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## **Injurious tail biting in pigs: How can it be controlled in existing systems without tail docking?**

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1 **Injurious tail biting in pigs: how can it be controlled in existing systems**  
2 **without tail docking?**

3

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19

20 Running head: Controlling tail biting without tail docking

21 **Abstract**

22 Tail biting is a serious animal welfare and economic problem in pig production. Tail  
23 docking, which reduces but does not eliminate tail-biting, remains widespread.  
24 However, in the EU tail docking may not be used routinely, and some "alternative"

25 forms of pig production and certain countries do not allow tail docking at all. Against  
26 this background, using a novel approach focussing on research where tail injuries  
27 were quantified, we review the measures that can be used to control tail biting in pigs  
28 without tail docking. Using this strict criterion, there was good evidence that  
29 manipulable substrates and feeder space affect damaging tail biting. Only  
30 epidemiological evidence was available for effects of temperature and season, and  
31 the effect of stocking density was unclear. Studies suggest that group size has little  
32 effect, and the effects of nutrition, disease and breed require further investigation.  
33 The review identifies a number of knowledge gaps and promising avenues for future  
34 research into prevention and mitigation. We illustrate the diversity of  
35 hypotheses concerning how different proposed risk factors might increase tail biting  
36 through their effect on each other or on the proposed underlying processes of tail  
37 biting. A quantitative comparison of the efficacy of different methods of provision of  
38 manipulable materials, and a review of current practices in countries and assurance  
39 schemes where tail docking is banned, both suggest that daily provision of small  
40 quantities of destructible, manipulable natural materials can be of considerable  
41 benefit. Further comparative research is needed into materials, such as ropes, which  
42 are compatible with slatted floors. Also, materials which double as fuel for anaerobic  
43 digesters could be utilised. As well as optimising housing and management to reduce  
44 risk, it is important to detect and treat tail biting as soon as it occurs. Early warning  
45 signs before the first bloody tails appear, such as pigs holding their tails tucked  
46 under, could in future be automatically detected using precision livestock farming  
47 methods enabling earlier reaction and prevention of tail damage. However, there is a  
48 lack of scientific studies on how best to respond to outbreaks: the effectiveness of  
49 e.g. removing biters and/or bitten pigs, increasing enrichment, or applying

50 substances to tails should be investigated. Finally, some breeding companies are  
51 exploring options for reducing the genetic propensity to tail bite. If these various  
52 approaches to reduce tail biting are implemented we propose that the need for tail-  
53 docking will be reduced.

54

55 **Keywords:** Pigs, housing, enrichment, tail biting, behaviour

56

## 57 **Implications**

58

59 Tail biting in growing pigs is a serious welfare and economic problem, and there is  
60 pressure to avoid tail docking. For the first time relying only on studies where tail  
61 damage was recorded, we review the evidence on controlling tail biting in pigs that  
62 are not tail docked. Adequate feeder space and manipulable substrate provision are  
63 important, but more work is needed on the type and quantity of substrate needed.  
64 Vigilance for behavioural signs which occur before the first damaging biting would  
65 enable rapid detection and prevention/early response to outbreaks. Genetic selection  
66 could play a role in reducing tail biting.

## 67 **Introduction**

68 Tail biting in domestic pigs occurs when pigs bite and chew the tails of pen-mates. It  
69 is a considerable animal welfare (Munsterhjelm *et al.*, 2013) and economic problem,  
70 causing painful injuries which are a site for further infection (Sihvo *et al.*, 2012),  
71 resulting in carcass losses for producers (Kritas and Morrison, 2007; Valros *et al.*,  
72 2004) and reducing weight gain (Sinisalo *et al.*, 2012; Wallgren and Lindahl, 1996).  
73 Several risk factors have been proposed, suggesting multi-factorial causation (EFSA,  
74 2007; Schrøder-Petersen and Simonsen, 2001) and three different aetiologies have

75 been proposed (Taylor *et al.*, 2010). Removal of part of the tail (tail docking) a few  
76 days after birth usually reduces the likelihood and severity of tail biting(Sutherland  
77 and Tucker, 2011). Where tail docking is banned, tail biting incidence usually  
78 increases, even when the housing environment and management are  
79 improved(D'Eath *et al.*, 2014).

80

81 However, even though tail-docking reduces tail biting, it does not eliminate it and has  
82 significant drawbacks: it is an acutely painful mutilation, and it may 'mask' the real  
83 underlying problems in housing and management that result in tail biting(Sutherland  
84 and Tucker, 2011). For these reasons, the EU Council Directive (2001/93/EC  
85 amending Directive 91/630/EEC, The Council of The European Union, 2001b) came  
86 into force from January 2003 banning the 'routine' tail-docking of pigs, unless 'there  
87 is evidence that injuries ... to other pigs' ears or tails have occurred' and insisting that  
88 before resorting to tail docking 'other measures shall be taken to prevent tail  
89 biting...taking into account environment and stocking densities'. It goes on to state  
90 that '...pigs must have permanent access to a sufficient quantity of material to  
91 enable proper investigation and manipulation activities, such as straw, hay, wood,  
92 sawdust, mushroom compost, peat or a mixture of such, which does not compromise  
93 the health of the animals.' Despite this clear legal signal, tail-docking continues for  
94 95% or more of pigs in European pig producing countries such asGermany,  
95 Denmark, Belgium, France, Ireland, Netherlands and Spain, and for over 80% in the  
96 UK (EFSA, 2007; Harley *et al.*, 2012).

97

98 Perhaps in response to this gap between policy and reality, the European  
99 Commission (Directorate-General for Health and Consumers, DG Sanco; Bergersen,

100 2013) is currently engaging in a process to agree and clarify the guidance to farmers  
101 associated with the mentioned Directive and its later versions (the latest being  
102 2008/120/EC on the protection of pigs). Some countries already go further than the  
103 EU directives in restricting tail docking(Mul *et al.*, 2010). In Denmark, no more than  
104 half of the tail may be docked, and in the Netherlands, a voluntary agreement exists  
105 between farmers and government to phase out tail docking entirely by 2023  
106 (Spoolder *et al.*, 2011).A few countries already have either a complete ban on tail-  
107 docking (Sweden, Finland, Switzerland; EFSA, 2007; Swiss Federal Council, 2008)  
108 or a ban on docking without anaesthesia (Norway; EFSA, 2007) so that tail docking  
109 is rare. At the same time animal welfare protection organisations in many European  
110 countries focus on tail docking as a sign of welfare problems in intensive pig  
111 production; and in some countries political pressure is building up in favour of an  
112 effective ban on tail docking.

113

114 In another article, we consider the decisions facing farmers under current EU rules  
115 as to whether to tail dock, and the economic, legal and pig welfare consequences of  
116 this decision(D'Eath *et al.*, 2014). In the present article, we ask how farmers can  
117 become better at controlling tail biting without the use of tail docking. Our  
118 review focuses on changes that would be possible in existing systems, rather than  
119 considering radical system re-design(De Greef *et al.*, 2011). Various knowledge  
120 gaps are identified and promising areas for future innovation are proposed. We begin  
121 by introducing the nature of tail biting, and then review risk factors relating to the  
122 pigs' environment. For the first time, we rely only on studies which reported effects  
123 on tail injuries, rather than those which describe pigs' non-injurious interactions with  
124 tails ('tail-in mouth'). The relationships between these risk factors and the underlying

125 process(es) that govern the expression of tail biting are poorly understood, and  
126 we present a new illustration of the diversity of hypotheses. A novel illustrated meta-  
127 analysis quantifies the effectiveness of enrichment on tail biting in undocked pigs,  
128 and the practical experiences of countries and production systems in which tail  
129 docking is banned are considered. The next section of the review then focuses on  
130 risk factors that relate to characteristics of the pigs themselves, including the  
131 possibility of genetic selection to reduce tail biting. Finally we consider the prospects  
132 for early detection of tail biting outbreaks, possibly by automated means, which could  
133 facilitate targeted prevention measures. Farmers react to tail biting in various ways  
134 but little is known about the efficacy of these measures in preventing the further  
135 escalation of an outbreak.

## 136 **Tail biting- why it remains an intractable problem**

### 137 *Tail biting occurs in outbreaks*

138 Damaging tail-biting occurs in a sporadic way, in unpredictable 'outbreaks', rather  
139 like an infectious disease (Blackshaw, 1981). For example, in one study using  
140 abattoir data, 'high incidence farms' were identified at one point in time, but when a  
141 similar 'high incidence' list was made a few months later, most of the farms were  
142 different - although there were a few farms with a persistent problem (Busch *et al.*,  
143 2004). In general, while some of the risk factors that affect the overall incidence of  
144 tail biting are known, for any given outbreak, the specific triggering factor(s) are  
145 usually difficult to identify. Sometimes a change (weather, season, food, or disease  
146 outbreak) can be identified, but often no obvious change has occurred, and the  
147 cause may be down to variability in individual pigs' threshold of response to risk  
148 factors.

149

150 *Tail biting can spread quickly within the group*

151 Tail biting begins with one pig in the pen starting to bite. Tail damage can increase  
152 rapidly, with one study reporting that progress from bite marks to a clearly visible tail  
153 wound took on average 7 days (Zonderland *et al.*, 2010b), although practical  
154 experience suggests that it can occur even more quickly. Over time, biting pigs may  
155 continue or escalate their biting of existing victims, but also begin biting other pigs in  
156 the group (Niemi *et al.*, 2011). Additionally, other pigs in an affected pen begin tail-  
157 biting too, perhaps because they copy the behaviour (social facilitation; Blackshaw,  
158 1981) or the bitten tails might stimulate investigation and biting (stimulus  
159 enhancement; Fraser, 1987a). Although never formally studied, there appears to be  
160 considerable variation in the rate at which a pig increases its tail biting behaviour, and  
161 in the rate of spread to new biters. In one study, a batch of pigs already showing tail  
162 biting, moved to an environment with considerable space and access to rooting  
163 substrates, subsequently showed healing and improvement over time (De Greef *et*  
164 *al.*, 2011), suggesting that escalation is not inevitable.

165

166 *Scientific investigation of tail biting is difficult*

167 Tail biting is challenging to study. Its apparently sudden, unpredictable appearance  
168 and rapid spread can make it hard to investigate the events immediately before and  
169 after an outbreak begins. Its sporadic occurrence also means that a number of  
170 experimental studies have failed to observe any damaging tail biting at all. Such  
171 studies often report the effects of experimental treatments on tail investigation  
172 behaviour ('tail in mouth' Petersen *et al.*, 1995; Schroder-Petersen *et al.*, 2004), which  
173 is at best an indirect indicator of tail biting, because 'tail in mouth' behaviour may or  
174 may not be a pre-cursor to damaging tail biting (EFSA, 2007). Other studies include



175 all pig-directed oral behaviours including ear and flank biting, and sometimes belly-  
176 nosing, together in a single category(e.g. Jensen *et al.*, 2010; Zwicker *et al.*, 2013).  
177 This lack of precision makes interpretation difficult if the focus is on tail biting  
178 alone(Taylor *et al.*, 2010). In order to avoid these problems with indirect or imprecise  
179 indicators, this review focuses on studies where tail damage (with evidence of partial  
180 tail loss or of injury severe enough that blood was drawn) was the end point.

181

182 The sporadic occurrence of tail biting, and difficulties with experimental studies mean  
183 that multi-farm epidemiological studies (Goossens *et al.*, 2008; Moinard *et al.*,  
184 2003)or abattoir data (Harley *et al.*, 2012; Valros *et al.*, 2004), sometimes combined  
185 with farm surveys (Hunter *et al.*, 2001), are often used to study tail biting. These  
186 usually record tail damage, and can find risk factors associated with it, but unlike  
187 experiments, are unable to determine cause and effect, so must be interpreted with  
188 caution. We begin by looking at risk factors in the pigs' environment, and then  
189 explore risk factors intrinsic to the pig. Some of these risk factors and causes of tail  
190 biting may also affect the related problems of ear- and flank-biting (Brunberg *et al.*,  
191 2011), but this is beyond the scope of this paper.

## 192 **Risk factors for tail biting in the pigs' environment and how to manage them**

193 Tail biting does not have a single cause. It is a multi-factorial problem, and a variety  
194 of risk factors have been identified which are associated with it. Various efforts have  
195 been made to review all the currently known risk factors to weight their importance in  
196 order to influence policy makers (Bracke *et al.*, 2006; EFSA, 2007; Spoolder *et al.*,  
197 2011) and to provide practical advice to farmers (Bracke *et al.*, 2004; Jensen *et al.*,  
198 2004; Taylor *et al.*, 2012).

199

200 Taylor *et al.*(2010) in a recent review made a convincing case that there were at least  
201 two and possibly three different types of tail biting: two-stage, sudden-forceful and  
202 obsessive. ‘Two stage’ tail biting results from re-directed foraging due to a lack of  
203 suitable substrates. There is a progression from investigation and gentle  
204 manipulation of tails (stage 1) to damaging biting (stage 2). The second type,  
205 ‘sudden forceful’ tail biting is an aggressive behaviour(Moinard *et al.*, 2003; Van  
206 Putten, 1969)apparently resulting from frustration over a lack of access to food,  
207 water or lying space. Pigs approaching a fully occupied resource such as a feeder  
208 may resort to biting at tails as the most readily available target for aggression. For  
209 example, in a recent study, 60% of the tail biting by pigs, which had limited feeder  
210 access (Palander *et al.*, 2013), occurred within 1m of the feeder (A. Valros pers.  
211 comm.). The third type, ‘obsessive tail biting’ is characterised by certain individual  
212 pigs which appear to be fixated on tails and go from one tail to another, inflicting  
213 damaging bites (Beattie *et al.*, 2005; Van de Weerd *et al.*, 2005). Here, we consider  
214 ‘obsessive’ biters to be individuals which are more likely than other pigs either to  
215 begin or to continue tail biting through the mechanisms explained above (and  
216 illustrated in Figure 1) for two-stage or sudden forceful tail biting.

217

218 The mechanism of action of each possible risk factor on the underlying processes  
219 controlling the expression of tail biting is in many cases unknown. Figure 1 illustrates  
220 many of the possible connections between proposed environmental risk factors and  
221 the underlying processes of ‘two stage’ and ‘sudden-forceful’ tail-biting (Taylor *et al.*,  
222 2010). The nature of each possible connection is described in Supplementary  
223 Material S1. Evidence for the effect of risk factors on damaging tail biting is  
224 discussed further below.

225 **Availability of manipulable materials**

226 Manipulable materials which are attractive to pigs as measured by their motivation to  
227 access them (Holm *et al.*, 2008; Jensen *et al.*, 2008) or by the time pigs spend  
228 interacting with them over a sustained period have the characteristics 'ingestible',  
229 'odorous', 'chewable', 'deformable' and 'destructible' (Studnitz *et al.*, 2007; Van de  
230 Weerd *et al.*, 2003; Van de Weerd and Day, 2009). The opportunity to perform  
231 investigation and manipulation behaviours are in themselves important for pig  
232 welfare (Studnitz *et al.*, 2007; Van de Weerd and Day, 2009), but here we focus on  
233 whether manipulable materials can reduce damaging tail biting apparently by  
234 providing an alternative outlet for investigatory behaviour.

235

236 *Difficulties with the provision of loose manipulable materials on the floor*

237 Systems making use of full or part-slatted floors, enabling automatic collection of pig  
238 faeces and urine (slurry) are common in indoor pig production. In comparison with  
239 straw-bedded systems, the labour (cleaning and waste handling) and input costs  
240 (e.g. of straw, peat and other substrates) are lower (Bornett *et al.*, 2003), some  
241 environmental impacts may be lower (Stern *et al.*, 2005), and liquid slurry is more  
242 valuable as a fertilizer than solid manure (Sanchez and Gonzalez, 2005). The  
243 requirement to provide manipulable materials to occupy pigs, presents a difficulty for  
244 farmers with systems which rely on slatted-floors and liquid slurry handling (via  
245 pumps). Materials such as long (unchopped) straw do not easily pass through slats  
246 leading to pen fouling. Additionally, too much straw can separate from the liquid  
247 slurry and build up in the slurry pit, or if it does flow, it can block parts of slurry-  
248 handling systems, such as holes, pipes or vacuum-based slurry pumps (Day *et al.*,  
249 2008; Tuytens, 2005). Ways to reduce the problem of straw blockage may include

250 use of chopped straw, in combination with engineering solutions, such as larger  
251 diameter pipes (Evira, 2013), slurry pumps fitted with chopper blades, the use of  
252 smaller, faster flowing slurry systems (PRC, 2011), or progressive cavity pumps  
253 which are suitable for viscous liquids. Depending on the quantity and type of  
254 substrate, these measures may not be 100% effective but are more likely to be  
255 successful if considered at the building design stage.

256

257 Non-destructible materials such as metal chains, or rubber or hard plastic objects  
258 have been tried. Although pigs may initially interact with these due to their novelty,  
259 interest in them usually declines rapidly over a few days (Van de Perre *et al.*, 2011;  
260 Van de Weerd *et al.*, 2003). Even a repeating cycle of different objects may not be  
261 enough, as re-introduction of the same object after an interval of several weeks is  
262 usually not as effective at sustaining interest as a novel object would be (Van de  
263 Perre *et al.*, 2011). The European Commission have made it clear that chains and  
264 other non-destructible materials are not sufficient to comply with the EU Council  
265 directive (EC, 2009). Gradually destructible materials, which take days or weeks to  
266 be chewed through such as wooden poles (often mounted vertically in a tube at the  
267 side of the pen, or suspended from a chain) are popular with farmers in some  
268 countries as they require less regular replenishment than other more readily  
269 destructible substrates and appear to comply with the EU Council directive  
270 (2001/93/EC) which lists wood as a suitable material. Wooden poles were found to  
271 be an effective enrichment for reducing tail damage in a recent unpublished Finnish  
272 study using freshly felled tree trunks 5-10cm in diameter suspended on chains  
273 horizontally below snout level (Telkänranta *et al.*, 2014). However, since some of the  
274 features required to make a material attractive to pigs are lacking (ingestible,

275 odorous) or weak (chewable, deformable, destructible) in hard wood poles, the need  
276 to use soft, fresh woods which do have these features could be important.

277

278 In the face of these difficulties, an important question is whether it is possible to  
279 provide sufficient manipulable materials to pigs within existing intensive housing  
280 systems in order to reduce tail-biting to a level which is acceptably low from a  
281 management, production and welfare perspective without the need to tail dock  
282 (D'Eath *et al.*, 2014).

283

#### 284 *Alternative ways of providing manipulable materials*

285 In part-slatted floored pens, it is possible to provide loose material such as chopped  
286 straw, peat or sawdust, which in small quantities may be used with slurry pumps  
287 (Munsterhjelm *et al.*, 2009). Substrate can be provided on the solid floor, while pigs  
288 defecate and urinate in the slatted part. To limit the passage of substrate from the  
289 solid to the slatted part of the floor, pen designs incorporating barriers (e.g. 50 mm  
290 high wooden strip, Zwicker *et al.*, 2013) or where the slatted area is raised (BPEX,  
291 2010) may be used. Practical experience suggests that such designs are usually not  
292 entirely successful, especially in high temperatures where pigs may choose to  
293 defecate in the lying area, wallowing in the wet faeces to keep cool, and at higher  
294 stocking densities where functional separation of lying and dunging areas becomes  
295 more difficult to achieve, particularly in older pigs (Jensen *et al.*, 2012).

296

297 Faecal contamination of manipulable substrates is a common problem which  
298 reduces their attractiveness to pigs (Scott *et al.*, 2009), and this contamination can be  
299 reduced by hanging objects in the pen. Hanging of substrates limits the form of

300 interaction, for example chewing may be possible but not rooting (Day *et al.*,  
301 2008). This might be important, or different forms of investigatory behaviour may  
302 substitute for one another in preventing tail biting, as long as the pigs are occupied.  
303 Hanging objects thus may have potential: in a meta-analysis of the time spent by  
304 pigs interacting with enrichment, properties promoting this interaction included  
305 enrichments which were suspended and/or deformable (Averós *et al.*, 2010). For  
306 example pigs show sustained interest in interacting with destructible ropes (Trickett  
307 *et al.*, 2009), or hanging objects with an edible component (Van de Weerd *et al.*,  
308 2003), and 'flavoured rope' devices for pigs are being sold commercially in Finland.  
309 However, the effects of these forms of enrichment on tail biting have not been  
310 investigated.

311

312 Another approach is to deliver loose manipulable materials by means of an elevated  
313 rack, so that pigs can gradually obtain the material for themselves over a  
314 period (Beattie *et al.*, 2001; Van de Weerd *et al.*, 2006; Zwicker *et al.*, 2012; Zwicker  
315 *et al.*, 2013). This has the potential advantage of 'double' interaction (in the rack, and  
316 beneath it: on the floor, or in a box or feeder; Zwicker *et al.*, 2012) which might mean  
317 less material can be used for the same total amount of interest from the pigs. A  
318 related approach is to use a low-level rooting box which can contain loose materials  
319 and keeps them separate from slats (De Greef *et al.*, 2011; Van de Weerd *et al.*,  
320 2003).

321

### 322 *Quantifying the effects of different enrichment methods on tail damage*

323 Studies published in refereed journals which compare the effect of different types  
324 and quantities of manipulable substrates on tail damage are summarised in Table

325 1. Most of the studies had pigs with intact tails, but some were docked, as indicated  
326 in the table legend. The studies all focus on grower-finisher pigs, except for  
327 Zonderland *et al.* (2008) which used weaners. Different indices of tail damage were  
328 used by different authors: Most studies report either the percentage of pigs removed  
329 from the study with severe tail injury, or the percentage of pigs or of pens having tail  
330 wounds. One study (Munsterhjelm *et al.*, 2009) used a tail lesion index (scoring from 0  
331 to 2). To compare studies that used different measures, we calculated the fold-  
332 change in tail damage for each pair of treatments in these studies (i.e. the reduction  
333 in tail injury following the provision of one type of manipulable substrate compared to  
334 another). Where one of a pair of substrates had zero damage, it was not possible to  
335 calculate a fold-change, so 'max' was reported in Table 1, and this value did not  
336 contribute to the mean fold change, probably resulting in an underestimate of the  
337 effect size. Most studies compared deep straw with either no enrichment, or with  
338 minimal enrichment with chains or hanging toys, considered to represent commercial  
339 practice. In Figure 2, the information from the studies in Table 1 is summarised  
340 graphically, giving a quantification of the relative value of different materials as it is  
341 drawn to scale using the mean log 'fold' difference between observed levels of biting  
342 damage as the distance between the materials. A log scale was used so that 'fold'  
343 differences could be added together on the same scale and shown relative to each  
344 other in a single diagram (since e.g.  $\log_2 + \log_3 = \log_6$ ).

345

346 In terms of manipulable substrate treatments that are compatible with fully or part-  
347 slatted floors, straw racks and light straw ( $\leq 20\text{g/pig/day}$ ) are probably the most  
348 promising treatments for which data are available. Provision of straw in racks  
349 reduces tail damage compared to a rubber hose, chain or hanging toy, with two

350 studies finding a small but consistent reduction in the percentage of pens with tail  
351 wounds (fold-improvement of 1.9 or 1.7, Van de Weerd *et al.*, 2006; Zonderland *et*  
352 *al.*, 2008). In one study, the straw rack affected minor tail injuries, but was more  
353 effective at reducing severe tail damage (Van de Weerd *et al.*, 2006), which suggests  
354 that the straw rack might have reduced the rate of escalation of biting.

355

356 Light straw (10g twice a day per pig, Zonderland *et al.*, 2008), or light chopped straw  
357 and wood shavings (12.5g a day per pig, Munsterhjelm *et al.*, 2009) were both highly  
358 effective at reducing tail damage compared to minimally enriched treatments in two  
359 studies, with fold-differences almost as high as for deep straw studies (see Figure 2).  
360 Unfortunately, neither of these studies included plentiful loose material as a positive  
361 control. In a producer survey combined with an abattoir study, Hunter *et al.* (2001)  
362 found that 'light straw' use reduced tail biting damage risk compared to no straw.  
363 Despite these positive findings, chopped straw may not be as attractive to pigs as  
364 long straw: A behaviour study comparing chopped with long straw (each  
365 400g/pig/day) suggested that chopped straw offers fewer possibilities for interaction  
366 and observed tail-biting behaviour increased (Day *et al.*, 2008). However, this study  
367 included non-injurious chewing and biting, and tail damage was not reported. In  
368 contrast, a Danish study suggested that chopped and long straw (each at  
369 100g/pig/day) occupied pigs for a similar amount of time (Lahrmann and Steinmetz,  
370 2011).

371

372 Our comparative survey has identified a number of data gaps: Only two studies  
373 included comparisons of more than one pair of treatments, allowing the substrates to  
374 be placed into an overall ranking (Van de Weerd *et al.*, 2006; Zonderland *et al.*,



375 2008), and there was a paucity of studies investigating how different quantities of  
376 straw or other materials affect tail damage. Time spent exploring and manipulating  
377 straw rather than other pigs increases with straw quantity until above 300g/pig/day  
378 (Olsson, 2011) or at around 500g/pig/day (Pedersen *et al.*, 2013). However, tail biting  
379 occurred at very low levels in these studies, even in treatments with only  
380 20g/pig/day (undocked pigs, Olsson, 2011) or 10g/pig/day (docked pigs, Pedersen *et*  
381 *al.*, 2013). Also, no studies have compared hanging toys with no enrichment, and  
382 none have looked at the effect of hanging destructible enrichments such as ropes on  
383 tail damage, except for one recent report in suckling piglets (Telkänranta *et al.*,  
384 2014b), so there is considerable scope for further research.

385

#### 386 *Manipulable materials as fuel for anaerobic digesters*

387 Materials which act as foraging enrichment for pigs could double as fuel for  
388 anaerobic digesters (AD). This idea is being tested in the “Starplus” system at  
389 Wageningen (Verdoes, 2014). ADs enable farmers to deal with farm wastes,  
390 producing energy (methane) and digestates which can be used as fertiliser. Pig slurry  
391 provides micronutrients and trace elements needed for bacterial growth, but its  
392 energy content is low, so (non-wood) biological materials are added, some which  
393 could provide rooting/foraging (and eating) opportunities for pigs: chopped grass,  
394 maize or grass silage, sugar beet and kitchen waste (if concerns over biosecurity  
395 could be addressed). For example, pigs prefer chopped straw mixed with Maize  
396 silage over straw (Jensen *et al.*, 2010; Jensen and Pedersen, 2007) possibly  
397 because it may include edible components. Many questions remain, however:  
398 materials must be compatible with floor slats/slurry systems, a method to deliver  
399 substrate to the pens is required, fungal growth in wet fermenting materials can be a

400 problem (T. Jensen pers. comm.), and there are hygiene issues if pigs are eating  
401 material from the floor. Finally, fuel source costs, energy prices and government  
402 policies affect the economic feasibility of AD.

403

#### 404 **Social factors- space allowance (stocking density),group size, mixing**

405 Atspace allowanceslower than those currently recommended in the EU, reduced  
406 space allowance increased tail damage in one experiment(Krider *et al.*, 1975). At  
407 space allowances closer to or withinthe recommended range, one multi-farm  
408 studyfound an association between reduced space allowance andtail  
409 injuries(Goossens *et al.*, 2008) but another similar study did not (Smulders *et al.*,  
410 2008), and no effect was found in an experimental study (Street and Gonyou,  
411 2008).Group size (Schmolke *et al.*, 2003; Smulders *et al.*, 2008; Street and Gonyou,  
412 2008) and mixing of groups(Smulders *et al.*, 2008; Zonderland *et al.*, 2008)had no  
413 effect in studies where tail damage was reported.

414

#### 415 **Feeding- feeder space, feed restriction, feed type, nutrients, minerals**

416 Restricted feeder space increased tail biting in one experimental study (damaged  
417 tails, Hansen *et al.*, 1982) and is a risk factor in epidemiological studies (Hunter *et*  
418 *al.*, 2001; Moinard *et al.*, 2003).Other experimental studies, in which low levels of tail  
419 biting occurred,found no effect of feeder space(Georgsson and Svendsen, 2001;  
420 Georgsson and Svendsen, 2002). The form and presentation of feed may be  
421 important: pigs fed pelleted diets showed higher levels of tail injury than meal or  
422 liquid fed pigs in one study(Hunter *et al.*, 2001)while Templeet a(2012) found liquid  
423 feed in a trough increased tail injury compared to wet feed in a hopper.

424

425 Nutritional qualities of the diet: protein, specific amino acids, minerals or high energy  
426 density have all been suggested to affect tail biting(Edwards, 2011), but there is little  
427 direct evidence of nutritional manipulations affecting tail damage. Experiments using  
428 'model' tails suggest that attraction to blood may be increased if the diet is  
429 nutritionally inadequate in terms of protein (Fraser *et al.*, 1991) or minerals (Fraser,  
430 1987b).Tail biting pigs were more attracted to cords soaked with pig blood than their  
431 non-biting pen mates(McIntyre and Edwards, 2002b) and this preference can be  
432 reduced by the addition of the amino acid tryptophan to their diets (McIntyre and  
433 Edwards, 2002a). Differences in serotonin metabolism in the prefrontal cortex and an  
434 altered pattern of tryptophan uptake have been reported in tail biting pigs in contrast  
435 to bitten and unaffected group-mates or unaffected pigs from another group (Valros  
436 *et al.*, 2013). Additional salt in the diet or on the floor of the pen can increase  
437 foraging and drinking behaviour(Brooks, 2005), which may reduce biting, but it is not  
438 clear whether this was effectively a foraging enrichment or addressing a nutritional  
439 deficiency. Jaeger *et al.*(2013)proposed a novel causal pathway for tail biting: high  
440 energy density diets for weaner pigs (as well as exposure to various pathogens)  
441 result in a build-up of endotoxins which cause ear or tail necrosis, which then attracts  
442 biting. If the necrotic tissue is itchy, this could increase the tolerance of tail  
443 investigation and biting in victim pigs.

444

#### 445 **Climate- temperature, draughts, seasonal effects**

446 Either low (Temple *et al.*, 2012), or both low and high temperatures (Geers *et al.*,  
447 1989) have been identified by epidemiological studies as risk factors for tail damage,  
448 and providing access to a water misting system can reduce tail injury in hot climates  
449 (Courboulay *et al.*, 2008). Seasonal effects on tail damage have been identified

450 (Schrøder-Petersen and Simonsen, 2001, Busch pers. comm.), the exact nature of  
451 which varies between different studies. It seems plausible that rapid changes in  
452 temperature (either up or down), an increase in draughts at certain times of  
453 year (known to affect activity, Scheepens *et al.*, 1991), or heat stress are likely to be  
454 the underlying cause of seasonal effects (Figure 1), as there is a limit to the capacity  
455 of ventilation/heating/cooling systems in most pig buildings.

456

### 457 **Disease, including parasitism**

458 Disease has been proposed to be a risk factor (Edwards, 2011). Levels of tail  
459 damage are higher in herds with higher levels of respiratory illness (Elst *et al.*, 1988  
460 cited by Edwards 2011; Moinard *et al.*, 2003), and in a study where health records  
461 from individual pigs were examined, leg disorders and tail damage were highly  
462 correlated (Niemi *et al.*, 2012). Caution is required with the interpretation of  
463 epidemiological data, as disease may result from infections that follow tail biting  
464 (Kritas and Morrison, 2007; Moinard *et al.*, 2003), or poor health status may be an  
465 indirect indicator of less technically efficient farms.

466

467 Controlled studies in which measures to improve health result in a reduction in tail  
468 damage provide better evidence. Currently there is only an anecdotal report of tail  
469 biting being reduced following anthelmintic treatment (Barnikol, 1978) and an as-yet  
470 unpublished study concerning PCV2 vaccination (Parker *et al.* in prep, cited by  
471 Edwards, 2011). So at this stage, the evidence for disease as a cause of tail biting is  
472 weak.

473 **The experience of countries and assurance schemes where tail docking is**  
474 **banned**

475 Pig producers in some countries and assurance schemes have already had to adapt  
476 their systems to cope with greater restrictions on tail docking, and the changes they  
477 have made are instructive. The tail docking and housing system rules for grower-  
478 finisher pigs applied by selected non-docking European countries and selected  
479 assurance schemes are summarised in Table 2, with some systems which permit tail  
480 docking included for comparison.

481

482 The 'tail docking restricted or banned' farms have a number of features in common,  
483 many of which may reduce tail biting risk. The space allowance is usually more  
484 generous, with up to 50% more space per pig being provided. Fully slatted pens are  
485 not allowed, enabling manipulable materials to be provided on the solid-floored part  
486 of the pen (although part slatted, part drained floors are permitted in Finland).  
487 Compared to the EU minimum provision, there are more specific rules on the  
488 quantity of materials, usually by specifying the frequency of replenishment, or the  
489 behaviour that pigs must be able to perform: in Finland pigs must be able to make  
490 small piles of material, Freedom Food requires sufficient quantities of material for  
491 rooting, pawing and chewing behaviour. The type of material provided is often also  
492 restricted, for example Sweden and the Danish assurance scheme Antonius require  
493 straw, and Norway repeats the EU list, but stipulates wood chips rather than 'wood'  
494 which rules out the use of wooden posts.

495

496 The smaller scale of farms in Finland, Norway and Switzerland, compared to the UK  
497 and Denmark (Table 2) might enable a greater supervision of the animals (assuming

498 more staff per pig), making detection and prevention of tail biting easier, and smaller  
499 farms often have lower disease risk (Goldberg et al 2000). For example, Finland is  
500 free from Porcine Reproductive and Respiratory disease, and mycoplasma and  
501 Salmonella are at low levels, although a lower density of farms and fewer pig  
502 movements including imports may also be important here.

503

504 Tail docking is not completely outlawed in all of the assurance schemes in Table 2.  
505 The assurance schemes Antonius, Outdoor (including Organic) in Denmark and  
506 Freedom Food allow farmers to apply for a dispensation to use tail docking for a  
507 limited time if a tail biting outbreak occurs. For example, Freedom Food farmers  
508 must annually seek written permission to dock, and if tail biting in the previous year  
509 was low, they are encouraged to trial a cessation of docking for some pigs, with the  
510 aim of stopping docking altogether. At each application, farmers must document the  
511 other measures they have taken to prevent tail biting and quantify their success. The  
512 standards give a detailed list of a number of environmental improvements that  
513 should be tried including providing straw and increasing feeder space. In 2010, 30%  
514 of Freedom Food breeding farms supplying indoor wean to finish herds requested  
515 permission to dock (Kate Parkes RSPCA pers. comm.). This suggests that the  
516 majority of scheme members are managing to rear intact tailed pigs, while those with  
517 tail biting problems are allowed to use taildocking to protect the welfare of potential  
518 victim pigs.

519

520 Finally, Table 2 gives figures on tail biting prevalence in the different countries and  
521 schemes, estimated from abattoirs. It is very difficult to compare the figures, since  
522 they are not collected in a standardised way, for example pigs with missing tails are

523 usually not counted as injured(EFSA, 2007; Keeling *et al.*, 2012). It is also difficult to  
524 compare between docked and undocked pigs; if the number of lesions are counted,  
525 long tails provide a greater area for biting than docked or part-docked tails (Webster  
526 and Day, 1998). To avoid this problem, it might be best to use data on partial carcass  
527 condemnations (PCC), which can be used as indicators of the most severe cases of  
528 tail biting(Kritas and Morrison, 2007; Valros *et al.*, 2004), but these are not always  
529 available. Occasionally, different housing systems are assessed in the same way  
530 during the same period at one abattoir. Data from a Danish study(Forkman *et al.*,  
531 2010) show that tail biting damage at slaughter was higher in intact-tailed pigs in  
532 organic (or outdoor)systems (range 1.0 – 4.0%), in comparison to docked pigs in  
533 conventional indoor housing (range 0.5-1.5%; Table 2). These data suggest that tail  
534 docking is more effective at reducing tail biting than the combined effect of various  
535 improvements to the environment(as reported by Hunter *et al.*, 2001). It also  
536 highlights how challenging it is for producers to rear intact-tailed pigs, even in  
537 improved environments. However it would be better to have data comparing  
538 countries and systems which used a standard scoring method and included PCC.

539 **Risk factors for tail biting which are characteristics of the pig and how to**  
540 **manage them**

541 Characteristics of the pigs themselves can affect their propensity to tail bite or to be  
542 bitten. This could involve any step of the tail biting process (Figure 1). To take the  
543 'two-stage' form of tail biting for example pigs could vary in:i) how much they perform  
544 exploratory behaviour(e.g. Zonderland *et al.*, 2011), ii) whether they explore tails  
545 rather than other things, iii) whether tail manipulation becomes biting, iv) whether  
546 one bite becomes many, and v) in the likelihood of learning tail biting from a pen

547 mate. Also, differences between pigs in their propensity to tail bite or be bitten could  
548 occur due to a greater sensitivity to any environmental risk factor (Figure 1).

549

550 *Characteristics of victim pigs: sex and breed*

551 Certain pigs may be more likely to become victims of tail biting. In several studies,  
552 castrated males were more likely to be the victims of tail biting than females (Kritas  
553 and Morrison, 2004; Kritas and Morrison, 2007; tail damage, Wallgren and Lindahl,  
554 1996), with the risk to males rising with the proportion of females in the pen (Kritas  
555 and Morrison, 2004). Tail biting was higher in pigs grouped by sex (intact males and  
556 females) in one abattoir study (Hunter *et al.*, 2001), but no relationship was found in  
557 an on-farm study of castrates and females (Steinmetz and Pedersen, 2009). All-  
558 female pens have been reported as having more (Zonderland *et al.*, 2010a) tail  
559 damage than pens of entire males. In another study, all female pens had less  
560 (Steinmetz and Pedersen, 2009) tail damage than pens of all-castrated males. It is  
561 not clear what causes these different findings in relation to sex.

562

563 Breed may affect the likelihood of being bitten. In a Swedish pedigree population of  
564 male pigs with low levels of tail biting, bitten pigs were: Yorkshire (3.5%), Landrace  
565 (1.8%) and Hampshire (0.1%, Westin, 2003). However this was based on small  
566 numbers (63 victims out of 3049) in mixed breed groups which were not composed in  
567 a systematic way. Thus the evidence for breed differences in the risk of being bitten  
568 is weak.

569

570 *Characteristics of tail biters: growth retardation, early experience, breed*



571 It has been suggested that tail biters are often the smaller pigs in a group(Sambraus,  
572 1985) which is in agreement with data from some studies(Zonderland *et al.*, 2011)  
573 although others have found that tail biters were no more likely to be smaller than  
574 average (Breuer *et al.*, 2005). Once tail biting begins, certain individual pigs show  
575 much higher levels of biting than others (Beattie *et al.*, 2005; Van de Weerd *et al.*,  
576 2005), and have been characterised as ‘fanatical’ or ‘obsessive’ biters (Taylor *et al.*,  
577 2010).In one study with small numbers of ‘obsessive’ biters, these pigs were smaller  
578 than average (Van de Weerd *et al.*, 2005). Beattie *et al.*(2005) found that ‘tail-in-  
579 mouth’ behaviour was higher in pigs which grew poorly in the first 3 weeks after  
580 weaning. Although poorly supported by evidence from studies which include tail  
581 damage, it remains a popular theory with farmers, that smaller pigs in a pen begin  
582 biting perhaps because they resort to this biting as an aggressive tactic when  
583 excluded from food (Schrøder-Petersen and Simonsen, 2001) and/or because of a  
584 problem with nutrition or metabolism (Edwards, 2006; EFSA, 2007).

585

586 EFSA (2007) concluded that the rearing environment is not as important as the  
587 current environment for tail-biting risk. Where pigs receive manipulable materials  
588 during the grower stage, past housing experience makes little difference to tail  
589 manipulation behaviours(Day *et al.*, 2002; no tail damage reported, Simonsen, 1995;  
590 Statham *et al.*, 2011).However, a greater risk of tail lesions caused by tail biting  
591 occurs in pigs which have experienced manipulable materials in the farrowing pen  
592 early in life, but which are then absent during later stages (Munsterhjelm *et al.*, 2009;  
593 Ruiterkamp, 1985). In contrast to the small effects seen in experimental studies,  
594 epidemiological studies have found associations betweenearly life factors and tail  
595 biting. These factors includeslatted floors (Smulders *et al.*, 2008)or absence of

596 substrates(Moinard *et al.*, 2003) in the farrowing pen, and limited feeder space or  
597 high temperatures in the nursery (Smulders *et al.*, 2008). Epidemiological studies of  
598 course do not prove a causal link and further research is required.

599

600 As well as breed differences in the propensity to become victims of tail biting  
601 (described above), some have reported breed differences in the propensity to  
602 perform tail biting. In the Swedish pedigree population with mixed breed pens of  
603 male pigs described earlier, the biters were: Landrace (1.7%), Yorkshire (0.64%) and  
604 Hampshires (0.1%), but only 27 biters out of 3049 animals were observed(Westin,  
605 2003).In a UK study, there was no effect of breed on tail biting, although there were  
606 breed differences in ear biting (Duroc>Large White>Landrace; Breuer *et al.*,  
607 2003).Two other studies reported finding no breed differences in the performance of  
608 tail biting(Guy *et al.*, 2002; Lund and Simonsen, 2000).Thus, as with breed  
609 differences in being tail bitten, breed differences in bitingmight occur, but the  
610 evidence is fairly weak.

611

#### 612 *Genetics of tail biting: biters, victims and unaffected pigs*

613 A single published quantitative genetic study exists which found that biting other  
614 pigs' tails was a heritable trait (Breuer *et al.*, 2005), at least in Landrace (but not in  
615 Large White) pigs. Heritability was low at  $0.05 \pm 0.02$ , although tail-biters were rare  
616 (295 tail biters in a population of 9018 pigs) and tail biting was treated as a binary  
617 trait, which reduces the power of genetic analysis.

618

619 Commercial pig breeding mainly focuses on economically important traits of lean  
620 growth rate, food conversion and reproductive traits such as litter size. Some pig

621 breeding companies are considering broadening their breeding goals, and traits  
622 relating to behaviour and welfare issues such as tail biting are of interest (Canario *et*  
623 *al.*, 2013; Merks *et al.*, 2012).The inclusion of additional traits in a breeding index  
624 inevitably leads to a reduced rate of genetic progress in other traits(Falconer and  
625 Mackay, 1996).However, breeding companies normallyuse economic weightings in  
626 breeding indices, andthe considerable costs of tail bitingcould make it economically  
627 optimal to include a trait linked to lowered levels of tail biting in a multi-trait index  
628 (Lawrence *et al.*, 2004)..

629

630 A number ofother factors stand in the way of conventional genetic selection against  
631 tail biting (see discussion in Turner, 2011).The positive genetic correlation  
632 relationship between tail biting and lean tissue growth rate found by Breuer *et*  
633 *al.*(2005) could slow genetic progress if found in other populations. Phenotyping is  
634 also a challenge:identification of 'biting' pigs is considerably more difficult than  
635 identification of victims. Direct observation of biting may be the most accurate  
636 method, but is time-consuming, especially since tail biting, as described above, often  
637 occurs in sporadic, unpredictable outbreaks. Also,it may be important to identify the  
638 individual pig which starts the outbreak ('first biter'), as once bloody tails appear in  
639 the pen, other pigs are more likely to begin biting. Because of these difficulties, there  
640 would be enormous value in identification of a proxy trait, associated with tailbiting.  
641 Unfortunately, tests based on artificial tails have proved largely disappointing in  
642 terms of their predictive value for real tail biting (Beattie *et al.*, 2005; Breuer *et al.*,  
643 2003; Statham, 2008), although in one study the time spent manipulating an  
644 enrichment device before tail biting began was higher in biters than  
645 victims(Zonderland *et al.*, 2011).Automated detection of tailbiting might be possible

646 using similar methods to those proposed for detection of early-warning signs (see  
647 next section).

648

649 There is some prospect of identifying molecular genetic markers of pigs at lower risk  
650 of tail biting, an approach which reduces the amount of phenotyping required. Single  
651 Nucleotide Polymorphism (SNP) markers of biting and victim pigs (in contrast to non-  
652 biting controls from the same pen) have been identified (Wilson *et al.*, 2012). Brain  
653 gene expression studies also suggest that biters and victims have more in common  
654 than unaffected pigs from the same group (Brunberg *et al.*, 2013a) or a different group  
655 (Brunberg *et al.*, 2013b). These authors suggest that unaffected pigs may show a  
656 'tail-biting resistant' phenotype. If confirmed in other populations, this idea suggests  
657 that selection against both biters and victims and for unaffected pigs might be  
658 possible.

659

660 Another approach which side-steps the problem of phenotyping tail biters is to  
661 use 'associative genetic effects' (Camerlink *et al.*, 2012; Turner, 2011). Quantitative  
662 genetic models for pig growth can be modified allowing pigs to have heritable  
663 influences on the growth of their pen-mates (Bijma *et al.*, 2007a; Bijma *et al.*, 2007b;  
664 Rodenburg *et al.*, 2010). Depending on the context, these 'social breeding values'  
665 might reflect differences in positive social behaviours such as social nosing  
666 (Camerlink *et al.*, 2012) or in negative behaviours such as aggression, food  
667 competition, disease transmission and ear, flank or tailbiting. To have a more direct  
668 effect on tail biting, modelling of associative genetic effects could be used in  
669 combination with phenotyping for tail damage. With sufficient representation of

670 different sires across pens, pigs with a high genetic propensity to cause tail damage  
671 to pen mates could be identified, without the need to observe biting behaviour.

672

673 Selection to reduce tail biting behaviour could raise ethical concerns, particularly  
674 concerning 'naturalness' (D'Eath *et al.*, 2010). Because 'two-stage' tail-biting results  
675 from frustrated foraging behaviour, we could speculate that selection for lower tail  
676 biting might also reduce foraging. Also, selecting animals to function well in poor  
677 environments, rather than improving the animals' environment to satisfy their needs  
678 might seem distasteful to some, and could lead to a decline in housing standards  
679 (Kanis *et al.*, 2004). However, given that pigs are already undergoing constant  
680 genetic change to alter production traits, alongside improvements to the housing  
681 environment we should perhaps consider whether genetic selection to reduce tail  
682 biting could be part of a solution which makes an end to tail docking possible (D'Eath  
683 *et al.*, 2014).

684

685 Although this is speculative, breeding to reduce tail length might be possible as tail  
686 length is heritable in various mammalian species (rodents, Barnett, 1965; sheep,  
687 Branford Oltenacu and Boylan, 1974; cats, Howell and Siegel, 1966), and naturally  
688 short-tailed pigs might be less prone to becoming victims of tail-biting. There are  
689 probably difficulties though as tail length is likely to be genetically correlated with  
690 back length (a desired trait in bacon pigs) and tail-less mutations may have  
691 undesirable side-effects such as those seen in Manx cats (Howell and Siegel, 1966).  
692 Even if breeding to reduce tail length were successful, other  
693 concerns remain. The curly tail could be seen by consumers as an essential pig  
694 characteristic (although it is absent in wild pig species) and may have a function in

695 communication (Kiley-Worthington, 1976). Finally, breeding rather than docking to  
696 shorten tails still sidesteps the problem that pigs need an outlet for their foraging  
697 behaviour.

### 698 **Early detection and targeted prevention**

699 An alternative approach to the problem of tail-biting is to detect outbreaks before or  
700 as soon as they begin, and to carry out targeted intervention (such as those  
701 discussed in the next section) to ameliorate or even prevent an outbreak (FAWC,  
702 2011). Regardless of the system, if pig producers could identify certain 'at risk'  
703 individuals, groups, or batches, and target them for preventive intervention, this  
704 would be cheaper and more practical compared to making changes for every pig.

705

706 Early detection of tail biting might be possible by identifying changes in pig behaviour  
707 that precede an outbreak. Four main types of early warning sign have been  
708 described, which appear in the days or weeks before an outbreak begins (first bloody  
709 tails): 1) General activity ('restlessness') increases (Statham *et al.*, 2009; Zonderland  
710 *et al.*, 2011), particularly in biters (Svendsen *et al.*, 2006). 2) Non-damaging 'tail in  
711 mouth' behaviour increases (Feddes and Fraser, 1994; Fraser, 1987a; Schröder-  
712 Petersen and Simonsen, 2001). 3) Tails are held down or 'tucked under' (Statham *et*  
713 *al.*, 2009; Zonderland *et al.*, 2009; 2010). 4) Feeding patterns might change. In one  
714 study, feeder visits tended ( $p < 0.1$ ) to be lower in groups which went on to tail bite 6-9  
715 weeks pre-outbreak, and tended ( $p < 0.1$ ) to increase during weeks 2-5 pre-outbreak  
716 in pigs which would become tail biting victims (Wallenbeck and Keeling, 2013). More  
717 research on feeding patterns is needed.

718

719 Increased observation of pigs by staff might identify these early warning signs, but  
720 staff time has a cost, so automatic detection ('precision livestock farming') would be  
721 attractive (reviewed by Rushen *et al.*, 2012).The detection of specific behaviours  
722 such as tail posture and tail in mouth behaviour may be possible (Sonoda *et al.*,  
723 2013), but increases in activity (and perhaps feeding patterns) are perhaps the  
724 easiest of the 'early warning signs' to detect automatically (Costa *et al.*, 2013). One  
725 promising approach is 'optical flow', which estimates animal activity by quantifying  
726 overall pixel changes from moment to moment in a video image.'Optical flow' has  
727 been used to detect the reduced activity of lame broiler chickens (Dawkins *et al.*,  
728 2009), and the disturbance of behaviour in laying hen flocks when feather pecking is  
729 occurring (Lee *et al.*, 2011).

730

731 The use of on-board animal devices (such as electronic ID ear tags), combined with  
732 detectors in the pen to record pig location also has potential to detect changes in  
733 activity (or feeding patterns).Currently, the infrastructure and consumable costs  
734 associated with either video or EID approaches to monitoring pig behaviour may be  
735 prohibitive. But with falling costs and various other benefits of electronic ID (easier  
736 record keeping for medicines and at weighing, or even for detecting when a pig has  
737 not visited the feeder in a long while) and video (estimation of pig size average and  
738 variability) the use of these technologies could become more widespread in future.  
739 Detection of changes in pig vocalisations is also a plausible approach (Manteuffel *et*  
740 *al.*, 2004) but would require considerable further research and validation.

#### 741 **Reacting to outbreaks**

742 Once a tail-biting outbreak occurs, pig producers react in various ways (Arey, 1991).  
743 Hunter *et al* (2001) surveyed British pig producers and found that 67% removed the

744 bitten pig(s), 51% added enrichment objects, 25% applied sprays or tar to injured  
745 tails, 16% added straw, 6% reduced stocking density and 6% gave antibiotics. In one  
746 study, moving pigs that were already biting to pens with substrates and more space  
747 resulted in reduced biting behaviour (De Greef *et al.*, 2011), and Edwards (2011) has  
748 suggested that the effectiveness of salt or other nutritional supplements should be  
749 investigated. There is considerable scope for more research in this area: Only one  
750 scientific study of the effectiveness of interventions has been reported. Zonderland *et*  
751 *al* (2008) compared the interventions of removing the biter or adding straw as soon  
752 as tail damage was detected and found them to be equally effective (the 'no  
753 intervention' control was considered unethical).

754

755 Where pigs are removed from a tail biting group, bitten pigs are easier to identify  
756 (Hunter *et al.*, 2001), but removing tail biters might have a greater impact. Since  
757 biting spreads rapidly to other pigs, the time window is small for removing the first  
758 biter. Even if biters are removed, leaving bitten pigs in the pen might encourage new  
759 biters (because they are attracted to the bloody or scabbed tails), so it has been  
760 suggested that removal of *both* biters *and* bitten pigs might be optimal (Boyle and  
761 Lemos Teixeira, 2010; Zonderland *et al.*, 2008).

762

763 The other difficulty with removing pigs is the question of how to manage the pigs that  
764 are removed (Boyle and Lemos Teixeira, 2010). In an outbreak where multiple pigs  
765 are removed, the farmer may be constrained by space to group house them. They  
766 must also decide whether to use a lower stocking density and/or substrates or other  
767 forms of enrichment for those removed pigs. There is obviously a concern that  
768 removing biters and putting them into new groups could result in further tailbiting,



769 although anecdotally, Zonderland *et al*(2008) reported that they did not experience  
770 this problem. Removing pigs to different groups and/or returning them needs to be  
771 carefully managed as it can result in social aggression including fighting and bullying  
772 (Marchant-Forde and Marchant-Forde, 2005).

773

774 Another intervention worthy of further research is the application of aversive  
775 substances to tails. Bracke (2009) found that when pigs were offered untreated  
776 ropes, or ropes treated with Dippel's oil or Stockholm tar to chew on, they avoided  
777 the treated ropes, suggesting that these treatments might be aversive when applied  
778 to tails. On the other hand, a concern over adding substances (including antibiotic  
779 sprays) to tails is that it might make them more novel, stimulating investigation and  
780 perhaps biting.

781

782 As suggested by Edwards (2011), there is clearly an urgent need for systematic  
783 research into the effectiveness of different methods for reacting to outbreaks. This  
784 research should: i) investigate the different methods separately or in combination  
785 and develop others, ii) investigate the quantity/frequency of enrichment that is  
786 necessary to reduce tail biting iii) investigate the optimal timing of interventions  
787 (there may be a point after which certain methods cease to be effective), iv)  
788 investigate whether it is most effective and efficient to target individuals, pens, or a  
789 whole room of pigs.

## 790 **Conclusions**

791 The risk factors affecting tail damage caused by tail biting were reviewed. A number  
792 of risk factors that have been proposed and reviewed elsewhere (EFSA, 2007;  
793 Schrøder-Petersen and Simonsen, 2001) are not currently well supported by

794 experimental studies where damaging tail biting was the end point. These include  
795 group size, nutrition, disease incidence and pig breed. Surprisingly, the evidence for  
796 an effect of stocking density was also quite weak. Epidemiological evidence alone  
797 suggests that temperature and season might be important. The evidence was  
798 strongest for the provision of manipulable substrates, and an effect of feeder space  
799 was also found.

800

801 Housing systems using slatted floors and liquid slurry handling are in widespread  
802 use due to their economic advantages, but limit the amount of loose manipulable  
803 substrates that can be used. A crucial question for this review was whether, at  
804 commercial stocking densities, in part solid-, part slatted-floored pens, small  
805 quantities of straw or similar manipulable substrate (perhaps delivered via a rack),  
806 can reduce tail-biting to the point where tail docking is no longer necessary. Very few  
807 studies have looked at this, but the few that have were promising. Damaging tail  
808 biting was greatly reduced in two studies with undocked pigs using light straw (10g  
809 twice a day per pig, Zonderland *et al.*, 2008) or light chopped straw and wood  
810 shavings (12.5g a day per pig, Munsterhjelm *et al.*, 2009), and the experience of  
811 Finland which uses small quantities of enrichment materials also positive. Further  
812 studies investigating the effect of quantity and type of enrichment material on tail  
813 biting risk are necessary, and such studies are especially valuable if treatments are  
814 compared to a negative control of very little enrichment and a positive control of a  
815 plentiful loose material. In particular, further studies of destructible hanging materials  
816 such as ropes and destructible fresh wood would be useful. As well as controlled  
817 scientific studies, investigations into the experiences of producers in assurance  
818 schemes which are working to phase out tail docking would also be worthwhile. As a

819 way of reducing the cost of using enrichment materials, the possibility of using  
820 materials which could combine with pig slurry as fuel for anaerobic digesters is  
821 interesting but faces a number of technical hurdles.

822

823 The mechanisms by which the various proposed environmental risk factors might  
824 affect the underlying process(es) of tail biting are largely unknown. Possible  
825 mechanisms are shown in Figure 1, but much of this is speculative (see  
826 Supplementary Material S1) and there is considerable scope for further research into  
827 whether and how these risk factors might cause or affect tail biting. Alongside  
828 optimising the environment, it may be possible to use genetic selection to reduce tail  
829 biting. The challenge of phenotyping by identifying biters (Breuer *et al.*, 2005) and  
830 especially the ‘first biter’ could potentially be made easier (using automatic detection  
831 or proxy measures), made into a smaller task (by identification of genetic markers) or  
832 side-stepped altogether (by the use of ‘associative genetic effects’ for growth, or  
833 possibly, for tail lesions). The possibility that a ‘tail-biting resistant’ phenotype might  
834 exist is interesting (Brunberg *et al.*, 2013b), but identifying these pigs would still be  
835 challenging; they are the pigs in an affected pen which are neither biters nor victims.

836

837 Another potential area for innovation is the use of precision livestock farming  
838 methods to automatically detect the early warning signs of a tail biting outbreak at  
839 the pre-damaging stage. Various behavioural signs have been identified, including  
840 tail position, ‘tail in mouth’ behaviour, and increased activity, some of which might be  
841 detectable by automatic methods based on electronic tags (see <http://pigit.ku.dk> and  
842 [www.pigwise.eu](http://www.pigwise.eu)) or on video (Sonoda *et al.*, 2013). If farmers could identify when and  
843 where an outbreak of tail-biting was about to begin, they could target preventative

844 measures, which would be more economic in terms of time and materials than  
845 making changes for all pigs. A final potential area for innovation is to test the efficacy  
846 of measures to stop tail-biting once it begins (or just before it begins), which has  
847 been the subject of only one scientific study (Zonderland *et al.*, 2008).

848

849 Spoolder *et al.*(2011) suggested that ‘an intact curly tail can be regarded as the single  
850 most important welfare indicator in finishing pigs, since to achieve this requires a  
851 high standard of housing and management over a pig’s lifetime, so it serves as an  
852 ‘iceberg indicator’ of welfare (FAWC, 2009) and demonstrates respect for the ‘animal  
853 integrity’ of the pig. Within a system type, it also indicates good management to  
854 prevent (or quickly deal with)tail biting.A current difficulty is that alternative systems  
855 with intact-tailed pigs usually suffer from higher levels of tailbiting than conventional  
856 systems that tail dock(Hunter *et al.*, 2001; Table 2). This means there is an ethical  
857 question as to how we should weigh a welfare impact on many (all pigs being  
858 docked as a precaution) with a worse welfare impact for a few (victims of tail  
859 biting)(D'Eath *et al.*, 2014). Would we consider that a ban on tail docking had led to  
860 improved welfare if it increased tail damage at slaughter from 1% of pigs to 4% of  
861 pigs?The threshold for what constitutes an‘acceptably low level’of tail biting must be  
862 decided in a wider ethical debate which considers the pigs’ perspective. The  
863 experience of countries with complete bans on tail docking is that farmers do learn to  
864 reduce tail biting in other ways, although the resulting economic costs of this  
865 adaptation may reduce competitiveness and participation in export markets.

866

867 In most EU countries where docking is permitted, the letter of the EU Directive  
868 (2001/93/EC) that requires provision of manipulable materials is being followed,

869 although the pressure group Compassion in World Farming found that on the farms  
870 they visited in a number of EU countries it was not (CIWF, 2008).However, the  
871 Directive states that docking should be used as a last resort only when there is  
872 evidence of a tail biting problem and other environmental measures have been  
873 tried,and this is only being enacted in reality by a minority of producers, for example  
874 some assurance schemes (e.g. Danish Antonius and Organic, UK Freedom Food).  
875 This approach seems a logical middle road (which appears to be the 'spirit' of the EU  
876 directive), allowing the majority of pigs in these schemes to benefit by avoiding  
877 docking and having their behavioural needs met, while still allowing docking to  
878 protect the welfare of potential tail biting victims on farms with a problem.However,  
879 itwould be more difficult to enforce than a complete ban on taildocking. Thusit would  
880 require considerably more detail in terms of the measures producers should take  
881 before resorting to tail docking, and these measures would most likely involve  
882 substantial changes from current practice, imposing considerable costs on  
883 producers.

884

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**Table 1.** Summary of comparative manipulable material studies in which tail injuries were reported for growing pigs. An asterisk (\*) by the reference indicates that pigs had intact (undocked) tails, a dagger (†) indicates they were tail docked, and a double dagger (‡) indicates that half the pigs were docked in a 2 x 2 experimental design. All of the studies were controlled experiments with the exception of Courboulayet *al* (2009) which scored tails in part- or fully-slatted and straw systems in an on-farm observational study of 82 farms. Fold-improvement is a result of the tail biting value for the first manipulable material divided by the value for the second. Where two similar materials are named, the average was taken.

Manipulable material A (g/pig/day)	Outcome variable	Value of outcome variable for material A	Manipulable material B (g/pig/day)	Value of outcome variable for material B	Number of pigs (pens) per treatment	P value of difference <sup>5</sup>	Fold-improvement in outcome of material B over A <sup>3</sup>	Mean fold-improvement of similar studies	Log <sub>10</sub> mean fold change	References
None <sup>1</sup>	% removed for tail injury	17.5	Compost rack (500)	<1	108 (6)	<0.05	17.5+	17.5+	1.24	*Beattieet <i>al</i> (2001)
None	% pigs with tail wounds	2.3	Straw bedding	0.5	~4,550 (40 farms)	<0.001	4.6	8.6	0.93	†Courboulayet <i>al</i> (2009)
None	% removed for tail injury	2.5	Straw (490)	0.2	512 (16)	N.S.	12.5			†Scottet <i>al</i> (2007)
Hanging toy	% pigs with tail wounds	42.2	Straw (400)	0	181 (12)	N.A.	(Max)			*Van de Weerd(2005)
Hanging toy	% died or were removed for tail injury	11.7	Straw (400)	1.4	2048 (64)	<0.001	8.4	6.7+	0.83	†Scottet <i>al</i> (2006)
Hanging toy	% pens with tail wounds	83	Straw (5 cm deep)	17	72 (6)	P<0.05	4.9 (Max)			*Van de Weerdet <i>al</i> (2006)
	% removed for tail injury	11.1		0						
None	Tail lesion index	0.7	Light chopped straw/wood shavings (12.5)	0.1	126 (31)	P<0.05	7	7	0.85	*Munsterhjelmet <i>al</i> (2009)

Rubber hose or Chain	% of pens with tail wounds	56	Light straw (20)	8	240 (24)	P<0.05	7	7	0.85	*Zonderland <i>et al</i> (2008)
Rubber hose or Chain	% of pens with tail wounds	56	Straw rack (5)	29	240 (24)	N.S./ P<0.05 <sup>2</sup>	1.9			*Zonderland <i>et al</i> (2008)
Chain & rubber-covered chain	% prevalence of tail lesions	10.6	Straw rack	12.9	336 (12)	N.S.	0.8			‡Scollo <i>et al</i> (2013)
Hanging toy	% pens with tail wounds	83	Straw rack <sup>4</sup>	50	72 (6)	(N.S.)	1.7	1.3	0.11	*Van de Weerd <i>et al</i> (2006)
	% removed for tail injury	11.1		1.4		N.A.	(7.9)			
Rootable feed dispenser	% pens with tail wounds	33	Straw rack <sup>4</sup>	50	72 (6)	(N.S.)	0.6			*Van de Weerd <i>et al</i> (2006)
	% removed for tail injury	1.4		1.4		N.A.	(1)			
Straw rack (5)	% of pens with tail wounds	29	Light straw (20)	8	240 (24)	N.S.	3.6	3.6	0.55	*Zonderland <i>et al</i> (2008)
Straw rack <sup>4</sup>	% pens with tail wounds	50	Straw (5 cm deep)	17	72 (6)	(N.S.)	2.9	2.9	0.46	*Van de Weerd <i>et al</i> (2006)
	% removed for tail injury	1.4		0		N.A.	(Max)			

Footnotes: <sup>1</sup>For the Beattie *et al* (2001) study, 'None' includes the average of pens with nothing and pens with the non-manipulable empty overhead racks.<sup>2</sup>In this study, straw rack and metal chain had significantly different % tail wounds, but straw rack and rubber hose did not. Metal chain and rubber hose had very similar levels of tail wounds so were combined for simplicity.<sup>3</sup>'Max' indicates that the improvement was such that tail biting reduced to zero in the second treatment, and this information was not used for the calculation of average fold improvement. Values in parentheses in this column were not used for calculation of the 'Mean fold improvement'- where two different outcome variables were reported for the same study, one of them had to be chosen for use with other studies- the most comparable outcome variables were used where possible.<sup>4</sup>The straw rack was described as a metal tube with a chain mail base which was filled with long straw (and with a tray on the floor underneath) but the quantity provided/used was not reported. <sup>5</sup>p values are reported where these are available in the source paper. N.S. means that the difference was not

significant, but numerical values have still been used to contribute to estimate the mean fold-change. N.A. means that the p value is not available as it was not reported in the source paper.

**Table 2** Comparison of minimum standards for housing grower-finisher pigs across countries and selected assurance schemes (from UK and Denmark) that restrict or completely ban tail docking, with housing standards where docking is widespread (EU, Denmark and UK standard indoor housing).

Country	EU Directives	Denmark	Denmark	Denmark	UK	UK	UK	Sweden	Finland	Norway	Switzerland
System	-	Standard Indoor <sup>3</sup>	Antoniuss	Outdoor (includes Organic) <sup>20</sup>	Standard Indoor	Freedom Food	Organic <sup>10</sup>	-	-	-	-
Farm Size (finish pigs)	234 <sup>1</sup>	2538 <sup>1</sup>	-	-	1038 <sup>1</sup>	-	-	1046 <sup>1</sup>	485 <sup>1</sup>	264 <sup>1</sup>	420 <sup>1</sup>
Space Allowance 41kg pigs (m2/pig)	0.4 <sup>2</sup>	0.4 <sup>3</sup>	0.5 <sup>4</sup>	1.4 (includes outdoor area) <sup>5</sup>	0.4 <sup>7</sup>	0.4 (1.17 for straw yard, mucked out monthly) <sup>9</sup>	555 (0.8 indoor only in extreme weather) <sup>10</sup>	0.48 <sup>11</sup>	0.6 <sup>13</sup> (0.4 <sup>21</sup> )	0.5 <sup>17</sup>	0.6 <sup>19</sup>
Space Allowance 101kg pigs (m2/pig)	0.65 <sup>2</sup>	0.65 <sup>3</sup>	0.85 <sup>4</sup>	2.3 (includes outdoor area) <sup>5</sup>	0.65 <sup>7</sup>	0.75 (1.54 for straw yard, mucked out monthly) <sup>9</sup>	625 (1.3 indoor only in extreme weather) <sup>10</sup>	0.94 <sup>11</sup>	0.9 <sup>13</sup> (0.65 <sup>21</sup> )	0.8 <sup>17</sup>	0.9 <sup>19</sup>
Floor-minimum solid area (% of pen)	0 <sup>2</sup>	33 (grower), 50 (weaner) solid or drained by July 2015. Most already comply <sup>3</sup>	33-50 <sup>4</sup>	50 (of indoor area) <sup>5</sup>	0 <sup>7</sup>	66 <sup>9</sup>	50 <sup>10</sup>	70 – 75 <sup>11</sup>	67 can include drained floor where perforations are up to 10% of the area <sup>13</sup>	Solid-floored area large enough for all pigs to lie. <sup>17</sup>	67 lying area, permitted to have 'low degree of perforation for the drainage of liquids' must be solid by 2018 <sup>19</sup>
Tail docking	Not allowed routinely, only if evidence of injuries to ears or tails. "Before..(tail docking).. other measures shall be taken to prevent tail	As EU, but no more than half the tail, and only 2-4 day old piglets) <sup>3</sup> , Docking is	No, but vet can give a time-limited dispensation for	No, but possible to get a dispensation for 60 days for tail	As EU. Docking is widespread. <sup>7</sup>	Outdoor no, indoor no but can apply for permission to dock to 6cm for 1 yr if they have tail biting (in 2010, 30% did). Must	No <sup>10</sup>	No <sup>11</sup>	No <sup>14</sup>	Only by a vet using anaesthetic and long-lasting analgesic <sup>17</sup>	No <sup>19</sup>

	biting and other vices taking into account environment and stocking densities. For this reason inadequate environmental conditions or management systems must be changed." (vet or competent person can dock <7 day old piglets) <sup>2</sup>	widespread	r tail biting problems <sup>4</sup>	biting problems <sup>5</sup>	take other steps to reduce tail biting to prove docking is a last resort <sup>9</sup>						
Manipulable materials	"Pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals." <sup>2</sup>	Denmark wide: Material must be of 'natural origin' and be used 'for rooting' and provided 'on the floor' <sup>3</sup>	Straw bedding- all pigs able to lie on straw. <sup>4</sup>	Straw-bedded indoor lying area, outdoor run can be concrete <sup>5</sup>	As EU: Chains alone not enough, tyres not allowed, objects not fouled and within reach of pigs <sup>7</sup>	Lying area and must have comfortable absorbent bedding (straw, sawdust, shredded paper). Permanent access to materials (straw, peat, silages, mushroom compost) in sufficient quantities to allow and encourage proper expression of rooting, pawing and chewing behaviours. <sup>9</sup>	Mainly outdoor, with soil, stones, green plants. If indoor, 'ample' bedding (straw, sawdust, sand, paper or natural materials such as bracken or rushes, not peat) <sup>10</sup>	Straw must be provided for all pigs <sup>11</sup>	Permanent and enough to make into small piles, or if not permanent, materials that can be re-shaped, replenished twice daily (typically straw, sawdust, wood shavings or peat are used), plus additional materials- ball, <sup>15</sup> chain or sticks. <sup>15</sup>	As EU, but 'wood(chips)' in the list of materials rather than wood <sup>17</sup>	Solid floor bedded with sawdust, straw rack provided <sup>19</sup>
Abattoir scoring to estimate tail biting prevalence		0.5 - 1.5% <sup>6</sup>	-	1.0-4.0% <sup>6</sup>	1.0% 'severe tail lesions' 2.4% 'evidence of tail biting' <sup>8</sup>			<2.0% tail damage <sup>12</sup>	1.8% tail damage, 5.1% partial condemnations <sup>16</sup>	4.0% tail damage <sup>18</sup>	

Footnotes: 1) Farm sizes were calculated from Eurostat (2013) figures for 2010 for 'other pigs' which includes grower/finisher pigs (available only at country level). Low EU average is due to the inclusion of many member states which do not have a major pig industry. 2) EU Directives 2001/88/EC and 2001/93/EC (The Council of The European Union, 2001a; The Council of The European Union, 2001b). 3) Banon fully-slatted floors applies from July 2000 for new buildings, and for all housing by July 2015. Drained floor defined as maximum 10% openings. Danish Government (2000; 2003a; 2003b) DVFA (2013) 4) Antonius: Danish Crown (2007) 5) Outdoor: Friland(2012), Ministeriet for Fødevarer, Landbrug og Fiskeri (MFLF, 2012) 6) Taken from figure j, p86 in Forkman *et al*(2010) 2008-2010 figures from one abattoir so are directly comparable between systems. 7) Defra(2003), BPEX (2010) 1% figure from Northern Ireland and Republic of Ireland (Harley *et al.*, 2012), 2.4% for 6 abattoirs in England (Hunter *et al.*, 2001) 9) RSPCA (2012) and Kate Parkes (RSPCA pers. comm.) 10) Soil Association (2012), Outdoor-based system, giving permanent access to soil and growing plant foods. Must provide summer wallows and/or shade. Rotational grazing required. Indoors only under exceptional circumstances and must have outside run allowing rooting and dunging. 11) Jordbruksverket(2010), Mule *et al*(2010) SLU and LRF (2009), 12) Holmgren & Lundeheim (2004), Keeling *et al*(2012). 13) Council of State (2012). The regulations came into effect in the first of January 2013. If a facility was already operating at that time, the space allowance regulations come into effect on the first of January 2018, and the minimum solid floor area on the first of January 2028, or both come into effect upon renovation if that is sooner 14) Tail docking prohibited since January 2003 (Council of State, 2002). 15) Evira(2013) 16) Partanen *et al*(2012) 17) LMD (2003) 18) Fjetland & Kjastad(2002) 19) Swiss Federal Council (2008), Wechsler (2013), CIWF (2009) 20) Outdoor access (can be concrete): 0.6m<sup>2</sup>/pig at 40kg and 1.0m<sup>2</sup>/pig at 100kg. 21) MAF (1997). Applies to all facilities until the 31<sup>st</sup> of December 2012 and to old facilities not renovated before 2018

**Figure 1:** Postulated relationships between the underlying processes of tail biting (text in bold, connected in order by solid arrows) and various known or suspected risk factors (text in plain type) connected with 19 dashed numbered arrows to show how some of the risk factors might influence each other or the underlying process of tail biting. Some proposed risk factors for which the evidence is currently weak (e.g. disease and parasitism, draughts) are included where a plausible hypothesis exists. The meaning of the numbered arrows is explained in Supplementary Material S1.

**Figure 2:** Enrichment materials' relative effect at reducing tail biting based on Log<sub>10</sub> fold reductions in tail damage, using studies from Table 1.

Footnotes:

Line thickness indicates the number of studies used; thinnest lines = 1 study, intermediate lines = 2 studies, thickest lines = 3 studies. Shading of the box indicates the amount of material that is used up. Compost and Straw (shown in black), at least 500 g/pig/day, light straw (in dark grey, 12.5 to 20 g/pig/day), straw rack (5 g/pig/day). None and Straw used as reference, as these are the most common materials used across studies. This means that none and straw each have only one horizontal line. Light straw and Straw rack have multiple lines, which show the range of positions they could occupy relative to other substrates based on a number of studies.