict meat inspection findings or to make risk assessment for slaughter batches has been found to be problematical in previous studies in other European countries (Meemken, 2006; Windhaus et al., 2007; van Wagenberg et al., 2012; Lupo et al., 2013; Blaha, 2012). It seems that in previous studies (Meemken, 2005; Ellerbroek, 2007) the adjusted threshold limits were concentrated on finding the best batches and directing them to visual meat inspection only. Visual meat inspection is now the new norm, though the emphasis has shifted towards finding the worst batches, which should then be directed to more rigorous inspection procedures. Dickhaus et al. (2009) have done a major work to create a herd health score (HHS)–index that reflects the general health status of pig groups. The HHS can be used to estimate the herd health of the slaughter pigs and for risk-based meat inspection. However, the HHS is designed to reflect the overall health status of the pig group and not specifically for finding groups that need additional inspection procedures in the current visual meat inspection system.

The simple scoring system introduced here, can be easily used as additional information to direct batches to the appropriate meat inspection procedures. Practically it is suggested that batches with a FCI declaration on constant coughing or a batch that comes from a holding with the previous year´s partial condemnation rate ≥8%, both would be considered candidates for additional inspections. The thresholds can be individually adjusted in every slaughterhouse, because the capacity of the detain rail varies. The majority of the batches studied here would have been directed to the appropriate inspection procedures by our scoring system. Nevertheless, there were few batches that were determined as potential for visual inspection, but which did not qualify. These slaughter batches might include considerable numbers of remnant pigs collected from several compartments of the holding. Such pigs typically are not the best ones. It was very typical that our data contained some batches with high condemnation rates and that the correlations we obtained did not apply to them. One would expect the farmer to have noticed something unusual in the animal batch during fattening, when the partial condemnation rate for the batch increases to over 10%. The only solution to find beforehand these remnant and outliner batches, is to improve the reliability of the FCI reporting and to include prior information on irregular slaughter batches. Before taking the suggested scoring system into practice, more testing for the precise selection of indicators are needed. This pilot study was based on data covering approximately 10% of the Finnish finisher pig production sites with historical data on app. 13% of the annually produced pigs, a coverage that can be regarded as representative. But since only one slaughter batch per a producer was regarded by the FCI, some indicator signals might overlooked. Despite all, with this data we managed to show the potential for pre-scoring of incoming slaughter batches.

To include the public health aspect, seroprevalences of the most relevant zoonoses were studied and compared to meat inspection findings. The presence of antibodies to a specific pathogen indicates that the animal has been exposed to the pathogen at some stage of life, although the seropositive animal may no longer be infective (Nielsen et al., 1995; Nielsen et al., 1996). The positive correlation we found between the current seroprevalence of *Salmonella* and previous year´s pneumonia and pleuritis findings during meat inspection could be just a coincidence. However, Smith et al. (2011) reported positive associations between enzootic pneumonia-like lesions and *Salmonella* -seropositivity. They suspected the reason to be shared risk factors. Finland is virtually free from enzootic pneumonia (Sikava - voluntary health monitoring system covering over 97% of production, www.sikava.fi). No other correlations between serology and meat inspection result were found, as expected. The main zoonotic pathogens do not yield gross pathological findings. Serological profiles are the way to control and monitor these risks rather than visual or traditional meat inspection (Felin et al., 2015). Serological profiles included in the FCI could help differentiate incoming slaughter batches in respect to the risk of main zoonotic pathogens. Thereafter, the meat from these high risk batches could be directed to appropriate heat- or freezing-based treatments when needed. At the farm level, serological monitoring could assist targeting the preventive risk management practices aiming to reduce the occurrence of main zoonotic pathogens in pigs.

5. CONCLUSIONS

This study found that meat inspection results of currently slaughtered batches are best predicted by previous meat inspection results of pigs from the same holding. Regarding the current FCI reports, declaration for constant coughing within the three months prior to slaughter, revealed as the most relevant sign to predict meat inspection results. To facilitate

520 the allocation of pigs for visual inspection, historical meat inspection results of pigs from the
521 same holding and well-chosen symptoms and signs with proper guidelines for reporting
522 should be included in the FCI. These results show that pre-scoring of incoming slaughter
523 batches can improve the FCI system and may be applicable also at EU level. A simple scoring
524 system was introduced that can be easily used as additional information to direct batches to
525 the appropriate meat inspection procedures. Our scoring system can be further improved after
526 reliability and uniformity of the FCI data are achieved. The FCI is an important part of the
527 modern food safety assurance system, and it is the tool to inform the slaughterhouse on any
528 condition at the holding or of the pigs that could compromise food safety or animal health.
529 Most of the zoonoses relevant to pig meat safety appear as latent infections, and since the
530 animals are asymptomatic the current FCI is not providing any useful information to control
531 these biological hazards. To detect the pigs affected by zoonoses relevant for food safety, the
532 FCI should also include surveillance information such as serological monitoring profiles of
533 pigs raised on the same holdings (Felin et al., 2015).
534

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538 slaughterhouse are gratefully acknowledged for their cooperation.
539

540 ## 7. DECLARATION OF INTEREST

541 Elias Jukola is the Manager of Corporate Responsibility for HKScan Corporation.
542 Saara Raulo is the head of the Finnish Zoonosis Centre at the Finnish Food Safety Authority
543 Evira.
544

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608

1 **TABLE 1 Data collected on randomly selected 85 slaughter batches of finishing pigs**

2 **from Finnish slaughterhouse**

A. Food chain information regarding the holding	**%** (number) **of batches** (n = 85)		**% of pigs in current batches** (n = 8954)	**Of concern to**
Salmonellosis occurred	0		0	P
Trichinellosis occurred	0		0	P
Erysipelas occurred	3.5 (3)		n/a	P
Official restrictions	0		0	A / P
Drug residues detected in animals	0		0	P
B. Food chain information regarding the batch				**Of concern to**
Includes pigs medicated within the last 3 months	52.9 (45)		n/a	A / P
Includes pigs with hernia	35.3 (30)		0.7	W / (P, higher risk of fecal contamination)
Includes pigs with abscesses/lumps	21.2 (18)		0.4	W
Includes lame pigs	15.3 (13)		0.3	W
Includes pigs with bitten tails	44.7 (38)		1.4	W
Constant coughing in three months prior to slaughter: a bit / a lot	4.7 (4) / 0.0		n/a	A
C. Meat inspection results	**Study data**		**Official statistics****	**Of concern to**
	Mean % (variation interval) **of batches** (n = 85)	**Mean %** (variation interval) **of holding results*** (n = 80)	**%** of all fattening pigs slaughtered in Finland 2013	
Total condemnation	0.2 (0.0-2.9)	0.3 (0.0-3.4)	0.3	A / P
Partial condemnation	5.0 (0.0-17.6)	5.6 (1.5-23.9)	6.4	A / W
Condemned organs	1.6 (0.0-19.5)	1.7 (0.2-11.7)°	n/a	A / W / P
Pneumonia	3.8 (0.0-29.2)	2.0 (0.0-11.7)	2.2	A

Pleuritis	35.0 (1.7-90.0)	17.8 (0.0-58.8)	15.9	A
Pericarditis	3.6 (0.0-32.9)	n/a	2.3	A
Condemned livers	9.1 (0.0-54.4)	6.0 (0.0-52.5)	6.3	A
Arthritis	1.7 (0.0-17.6)	2.4 (0.6-18.0)	3.0	W
Bitten tails	1.5 (0.0-8.3)	0.5 (0.0-1.7)°	1.0	W
Abscesses	4.1 (0.0-12.9)	4.5 (0.0-11.3)	3.2	A / W
Findings related to *Mycobacterium avium* complex	0.5 (0.0-6.8)	0.4 (0.0-4.7)	0.3	P
D. Serological analysis results	**Positive batches**, %** (n = 85)		**Positive pigs, %** (n= 431)	**Of concern to**
Salmonella spp.	14.1		3.5	P
Pathogenic *Yersinia* spp.	81.2		56.1	P
Trichinella spp.	0.0		0.0	P
Toxoplasma gondii	8.2		2.6	P
E. Other data	**Mean of batches, % (variation interval)**			**Of concern to**
Mortality rate of the batch during the fattening period	1.7 (0.0-8.4)****		n/a	A / W

Note: A = animal health; W = animal welfare; P = public health; adapted from EFSA, 2011
*holding result = result of all pigs slaughtered from the holding the previous year
**meat inspection statistics 2013, Food Safety Authority Evira
*** 3-10 pigs per batch tested
****data from Sikava - Stakeholders health and welfare register for pig herds in Finland, available for 82/85 batches
°previous years meat inspection data considering organ condemnations and bitten tails was available for 31/80 holdings
n/a= not available

TABLE 2 Statistically significant correlations (p<0.05) between meat inspection results for the currently slaughtered batch (n=85)and between meat inspection results for pigs sent from the same holding for slaughter the previous year

Currently slaughtered batch	**Slaughtered pigs from the holding during previous year**	**Pearson correlation coefficient**	**p-value**	**Number of batches concern**
partial condemnations, %	partial condemnations %, abscesses %, bitten tails %	0.32 0.37 0.42	<0.01 <0.01 0.02	85 85 31
organ condemnations, %	organ condemnations %; pleuritis %; pneumonia %	0.42 -0.25 -0.23	0.02 0.02 0.03	31 85 85
abscesses, %	abscesses %; bitten tails %; partial condemnations%	0.41 0.51 0.31	<0.01 <0.01 <0.01	85 31 85
bitten tails, %	bitten tails %; abscesses %	0.45 0.35	0.01 <0.01	31 85
pleuritis, %	pleuritis, %	0.28	<0.01	85
pericarditis, %	organ condemnations %; liver condemnations %	0.91 0.27	<0.01 0.01	31 85
liver condemnation, %	liver condemnations %; organ condemnations %	0.56 0.63	<0.01 <0.01	85 31
Mycobacterium avium –complex, %	*Mycobacterium avium* – complex, %	0.30	<0.01	85

TABLE 3 Scoring of 85 batches of slaughter pigs according to food chain information provided

Scouring points	0	1	2	3	4
Previous year's partial condemnation rate	< 3%	3-8%	>8%	3-8%	>8 %
Declaration for constant cough	no	no	no	yes	yes
% of batches	9.4	75.3	10.6	4.7	0.0

TABLE 4 Sensitivity and specificity of the scoring system to find slaughter batches of pigs unsuitable for visual meat inspection

	Previous year´s partial condemnation rate >8% or reported cough	Previous year´s partial condemnation rate≤ 8% no reported cough	
Batches unsuitable for visual meat inspection	6	5	11
Batches suitable for visual meat inspection	7	67	74
Total	13	72	85

Sensitivity 55 % (95 % confidence interval 28-79%) and specificity 91 % (CI95: 82-95 %).

Figure1

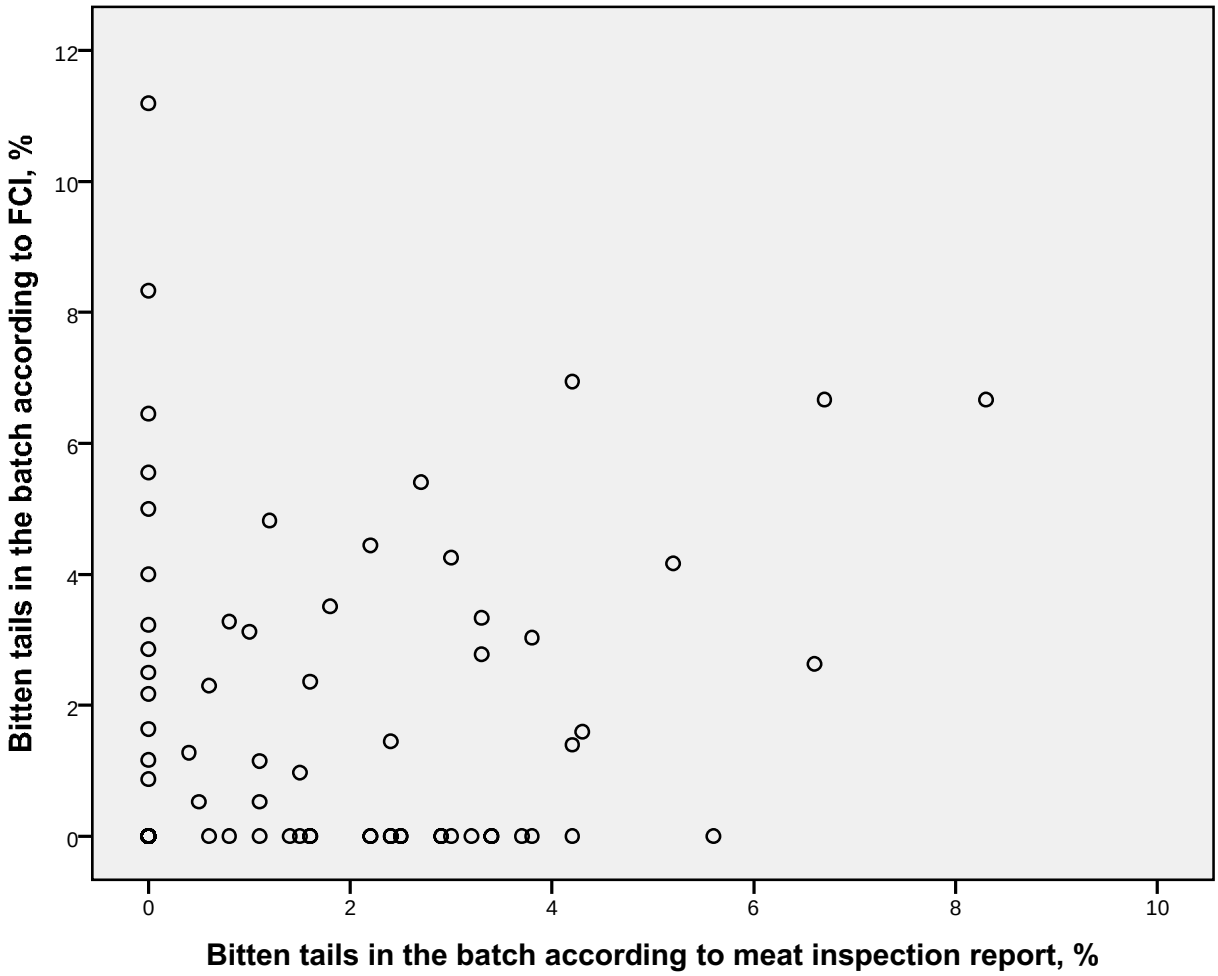
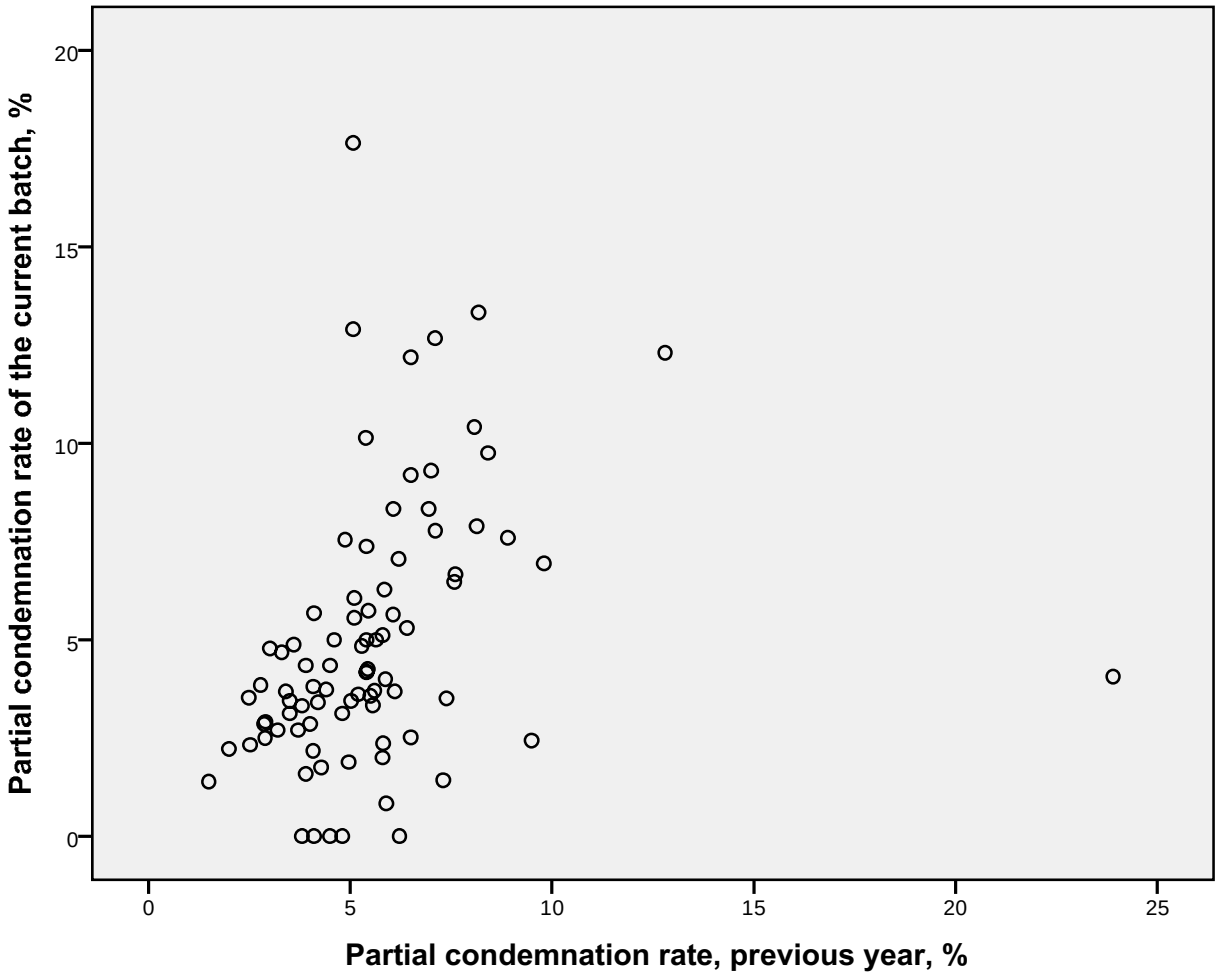

Bitten tails in the batch according to FCI, %
12
10
8
6
4
2
0
0
2
4
6
8
10
Bitten tails in the batch according to meat inspection report, %

Figure2


Partial condemnation rate of the current batch, %
20
15
10
5
0
0
5
10
15
20
25
Partial condemnation rate, previous year, %