Effects of scalding and dehairing of pig carcasses at abattoirs on the visibility of welfare-related lesions

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1 **Effects of scalding and dehairing of pig carcasses at abattoirs on the visibility**

2 **of welfare-related lesions**

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15 Short title: Visibility of welfare lesions in slaughter pigs

16

Abstract

18 There is increasing interest in developing abattoir-based measures to assist in

19 determining the welfare status of pigs. The primary aim of this study was to determine

20 the most appropriate place on the slaughter line to conduct assessments of welfare-

21 related lesions, namely apparent aggression-related skin lesions (hereafter referred to

22 as 'skin lesions'), loin bruising and apparent tail biting damage. The study also lent

23 itself to an assessment of the prevalence of these lesions, and the extent to which they

24 were linked with production variables. Finishing pigs processed at two abattoirs on the

25 Island of Ireland (n = 1 950 in abattoir 1, and n = 1 939 in abattoir 2) were used. Data

26   were collected over 6 days in each abattoir in July 2014. Lesion scoring took place at

27   two points on the slaughter line: (1) at exsanguination (Slaughter Stage 1 [SS1]), and

28   (2) following scalding and dehairing of carcasses (Slaughter Stage 2 [SS2]). At both

29   points, each carcass was assigned a skin and tail lesion score ranging from 0 (lesion

30   absent) to 3 or 4 (severe lesions), respectively. Loin bruising was recorded as present

31   or absent. Differences in the percentage of pigs with observable lesions of each type

32   were compared between SS1 and SS2 using McNemar/McNemar-Bowker tests. The

33   associations between each lesion type, and both cold carcass weight and

34   condemnations, were examined at batch level using Pearson's correlations. Batch was

35   defined as the group of animals with a particular farm identification code on a given

36   day. The overall percentage of pigs with a visible skin lesion (i.e. score > 0) decreased

37   between SS1 and SS2 ($P < 0.001$). However, the percentage of pigs with a severe skin

38   lesion increased numerically from SS1 to SS2. The percentage of pigs with a visible

39   tail lesion and with loin bruising also increased between SS1 and SS2 ($P < 0.001$).

40   There was a positive correlation between the percentage of carcasses that were

41   partially condemned, and the percentage of pigs with skin lesions, tail lesions and loin

42   bruising ($P < 0.05$). Additionally, as the batch-level frequency of each lesion type

43   increased, average cold carcass weight decreased ($P < 0.001$). These findings suggest

44   that severe skin lesions, tail lesions and loin bruising are more visible on pig carcasses

45   after they have been scalded and dehaired, and that this is when abattoir-based lesion

46   scoring should take place. The high prevalence of all three lesion types, and the links

47   with economically important production parameters, suggests that more research into

48   identifying key risk factors is warranted.

49

50   **Keywords:** Animal welfare, carcass condemnation, pigs, skin lesions, tail lesions

51

Implications

Animal welfare assessment at abattoirs has several advantages over traditional farm-based assessments. However, the extent to which routine carcass processing either masks or enhances the visibility of key welfare lesions is unclear. This research has confirmed that the visibility of loin bruising and tail lesions is improved by scalding and dehairing of carcasses. Mild apparent aggression-related skin lesions are less visible, but severe skin lesions appear to become more visible following these processes. This research also reinforces earlier findings, which suggest a link between welfare-related carcass damage and both increased carcass condemnations and reduced carcass weight, strengthening the argument that reducing these lesions will have economic benefits.

Introduction

There is increasing interest in developing abattoir-based welfare measures to assist in determining the welfare status of pigs (Harley *et al*., 2012a). In addition to avoiding biosecurity issues associated with entering farms, abattoir-based welfare assessment avoids potential problems associated with having to assess animals in crowded, dirty or poorly-lit conditions (Edwards *et al*., 1997; Velarde *et al*., 2005). However, the extent to which routine carcass processing, in the form of scalding and dehairing, either masks or unveils key welfare-related skin lesions in pigs is unclear. Understanding these effects may help to answer questions such as whether ante- or post-mortem lesion inspection is the best option for abattoir-based welfare assessment in pigs.

75   Stärk *et al.* (2014) note that bruising to the skin of pigs is more likely to be observed at

76   post mortem rather than ante mortem inspection. This suggests that the scalding and

77   dehairing of pig carcasses make bruising to the skin more visible, and it is possible that

78   other types of skin damage will also become more visible on the carcass after it has

79   been subjected to these processes. On the other hand, it has been suggested that

80   scalding and dehairing of the carcass may remove evidence of mild skin damage

81   (Aaslyng *et al.*, 2013) and tail lesions (Taylor *et al.*, 2010). These theories have yet to

82   be tested in a controlled manner.

83

84   Assessing the prevalence of welfare issues in farm animals is important, as it can be

85   used as a point of reference for benchmarking purposes. Tail lesion prevalence data

86   collected on farms is seldom used to determine nation-wide prevalence (Taylor *et al.*,

87   2010). Furthermore, only a handful of isolated studies have examined tail lesion

88   prevalence by carrying out abattoir-based assessments (Hunter *et al.*, 1999; Valros *et*

89   *al.*, 2004; Harley *et al.*, 2012b). Similarly, information on loin bruising prevalence is

90   limited, perhaps due to the fact that it has only recently been identified as a welfare

91   issue (Harley *et al.*, 2014). Skin lesions, on the other hand, have been studied for

92   decades. Despite this, few studies have examined skin lesion prevalence, particularly

93   in an animal welfare context (Nielsen *et al.*, 2014). Skin lesions are a concern as they

94   can reflect poor social and physical environments (Dalmau *et al.*, 2009). Indeed, along

95   with tail lesions, skin lesions were recently deemed to be one of the most important

96   indicators of pig welfare status by a panel of international animal welfare experts

97   (European Food Safety Authority [EFSA], 2012). In addition to determining prevalence

98   of welfare-related lesions, understanding how they relate to production traits may also

99   be important in establishing priorities for addressing them.

100

101   The primary aim of this study was to determine the most appropriate place on the

102   slaughter line to conduct assessments of welfare-related lesions, namely apparent

103   aggression-related skin lesions (hereafter referred to as 'skin lesions'), loin bruising,

104   and apparent tail biting damage (hereafter referred to as 'tail lesions'). This research

105   also lent itself to an assessment of the prevalence of these lesions. Furthermore,

106   relationships between the presence of welfare-related lesions and production

107   parameters such as carcass weight and level of carcass condemnation were explored.

108

109   **Material and methods**

110   This research was conducted over 6 days in each of two commercial pig abattoirs on

111   the island of Ireland in July 2014. One abattoir was located in Northern Ireland (NI)

112   (Abattoir A) and one in the Republic of Ireland (ROI) (Abattoir B). Pigs from both NI

113   and ROI were slaughtered in Abattoir A, whereas only pigs from ROI were slaughtered

114   in Abattoir B. The presence and severity of different welfare-related lesions was

115   recorded in 1 950 pigs in Abattoir A and 1 939 pigs in Abattoir B. Only

116   finishing/fattening pigs were assessed.

117

118

119 *Determination of sample size*

120 Sample size determination was based on requirements to assess prevalence of skin

121 lesions. This was because pig skin lesion prevalence had not yet been determined on

122 the Island of Ireland to our knowledge, and therefore was the main focus when

123 examining welfare lesion prevalence. Sample size was determined by considering the

124 total number of pig farms on the island of Ireland (approximately 400 pig farms account

125 for the vast majority of the pig population [Department of Agriculture and Rural

126 Development (DARD), 2013; Teagasc, 2011]) and the frequency of skin lesions

127 (approximately 70% of the pig population on average have skin lesions, based on

128 previous studies [Warriss *et al.*, 1998; Guardia *et al.*, 2009; Aaslyng *et al.*, 2013]).

129 Population size (400), average proportion of pigs with skin lesions (0.70), 95%

130 confidence level and a standard error of 0.05 were entered into the National Statistics

131 Service sample size calculator (NSS, 2014). Based on this information, the required

132 number of farms was 70. Previous research showed that the average batch size of

133 pigs submitted to abattoirs on the island of Ireland was 142 (Harley *et al.*, 2012b). It

134 was decided that one third of pigs in each batch (approximately 47 pigs) would be

135 assessed. This figure was chosen as: (a) it would allow the assessment of every third

136 pig on the slaughter line (which seemed practically feasible), and (b) it was similar to

137 the figure of 50 pigs that is used in commercial pig health assessment schemes (BPEX,

138 2010) and has been deemed adequate for detection of health and welfare issues post-

139 mortem (Sanchez-Vasquez *et al.*, 2011). The required number of pigs for assessment

140 was thus calculated to be 3 313. This figure was increased by 15% to account for

141 clustering effects. Thus, the final required sample size was 3 810 pigs. As a result of

142 scoring carcasses at varying line speeds between abattoirs, there was variation in the

143 number of farms that were assessed between abattoir A and B. However, as abattoir

144   A processed pigs from both regions of Ireland, there were a comparable number of

145   farms from both regions in the final data set.

146

147   *Abattoir handling and slaughter practices*

148   At both abattoirs, pigs were unloaded from the lorry and driven into lairage pens using

149   a pig board and a paddle when deemed necessary. In abattoir A, pigs exited the lairage

150   through a horizontal gate, and were driven to a CO_2 chamber in small groups by

151   moveable walls. One operator used a paddle to move the pigs into the final holding

152   position preceding the CO_2 chamber. In abattoir B, pigs exited the lairage through

153   vertically moving gates that doubled as moving walls. Pigs were driven from this area

154   by one operator using a paddle and pig board. A second operator used a paddle to

155   separate the pigs into smaller groups by moving them through a second vertical gate.

156   Two more operators moved pigs to the final holding position preceding the CO_2

157   chamber using a paddle. In both abattoirs, pigs were lowered into the CO_2 chambers

158   and stunned. After stunning, pigs were hung by their hind legs for exsanguination.

159

160   Pigs were submerged in the scalding tank for 7.5 minutes in abattoir A, in water heated

161   to between 58.5 and 62°C. At abattoir B, pigs were submerged in the scalding tank for

162   10 minutes in water heated to 62°C. Pigs passed through a singeing furnace followed

163   by a scraping tunnel where rubber scrapers removed residual hair.

164

165   *Data collection*

166   Data were collected at each abattoir for 6 consecutive days in July 2014 (excluding

167   weekends). Data collection began at 09:00 and continued for approximately 5 hours

168   each day until the required sample size was reached. Total required sample size was

169 divided evenly among the data collection days (346 pigs per day) with day 1 dedicated

170 to inter-rater reliability scoring (see section below). Two trained researchers took

171 positions on the slaughter line; Researcher 1 was positioned at the beginning of the

172 line immediately following the exsanguination area (slaughter stage 1 [SS1]).

173 Researcher 2 was positioned on the line following scalding and dehairing of the

174 carcass (slaughter stage 2 [SS2]). The researchers alternated between positions SS1

175 and SS2 daily, and both spent an equal amount of time scoring at each position. Each

176 carcass took approximately 25 minutes to pass from SS1 to SS2. An assistant was

177 located at SS1. The assistant gave each pig an individual ink tattoo number to ensure

178 that it was identifiable at both data collection points. These numbers were placed on

179 the upper back area of the pig so as not to disguise or be confused with the farm

180 identification number which was usually tattooed on the shoulder region. As stated

181 previously, it was initially planned to assess every 3rd carcass on the slaughter line at

182 both abattoirs. However, this was not practically possible due to the substantial

183 differences in line speed between the two abattoirs. Every 4th pig to pass along the

184 slaughter line was scored at Abattoir A, and every 2nd pig was scored at Abattoir B.

185

186 Dark-haired pig breeds were rarely seen. However, when present, the pig succeeding

187 the dark-haired pig was scored. These pigs were avoided as lesion visibility at SS1

188 would have been significantly reduced.

189

190 *Injury scoring measures*

191 *Loin bruises.* A simplified version of Harley *et al.*'s (2014) loin bruise scoring system

192 was used whereby 'mild' and 'severe' bruise categories were combined. Therefore,

193   loin bruises were recorded as being either present (when observed in either mild or

194   severe form) or absent (Figure 1).

195

196   *Tail lesions.* Tail lesions were scored using an adapted version of Kritas and Morrison's

197   (2007) tail scoring system used by Harley *et al.* [2012b] (Figure 2).

198

199   *Skin lesions.* A skin lesion scoring system developed by Aaslyng et al. (2013) was used

200   in this study. Scores ranged from 0 to 3; (0) no damage, or a little superficial damage;

201   (1) some superficial damage, clearly marked or up to three short (2 - 3 cm) and deep

202   lesions; (2) clear deep and/or long damage (> 3cm) including much superficial damage

203   or circular areas; (3) much deep damage. The carcass was scored for skin lesions in

204   two parts (Figure 3), the "rear" region and the "front" region. The "rear" region was

205   defined as the loin and everything below it. The "front" region was defined as everything

206   above the loin. Both sides of the carcass were scored as the carcass passed along the

207   slaughter line. Each animal was given an overall skin lesion score based on the highest

208   score assigned to that animal in either body region. Tails were not included in the

209   scoring of skin lesions (as they were scored separately).

210

211   *Inter-rater reliability*

212   In order to ensure that any differences in skin lesions, tail lesions and loin bruising

213   scores were due to varying levels of lesion visibility as opposed to rater effects, inter-

214   rater reliability tests were carried out prior to data collection. The scoring system for

215   each welfare-related lesion was first viewed by both raters and discussed to gain

216   consensus in the scores that should be assigned to each lesion type. Previous

217   literature suggests that levels of agreement become stable after the 5th scoring event

218 (March *et al.*, 2007; D'Eath, 2012). Therefore, 5 sessions were conducted at SS1 and

219 SS2 each. Sample sizes of 300 (60 pigs x 5 sessions) and 150 (30 pigs x 5 sessions)

220 were used for the testing and training sessions, respectively. In each training session,

221 both researchers jointly scored every 3rd carcass passing on the slaughter line until

222 the required number of pigs had been assessed. Any disagreements in assigned

223 scores were discussed. Each testing session involved blind scoring of every 3rd

224 carcass passing on the slaughter line until 60 carcasses were assessed. During testing

225 sessions the researchers scored the same carcasses independently. Levels of

226 agreement between raters was analysed using the Inter Class Correlation Coefficient

227 (ICC) test. Very good (>0.80) levels of agreement were reached by the final scoring

228 event.

229

230 *Other measures*

231 For individual pigs, information on the sex (entire male or female) and farm of origin

232 was taken from the carcass at SS2. Tail-dock status was recorded at both slaughter

233 stages. Meat inspection data were collected at the end of each day. This included

234 information on the number of whole and partial condemnations for each batch of pigs

235 with a particular farm identification number on a given day. In addition, average cold

236 carcass weights (CCW) for each batch of pigs were obtained at abattoir B. This

237 information was unavailable at abattoir A.

238

239

240 *Statistical analysis*

241 In a repeated measures design, the effects of slaughter stage (SS1 versus SS2) on

242 skin lesion, tail lesion and loin bruise scores were examined at the individual animal

level using McNemar and McNemar-Bowker tests for dichotomous (loin bruising) and ordinal (skin and tail lesions) variables, respectively. The prevalence of skin lesions, tail lesions and loin bruising (i.e. greater than 0) was determined using descriptive statistics. Prevalence of skin lesions was based on values recorded at SS1, and prevalence of tail lesions and loin bruising was based on values recorded at SS2 (please see results section for explanation), and these data were also used for calculations below. Using Pearson's correlations, associations were examined between the batch-level percentage of animals with welfare-related carcass damage (skin lesions, tail lesions and loin bruising) and the batch-level percentage of pigs whose carcasses were partially or fully condemned. The batch-level percentage of animals with skin lesions, tail lesions and loin bruising was also compared to average batch-level CCW for pigs slaughtered at abattoir B. Relevant data met the assumptions of the Pearson's correlation test. All statistical analysis was carried out using SPSS version 20.

258   **Results**

259   In total, 110 batches of pigs from 96 farms were assessed. The number of batches

260   was greater than the number of farms assessed due to some farms sending pigs to

261   both abattoirs. The average batch size was 127 pigs. A slight majority of pigs assessed

262   were male (52.1% versus 47.9%), and all pigs, excluding one, appeared to be tail-

263   docked.

264

265   *The effect of scalding and dehairing of carcasses on the visibility of lesions*

266   Average skin lesion, tail lesion and loin bruise scores changed significantly between

267   SS1 and SS2 ($P < 0.001$, see Table 1). The percentage of animals with a detectable

268   skin lesion decreased, whereas those with loin bruising or a detectable tail lesion

269   increased. It is worth noting, however, that the percentage of pigs observed to have

270   *severe* skin lesions increased numerically between SS1 and SS2.

271

272   *Welfare-related carcass lesion prevalence*

273   The prevalence of skin lesions, tail lesions and loin bruising is based on the slaughter

274   stage with the highest level of lesion detection i.e. SS1 for skin lesions and SS2 for tail

275   lesion and loin bruising (Table 1).

276

277   *Relationship between welfare-related carcass lesions, and carcass parameters*

278   Partial carcass condemnations were moderately correlated with the batch-level

279   frequency of skin lesions (r = .358, $P < 0.001$), tail lesions (r = .413, $P < 0.001$), and

280   loin bruising (r = .499, $P < 0.001$). Associations between whole carcass condemnations

281   and skin lesions, tail lesions and loin bruising were not statistically significant ($P >$

282   0.05). Average cold carcass weights were strongly and negatively associated with the

12

283   percentage of pigs per batch with skin lesions (r = -.667, *P* < 0.001), tail lesions (r =. -

284   .615, *P* < 0.001), and loin bruising (r = -.739, *P* < 0.001).

285

286

287 **Discussion**

288 *Effect of slaughter processes on visibility of skin lesions, tail lesions and loin bruising*

289 There are conflicting suggestions on the effects of routine processing of carcasses at

290 abattoirs (such as scalding and dehairing) on the visibility of skin lesions, tail lesions

291 and loin bruising. Some researchers argue that these processes could make welfare-

292 related carcass damage difficult to detect (Taylor *et al.*, 2010; Aaslyng *et al.*, 2013).

293 However, others suggest that this damage may be *more* detectable after these

294 processes (Harley *et al.*, 2014; Stärk *et al.*, 2014). It appears that the current study is

295 the first to actually investigate this in a controlled way.

296

297 The findings show that tail lesions of every severity category become more visible after

298 scalding and dehairing. The percentage increase in the visibility of *mild* tail lesions from

299 SS1 to SS2 was particularly high (131.4% increase). Tail lesions, particularly more

300 serious lesions, are related to secondary conditions such as abscessation and pleuritic

301 lesions of the lungs (Huey, 1996; Marques *et al.*, 2012), and are associated to a greater

302 extent with trimming of the carcass than milder lesions (Kritas and Morrison, 2007).

303 Nonetheless, even mild tail lesions are associated with carcass condemnations and

304 reduced carcass weights (Harley *et al.*, 2012b; Harley *et al.*, 2014). Therefore, scoring

305 of tail lesions after, rather than before, scalding and dehairing of carcasses offers clear

306 advantages if the information is to be used to inform herd health and welfare

307 management plans. It is possible that damage caused to the carcass by the scalding

308 and dehairing processes could have been misinterpreted for tail biting injuries,

309 however this is unlikely. Informal observations suggested that machinery-related

310 damage to the carcass manifested as shredding and peeling of the skin. These lesions

311 lacked colour which most likely reflected the fact that they occurred after

14

312   exsanguination. Tail lesions, on the other hand, were coloured (even in mild cases),

313   had visible bite marks or, in the case of healed tail lesions, had significant scar tissue.

314

315   The results clearly showed that loin bruising was much more evident at SS2 than at

316   SS1, and should therefore be recorded at this point. It follows from this that bruising to

317   other areas of the body may also become more visible subsequent to scalding and

318   dehairing of the carcass. The removal of dirt and hair that was present at

319   exsanguination could perhaps explain the increased visibility of bruising. However,

320   given the almost 13 fold increase in bruise visibility from SS1 to SS2, it is likely that

321   other factors are influencing its perceptibility. Bruises are formed when blood leaks

322   from capillaries and becomes trapped under the skin (Robin et al., 2015). A possible

323   factor contributing to the increased visibility of bruises at SS2 was a greater contrast

324   in colour with non-bruised skin as time since exsanguination increased. At SS1 the

325   process of exsanguination had just begun, and it is reasonable to assume that the

326   (non-bruised) skin tone of pigs become lighter as this process completed. This

327   explanation is merely speculative, however, and further research is required to explain

328   why bruise visibility increased following processing of the carcass.

329

330   The best stage for assessing skin lesions on the slaughter line was less clear. The

331   prevalence of mild and moderate skin lesions decreased between SS1 and SS2 by

332   5.9% and 4.9%, respectively. This suggests that some evidence of milder skin lesions

333   is removed by scalding and dehairing. However, the prevalence of severe skin lesions

334   increased by 66% between SS1 and SS2, suggesting that they may previously have

335   been concealed by hair and dirt. Therefore, scoring of skin lesions at SS2 appears

336   more effective in detecting serious skin damage. The severity of skin lesions scored

337 on the carcass has been found to be positively associated with the levels of aggressive

338 interactions that pigs have been subject to (Teixeira and Boyle, 2014). Thus, it could

339 be argued that scoring of skin lesions subsequent to scalding and dehairing of

340 carcasses gives the best indication of the levels of aggressive interactions on farm.

341

342 *Skin lesions, tail lesions and loin bruising prevalence*

343 Only a limited number of previous studies have examined skin lesion prevalence in

344 pigs (e.g. Nielsen *et al.*, 2014). The current study appears to be the first to assess the

345 prevalence of skin lesions on pigs on the island of Ireland. The relatively high

346 percentage of pigs in this study with serious skin lesions warrants further investigation

347 into methods of prevention. In addition, over a quarter of pigs assessed in the current

348 study appeared to have some degree of loin bruising. A key step in reducing the

349 prevalence of both type of skin lesion will be to gain a greater understanding of the

350 point, or points, at which pigs sustain this damage. Distinguishing between levels of

351 skin lesions and loin bruising attributable to general on-farm conditions, and those

352 associated with the marketing process will be particularly important in this respect. This

353 may be a difficult task, particularly with regard to loin bruising, the aetiology of which

354 remains uncertain. It has been theorised that mounting behaviour contributes to loin

355 bruising (Harley et al., 2014b). However, there has been no conclusive evidence to

356 date that this is the case. It is also possible that loin bruising occurs due to the handling

357 practices employed on farm or during marketing of the animals.

358 Tail lesion prevalence in the current study was approximately half the prevalence

359 reported in previous studies examining tail lesions in pig herds on the island of Ireland

360 (Harley *et al.*, 2012b; Harley *et al.*, 2014). It is possible that this reflects a decrease in

361 the prevalence of tail lesions in pig herds on the island of Ireland. However, the

362 prevalence of severe tail lesions is similar between this and previous studies (i.e.

363 Harley *et al.*, 2012b; Harley *et al.*, 2014).

364

365 *Relationship between welfare-related carcass lesions and carcass condemnation and*

366 *weight*

367 The statistical link between welfare-related lesions and partial carcass condemnations

368 that was shown is not evidence of a causal relationship. It is clear that on-farm

369 management factors could independently have affected both measures, however more

370 direct relationships can also be speculated. For example, welfare-related lesions are

371 associated with chronic stress (e.g. hypocortisolism [Valros *et al.*, 2013]) which can

372 weaken the immune system, leading to greater susceptibility to disease (Reimert *et al.*,

373 2014). Furthermore, abscessation, the most common cause of partial carcass

374 condemnation in Irish pig herds (Harley *et al.*, 2012b), is directly related to welfare

375 lesions. For example, infections originating in the tail can spread to other body regions

376 via the blood stream and cerebrospinal fluid (Huey, 1996), resulting in secondary

377 abscessation. Similarly, skin lesions can lead to the spread of secondary infection

378 (Pluym *et al.*, 2011) and may be the source of single-site abscessation in the limbs,

379 flank and shoulders of pigs (Huey, 1996). In general, information on the cause of

380 partial and whole carcass condemnation in pigs is limited (Garcia-Diaz and Coelho,

381 2014), and improved knowledge of the risk factors involved is needed if they are to be

382 reduced.

383

384 The association between welfare-related carcass lesion frequency and average CCW

385 is unsurprising; previous research has found that skin and tail lesions are associated

386 with reduced feed intake and growth due to the effects of infection and stress (Wallgren

387 and Lindahl, 1996; Ruis *et al.*, 2002; Marques *et al.*, 2012). Lower carcass weights are

388 a source of indirect financial loss to producers (Harley *et al.*, 2014). Coupled with direct

389 losses associated with carcass condemnation, the possible economic benefits of

390 reducing skin lesions, tail lesions and loin bruising in pig populations becomes evident

391 and should be investigated further.

392

393 *Conclusion*

394 Findings from this study indicate that tail lesions and loin bruising increase in visibility

395 subsequent to scalding and dehairing of the carcass. Overall, skin lesion visibility is

396 reduced. However, given the considerable increase in tail lesion and loin bruise

397 visibility from SS1 to SS2, in addition to the greater detectability of severe skin lesions

398 at SS2, there is a clear advantage to lesion scoring subsequent to scalding and

399 dehairing of carcasses. Skin lesion prevalence, detected at this stage, should be

400 adjusted in order to account for the removal of milder skin lesions.

401 The prevalence of skin lesions in pig herds on the island of Ireland was established for

402 the first time in this study. Overall levels of tail lesions appear to have declined from

403 previous similar surveys, but levels of severe lesions remain similar. The associations

404 demonstrated between welfare-related lesions and both carcass condemnations and

405 reduced carcass weight concur with previous research. This suggests both welfare

406 and economic advantages to reducing harmful social and aggressive behaviour in pigs.

407 This is speculative, however, as the nature of the relationship between welfare-related

408 lesions and production performance was not investigated in this study.

409

410 **Acknowledgements**

18

References

Aaslyng MD, Brandt P, Blaabjerg L and Støier S 2013. Assessment and Incidence of Skin Damage in Slaughter pigs. Proceedings of the 59th International Congress of Meat Science and Technology, 13-23 August 2013, Izmir, Turkey.

BPEX 2010. Key industry statistics, pig performance data and details of knowledge transfer, research and development activity. Retrieved March 31st, 2015, from http://smartstore.bpex.org.uk/listarticles.asp?Category=18335.

Dalmau A, Temple D, Rodriguez P, Llonch P and Velarde A 2009. Application of the Welfare Quality (R) protocol at pig slaughterhouses. Animal Welfare, 18 497-505.

Department of Agriculture and Rural Development (DARD) 2013. The Agricultural Census in Northern Ireland. Retrieved January 12, 2015, from http://www.dardni.gov.uk/agricultural_census_in_ni_2013_1.pdf.

D'Eath RB 2012. Repeated locomotion scoring of a sow herd to measure lameness: consistency over time, the effect of sow characteristics and inter-observer reliability. Animal Welfare, 21 219-231.

Edwards DS, Johnston AM and Mead, G. C. 1997. Meat inspection: An overview of present practices and future trends. Veterinary Journal, 154 135-147.

European Food Safety Authority (EFSA) 2012. Scientific Opinion on the use of animal-based measures to assess welfare in pigs. The EFSA Journal, 10 2512.

Garcia-Diaz J and Coelho AC 2014. Causes and factors related to pig carcass condemnation. Veterinarni medicina, 59 194-201.

437   Guardia MD, Estany J, Balasch S, Oliver MA, Gispert M and Diestre A 2009. Risk assessment

438   of skin damage due to pre-slaughter conditions and RYR1 gene in pigs. Meat

439   Science, 81 745-751.

440   Harley S, More SJ, O'Connell NE, Hanlon A, Teixeira D and Boyle L 2012a. Evaluating the

441   prevalence of tail biting and carcase condemnations in slaughter pigs in the Republic

442   and Northern Ireland, and the potential of abattoir meat inspection as a welfare

443   surveillance tool. Veterinary Record, 171 621-621.

444   Harley S, More S, Boyle L, O'Connell NE and Hanlon A 2012b. Good animal welfare makes

445   economic sense: potential of pig abattoir meat inspection as a welfare surveillance tool.

446   Irish Veterinary Journal, 65 1-12.

447   Harley S, Boyle LA, O'Connell NE, More SJ, Teixeira DL and Hanlon A 2014.

448   Docking the value of pigmeat? Prevalence and financial implications of

449   welfare lesions in Irish slaughter pigs. Animal Welfare, 23 275-285.

450   Huey R 1996. Incidence, location and interrelationships between the sites of abscesses

451   recorded in pigs at a bacon factory in Northern Ireland. Veterinary Record, 138 511-514.

452   Hunter EJ, Jones TA, Guise HJ, Penny RHC and Hoste S 1999. Tail biting in pigs 1: the

453   prevalence at six UK abattoirs and the relationship of tail biting with docking, sex and

454   other carcass damage. Pig Journal, 43 18–32.

455   Kritas SK and Morrison RB 2007. Relationships between tail biting in pigs and disease lesions

456   and condemnations at slaughter. Veterinary Record, 160 149-152.

457   March S, Brinkmann J and Winkler C 2007. Effect of training on the inter-observer reliability of

458   lameness scoring in dairy cattle. Animal Welfare, 16 131-133.

459   Marques BMFPP, Bernardi ML, Coelho CF, Almeida M, Morales OE, Mores TJ, Borowski SM

460   and Barcellos DESN 2012. Influence of tail biting on weight gain, lesions and

461   condemnations at slaughter of finishing pigs. Pesquisa Veterinaria Brasileira, 32 967-

462   974.

463   National Statistics Service (NSS) 2014. Sample size calculator. Retrieved December 9,

464   2014, from http://www.nss.gov.au/nss/home.nsf/pages/Sample+size+calculator

465 Nielsen SS, Michelsen AM, Jensen HE, Barington K, Opstrup KV and Agger JF 2014. The

466   apparent prevalence of skin lesions suspected to be human-inflicted in Danish finishing

467   pigs at slaughter. Preventive veterinary medicine, 117 200-206.

468 Pluym L, Van Nuffel A, Dewulf, J, Cools A, Vangroenweghe F, Van Hoorebeke S and Maes D

469   2011. Prevalence and risk factors of claw lesions and lameness in pregnant sows in two

470   types of group housing. Veterinarni medicina, 56 101-109.

471 Reimert I, Rodenburg TB, Ursinus WW, Kemp B and Bolhuis JE 2014. Selection Based on

472   Indirect Genetic Effects for Growth, Environmental Enrichment and Coping Style Affect

473   the Immune Status of Pigs. Plos One 9 e108700.

474 Robin S, Courderot-Masuyer C, Tauzin H, Harbon S, Chavagnac-Bonneville M, Cadars B,

475   Jourdan E, Trompezinski S and Humbert P 2015. Use of a Model of a Blood-Induced

476   Bruise for the Evaluation of Formulations on Bruising. Journal of Cosmetics,

477   Dermatological Sciences and Applications, 5 7-14.

478 Ruis MAW, te Brake JHA, Engel B, Buist WG, Blokhuis HJ and Koolhaas M 2002. Implications

479   of coping characteristics and social status for welfare and production of paired growing

480   gilts. Applied Animal Behaviour Science, 75 207-231.

481 Sanchez-Vazquez MJ, Strachan WD, Armstrong D, Nielen M and Gunn GJ 2011. The British

482   pig health schemes: integrated systems for large-scale pig abattoir lesion monitoring.

483   Veterinary Record, 169 413-U93.

484 Stärk KDC, Alonso S, Dadios N, Dupuy C, Ellerbroek L, Georgiev M, Hardstaff J, Huneau-

485   Salauen A, Laugier C, Mateus A, Nigsch A, Afonso A and Lindberg A 2014. Strengths

486   and weaknesses of meat inspection as a contribution to animal health and welfare

487   surveillance. Food Control, 39 154-162.

488 Taylor N R, Main D C J, Mendl M and Edwards S A 2010. Tail-biting: A new

489   perspective. Veterinary Journal, 186 137-147.

490 Teagasc 2011. Irish Pig Herd Survey. Retrieved January 12, 2015

491   from http://www.teagasc.ie/publications/2011/1411/PigNewsletterApr2011.pdf

492 Teixeira DL and Boyle LA 2014. A comparison of the impact of behaviours performed by entire
493   male and female pigs prior to slaughter on skin lesion scores of the carcass. Livestock
494   Science, 170 142-149.

495 Valros A, Ahlstrom S, Rintala H, Hakkinen T and Saloniemi H 2004. The prevalence of tail
496   damage in slaughter pigs in Finland and associations to carcass condemnations. Acta
497   Agriculturae Scandinavica Section A-Animal Science, 54 213-219.

498 Valros A, Munsterhjelm C, Puolanne E, Ruusunen M, Heinonen M, Peltoniemi OAT and Poso
499   AR 2013. Physiological indicators of stress and meat and carcass characteristics in tail
500   bitten slaughter pigs. Acta Veterinaria Scandinavica, 55 75.

501 Velarde A, Dalmau A, Fàbrega E and Manteca X 2005. Health and welfare management
502 of pigs based on slaughterline records. 56th Annual Meeting of the European Association for
503   Animal Production, Uppsala, Sweden.

504 Wallgren P and Lindahl E 1996. The influence of tail biting on performance of fattening pigs.
505   Acta Veterinaria Scandinavica, 37 453–460.

506 Warriss P, Brown S, Gade P, Santos C, Costa L, Lambooij E and Geers R 1998. An analysis
507   of data relating to pig carcass quality and indices of stress collected in the European
508   Union. Meat Science, 49 137-144.

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517 Figure captions

518

519 **Figure 1** Pig loin bruise scoring system used at slaughter stage 1 and slaughter stage

520 2. (0) absent, (1) present

521

522 **Figure 2** Pig tail lesion scoring system used at slaughter stage 1 and slaughter stage

523 2**.** (0) no evidence of tail biting (1) mild/healed lesions (2) evidence of chewing or

524 puncture wounds, but no evidence of swelling (3) evidence of chewing or puncture

525 wounds, with swelling and signs of possible infection (4) partial or total loss of tail

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527 **Figure 3** Front (indicated by black line) and rear (indicated by red line) body regions

528 of the pig used for assessing skin lesions at slaughter stage 1 and slaughter stage 2

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530

531   **Table 1** *Effects of slaughter stage (SS1 versus SS2) on prevalence of skin lesions, tail lesions and loin bruising in pigs †*

	Slaughter Stage		Percentage Increase	SEM*	P
	SS1	SS2			
Skin lesions (%)				0.012	<0.001
Absent	45.7	48.3	5.7		
Mild	39.3	37.0	- 5.9		
Moderate	14.4	13.7	- 4.9		
Severe	0.6	1.0	66.7		
Total prevalence	54.3	51.7	- 4.8		
Tail lesions (%)				0.013	<0.001
Absent	85.3	69.2	-18.9		
Mild	11.8	27.3	131.4		
Moderate	1.4	1.9	35.7		
Severe	1.5	1.6	7.0		
Total prevalence	14.7	30.8	109.5		
Loin bruising (%)				0.007	<0.001
Absent	98.1	74.0	-24.6		
Present	1.9	26.0	1 268.4		

532   † Abbreviations are: SS1: slaughter stage 1, SS2: slaughter stage 2, SEM: standard error of the mean. *SEM is based on the lesion scores from the slaughter
533   stage with the highest level of lesion detection i.e. SS1 for skin lesions and SS2 for tail lesion and loin bruising.