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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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14

15 Short title: Visibility of welfare lesions in slaughter pigs

16

17 **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

52 **Implications**

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

63

64 **Introduction**

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

74

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 CO₂ 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 CO₂ 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 CO₂
157 chamber using a paddle. In both abattoirs, pigs were lowered into the CO₂ 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

243 level using McNemar and McNemar-Bowker tests for dichotomous (loin bruising) and
244 ordinal (skin and tail lesions) variables, respectively. The prevalence of skin lesions,
245 tail lesions and loin bruising (i.e. greater than 0) was determined using descriptive
246 statistics. Prevalence of skin lesions was based on values recorded at SS1, and
247 prevalence of tail lesions and loin bruising was based on values recorded at SS2
248 (please see results section for explanation), and these data were also used for
249 calculations below. Using Pearson's correlations, associations were examined
250 between the batch-level percentage of animals with welfare-related carcass damage
251 (skin lesions, tail lesions and loin bruising) and the batch-level percentage of pigs
252 whose carcasses were partially or fully condemned. The batch-level percentage of
253 animals with skin lesions, tail lesions and loin bruising was also compared to average
254 batch-level CCW for pigs slaughtered at abattoir B. Relevant data met the assumptions
255 of the Pearson's correlation test. All statistical analysis was carried out using SPSS
256 version 20.
257

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

283 percentage of pigs per batch with skin lesions ($r = -0.667$, $P < 0.001$), tail lesions ($r = -$
284 0.615 , $P < 0.001$), and loin bruising ($r = -0.739$, $P < 0.001$).

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

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

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415

416 **References**

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

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

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

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

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

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

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

435 Garcia-Diaz J and Coelho AC 2014. Causes and factors related to pig carcass condemnation.
436 *Veterinari 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 carcass 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, Lambooj 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

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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

529

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.