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Docking the value of pigmeat? Prevalence and financial implications of welfare lesions in Irish slaughter pigs

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Abstract

*Expansion of the meat inspection process to incorporate animal-based welfare measurements could contribute towards significant improvements in pig (*Sus scrofa domesticus*) welfare and farm profitability. This study aimed to determine the prevalence of different welfare-related lesions on the carcase and their relationship with carcase condemnations (CC) and carcase weight (CW). The financial implications of losses associated with CC and CW reductions related to the welfare lesions were also estimated. Data on tail lesions, loin bruising and bursitis, CW and condemnation/trimming outcome (and associated weights) were collected for 3,537 slaughter pigs (mean [± SEM] carcase weight: 79.2 [± 8.82] kg). Overall, 72.5% of pigs had detectable tail lesions, whilst 16.0 and 44.0% were affected by severe loin bruising and hind limb bursitis, respectively. There were 2.5% of study carcases condemned and a further 3.3% were trimmed. The primary cause of CC was abscessation. While tail lesion severity did not increase the risk of abscessation, it was significantly associated with CC. Male pigs had a higher risk of tail lesions and of CC. The financial loss to producers associated with CC and trimmings was estimated at €1.10 per study pig. CW was reduced by up to 12 kg in cases of severe tail lesions. However, even mild lesions were associated with a significant reduction in CW of 1.2 kg. The value of the loss in potential CW associated with tail lesions was €0.59 per study pig. Combined with losses attributable to CC and trimmings this represented a loss of 43% of the profit margin per pig, at the time of the study, attributable to tail biting. These findings illustrate the magnitude of the impact of tail biting on pig welfare and on profitability of the pig industry. They also emphasise the potential contribution that the inclusion of welfare parameters at meat inspection could make to pig producers in informing herd health and welfare management plans.*

Keywords: *animal welfare, carcase, economics, meat inspection, pig, tail biting*

Introduction

It is widely accepted that the most valid approach to animal welfare assessment is to focus on the animal rather than its environment (Keeling & Veissier 2005; Smulders *et al* 2006; Main *et al* 2007). Consequently, assurance schemes increasingly measure 'welfare outcomes' such as the prevalence of skin lesions in pigs (*Sus scrofa domesticus*) (Velarde & Geers 2007). Abattoir meat inspection involves examination of each carcase and, hence, presents an ideal opportunity to measure animal-based welfare outcomes (Harley *et al* 2012a). The extensive use of meat inspection data in epidemiological studies over a number of decades corroborates this (Cleveland-Nielsen *et al* 2004; Mullan *et al* 2011; Swaby & Gregory 2012). Additionally, meat inspection is a cost effective means of collecting data over long time-periods as it is a continuous practice which is already in place (Huey 1996; Cleveland-Nielsen *et al* 2004). For this reason, and also for biosecurity reasons, it has advantages over welfare inspections of pigs at farm level.

Tail biting is a major welfare problem in modern pig farming systems. In spite of a ban on routine tail docking, many pigs are still tail docked in EU countries (eg Harley *et al* 2012b) in an attempt to control tail biting. There have been extensive investigations into the epidemiology and consequences of tail biting (Wallgren & Lindahl 1996; Moinard *et al* 2003; Sinisalo *et al* 2012). Its reported association with carcase disease lesions, decreased carcase weights and condemnations at slaughter means that it has adverse economic implications for producers (Huey 1996; Valros *et al* 2004; Kritas & Morrison 2007; Heinonen *et al* 2010). Furthermore, tail wounds are an important welfare outcome measure (EFSA Panel on Animal Health and Welfare 2007) as lesions seen at slaughter can generally be attributed to practices at farm level. Indeed, a recent technical report to EFSA on the future development of animal-based measures for assessing the welfare of pigs recommended that tail length and injury status be monitored in slaughter pigs (Spoolder *et al* 2011).

During an earlier study of over 36,000 slaughter pigs by Harley *et al* (2012b), several other lesions potentially related to pig welfare were readily observed. These included loin bruising and hind limb bursitis. Anecdotal evidence from pigmeat processors in the Republic of Ireland (where entire male pigs are produced) suggests that the prevalence of loin bruising is increasing. This lesion necessitates carcase trimming at the processing stage and therefore results in downgrading of the value of the loins. This contributes to financial losses for the processor which have not been quantified. Both the localisation of the bruising to the loin region and its diffuse nature suggests that mounting behaviour plays a part in its aetiology. Mounting is performed as part of the sexual behavioural repertoire of entire male pigs (Conte *et al* 2010). When a male pig mounts another, its sternum applies significant pressure to the loin area of the pig being mounted (L Boyle, personal observation 2012). This may cause injury, and usually elicits vocalisations and escape behaviour by the mounted pig, which are suggestive of poor welfare (Faucitano 2001; Rydhmer *et al* 2006).

Bursitis is a lesion found on the metatarsal region of the hind limbs of pigs (Gillman *et al* 2008). Bursae are naturally occurring fluid-filled sacs that decrease friction at points where muscles and tendons glide over bones (McFarland *et al* 2000). Bursitis is a pathological response to trauma, the prevalence and severity of which is influenced by the degree of pressure exerted on the limbs by commercial pig flooring systems (Smith 1993; Lyons *et al* 1995; Mouttotou *et al* 1998). It is therefore representative of sub-optimal environmental conditions on farms (Gillman *et al* 2008; Kilbride *et al* 2008). Bursitis has implications for animal welfare, not least due to its associations with lameness, which can infringe all of the five freedoms (Heinonen *et al* 2013).

Harley *et al* (2012b) conducted investigations in Irish and Northern Irish abattoirs and provided herd-level data on the prevalence of tail biting and of carcase condemnation. Studies in Northern Ireland and other parts of Europe (Tuovinen *et al* 1994; Huey 1996; Hunter *et al* 1999; Valros *et al* 2004; Martínez *et al* 2007) also explored tail biting in this way. However, the potential link between tail lesion severity and carcase weight does not appear to have been investigated previously. Similarly, the prevalence of other welfare outcomes in slaughter pigs (such as loin bruising and bursitis), and their effects on economically important parameters, such as carcase condemnations and carcase weight, have not been investigated. Consequently, the aims of this study were: i) to determine the prevalence of loin bruising and severe hind-limb bursitis; ii) to assess pig-level associations between these welfare-related lesions (and tail lesions) and carcase condemnation, carcase trimming and carcase weights; and iii) to estimate the financial losses associated with the parameters measured. It was postulated that such information might strengthen the case for developing meat inspection as an animal welfare surveillance tool in the Republic of Ireland which could, in turn, contribute not only to improvements in pig productivity, health and welfare, but also to the profitability of pig production at producer and processor level.

Materials and methods

Data collection

Data collection was carried out by four people over seven days during April 2012. The study took place in a single abattoir with a weekly throughput of approximately 10,500 pigs (*circa* 20% of total pigs slaughtered per week in the Republic of Ireland during April 2012) (Irish Central Statistics Office 2012). Data collection began at 0900h and continued until the end of the working day at approximately 1800h. The appropriate sample size for the study was generated using data from the literature (Valros *et al* 2004) and AusVet Epitools software (AusVet Animal Health Services 2009). To account for the effect of clustering at herd level, the sample size was expanded by 15% (Dohoo *et al* 2003), to 3,492 study pigs. The sampling interval of every third pig on the slaughterline was determined by dividing the study population size (in this case weekly abattoir throughput) by the required sample size (Dohoo *et al* 2003; EFSA 2011).

Data were collected at three points on the slaughter line: i) between dehairing and evisceration; ii) at post mortem meat inspection; and iii) at the weighing scales. An identification tag was suspended from one hind foot of each study pig at the first data collection point, enabling identification of study pigs at the later stages. Pig gender and herd identification code were also recorded at this stage. The latter measure enabled estimation of batch size, which is correlated with herd size (Harley *et al* 2012b). Tail and loin lesion scoring also occurred at the first data collection point and was conducted by the same person throughout. Tails were scored on a 0–4 scale (Figure 1). As it was already established that over 99% of Irish pigs are tail docked (Harley *et al* 2012b), tail length was not recorded in this study. Loin bruising was recorded on a three-point scale (Figure 2).

The reason and anatomical locations of carcase condemnations and trimmings were recorded by the second data collector at the point of meat inspection, on the basis of the decision of the acting Department of Agriculture, Food and the Marine (DAFM) Temporary Veterinary Inspector(s) (TVI) on the line (see Table 1). Hind-limb bursitis (see Figure 3) was recorded as severe or absent/mild by the same person at this point. Partial condemnations (ie, removal of a limb/head on public health grounds and trimmings (ie, removal of a superficial lesion — tail abscess, bursitis, skin wound) from the study pigs were weighed by a third person. It was not possible to weigh carcases that were entirely condemned.

There were three TVI teams, each of three people, working separate shifts to the following schedule each day: shift 1, 0700–1030h; shift 2, 1050–1420h; and shift 3, 1450–1750h.

For the majority of shifts, the TVI teams included the same individuals, however there were some substitutions during the study.

At the third data collection point, a fourth person recorded the line 'kill number' of each study carcase and removed the identification tag from the leg of study carcases before they entered the chill rooms. Using this

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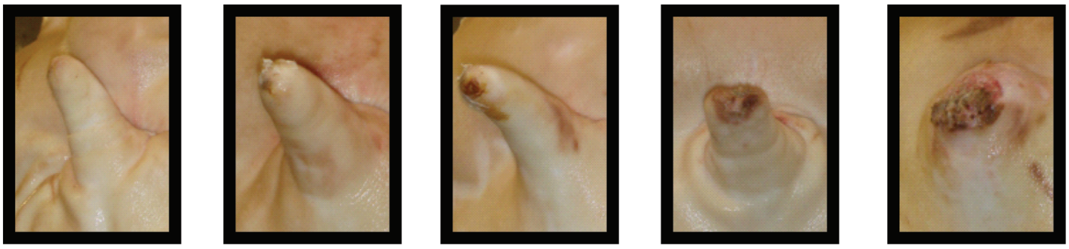
Figure 1

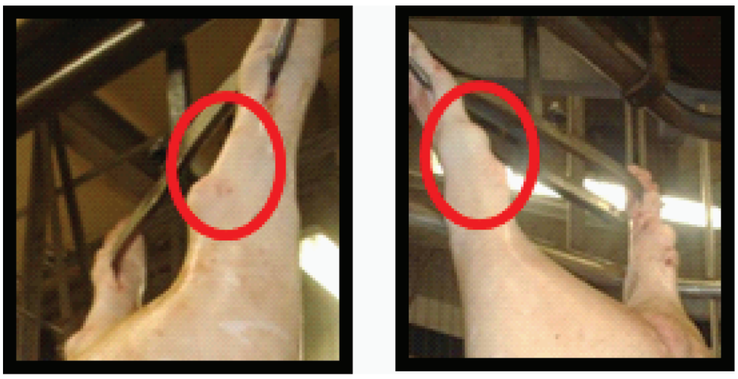


Tail-lesion scoring system (Scores 0–4, left to right).

Figure 2

Loin-bruising scoring system (Scores 0–2, left to right).

Figure 3



Hind-limb bursitis (absent/mild and severe, left to right).

approach, it was possible to subsequently capture the carcase weight and grade of each study pig. The carcase weight of a pig corresponded to the cold weight following bleeding and removal of the internal organs (including genitalia), tongue, bristles, hooves and flare fat (Irish Central Statistics Office 2012).

Data analysis

Descriptive statistics were calculated using Microsoft® Excel® for Windows. Tail-biting scores were re-organised into four categories: no lesion (score = 0); any tail lesion (score $\geq$ 1); moderate lesions (score $\geq$ 2); and severe lesions (score $\geq$ 3). Carcase condemnations, trimmings and absces-

Table 1 Definition of disease lesions and carcase condemnations* as per Straw *et al* (2006) and Ellerbroek *et al* (2011) detected at meat inspection.

Anatomy affected	Disease	Appearance/description
Entire carcase*	Various	Systemic disease
*Partial carcase**		Localised disease/injury
Hindquarter*		Localised disease/injury affecting one or both hind limbs
Forequarter*		Localised disease/injury affecting one or both forelimbs
Abscess	Abscessation	Single or multiple focal, spherical, encapsulated purulent lesions
Other infectious	Septicaemia, septic peritonitis/endocarditis/arthritis	Localised or systemic caused by an infectious agent
Trimmings	Various	Small, superficial disease/injury lesion/external abscess

sation were classified as present (score = 1) or absent (score = 0). Loin bruising was recorded on a three-point scale which was collapsed to either severe (score of 2) or none/mild (scores of 0+1).

The relationship between gender of the pigs and welfare lesions (tail lesions, loin bruising and hind-limb bursitis) were analysed using generalised estimated equations in PROC GENMOD of SAS (SAS Institute Inc 1988). Gender was considered as the dependent variable. Univariable models were built separately to assess the influence of each predictor variable on the dependent variables. Tail lesions, loin bruising and hind-limb bursitis were included as categorical variables.

The relationship between welfare indicators (tail lesions, loin bruising and hind-limb bursitis) and the total number of carcase condemnations (partial + entire), carcases condemned for abscessation and carcases trimmed were also analysed using generalised estimated equations in PROC GENMOD of SAS (SAS Institute Inc 1988). Total carcase condemnations, carcases condemned for abscessation and carcases trimmed were considered as the dependent variables. Firstly, univariable models were built to separately assess the influence of each predictor variable on the dependent variables. Predictor variables with $P < 0.20$ (Dohoo *et al* 2003) were used to build multivariate models. TVI shift and gender were forced into the models to assess their influence on the outcome variables. The tail-lesion scores were also included as a categorical variable in the model for carcases condemned for abscessation. Tail-lesion scores and hind-limb bursitis scores were included in the model for total number of carcase condemnations. Finally, tail-lesion and loin-bruising scores were included as categorical variables in the model for carcases trimmed. Backward selection was used to eliminate predictor variables until only those with $P < 0.05$ remained in the model.

Carcase weight was tested for normality before analysis using the Shapiro-Wilk test and examination of the normal plot. One hundred and ninety-four carcases were excluded from the analysis of the relationship between the severity of welfare lesions and carcase weight as their weight was reduced because of being partially/entirely condemned and/or trimmed. The relationship between welfare lesions and carcase weight was assessed using mixed model equations in PROC MIXED (SAS Inst Inc, Cary, NC, USA). Tail-lesion score, loin bruising and hind-limb bursitis were included as fixed effects and carcase weight as a random effect. Statistical differences were reported when $P < 0.05$. Results are reported as least square means (± SEM).

The direct financial losses resulting from carcase condemnation and trimming at the point of meat inspection were calculated by multiplying recorded weights of condemned and trimmed material by the average Irish pig meat price at the time of writing up the study (€1.70 per kg) (Cleary 2012), using Microsoft® Excel® for Windows v 2000. In the absence of weights of carcases that were entirely condemned, the average weight for such carcases based on recordings made at Northern Irish abattoirs as per Harley *et al* (2012b) was used. It was not possible to weigh or calculate the losses associated with fat/muscle trimming beyond the point of meat inspection and thus the impact of loin bruising on trimming during processing could not be evaluated.

In the economic analysis, the potential impact of tail-lesion severity on final carcase weight considered the carcase weight for each score ≥ 2 relative to carcases with tail-lesion scores of 0 or 1 (ie, unaffected carcases). Carcases that were partially condemned or trimmed were not included in this analysis as they would automatically have been lighter irrespective of their tail-lesion score.

Results

Descriptive results

A total of 3,537 pigs were observed during the study. In the absence of a full dataset for 115 of the pigs, the final study population was 3,422 pigs. A general description of the study population is shown in Table 2. Of the final study population, 85 carcases were condemned. The majority were partial condemnations, of which the hindquarters were the most commonly affected anatomical region. Abscessation alone accounted for almost 70% of total condemnations. Carcase trimming occurred more frequently than condemnation; cumulatively 5.7% of the study population was either trimmed or condemned.

Tail lesions (score ≥ 1) were observed in 72.5% of the study pigs (Table 2), with 2.5% affected by severe tail lesions (ie,

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Table 2 General description of the study population, including the prevalence of carcase condemnations and trimmings, tail and loin lesions, hind-limb bursitis and carcases condemned for abscessation.

			Total	% study population
Farms			49	–
Batches			74	–
Pigs	Male		1,777	51.9
	Female		1,645	48.1
	Total		3,422	100.0
Condemnations	Total		85	2.5
	Entire carcase		14	0.4
	Partial carcase		71	2.1
Partial condemnations	Hindquarters		48	1.4
	Forequarters		10	0.3
	Head		8	0.2
	Other		5	0.1
Causes	Abscessation		58	1.7
	Other		27	0.8
Trimmings			113	3.3
Trimmings and condemnations†			194	5.7
Welfare lesions				
Tail lesions	None	Male	401	22.6
		Female	540	32.9
		Total	941	27.5
	Score ≥ 1	Male	1,376	40.2
		Female	1,105	32.3
		Total	2,481	72.5
	Score ≥ 2	Male	533	15.6
		Female	371	10.8
		Total	904	26.4
	Score ≥ 3	Male	67	1.9
		Female	20	0.6
		Total	87	2.5
Loin bruising	None/mild	Male	1,493	43.6
		Female	1,380	40.4
		Total	2,873	84.0
	Severe	Male	284	8.3
		Female	265	7.7
		Total	549	16.0
Hind-limb bursitis	None/mild	Male	984	28.7
		Female	934	27.3
		Total	1,918	56.0
	Severe	Male	793	23.2
		Female	711	20.8
		Total	1,504	44.0
Carcase condemned for abscessation				
	Tail lesions	None	23	0.7
		Score ≥ 1	62	1.8
		Score ≥ 2	33	1.0
		Score ≥ 3	13	0.4

† Four carcases were both trimmed and condemned.

Table 3 Final generalised estimating equation (GEE) model of risk factors associated with carcase condemnation (includes entire and partial condemnations), carcases condemned for abscessation and carcases trimmed. The variables gender and Temporary Veterinary Inspector (TVI) shift were forced into the final model.

Explanatory variables		Carcase condemnation		Carcase condemned for abscessation		Carcase trimmed	
		OR	CI	OR	CI	OR	CI
Tail lesion score	0						
	1	0.66	0.380–1.159	1.22	0.347–4.308	0.86	0.503–1.456
	2	0.85	0.461–1.572	1.74	0.417–7.262	1.26	0.702–2.246
	≥ 3	5.07*	2.428–10.581	0.78	0.167–3.656	25.84*	13.83–48.29
Gender	Female (0)						
	Male (1)	2.55*	1.547–4.200	0.26	0.067–1.003	0.70	0.463–1.059
TVI shift	1						
	2	0.97	0.546–1.704	0.27	0.064–1.136	1.09	0.665–1.794
	3	0.89	0.480–1.650	0.44	0.092–2.144	0.52*	0.286–0.961
Hind-limb bursitis	None/mild						
	Severe	0.59*	0.373–0.950	NI	NI	NI	NI
Loin bruising	None/mild						
	Severe	NI	NI	NI	NI	0.67	0.438–1.023

* Significantly different from reference category; $P \leq 0.05$.
OR = Odds ratios.
CI = 95% confidence interval.
NI = Not included in the model.

Table 4 Mean (± SEM) carcase weight (kg) of pigs (not condemned and/or trimmed) in each of the tail lesion, loin lesion and hind-limb bursitis score categories.

Welfare-related lesions	Carcase weight
Tail lesion score	
≤ 1	80.02 (± 0.18)[a]
2	78.83 (± 0.31)[b]
3	76.45 (± 1.45)[b]
4	68.02 (± 2.28)[c]
Loin bruising	
None/mild	79.63 (± 0.17)
Severe	79.53 (± 0.36)
Hind-limb bursitis	
None/mild	79.46 (± 0.20)
Severe	79.79 (± 0.23)

[abc] Carcase weights differ significantly ($P \leq 0.05$).

score ≥ 3). Males were more frequently affected by tail lesions than females, a trend which became exaggerated with increasing tail-lesion severity (Score 1: OR = 1.55; 95% CI 1.314–1.819; $P < 0.001$; Score 2: OR = 1.78; 95% CI 1.479–2.160; $P < 0.001$; Score ≥ 3: OR = 4.51; 95% CI 2.693–7.556; $P < 0.001$). Severe loin bruising affected 16.0% of pigs and severe hind-limb bursitis was detected in almost half the study population. Male gender was not a risk factor for severe loin bruising (OR = 0.99; 95% CI 0.825–0.189; $P > 0.05$) or severe hind-limb bursitis (OR = 1.06; 95% CI 0.924–1.212; $P > 0.05$).

Factors affecting carcase condemnations and trimmings

Hind-limb bursitis, tail-lesion score and gender were significantly associated with carcase condemnation ($P \leq 0.05$; Table 3). Tail lesions with a score ≥ 3 and male gender increased the risk of condemnations, whilst bursitis was a protective factor. TVI shift and loin bruising were not significantly associated with carcase condemnations. Tail lesions with a score ≥ 3 and TVI were significantly associated with carcase trimming ($P \leq 0.05$).

Factors affecting carcase weight

There was a significant negative effect of tail-lesion severity score on carcase weight ($P \leq 0.05$) such that there was an average reduction in weight of 1.19, 3.27 and 12.0 kg associated with tail lesions scored 2, 3 and 4, respectively, relative to tails scored 0 or 1 (Table 4). In contrast, there was no effect of loin bruising or hind-limb bursitis on carcase weights ($P > 0.05$).

Economic analysis

The pigmeat losses associated with the 85 carcase condemnations in the study population amounted to over 1,800 kg and had a value of more than €3,200. This equated to €0.94 per study pig and increased to €1.10 per study pig when costs associated with approximately 330 kg of trimmings were included (Table 5).

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Table 5 Weight (kg) of carcase condemnations and trimmings, the average reduction in carcase weight associated with tail-lesion score and their associated financial cost (€).

Prevalence (number of pigs affected)		Weight (kg)	Cost (€)[‡] (Total)	Cost (€)[‡] (Per study pig)
Carcase condemnations				
Entire	14	977.62[†]	1,661.95	0.48
Partial	71	911.53	1,549.60	0.45
Total	85	1,889.15	3,211.55	0.94
Carcase trimmings				
Total	113	329.84	560.73	0.16
Cumulative carcase condemnations and trimmings[§]				
Total	194	2,218.99	3,772.28	1.10
Potential loss associated with final carcase weight				
Score 2 (less 1.19 kg)	774	921.06	1,565.80	0.46
Score 3 (less 3.27 kg)	32	104.64	177.89	0.05
Score 4 (less 12 kg)	13	156.00	265.20	0.08
Total		1,181.70	2,008.89	0.59
Cumulative carcase condemnations, trimmings and loss in carcase weight				
Total		3,400.69	5,781.17	1.69

[†] Using the average weight of entirely condemned carcases recorded by Harley *et al* (2012b).
[‡] Using average Irish value for pig meat over the study period (€1.70 per kg).
[§] Four carcases were both trimmed and condemned.

The total estimated reduction in carcase weight in the study population when tail lesions were scored greater than 1 was 1.182 kg (Table 5). This equated to a loss of €0.59 per pig in the final study population. There was an estimated loss of €1.69 per study pig when the value of pigmeat lost as a result of carcase condemnation/trimming and reduced carcase weights were combined.

Discussion

Data recording at abattoir meat inspection is a valuable way of monitoring the prevalence of a number of health and welfare conditions that affect food-producing animals. This study found a high prevalence of tail biting, loin bruising and hind-limb bursitis, as well as a high frequency of carcase condemnations within the study population. In association with these findings, considerable financial losses were identified which were primarily associated with lesions caused by tail biting. These findings highlight the potential value of enhanced data capture and feedback at abattoir meat inspection.

In this study, 72.5% of inspected pigs had detectable tail lesions. This figure is higher than the mean prevalence of detectable tail lesions found by Harley *et al* (2012b) for over 36,000 pigs. However, the abattoir involved in the current study was also included in the study by Harley *et al* (2012b), and the current figure corresponds well with the previous figure for detectable tail lesions in slaughter pigs of 76% in that abattoir under the same scoring system. Harley *et al* (2012b) discussed some of the potential reasons why the prevalence of detectable tail lesions in the pigs supplied to this particular abattoir was so high compared to the national average. However, even the national average figure for pigs affected by detectable tail lesions demonstrates that tail biting is a widespread behavioural problem, and that the widely practised control method of docking (Harley *et al* 2012a) is ineffective.

The observed prevalence of tail lesions in this study is much higher than reported for other countries where comparable studies were conducted (Finland: Valros *et al* [2004] and Sweden: Keeling *et al* [2012]). This may reflect differences in animal welfare policy (eg, tail docking is totally banned in Finland) and farm management. For example, straw is widely used in pig production in Sweden and this is likely to have had a significant positive impact on tail biting (EFSA Panel on Animal Health and Welfare 2007). Nevertheless, the lesion-scoring systems and lesion threshold criteria used also differed greatly between the studies, and this will have influenced the findings on tail lesions (Keeling *et al* 2012). Furthermore, the location where the tails were inspected differed between the three studies. In both the current study and the study by Valros *et al* (2004), pigs were inspected after scalding whereas they were inspected after exsanguination in the study by Keeling *et al* (2012). Based on our observations, minor lesions (scores 1 and 2 in this study) are not detectable unless the pigs are scalded and dehaired. Keeling *et al* (2012) cite concerns about mechanical damage to the tails during the scalding process as a reason for choosing their scoring location. However, the fact that gender differences prevailed even between the milder scores in the study by

Harley *et al* (2012b) suggests that the aetiology of such damage is animal-based and not mechanical.

Tail-biting lesions provide not only a point of entry for infection (Heinonen *et al* 2010), but three separate routes for its dissemination around the body (venous, lymphatic and cerebro-spinal drainage) (Huey 1996). Hence, there is a close association between tail lesions and abscessation (Huey 1996; Valros *et al* 2004; Heinonen *et al* 2010). However, in spite of the high prevalence of tail damage in the current study, no significant association between tail lesions and condemnation due to abscessation was detected. This may possibly reflect the smaller sample size and subsequent inadequate statistical power of the current study relative to those mentioned above. However, there was a significant association between the severity of tail lesions and carcase condemnations, and abscesses were the primary cause of condemnations.

The findings of the current study support observations by Harley *et al* (2012b) that, similar to castrates (Hunter *et al* 1999; Valros *et al* 2004), entire male pigs are more frequently and severely affected by lesions caused by tail biting than females. The reason behind gender differences in propensity to be (severely) bitten has yet to be established (Schrøder-Petersen & Simonsen 2001; Taylor *et al* 2010). However, our findings extend those of Harley *et al* (2012b) by showing that male carcases are also more likely to be condemned than female carcases. Even though there was no association between gender and condemnation for abscessation, it is probable that the greater likelihood of males having internal infections arising from tail lesions was responsible for the increased risk of condemnation. These findings need to be confirmed with larger numbers of animals.

We can conclude from the above that tail biting is a major cause of financial loss to producers arising from carcase condemnation. However, severe tail lesions are also positively associated with carcase trimming which represents another source of financial loss not only to the producer because of the reduction in carcase weight but also to the processor because of the associated labour. The direct losses to producers from carcase condemnations and trimmings recorded in this study were valued at €1.10 per pig slaughtered.

Another source of financial loss associated with tail biting arises from the reduction in animal performance (Sinisalo *et al* 2012) which, in this study, was reflected in the lower weights of carcases affected by tail lesions. It is likely that inflammatory processes associated with infection arising from the tail lesions (Valros *et al* 2004) interfered with growth performance, but the effect of stress on the victim of tail biting cannot be discounted (Schrøder-Petersen & Simonsen 2001). It could be argued that lighter/smaller pigs are more susceptible to being bitten, however, there is little scientific evidence to support this. In fact there is evidence that smaller pigs (or 'runts') are more likely to be tail biters (Van de Weerd *et al* 2005).

The most severe tail lesions were associated with carcases which were, on average, 12 kg lighter than unaffected carcases (ie, carcases with a tail score of 0 or 1). However, even carcases with tail-lesion scores of two (which could be considered to be relatively 'mild' lesions) were associated with a 1.2 kg reduction in weight relative to unaffected carcases. Such lesions likely arise from tail manipulation/chewing (rather than biting) which can occur at chronically high levels in intensive pig production systems (Schrøder-Petersen & Simonsen 2001). It is possible that this can occur even in the absence of severe/acute outbreaks of tail biting, ie those leading to cannibalism. Producers are often unaware that tail manipulation is being performed because of the absence of blood and of overt behavioural reactions of the recipient. In spite of this, tail manipulation is likely a stressor, with implications for animal performance and therefore for profitability at farm level. Information on these minor/moderate tail lesions might lead producers to improve the types/quantities of environmental enrichment provided to pigs as this could reduce levels of tail manipulation (Taylor *et al* 2010) or to make other management changes, eg reduce stocking densities, improve ventilation etc. Such changes would not only lead to improvements in pig welfare but could also improve farm finances. Minor, and sometimes moderate, lesions are not visible on the live animal. Therefore, the only way in which producers can be provided with information on such lesions, to inform their herd health and welfare management plans, is if they are recorded on the carcase at meat inspection.

As producers are paid on a per kg basis, a reduction in carcase weight represents a serious financial loss to producers. The lost potential carcase weight associated with tail lesions was equivalent to 1,181.70 kg or €0.59 per pig slaughtered. When combined with losses arising from carcase condemnation (€1.10 per pig), the resulting figure of €1.69 represents almost 43% of the current profit margin (estimated at €0.05 kg or *circa* €3.95 per 79 kg carcase) for Irish pig producers. In the context of increased production costs in a number of EU countries since 2010 (BPEX 2012), such losses represent a serious threat to the viability of pig farms. In an industry with such tight margins, financial implications such as these may act as a significant driver for addressing the problem of tail biting by improving pig husbandry and welfare.

This study is the first to report on the prevalence of loin bruising as a welfare outcome at slaughter. Severe bruising was detected in 16.0% of study carcases, confirming anecdotal reports from processors in the Republic of Ireland that loin bruising is prevalent in slaughter pigs. It was beyond the scope of this study to determine the aetiology of loin bruises but the absence of a gender effect on this lesion could reflect the fact that most pigs are kept in mixed sex groups on Irish farms and entire male pigs in mixed sex groups mount other males as frequently as they mount females (Conte *et al* 2010). Severe loin bruising also incurs costs to processors (L Boyle, personal communications with pigmeat processors 2012). This is because affected cuts are downgraded, diminishing the retail value by over 50%, and the removal/trimming of damaged tissue incurs labour and disposal costs. Such trimming occurs at the processing stage and was not included in the trimming measured in this study

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(which took place on the slaughter line). Hence, the specific financial impact of such welfare lesions is unknown. Trimming of bruised loins often removes the rind upon which slapmarks or kill numbers are stamped, preventing identification of producers with batches showing a high prevalence of loin bruising. However, scoring of loin bruising at meat inspection provides a solution to this problem because the identification of the producer can be recorded simultaneously. If the financial impact of loin bruising is established, processors may consider introducing penalties for carcases with bruised loins in the future. Hence, a better understanding of the aetiology of such lesions will be required in order to be able to advise pig producers on ways to reduce these lesions in their slaughter pigs.

Though it is difficult to quantify its implications for productivity and profit, hind-limb bursitis is a valuable indicator of flooring quality (Gillman *et al* 2008). Hind-limb bursitis was identified in 44% of pigs in this study, in contrast to a lower prevalence observed in finishing pigs in the UK (Kilbride *et al* 2009). This may reflect the fact that straw-based systems are more commonly employed in the UK than in the Republic of Ireland. The current study provides further evidence that concrete slatted flooring (which is the predominant flooring used in intensive systems of pig production in the Republic of Ireland) has adverse effects on limb health. There is a strong relationship between bursitis and lameness (Kilbride *et al* 2009), but it is not known whether bursitis causes lameness or is simply a consequence of lameness, mediated perhaps by prolonged lying in lame animals (Bonde *et al* 2004). However, the relationship between bursitis and lameness suggests that it is a good measure of on-farm welfare, and this is supported by the fact that it is included in the Welfare Quality® protocol (Welfare Quality® 2009). Lameness in pigs is associated with large industry losses arising from decreased productivity and rejection of breeding animals (Kilbride *et al* 2009), so bursitis potentially merits inclusion for measurement at meat inspection as an animal welfare surveillance measure. The finding that hind-limb bursitis was a protective factor for the risk of condemnation was unexpected and is difficult to explain.

It is worth noting that abattoir meat inspection has limitations as a tool for animal welfare surveillance. Severely affected animals may die or be culled during production, whilst detection and recording of lesions that resolve pre-slaughter is similarly impossible. Consequently, the prevalence of welfare lesions recorded at meat inspection is likely to underestimate that on-farm (Marques *et al* 2012). Conversely, lesions occurring during transport or lairage, eg limb fractures and fresh tail lesions, may cause an overestimation of the prevalence at production level.

Despite the above limitations and as illustrated in this study, the health and welfare status of food-producing animals can be assessed and recorded during abattoir meat inspection (Alban *et al* 2011; Swaby & Gregory 2012). Denmark and The Netherlands are examples of countries which routinely record such information and use it to target problem areas at production level (Willeberg *et al* 1984; Stärk 1996; Nielsen 2011). Indeed, producers provided with such information have lower incidences of disease and welfare problems on their farms (Sanchez-Vazquez *et al* 2011). However, despite the potential value of this information, many countries still have no recording and feedback system in place (Harley *et al* 2012b).

Animal welfare implications

This paper outlines the high prevalence of three welfare lesions detected at slaughter, and their association with carcase condemnations, trimmings and carcase weight. Additionally, it calculates the financial losses incurred by pig producers as a result of carcase condemnations, trimmings and reduced carcase weights primarily associated with lesions caused by tail biting. Importantly, the paper also illustrates that the behaviour of tail manipulation, as opposed to tail biting, is highly prevalent on farms, and, for the first time, that the resulting minor to moderate lesions are also associated with significant reductions in carcase weight. This paper also illustrates that there are significant advantages associated with monitoring the incidence and severity of a number of animal diseases and welfare outcomes during the process of abattoir meat inspection. Expansion of the meat inspection process to incorporate such lesions has the potential to be highly valuable for producers and the pig industry as a whole.

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