<https://helda.helsinki.fi>

Sow mortality is associated with meat inspection findings

Heinonen, Mari

2018-02

Heinonen , M , Bergman , P , Fredriksson-Ahomaa , M , Virtala , A-M , Munsterhjelm , C , Valros , A , Oliviero , C , Peltoniemi , O & Hälli , O 2018 , ' Sow mortality is associated with meat inspection findings ' , Livestock Science , vol. 208 , pp. 90-95 . <https://doi.org/10.1016/j.livsci.2017.12.011>

<http://hdl.handle.net/10138/298560>

<https://doi.org/10.1016/j.livsci.2017.12.011>

cc_by_nc_nd

acceptedVersion

Downloaded from Helda, University of Helsinki institutional repository.

This is an electronic reprint of the original article.

This reprint may differ from the original in pagination and typographic detail.

Please cite the original version.

Sow mortality is associated with meat inspection findings

Mari Heinonen^{a,d*}, Paula Bergman^a, Maria Fredriksson-Ahomaa^b, Anna-Maija Virtala^c, Camilla Munsterhjelm^d, Anna Valros^d, Claudio Oliviero^a, Olli Peltoniemi^a, Outi Hälli^a

^aUniversity of Helsinki, Faculty of Veterinary Medicine, Department of Production Animal Medicine, Paroninkuja 20, 04920 Saarentaus, Finland

^bUniversity of Helsinki, Faculty of Veterinary Medicine, Department of Food Hygiene and Environmental Health, P.O. Box 66, 00014 University of Helsinki, Finland

^cUniversity of Helsinki, Faculty of Veterinary Medicine, Department of Veterinary Biosciences, P.O. Box 66, 00014 University of Helsinki, Finland

^dResearch Centre for Animal Welfare, Department of Production Animal Medicine, Faculty of Veterinary Medicine, P.O. Box 57, 00014 University of Helsinki, Finland

*corresponding author, e-mail mari.heinonen@helsinki.fi, telephone +358 400 687 915

Other e-mails: paula.bergman@helsinki.fi, maria.fredriksson-ahomaa@helsinki.fi, anna-maija.virtala@helsinki.fi, camilla.munsterhjelm@helsinki.fi, anna.valros@helsinki.fi, claudio.oliviero@helsinki.fi, olli.peltoniemi@helsinki.fi, outihalli75@gmail.com

27 Abstract

28 Sow meat inspection (MI) and mortality data are important sources of information for use in herd
 29 health work. This observational study examined whether MI results of sows associate with sow mortality in
 30 Finnish sow herds. We also described some MI findings of sows to create basic references in order to
 31 encourage their use in herd health work. The project was widely advertised to farmers of sow herds and
 32 practicing veterinarians. Ten herds joined the project voluntarily and 36 other herds after they were
 33 contacted by the researchers. MI data (carcass weight, lean meat percentage, arthritis, abscesses, liver
 34 condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers, tail biting, whole
 35 carcass condemnations, partial carcass condemnations and kg of meat condemned) were made available by
 36 the three largest slaughterhouses in Finland, and sow mortality data were obtained from the National
 37 Swine Herd Register for 39 of the study herds for the year 2014. The mean herd size of participating herds
 38 was 529 females with a standard deviation of ± 479 and mean annual mortality $9.0\% \pm 5.2\%$. As much as
 39 22.8% of the 7437 slaughtered sows had at least one MI finding. Heavy carcasses were less likely to have at
 40 least one MI finding. A median (range) of 1.8 % (0-7.2) and 11.8 % (0-34.6) of the sows were recorded to
 41 have a whole and partial carcass condemnation, respectively. The most common MI findings were
 42 abscesses (5.7 %, 0-16.3), shoulder ulcers (3.6 %, 0-22.9) and arthritis (2.1 %, 0-13.3). In individual
 43 carcasses, abscesses were associated with arthritis, shoulder ulcers and pneumonia, which was indicative
 44 that these animals most likely had had a systemic infection. Pneumonia findings were associated with
 45 pleuritis. At the herd level, the increase of sow mortality by 1% was associated with an increased
 46 percentage of slaughtered females with at least one MI finding 0.8% ($P=0.01$). If sow mortality increased by
 47 1%, the odds ratio for the herd having more than a median percentage of pleuritis was 1.3 (95% confidence
 48 interval; 1.01–1.57, $P=0.04$) compared to the situation of the herd having less than a median percentage of
 49 pleuritis. Also, if sow mortality increased by 1%, the percentage of partial carcass condemnations of
 50 females increased by 0.4% ($P=0.08$). These results suggest that high mortality was associated with an
 51 increase of some MI findings. MI results of sows should be used in herd health follow-up of sow health.

52

53 Keywords

54 Sow, mortality, meat inspection, condemnations

55

56 1. Introduction

57 About half of the sows in modern pig production are removed from sow herds yearly (Engblom et al.,
58 2007). These animals include culled sows and sows that were euthanized or died on-farm. Culled sows are
59 slaughtered in slaughterhouses, their carcasses are subsequently inspected and, depending on the findings
60 of the carcass inspection, their meat is used for human consumption. The slaughtering procedure is the
61 same as that used for finishing-pigs. The meat inspection (MI) data collected in the slaughterhouse have
62 been effectively used for following-up herd health in addition to inspecting meat for the human food chain.

63 Originally, MI procedures were developed to reduce food-borne risks to humans (Edwards et al.,
64 1997). Gradually these procedures are also becoming used in extensive epidemiological animal health
65 investigations (Harley et al., 2012b). Consequently, MI recording also includes findings about conditions
66 that are primarily a risk for the animals in addition to those that affect human health (Elbers et al., 1992)
67 and there is thus an increasing need and interest in expanding these MI data to be used as a welfare
68 surveillance tool (Harley et al., 2014). There is, therefore, a clear need to increase knowledge about sow MI
69 findings in general.

70 Some studies about MI procedures and results have already been published (Harbers et al., 1999,
71 Straw et al., 1986) and their use in herd health improvement work (Straw et al., 1986) and in disease
72 investigations (Cleveland-Nielsen, 2002, Jirawattanapong, 2010). The association between MI findings of
73 finishing pigs and herd parameters has been particularly studied (Cleveland-Nielsen, 2002, Fraile et al.,
74 2010, Heinonen et al., 2001, Heinonen et al., 2007, Jäger et al., 2012, Maes et al., 2001, Martinez et al.,
75 2009, Merialdi et al., 2012): especially risk factors for MI findings in respiratory organs.

76 Several earlier studies concentrated on sow mortality, the risks associated with it and possible
77 reasons for mortality (Abiven et al., 1998, Engblom 2008, Jensen et al., 2012, Sanz et al., 2007, Sasaki and
78 Koketsu, 2008). However, there are very few studies published about MI findings in sows (Cleveland-

Nielsen et al., 2004a, Cleveland-Nielsen et al., 2004b, Flesja and Ulvesaeter, 1979). Moreover, textbooks on meat inspection only consider fattening pigs, even though sows also produce a considerable amount of meat. A total of 41 882 sows were sent to slaughter in Finland in 2014 and about 6.8 million kg of sow meat was accepted for human consumption (Eva Kaisti, Finnish Food Safety Authority Evira national records, personal communication 2016), whereas the corresponding meat quantity from fattening pigs was about 176 million kg. Thus, the mean quantity of meat from culled sows is still a noteworthy contribution to the pig meat consumed in Finland.

At some stage of production sows inevitably become diseased or less productive and the farmer decides whether to send the animal to slaughter or to euthanize her on-farm. In addition, some sows die unexpectedly. Some farmers may be more likely than the others not to send a diseased sow to slaughter. Others may try to save disposal costs of sow carcasses and therefore also send some unfit animals to slaughter. Some sows die in the herd or are euthanized on the farm, therefore the meat inspection results may underestimate the extent of the sow health and welfare situation on-farm. We have not found studies investigating the association of mortality in the herd and meat inspection results of sows from the same herds.

The aim of this study was therefore to examine if MI results of sows were associated with sow mortality in Finnish sow herds. We hypothesized that some farms may have fewer MI findings, because they have higher mortality due to euthanasia in-herd. We also describe some MI findings of sows in order to create basic figures to encourage herd veterinarians and herd owners to use them in preventive herd health work in sow herds. We compare our sow data to those of finishing pigs and discuss them. The results concerning the herd-level risk factors for culling, mortality and meat inspection findings in these same herds are presented in another article (Munsterhjelm et al., submitted).

2. Materials and methods

103 This observational study between mortality and MI is a part of a larger sow longevity project
104 collecting information from Finnish sow herds. The websites of the three largest slaughterhouses in the
105 country recommend the longevity project to their client herd producers. The longevity project was also
106 advertised on the websites of the research group, Finnish Pig Producers and Animal Health ETT and in
107 Facebook of the advisory organization ProAgria. The research personnel also spread the information about
108 the longevity project in farmers' meetings and in farmers' professional journals. Finally, all client farms of
109 the three largest slaughterhouses received an invitation letter to participate in the project. A total of 46
110 herds participated in the sow longevity study. Ten of them informed the research group voluntarily about
111 their willingness to join the project and allowed the researcher to visit the herd for data collection. The rest
112 of the herds in this study consisted of a convenience sample of herds after making telephone contact
113 between the research personnel and the producers. Mortality and slaughterhouse data were collected
114 from these 46 herds for the year 2014.

115 Sow mortality data were collected from the National Swine Herd Register maintained by the Finnish
116 Food Safety Authority Evira. Herd owners report their monthly numbers of animals to this register: the
117 numbers of sows and young breeding animals (hereafter females) present in the herd on the first day of
118 each month and the numbers of females found dead or euthanized (hereafter referred to as dead) in the
119 herd each month. Finnish legislation defines a gilt as a sexually mature female pig from mating until the
120 first farrowing, however, we do not know exactly how the farmers in the study applied the term 'gilt'. The
121 slaughterhouses send a report to the National Swine Herd Register the numbers of females they receive
122 from the herds for slaughter each month. These data were obtained directly from the Register for 44 herds
123 that participate in the longevity study for a 12-month period from January to December 2014. The 12-
124 month mean female inventory of the herd was calculated by summing up the number of females on the
125 first day of each month and dividing the sum by 12. The number of dead females were the sum of females
126 reported to have been euthanized or found dead during the whole year 2014. Similarly, the number of
127 slaughtered (culled) animals summed up the females sent to slaughter during the same year. The mortality
128 and culling percentage were calculated as the number of dead females in the herd or slaughtered animals

divided by the 12-month mean female inventory. The removal percentage included all females removed from the herds due to death, euthanasia and slaughter.

The MI data of slaughtered females from 40 out of the 46 herds that participated in the longevity study were obtained directly from three large Finnish slaughterhouses. Slaughterhouse information could not be obtained from those study herds that sent their animals to small slaughterhouses that were not able or willing to transfer these data for the research purposes. The data obtained included individual, animal level MI findings for each slaughtered animal: carcass weight, lean meat percentage of the carcass and meat inspection findings (arthritis, abscesses, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers, tail biting, whole carcass condemnation, partial carcass condemnation, and kg of condemned meat). Detailed sow culling reasons from farm records were not available for the study. Therefore, comparisons between MI findings and the most important culling reasons, namely reproductive failures and locomotion problems, could not be carried out. In order to numerically compare the levels of MI findings in sows and finishing pigs, we also obtained data for finishers (n=1 998 124) from Evira Finland's Food Safety Authority's national records by collecting information from pigs slaughtered in all slaughterhouses in Finland during the same time period as for the sows investigated in this study.

When calculating the financial loss caused by carcass condemnations, the producer price of 0.8474 €/kg for sow meat was used.

The complete set of data (both Swine Herd Register data and MI findings) for this observational study investigating the association between mortality and MI findings was obtained for 39 herds.

2.1 Statistical analyses

Herd level data

The unit of interest was a herd. All outcome variables were originally expressed as herd level percentages. First, descriptive statistics were calculated for all outcome variables (abscesses, arthritis, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, tail biting, shoulder ulcers and a

summary variable “condemnation due to any reason” in addition to lean meat percentage, partial or whole carcass condemnations and kg of condemnations). Because of clear differences in coding practices regarding pleuritis between different slaughterhouses (Hälli et al., 2012), descriptive statistics for pleuritis were calculated separately for each slaughterhouse. Descriptive statistics were also calculated for "low mortality herds" and "high mortality herds", separately, according to their mean annual mortality percentage.

Outcome variables were modelled as continuous variables unless categorizing of the variable was required by the data distributions. The median was used as a cut-off point in categorizing. The variables "carcass with at least one meat inspection finding", abscesses and partial carcass condemnations were modelled as continuous variables and thus, linear regression was used for analysis. For the variable "whole carcass condemnations", the outcome variable was log transformed to correct any obvious heteroscedasticity. The variables of arthritis, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers and kg of meat condemned were modelled as binary variables and thus, logistic regression was used for analysis.

The main explanatory variable used was “mortality”, which was modelled as a continuous variable unless categorizing of the variable was needed. In the latter case, the mean was used as the cut-off point. For “at least one meat inspection finding”, abscesses, arthritis, pleuritis, pneumonia, liver condemnations, shoulder ulcers, partial and whole carcass condemnations and kg of condemned meat, “mortality” was modelled as the continuous variable. For milk spots the “mortality” was modelled as a binary variable.

Other explanatory variables were “herd size” (only adult female pigs), “carcass weight”, “lean meat percentage”, “slaughterhouse” and “gilts” (=proportion of gilts out of female pigs). Crude associations (only one explanatory variable in the model at a time) between outcome and explanatory variables were evaluated using liberal p-value of 0.2 as a “drop-out/keep-in” criterion.

Finally, multivariable models (either linear or logistic regression, depending on the outcome variable) were built for the outcomes (meat inspection findings) abscesses, arthritis, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers, whole or partial carcass condemnations and

kg of condemned meat. The corresponding random effects models including herd as a random factor were built, but no difference was observed compared to models without the random effect. Thus, random effects models were not used.

During model building for herd level data, assumptions of linear regression model were evaluated by performing a formal test for heteroscedasticity (Breusch-Pagan and Cook-Weisberg test) and a normal distribution of errors test (Shapiro-Wilk W test), a graphical evaluation of residuals and linear prediction and of residuals plotted against outcome. If any concerns were detected, suitable modifications in explanatory variables were performed as described earlier in the text. After fitting the final linear model, variance inflation factors were calculated and evaluated.

Diagnostics for logistic regression included evaluation of Pearson goodness of fit test and the ability of the model to correctly classify the outcome.

192

Individual level data

Individual level data were used in testing two outcome variables, “abscesses” and “pneumonia”. The unit of interest for these analyses was an individual female pig. First, descriptive statistics were calculated for all variables. We used categorical variables “slaughterhouse”, “arthritis”, “shoulder ulcers”, “pleuritis” and “pneumonia” as explanatory variables for the outcome variable “abscesses” (yes/no). Correlations between explanatory variables were evaluated using the “correlate” function in STATA. Despite multiple comparisons no Bonferroni corrections were used, because of the preliminary type of analysis. Moreover, no strong correlations were detected. Unconditional associations between the outcome and explanatory variables were evaluated using the liberal p-value of 0.2 as a drop-out/keep-in criterion. Finally, a multivariable random effects model was built for the outcome with explanatory variables “arthritis”, “shoulder ulcers”, “pleuritis” and “pneumonia” with the herd as a group-level variable.

The second outcome variable tested was the categorical variable “pneumonia” (yes/no) and the explanatory variables used were categorical variables “pleuritis” and “slaughterhouse”. A logistic model was built that contained both the abovementioned variables. The corresponding random effects model,

207 which included herd as a random factor was built, but no difference was observed compared to the model
 208 without the random effect. Thus, the random effects model was not used. Similar model diagnostics as for
 209 herd level data were performed.

210 All statistical data analyses were performed using Stata 14.0 (StataCorp LP, Texas, USA).

211

212 3. Results

213 3.1. Descriptive statistics and crude analyses

214 The data consisted of records from 39 Finnish sow herds that had sent their animals to one of the
 215 three largest slaughterhouses in Finland (9 herds to slaughterhouse A, 17 herds to slaughterhouse B and 13
 216 herds to slaughterhouse C). These herds had a mean of 529 females (standard deviation, $sd/\pm/479$), and
 217 totalled 20 614 females in the study (2 206 gilts and 18 409 sows). During the follow-up time of the year
 218 2014, the study herds sent altogether 7 531 females to slaughter, resulting in a median culling percentage
 219 of 32.8 % (range 21.5-80.3) of females in a herd. The herd mortality (females found dead or euthanized)
 220 was a mean of 9.0% ($\pm 5.2\%$) and a median of 7.8% (range 0–18.2 %). A total of 9 742 (44.1%) animals were
 221 removed from the herds, i.e. they were found dead, euthanized or sent for slaughter.

222 We were able to obtain MI findings for 7 437 females, which was 98.8% of all females sent to
 223 slaughter during the study period. Their mean carcass weight was $188.8 \text{ kg} \pm 12.9 \text{ kg}$ and the median lean
 224 meat percentage was 60.0% (range 48.8–63.4 %). The slaughterhouse records of the sows in the study
 225 herds are presented in Table 1 together with the MI results of all the finishers slaughtered in Finland during
 226 the same time period.

227 A total of 38 038 kg of carcass condemnations were recorded during the study, which was a mean of
 228 $975 \text{ kg} \pm 1350 \text{ kg}$ per herd (median 513 kg and range 0–5366 kg). When calculated for each herd, a mean of
 229 $4.4 \text{ kg} \pm 3.9 \text{ kg}$ per slaughtered female was condemned (median 3.2 kg and range 0–16.1 kg), corresponding
 230 to a mean of 826.5 € per herd and 3.7 € per slaughtered female.

231 Descriptive results and crude analysis of the MI findings divided by the classification of the herds
 232 according to their mortality (higher or lower than the mean of the study herds) are presented in Table 2.

233

234 3.2 The association between mortality and MI findings

235 Multivariable modelling revealed that mortality of the females was associated with some of the MI findings
 236 of the slaughtered animals in the study herds. When mortality increased by 1%, the percentage of
 237 slaughtered females with at least one MI finding increased by 0.8% ($P=0.01$). Similarly, when carcass weight
 238 increased by 1 kg, the percentage of slaughtered females with at least one MI finding increased by 0.3%
 239 ($P=0.04$). When mortality increased by 1%, the odds ratio for the herd having more than median
 240 percentage of pleuritis was 1.3 (95% CI, 1.01–1.57, $P=0.04$). Mortality also tended to have an association
 241 with partial carcass condemnations. When mortality increased by 1%, the percentage of partial carcass
 242 condemnations of females increased by 0.4% ($P=0.08$).

243 Mortality was not associated with whole carcass condemnations, kg of carcass condemnations or with MI
 244 findings due to abscesses, arthritis, liver condemnations, milk spots, organ condemnations, pneumonia, or
 245 shoulder ulcers.

246

247 3.3. Associations of MI findings in individual animals

248 On the individual animal level, the MI finding “abscess” was associated with some of the other MI
 249 findings, namely: arthritis, shoulder ulcer and pneumonia (Table 3). The intra class correlation (ICC) of the
 250 final model was 0.042, which indicated that most of the variance was within the herds. Similarly, sows that
 251 had pneumonia recordings in MI were more likely to have pleuritis (Table 4).

252

253 4. Discussion

254 Sow mortality of herds involved in the study was associated with MI findings. All MI recordings were
 255 more common in high mortality herds compared with those in low mortality herds, but the difference was
 256 statistically significant after modelling for only two MI findings, namely: pleuritis and carcasses with at least
 257 one MI finding. Partial carcass condemnations showed a tendency ($P=0.08$) to be significant.

258 The 9% annual mortality corresponds well with the mortality rates reported by other studies (Abiven
 259 et al., 1998, Engblom, 2008, Jensen et al., 2012, Sanz et al., 2007, Sasaki and Koketsu, 2008) and the figures
 260 from the National Herd Health Register, Sikava (Nikunen and Kortensniemi, 2014). However, only a median
 261 of 32.8 % of the animals had been culled annually from the herds being clearly less than that reported
 262 elsewhere. The figures differ considerably between different countries. For example, a culling percentage
 263 of 51% and mortality of 9% was reported in the U.S.A. (Mote et al., 2009). In Hungary, the corresponding
 264 figures were 45% and 16% (Balogh et al., 2015). In addition, we were able to obtain data only from
 265 volunteer herds, not from randomly selected herds, and this may have led to selection of better managed
 266 herds. Our study herds were also noticeably larger than the mean sow herd size for Finland, which was 128
 267 sows per herd for 2014. Therefore, these results cannot be generalized to the whole sow population in
 268 Finland.

269 In contrast to our hypothesis, high mortality was not associated with a low percentage of MI findings.
 270 In the crude analyses, high mortality herds had a higher percentage of most MI recordings. According to
 271 multivariable model analyses, there was an association between mortality and the MI recordings “at least
 272 for one MI finding”, “pleuritis” and a tendency towards an association for “partial carcass condemnation”.
 273 These results suggest that there may be some health or management problems in our study herds. Similar
 274 studies that were conducted on finishing pigs have shown that pleuritis was associated with different
 275 infectious and non-infectious herd factors (Jäger et al., 2012, Martinez et al., 2009, Merialdi et al., 2012).

276 A lost sum of 3.7 € per slaughtered female due to condemnations should not be overlooked.
 277 Financial implications have not usually been published in conjunction to these kind of data, even though
 278 they are of great commercial importance. Harley et al. (2014) studied the prevalence of welfare-related
 279 lesions on carcasses of finishing pigs and calculated that the financial loss associated with carcass
 280 condemnations and trimmings for the producers was 1.10 € per study pig. This emphasizes the fact that
 281 carcass condemnations are not only related to sow welfare, but also affects the producer farm’s economics.

282 The MI data showed that findings in sows seem to differ from the results obtained from finishing
 283 pigs. When observing only the crude figures (Table 1) without statistical testing, we can see that in our data

284 obtained for finishing pigs that pneumonia, pleuritis, milk spots, arthritis and tail biting are more common
 285 than in sows, whereas in sows whole and partial carcass condemnations and abscesses seem to be the
 286 predominant findings. The MI findings of these different age categories seem to reflect what is often seen
 287 at the farm level. Respiratory infections are common problems in finishing pigs and these are also evident
 288 in MI results reported elsewhere (Merialdi et al., 2012). Our results show that in addition to finishing pig
 289 herds some sow herds can also have high pleuritis or pneumonia recordings in MI.

290 Milk spots in the liver are associated with migrating *Ascaris suum* larvae (Roepstorff et al., 2011).
 291 Their lower occurrence in sows than in finishing pigs is understandable, because most of these adult
 292 animals were likely to have developed immunity against the parasite. Unfortunately, we did not have
 293 information about the age of the slaughtered females and in some herds they may have also included a
 294 high percentage of gilts.

295 Tail-biting is a common behavioral disorder in growing pigs (Valros and Heinonen, 2015), but to our
 296 knowledge no papers have been published about its occurrence in sows. One reason for this might be the
 297 fact that group housing has not been practiced widely and it has become mandatory for pregnant sows in
 298 EU since 2013 (Maes et. al, 2016, Peltoniemi et al., 2016). However, according to the long experience in
 299 managing group-housed sows in some countries, we conclude that generally tail-biting damage is not a
 300 problem in adult sows. Our results show that some females also have tail biting damage, but its aetiology
 301 remains unclear. Tail-biting has been found in gilt rearing (Ursinus et al., 2014) and it is also possible that
 302 those few females recorded to have tail damage in our study may have been gilts.

303 According to our data almost 1/5 of animals had at least one MI finding. Such a high figure has not
 304 usually been reported in articles, because only herd level data concerning separate MI findings are
 305 available. We also found that heavier carcasses had fewer partial carcass condemnations than lighter
 306 carcasses. Heavy carcasses are more likely to be from older sows and it is difficult to speculate, why older
 307 sows / heavy carcasses would have fewer condemnations than younger sows / lighter carcasses. Individual
 308 carcasses with an abscess were clearly more likely to also have other infections, such as arthritis, shoulder
 309 ulcers or pneumonia. It is possible that these individuals had had a systemic infection spreading in the body

310 of the animal. Moreover, carcasses with pneumonia were also likely to have pleuritis, which shows that
 311 these conditions occurred simultaneously in the study sows. This kind of individual, detailed information
 312 would be very valuable in herd health follow-up not only for sow herds but also for herds growing finishing
 313 pigs.

314 Some of the present sow MI findings can be compared with those reported in the few previous
 315 studies including MI findings in sows (Cleveland-Nielsen et al., 2004a, Cleveland-Nielsen et al., 2004b, Flesja
 316 and Ulvesaeter, 1979, Knage-Rasmussen et al., 2015). An old study by Flesja et al. (1979) collected the MI
 317 results of 10 0541 apparently healthy sows. They reported similar results to ours in the percentage of
 318 pyemia together with abscesses (4.7% Flesja et al. 1979 vs. 5.7% in our study), at least one pathological
 319 lesion (17.0% vs. 18.5% in our study), milk spots (1.5% vs 0.0% in our study), shoulder ulcer (1.1% vs 3.6% in
 320 our study), arthritis (1.9% vs. 2.1% in our study), tail biting (0.4% vs. 1.4% in our study), pleuritis (1.4% vs.
 321 1.7% in our study) and pneumonia (0.6% vs. 1.0% in our study). When comparing the MI findings of sows to
 322 those of finishers, Flesja et al. (1979) also concluded that abscesses were more frequent in sows, but that
 323 lower frequencies for all the other commonly observed lesions were seen in sows than in finishing pigs.
 324 However, the definitions of MI findings are not the same in these two studies and their study is relatively
 325 old. Therefore, their comparison only sets an example. MI procedures and criteria are not uniform even in
 326 different slaughterhouses within the same country, let alone in slaughterhouses among different countries.
 327 For example, in Finland, clear differences were found for how pleuritis was recorded in finishers in different
 328 slaughterhouses (Hälli et al., 2012). Similarly, Bonde et al. (2010) reported that sensitivities and specificities
 329 to detect pathological lesions in different disease conditions varied between Danish slaughterhouses
 330 inducing variations in MI results (Bonde et al., 2010). Cleveland-Nielsen et al. (2004b) found generally lower
 331 percentages of MI findings than we obtained in our study except for shoulder ulcers. A study that
 332 concentrated only on decubital ulcers (possibly comparable to shoulder ulcers in our study), reported a
 333 somewhat higher prevalence to that found in our study (Cleveland-Nielsen et al., 2004a). Knage-Rasmussen
 334 et al. (2015) tried to use MI findings in estimating their suitability in replacing an animal welfare index but
 335 they did not report mean MI findings in detail. As mentioned earlier, however, the recording systems and

336 the study populations in other studies were different and therefore the results are only roughly
337 comparable. There are also inconsistencies in MI recordings due to variations in the description of similar
338 MI findings, which also makes the comparisons difficult (Harley et al., 2012a).

339 Cleveland-Nielsen et al. (2004b) divided MI data of sows into infectious or welfare-related causes
340 based on a factor analysis. They found that, generally, the prevalence of different lesions was low, but large
341 herd-to-herd variation existed. They suggested that MI might be used as an inexpensive diagnostic tool in
342 herd welfare classification. Other publications have also shared the same opinion (Harley et al., 2012a,
343 Harley et al., 2014, Sanchez-Vazquez et al., 2011). However, Harley et al. (2012b) stated that MI data
344 cannot be used reliably in large scale welfare surveillance schemes until some standardization and reforms
345 have been made. However, we suggest that MI findings of single herds or different herds within one
346 slaughterhouse could well be used in herd health veterinary work and follow-up. The type of basic MI data
347 of sows used in our study are needed to increase overall knowledge about the subject. Moreover, farmers
348 were shown to have recognized the benefit of the utilization of MI data as a tool in herd health work in one
349 study (Devitt et al., 2016). The same study reported that farmers also thought that private veterinary
350 practitioners are important in helping to interpret the MI findings.

351 Some studies have attempted to use the MI data in combination with other data to evaluate the
352 welfare of sows. For example, Knage-Rasmussen et al. (2015) tried to develop a cost-effective alternative
353 to those welfare assessment methods that are based on costly on-farm data collection. They aimed to
354 combine several databases into one animal welfare index: mortality data from rendering plants, medicine
355 records from national Danish database Vetstat and MI findings from slaughterhouses. However, they
356 concluded that this kind of an index cannot entirely replace on-farm animal-based measurement data. An
357 animal-based welfare index was developed by the Welfare Quality project (Anonymous 2009). This index
358 also includes some MI findings when finishing pigs are evaluated, but not when the data for the index for
359 sows have been collected. Other animal-based indices include: the Animal Needs Index TGI 35L (Bartussek,
360 1999) and a modification to it, the A-Index (Munsterhjelm et al., 2006). However, neither of these indices
361 include MI findings.

5. Conclusions

Sow mortality in medium to large size sow herds was found to be associated with some of the meat inspection findings in slaughterhouses, specifically: the percentage of females with at least one meat inspection finding and pleuritis. There was also a tendency for an association between mortality and partial carcass condemnation. In contrast to our hypothesis, high mortality was associated with high percentage of MI findings. This study also provided basic MI data that can be used in sow herd health veterinary and follow-up work. In general, sows seemed to have a high preponderance of MI findings. Heavier sow carcasses were less likely to have at least one MI finding. In individual carcasses, abscesses were associated with arthritis, shoulder ulcers and pneumonia. Similarly, pneumonia was associated with pleuritis.

Conflicts of interest

The authors report that there are no conflicts of interest relevant to this publication.

Acknowledgments

This study was supported by Finnish Ministry of Agriculture and Forestry and three Finnish slaughterhouses, Atria Ltd, HK Scan and Oy Snellman Ab. The authors wish to thank all participating farmers and their organization, Finnish Pig Producers, personnel of the slaughterhouses and of the National Swine Herd Register Data.

References

- Anonymous, 2009. Welfare Quality® assessment protocol for pigs (sows and piglets, growing and finishing pigs). Welfare Quality® Consortium, Lelystad, the Netherlands, ISBN/EAN 978-90-78240-05-1.
- Abiven, N., Seegers, H., Beaudeau, F., Laval, A., Fourichon, C., 1998. Risk factors for high sow mortality in French swine herds. *Prev. Vet. Med.* 33, 109-119.
- Balogh, P., Kapelanski, W., Jankowiak, H., Kovacs, S., Huzsvai, L., Popp, J., Posta, J., Soltesz, A., 2015. The productive lifetime of sows on two farms from the aspect of culling source. *Anim. Sci.*, 15, 747-758.

- 389 Bartussek, H., 1999. A review of the animal needs index (ANI) for the assessment of animals' well-being in
390 the housing systems for Austrian proprietary products and legislation. *Livestock Prod. Sci.* 61, 2-3, 179-
391 192.
- 392 Bonde, M., Toft, N., Thomsen, P.T., Sørensen, J.T., 2010. Evaluation of sensitivity and specificity of routine
393 meat inspection of Danish slaughter pigs using Latent Class Analysis. *Prev. Vet. Med.* 94, 165-169.
- 394 Cleveland-Nielsen, A., 2002. Chronic pleuritis in Danish slaughter pig herds. *Prev. Vet. Med.* 55, 121.
- 395 Cleveland-Nielsen, A., Baekbo, P., Ersboll, A.K., 2004a. Herd-related risk factors for decubital ulcers present
396 at post-mortem meat-inspection of Danish sows. *Prev. Vet. Med.* 64, 113-122.
- 397 Cleveland-Nielsen, A., Christensen, G., Ersboll, A.K., 2004b. Prevalences of welfare-related lesions at post-
398 mortem meat-inspection in Danish sows. *Prev. Vet. Med.* 64, 123-131.
- 399 Devitt, C., Boyle, L., Teixeira, D.L., O'Connell, N.E., Hawe, M., Hanlon, A., 2016. Pig producer perspectives on
400 the use of meat inspection as an animal health and welfare diagnostic tool in the Republic of Ireland
401 and Northern Ireland. *Ir. Vet. J.* 69, 2.
- 402 Edwards, D.S., Johnston, A.M., Mead, G.C., 1997. Meat inspection: an overview of present practices and
403 future trends. *Veterinary Journal.* 154, 135-147.
- 404 Elbers, A.R.W., Tielen, M.J.M., Snijders, J.M.A., Cromwijk, W.A., Hunneman, W.A., 1992. Epidemiological
405 studies on lesions in finishing pigs in the Netherlands. I. Prevalence, seasonality and interrelationship.
406 *Prev. Vet. Med.* 14, 217-231.
- 407 Engblom, L., Lundeheim, N., Dalin, A.M., Andersson, K., 2007. Sow removal in Swedish commercial herds.
408 *Livestock science.* 106, 76-86.
- 409 Engblom, L., 2008. Post mortem findings in sows and gilts euthanised or found dead in a large Swedish
410 herd. *Acta Vet. Scand.*, 1-10.
- 411 Flesja, K.I., Ulvesaeter, H.O., 1979. Pathological lesions of swine at slaughter II: Culled sows. *Acta Vet.*
412 *Scand.* 20, 515-524.
- 413 Fraile, L., Alegre, A., Lopez-Jimenez, R., Nofrarias, M., Segales, J., 2010. Risk factors associated with pleuritis
414 and cranio-ventral pulmonary consolidation in slaughter-aged pigs. *The Veterinary Journal.* 184, 326-
415 333.
- 416 Hälli, O., Laurila, T., Riihimäki, A., Heinonen, M., 2012. Post mortem inspection criteria for pleuritis in swine
417 differs between slaughterhouses. *Proceedings of the 4th European Symposium of Porcine Health*
418 *Management, April 25.-27.2012, Bruges, Belgium.* 59, 141.
- 419 Harbers, T.H.M., Smeets, J.F.M., Faber, J.A.J., Snijders, J.M.A., Logtestijn, J.G., 1999. A comparative study
420 into procedures for postmortem inspection for finishing pigs. *J. Food Prot.* 55, 620-626.
- 421 Harley, S., Boyle, L., O'Connell, N.E., More, S.J., Teixeira, D.L., Hanlon, A., 2014. Docking the value of
422 pigmeat? Prevalence and financial implications of welfare lesions in Irish slaughter pigs. *Anim.*
423 *Welfare.* 23, 275-285.

- 424 Harley, S., More, S., Boyle, L., O'Connell, N., Hanlon, A., 2012a. Good animal welfare makes economic
425 sense: potential of pig abattoir meat inspection as a welfare surveillance tool. *Ir. Vet. J.* 65, 11.
- 426 Harley, S., More, S.J., O'Connell, N.E., Hanlon, A., Teixeira, D., Boyle, L., 2012b. Evaluating the prevalence of
427 tail biting and carcase condemnations in slaughter pigs in the Republic and Northern Ireland, and the
428 potential of abattoir meat inspection as a welfare surveillance tool. *Vet. Rec.* 171, 621.
- 429 Heinonen, M., Grohn, Y.T., Saloniemi, H., Eskola, E., Tuovinen, V.K., 2001. The effects of health classification
430 and housing and management of feeder pigs on performance and meat inspection findings of all-in -
431 all-out swine-finishing herds. *Prev. Vet. Med.* 49, 41-54.
- 432 Heinonen, M., Hakala, S., Hämeenöja, P., Murro, A., Kokkonen, T., Levonen, K., Peltoniemi, O.A.T., 2007.
433 Case-control study of factors associated with arthritis detected at slaughter in pigs from 49 farms. *Vet.*
434 *Rec.* 160, 573-578.
- 435 Jäger, H.C., McKinley, T.J., Wood, J.L.N., Pearce, G.P., Williamson, S., Strugnell, B., Done, S., Habernoll, H.,
436 Palzer, A., Tucker, A.W., 2012. Factors associated with pleurisy in pigs: a case-control analysis of
437 slaughter pig data for England and Wales. *PLoS ONE.* 7, e29655.
- 438 Jensen, T.B., Toft, N., Bonde, M.K., Kongsted, A.G., Kristensen, A.R., Sørensen, J.T., 2012. Herd and sow-
439 related risk factors for mortality in sows in group-housed systems. *Prev. Vet. Med.* 103, 31-37.
- 440 Jirawattanapong, P., 2010. Pleuritis in slaughter pigs: Relations between lung lesions and bacteriology in 10
441 herds with high pleuritis. *Res. Vet. Sci.* 88, 11-15.
- 442 Knage-Rasmussen, K., Rousing, T., Sorensen, T.J., Houe, H., 2015. Assessing animal welfare in sow herds
443 using data on meat inspection, medication and mortality. *Animal.* 9, 509-15.
- 444 Maes, D.G., Deluyker, H., Verdonck, M., Castryck, F., Miry, C., Vrijens, B., Ducatelle, R., de, K.A., 2001. Non-
445 infectious factors associated with macroscopic and microscopic lung lesions in slaughter pigs from
446 farrow-to-finish herds. *Vet. Rec.* 148, 41-46.
- 447 Maes, D.G., Pluym, L., Peltoniemi, O.A.T., 2016. Impact of group housing of pregnant sows on health.
448 *Porcine Health Management*, 2, 17.
- 449 Martinez, J., Peris, B., Gomez, E.A., Corpa, J.M., 2009. The relationship between infectious and non-
450 infectious herd factors with pneumonia at slaughter and productive parameters in fattening pigs. *Vet.*
451 *J.* 179, 240-246.
- 452 Merialdi, G., Dottori, M., Bonilauri, P., Luppi, A., Gozio, S., Pozzi, P., Spaggiari, B., Martelli, P., 2012. Survey
453 of pleuritis and pulmonary lesions in pigs at abattoir with a focus on the extent of the condition and
454 herd risk factors. *Vet. J.* 193, 234-239.
- 455 Mote, B.E., Mabry, J.W., Stalder K.J., Rotschild, M.F., 2009. Evaluation of current reasons for removal of
456 sows from commercial farms. *The Professional Animal Scientist* 25, 1-7.
- 457 Munsterhjelm, C., Valros, A., Heinonen, M., Hälli, O., Peltoniemi, O., 2006. Welfare index and reproductive
458 performance in the sow. *Reprod. Dom. Anim.* 41, 494-500.

- 459 Munsterhjelm, C., Bergman, P., Virtala, A.-M., Hälli, O., Fredriksson-Ahomaa, M., Oliviero, C., Peltoniemi, O.,
 460 Valros, A., Heinonen, M., Herd-level factors associated with sow culling, mortality and meat inspection
 461 findings: an observational, cross-sectional study, Submitted, 2017.
- 462 Nikunen, S., Kortenesniemi, P., 2014. National health care and welfare program for swine in Finland 2012.
 463 Proceedings of the 5th European Symposium of Porcine Health Management, May 7.-9.2014,
 464 Sorrento, Italy. 183.
- 465 Peltoniemi, O.A.T., Björkman, S., Maes, D.G., 2016. Reproduction in group housed sows. Porcine Health
 466 Management, 2, 15.
- 467 Roepstorff, A., Mejer, H., Nejsum, P., Thamsborg, S.M., 2011. Helminth parasites in pigs: new challenges in
 468 pig production and current research highlights. Vet. Parasitol. 180, 72-81.
- 469 Sanchez-Vazquez, M., Strachan, W.D., Armstrong, D., Nielen, M., Gunn, G.J., 2011. Papers: The British pig
 470 health schemes: Integrated systems for large-scale pig abattoir lesion monitoring. Vet. Rec. 169, 413.
- 471 Sanz, M., Roberts, J.D., Perfumo, C.J., Alvarez, R.M., Donovan, T., Almond, G.W., 2007. Assessment of sow
 472 mortality in a large herd. J. of Swine Health and Prod. 15, 30-36.
- 473 Sasaki, Y., Koketsu, Y., 2008. Mortality, death interval, survivals, and herd factors for death in gilts and sows
 474 in commercial breeding herds. J. Anim. Sci. 86, 3159-3165.
- 475 Straw, B.E., Backstrom, L., Leman, A.D., 1986. Examination of swine at slaughter. Part I The mechanics of
 476 slaughter examination and epidemiologic considerations. Comp. on Cont. Educ. for the Pract. Vet. 8,
 477 S41-S47.
- 478 Ursinus W.W., Wijnen, H.J., Bartels, A.C., Dijvesteijn, N., van Reenen, C.G., Bolhuis, J.E., 2014. Damaging
 479 biting behaviours in intensively kept rearing gilts: the effect of jute sacks and relations with produciton
 480 characteristics. J. An. Sci. 92, 11, 5193-5202.
- 481 Valros, A., Heinonen, M., 2015. Save the pig tail (Review). Porcine Health Management. 1, 2.
- 482
- 483
- 484
- 485
- 486
- 487
- 488
- 489
- 490
- 491
- 492
- 493
- 494
- 495
- 496

497 Table 1. Meat inspection findings of 7 437 slaughtered gilts and sows in 39 study herds and of all finishing
 498 pigs slaughtered in Finland during 2014.
 499

Meat inspection finding	N of gilts and sows	Median % of 39 study herds (range)	Average % of Finnish finishing pigs (N=1 998 124) ^b
Whole carcass condemnation	158	1.8 (0.0–7.2)	0.3
Partial carcass condemnation	1006	11.8 (0.0–34.6)	7.7
≥1 meat inspection finding in the carcass	2175	18.5 (0.0–55.1)	na
Abscess	619	5.7 (0.0–16.3)	3.3
Arthritis	201	2.1 (0.0–13.3)	3.2
Liver condemnation	49	0.0 (0.0–11.3)	na
Milk spots	57	0.0 (0.0–5.0)	6.8
Organ condemnation	44	0.0 (0.0–13.3)	na
Pneumonia	87	1.0 (0.0–3.6)	2.3
Pleuritis ^a			
All slaughterhouses	1 034	1.7 (0.0–36.4)	16.7
Slaughterhouse A	11	1.3 (0.0–4.7)	na
Slaughterhouse B	69	1.5 (0.0–5.1)	na
Slaughterhouse C	954	26.3 (0.0–36.4)	na
Shoulder ulcer	411	3.6 (0.0–22.9)	na
Tail biting	4	0.0 (0.0–1.1)	1.4

500 ^aBecause of clear differences in coding practices regarding pleuritis between different slaughterhouses,
 501 pleuritis data are presented separately for each slaughterhouse.

502 ^bData received from Eva Kaisti, Finnish Food Safety Authority, personal communication, 2016.

503 na=not available

504

505

506

507

508

509

510

511

512

513

514

515

516

517

518

519

520

521

Table 2. Percentage of females (gilts and sows) with selected meat inspection findings in slaughterhouses. Data were collected from 7 437 females in 39 herds, which have been classified according to their mean mortality (higher or lower than the mean of the study herds, 9.0%).

Meat inspection finding, 7 437 females from 39 herds	High mortality herds ^b median % (range), N=17	Low mortality herds ^c median % (range) N=22	P-value, crude analysis
Carcass weight kg	192.4	185.9	0.3
Whole carcass condemnation	1.3 (0.0–7.2)	1.1(0.0–5.3)	0.04
Partial carcass condemnation	11.2 (0.0–20.0)	10. (0.0–34.6)	0.2
Lean meat percentage	60.3 (48.9–61.9)	58.5 (53.2–63.4)	0.9
At least one MI finding	20.3 (4.2–49.4)	17.2 (0.0–55.1)	0.04
Abscess	7.3 (0.0–15.2)	5.3 (0.0–16.3)	0.1
Arthritis	3.2 (0.0–13.3)	2.6 (0.0–10.8)	0.4
Liver condemnations	0.0 (0.0–11.3)	0.0 (0.0–7.2)	1.0
Milk spots	0.0 (0.0–2.0)	0.0 (0.0–5.0)	0.3
Organ condemnations	0.0 (0.0–13.3)	0.0 (0.0–6.4)	1.0
Pneumonia	1.3 (0.03.6)	0.5 (0.0–3.6)	0.5
Pleuritis			
All slaughterhouses ^a	3.1 (0.0–36.4)	1.3 (0.0–30.5)	0.05
Slaughterhouse A+B	0.9 (0.0–1.9)	0.4 (0.0–3.6)	0.02
Slaughterhouse C	28.5 (10.1–36.4)	14.0 (0.0–30.5)	0.4
Shoulder ulcer	6.7 (0.0–13.3)	2.6 (0.0–6.4)	0.2

^aFor pleuritis determinations, slaughterhouse specific median value was used because of differences in pleuritis coding practices in these slaughterhouses (Hälli et al., 2012).

^bMortality higher than 9.0% (the mean of the study herds)

^c Mortality lower than 9.0% (the mean of the study herds)

547 Table 3. Results of random effects (herd as group level variable) multivariable logistic regression model of
 548 the risk for an individual sow to have an abscess (outcome) in meat inspection in three Finnish
 549 slaughterhouses in 2014.

Variable	Categories	Odds Ratio	95 % Confidence Interval, CI	Wald's P
Arthritis	No	Ref		
	Yes	1.9	1.2–2.8	0.002
Shoulder ulcer	No	Ref		
	Yes	2.3	1.7–3.0	<0.01
Pneumonia	No	Ref		
	Yes	6.8	4.3–10.7	<0.01
Constant		0.06	0.05–0.08	<0.01

578 Table 4. Results of multivariable logistic regression model between pneumonia (outcome) and pleuritis
 579 (explanatory variable) in individual sows slaughtered in three Finnish slaughterhouses in 2014.
 580

Variable	Categories	Odds Ratio	95 % Confidence Interval, CI	Wald's P
Pleuritis	No	Ref		
	Yes	24.6	13.9–43.7	<0.01
Slaughterhouse	A	Ref		
	B	0.6	0.3–1.4	0.25
	C	0.2	0.07–0.4	<0.01
Constant		0.01	0.005–0.2	<0.01

581
 582