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Hertfordshire AL4 8AN, UK
www.ufaw.org.uk

Animal Welfare 2016, 25: 287-296
ISSN 0962-7286
doi: 10.7120/09627286.25.2.287

Behavioural differences between weaner pigs with intact and docked tails

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Abstract

*Tail-biting in pigs (*Sus scrofa*) reduces welfare and production. Tail-docking reduces (but does not eliminate) tail-biting damage. The reason tail-docking reduces tail damage is unknown. It may reduce pigs' attraction to tails (H1), or increase tails' sensitivity to investigation (H2). To investigate these hypotheses, behavioural differences between 472 individually marked grower pigs with intact tails (nine groups of 25–34 pigs) or docked tails (nine groups of 22–24 pigs) were observed from 5–8 weeks of age on a commercial farm in Denmark. Pens had part-slatted floors, dry feeding and two handfuls of straw per day, and enrichment objects were provided. Behavioural sampling recorded actor and recipient for tail-directed (tail interest, tail in mouth, tail reaction) and investigatory behaviours (belly-nosing, ear-chewing, interaction with enrichment). Scan sampling recorded pig posture/activity and tail posture. Intact-tail pigs performed more overall investigatory behaviours but tail type did not affect the amount of tail-directed behaviours. Larger pigs performed more investigatory and tail-directed behaviours than smaller pigs and females performed slightly more tail investigation. Tail-directed behaviours were not consistent over time at the individual or group level. However, ear-chewing was consistent at the group level. One group with intact tails was affected by a tail-biting outbreak in the final week of the study (evidenced by tail-damage scores) and showed an increase over time in tail posture (tail down) and tail-directed behaviour but not activity. Overall, there were few behavioural differences between docked and undocked pigs: no evidence of reduced tail investigation (H1) or an increased reaction to tail investigation (H2) in docked pigs, and yet docked pigs had less tail damage. We propose that docking might be effective because longer tails are more easily damaged as pigs are able to bite them with their cheek teeth.*

Keywords: *abnormal behaviour, animal welfare, intact tail, pigs, tail-biting, tail-docking*

Introduction

Tail-biting in pigs occurs when the oral manipulation of the tail by a conspecific results in physical damage to the tail (Schrøder-Petersen & Simonsen 2001; Taylor *et al* 2010). Tail-biting is a multifactorial issue (Taylor *et al* 2010; D'Eath *et al* 2014), influenced primarily by limited access to substrates which allow for normal rooting, foraging and investigatory behaviour (Van de Weerd *et al* 2006) and by limited feeder space (Hansen *et al* 1982) but may also be affected by factors including genetics (Breuer *et al* 2005), sex (Kritas & Morrison 2004), stocking density (Goossens *et al* 2008), nutrition (Fraser 1987) and housing system (Hunter *et al* 2001).

Tail-biting is a welfare and production issue: bitten pigs experience acute pain (Zonderland *et al* 2009) and stress (Zupan *et al* 2012), are less productive (Sinsalo *et al* 2012) and have increased carcase condemnation at abattoirs, primarily due to pyaemia (Kritas & Morrison 2007). Tail-biting also suggests reduced welfare for the biting pigs, as the environment is deficient in some way, leading to re-directed foraging behaviour (Sambraus 1985; FAWC 2009).

Tail-docking, or the removal of a distal portion of the tail, is commonly used as a 'preventative' treatment of tail-biting. Even though it does reduce tail-biting damage, tail-docking is also a welfare issue. It is known to cause acute pain and stress (Marchant-Forde *et al* 2009) and there is the potential for chronic pain due to neuroma formation in the tail stump (Simonsen *et al* 1991; Done *et al* 2003), although this has never been proven. Due to the negative animal welfare consequences of tail-docking, 'routine' use of tail-docking in pigs is banned in EU member states (EU Council Directive 2008/120/EC; Council of European Union 2008), but continues to be used in the majority of indoor systems.

Despite its widespread use, tail-docking is not 100% effective — it only reduces the amount of tail-biting damage and does not eliminate it (Hunter *et al* 2001; Sutherland & Tucker 2011). The reason for this is unknown. It is possible that long tails are more attractive and cause pigs to tail bite more (Hypothesis 1 [H1]; Feddes & Fraser 1994). It is also possible that pigs with docked tails are more sensitive and move away more quickly when they are investigated or bitten by other pigs, not allowing as much damage to be done (Hypothesis 2 [H2]; Simonsen *et al* 1991).

The primary aim of the present study was to observe behavioural differences between contemporary groups of otherwise similar pigs with docked and intact tails, in order to better understand the changes in behaviour which might contribute to the effectiveness of tail-docking in reducing tail damage. To address the two hypotheses given above, the level of tail-directed behaviours (H1), and the response to tail investigation (H2) were recorded. We observed young weaner pigs (5–8 weeks of age) on a commercial farm and provided enrichments in order that damaging tail-biting would not (yet) be occurring. However, it can be difficult to tell the difference between damaging and non-damaging tail manipulation, so tail damage was also scored. Since sex and pig size are known to affect investigatory behaviours and tail-biting, these were noted and included in analyses.

Non-damaging tail manipulation is thought to occur as a precursor to a damaging tail-biting outbreak (Taylor *et al* 2010; 'Two stage' tail-biting). This background level of tail manipulation may be higher for some pigs or groups than others, resulting in a greater background risk for tail-biting. If this is correct, we would expect that certain individuals or groups show higher levels of tail-directed behaviours in a consistent way over time. Our study involved 12 observation days over four weeks, so our second aim was to look for evidence of consistency in these behaviours.

Finally, although damaging tail-biting was not expected in our study, there have been reports that increased activity and lowered tail posture can act as 'early warning' signs before damaging tail-biting begins (Statham *et al* 2009; Zonderland *et al* 2009). We recorded these behaviours by scan sampling in case tail-biting outbreaks occurred.

Materials and methods

The study took place at a commercial grower/finisher farm located in North Jutland, Denmark.

Study animals

The subjects of this study were 472 weaner pigs housed in nine groups of tail-docked and nine groups of intact pigs (223 males, 235 females and 14 unknown). At the start of the study, there were a mean (± SD) of 29.6 (± 3.7) pigs in tail-docked groups (range 25–34) and 23.1 (± 0.6) pigs in the intact groups (range 22–24). After ten days, the smallest docked pigs were removed by farm staff to another pen, resulting in a mean group size of 27.3 (± 2.6); (range 25–31). Three groups of docked and intact pigs were used from each of three batches of weaner pigs born four weeks apart. All pigs were DanBred crosses (Sow: Danish Landrace × Danish Large White, Boar: Duroc) that had been born and raised in a system with farrowing crates at a separate sow farm. The pigs in the docked-tail-type group had been tail-docked at three days of age by hot blade cutting to approximately 50% of the natural tail length, in accordance with Danish legislation (Anonymous 2003). All piglets had been given iron injections and all males had been castrated. This occurred at the same time as tail-docking for docked pigs. Castrated piglets were given a short-term analgesic (intra-muscular 5 mg ml^{-1}, 0.1 ml per pig, Metacam®, Boehringer Ingelheim Vetmedica GmbH, Ingelheim, Rhein, Germany) at the time of the procedure, but no additional analgesic was provided for tail-docking. At four weeks of age, the pigs were weaned and moved to the grower/finisher farm where the data were collected.

Diets, housing and husbandry

Pigs arrived at the grower/finisher farm at approximately 28 days of age and group-mixing occurred at this time. Each grower pen measured 5 × 2.35 m (length × width) and the floors were 1/3 solid, 1/3 drained, and 1/3 slatted. The solid floor was partially covered with a retractable cover and had a heat lamp.

Pigs were fed complete diets of dry feed via an *ad libitum* dry feeder and approximately 1 kg of the same diet was provided four times per day on the floor for the first ten days post-weaning. The diet was matched to the average weight of the pigs in each batch (diets for 7–10, 10–20 and 20–30 kg) and there was an abrupt transition between diets. One nipple drinker was provided in the slatted area of each pen. The average barn temperature was 18.9 (± 2.0)°C; (range: 16.7–23.9°C) and the barns had low-pressure-based ventilation systems. The barns had natural and artificial lighting; daylight was approximately 0500–2100h and artificial lights were on between approximately 1000–1700h. Two large handfuls of chopped straw were provided to each pen on a daily basis. Each pen-point source had enrichments provided: linked chain (4-cm links), two or three wooden blocks (30 × 5 × 3 cm; length × width × height), and blue polypropylene rope. The rope was approximately 1.5-m long and tied in half, creating two pieces of rope to be chewed. Knots were tied along the rope every 8–10 cm to slow the destruction of the rope and the rope was replaced when it had been chewed to approximately 10-cm long. The chain was attached to the side of the pens and the rope and wood were attached to the chain.

Non-behavioural procedures

Every pig was individually identifiable via coloured ear-tag or paint markings. Ear-tags were placed in ten randomly selected pigs per pen when they arrived at the grower/finisher farm. Five different colours of ear-tag were used and one tag was placed in the right or left ear of a pig, providing ten unique identifications per pen. Non-toxic, pig-marking paint was used to identify the remaining pigs in each pen. Different colour combinations of marking paint were applied to the shoulder and/or hindquarters of each pig to allow individual identification. Paint was reapplied 2–3 times per week after observation periods in order to minimise the disturbance of the researcher entering the pen.

At eight weeks of age, the pig's sex was recorded and the pig's size relative to its pen-mates (small, medium, or large) was estimated via direct visual comparison within each pen, as it was not practical to obtain accurate weights. The percentage of pigs assigned to each category were as follows (small: 26.6%; medium: 48.9%; large: 24.4%). Also at eight weeks of age, tail-biting scores were

https://doi.org/10.7120/09627286.25.2.287 Published online by Cambridge University Press

recorded for the second and third batches of pigs (the first batch was missed in error). The scoring was carried out by the same researcher using the following scoring system: 0) Normal tail; no lesion; 1) Slightly red; clean and no visible tissue damage; 2) Scratched; mild damage to the skin, possibly small amounts of blood or scabs present; 3) Wound; lacerations, blood or scabs present; and 4) Tail partially missing, blood or scabs may be present. During the study, two pigs were removed due to hernias, but none were removed because of tail-biting.

Behavioural observations

Pigs were observed three days a week over four weeks from 5–8 weeks of age. Observations took place between 1200 and 1700h as pigs were active during this period (as determined by a pilot study), but farm staff were not working in the room at that time, so disturbance to the pigs was minimised. Two types of sampling were done each day — instantaneous scan sampling and behaviour sampling. All observations were made live by one researcher from the alleyway between the pens and observations were recorded via pen and paper. The pens were observed in a randomised order, according to a pre-planned schedule, on each day of observations.

Scan sampling

Six scans (mean [± SD] = 31.1 [± 5.7] min apart) were carried out on each observation day. All six pens in the batch were observed during each scan sample within 10 min of one another. The scan sampling observed all pigs in a pen and recorded the number of pigs showing the following: body position (standing, sitting, or lying); tail posture (curled up, neutral/hanging, or tucked); and tail movement (moving or not moving) as described in Table 1.

Behavioural sampling

We did not record interactions with straw, the floor, wall, pen fixtures as these were incredibly common, occurring all the time by many of the pigs whenever they were active. Instead, the behaviour sampling ethogram focused on pig-directed behaviours which have been considered to be abnormal or potentially harmful: belly-nosing, ear-chewing, tail interest, tail in mouth, and tail reaction. For tail-directed behaviours it can be difficult to identify when damaging biting has occurred, but a reaction (or not) by the bitten pig is more obvious and may indicate a tail bite, or a pig with a sensitive tail responding to a lesser insult. Finally, we also recorded interaction with point-source enrichment objects, which are meant to provide an alternative outlet to pig-directed harmful behaviours (Table 2). Behavioural sampling observations lasted 30 min per pen per day. The start and stop time of each behaviour was recorded as well as the identity of the actor and recipient. It was not always possible to identify individuals (eg the pig was lying with its back away from the researcher), so these were recorded as 'unknown'.

Table 1 Ethogram of scan sample behaviours.

Behaviour	Description
Standing	Body supported in an upright position, all four limbs extended
Sitting	Body resting on the caudal part of the pig with the front limbs extended, holding the cranial part of the body off the ground
Lying	In a recumbent position, resting on the ground; includes lying with the sternum or side of the body on the ground
Tail up*	Curled or straight but in an upright position, tail tip level with or above the base of the tail
Tail neutral*	Intermediate position; tail is straight and hanging, end of the tail not touching the body
Tail down*	Pig holds the tail pressed flush against the body; tail cannot be moving as it is held down against the body
Tail moving	Visible side to side or wagging movement
Tail not moving	No movement visible
Tail unknown	Tail is not visible to researcher

* Adapted from Zonderland *et al* (2009).

Table 2 Ethogram for behavioural sampling.

Behaviour	Description
Belly-nosing (BN)	Repeated nosing or manipulation of a conspecifics belly by the acting pig's nose
Ear-chewing (EC)	Chewing, sucking, or having a conspecific's ear in its mouth
Enrichment interaction*	Touching, sucking, nosing, chewing, or actively interacting with the point source enrichment (ropes, wood pieces, and chains) in the pen
Tail reaction (TR)*	Having the tail of a conspecific in its mouth resulting in a physical reaction (squealing, grunting, moving away) from the conspecific
Tail in mouth (TIM)	Having the tail of a conspecific in its mouth but with no physical reaction from the conspecific. May include mastication of tail
Tail interest (TI)*	Touching, sniffing, or manipulating the tail of a conspecific without taking the tail into its mouth

* Adapted from Statham *et al* (2009).

Ethical considerations

The animals used in this study were all part of the Danish Pig Research Centre's 'Handling of pigs with intact tails' project. There is a welfare concern about leaving pigs' tails intact, as that is known to increase the risk of tail-biting in a commercial rearing system (Hunter *et al* 2001). There is also a welfare concern in docking pigs' tails, as this is known to cause acute pain, stress, and potentially chronic pain (Simonsen *et al* 1991; Marchant-Forde *et al* 2009). This project was approved by The Veterinary Ethical Review

Committee of Edinburgh University's Royal (Dick) School of Veterinary Studies. This research took place at a commercial farm and in case of a tail-biting outbreak, a protocol was in place, involving additional enrichment materials and straw to be added to the pen, while injured pigs would be removed to a separate, enriched pen. Only one pen was affected by an outbreak at the end of the study, and it was dealt with by increasing enrichment in the affected pen.

Statistical analysis

Investigatory behaviour

Behaviour sampling data were summarised into individual pig frequencies of behaviour summed across all observation periods. We summed the three tail behaviours (TI [Tail interest], TIM [Tail in mouth] and TR [Tail reaction] = 'all tail behaviours') and all six behaviours ('total investigation'). These behaviours and 'enrichment interaction' were log-transformed to improve normality and analysed as response variables in Linear mixed models which were fitted using REML in Genstat 15. Tail type (docked or intact), sex, size and the number of pigs in the pen (as a covariate) were fitted as fixed effects. Pen and Pig ID were fitted as random effects. The other behaviours contained too many zeroes to be transformed, so were modelled using Generalised Linear Mixed Models in Genstat 15, fitting a Poisson distribution with a Log-link function. The fixed and random models were the same as those used for REML. To investigate the effect of observation week (pig age in weeks) on investigatory behaviour, the above analyses were repeated after summarising by individual pig for each week, and re-analysing with 'week' in the fixed effects, and including the interaction of week with tail type.

Consistency over time in investigatory behaviour was examined by quantifying behaviour in each of the four separate observation weeks and comparing these using (Pearson) correlation matrices of the six possible comparisons. This was done at both the group (pen) and individual levels.

Posture and tail posture

Scan sample data were analysed using ANOVA in Genstat 15. For each posture (stand, sit, lie) and tail posture (up, neutral, down) the proportion of pigs observed performing that behaviour at each scan were used as response variables. In the case of tail posture, this proportion was out of those that had visible tails. Tail type (docked or intact) and day were the treatment, while the six scans each day nested within day, nested within pen were the blocks. The blocking structure means that Genstat investigates the effect of treatment at the pen level, using appropriate error degrees of freedom.

Results

Investigatory behaviour — effects of tail type, sex, size and week

The number of pigs in the pen had no significant effect in any of the analyses, but was always retained in the model to ensure that other factors were always adjusted for any effect.

During behaviour sampling, the behaviours of interest were observed 9,231 times. Pigs were most often observed investigating the point-source enrichment items (77.5%), with the remaining behaviours being pig-directed: belly-nosing (6.8%), ear-chewing (7.6%) and tail-directed (8.1%), the latter being divided into tail investigation (3.7%), tail in mouth (3.4%) and tail reaction (1.1%). Although tail-directed behaviours were not very common, 55.8% of the pigs performed at least one tail-directed behaviour.

Tail type affected the frequency of 'total investigation' (the total of all six oral/nasal investigatory behaviours recorded during behaviour sampling): intact pigs performed more investigatory behaviour than docked pigs ($F_{1,\ 15.1}$ = 4.64; P = 0.048; Figure 1). Intact pigs also performed more enrichment-directed behaviour than docked pigs ($F_{1,\ 14.5}$ = 10.24; P = 0.006; Figure 1), but there were no effects of tail type on tail-directed behaviours individually or combined (Figure 2).

In total, females performed more investigatory behaviour than castrated males. Females performed 'total investigation' at a higher frequency than castrated males ($F_{1, 447.4}$ = 6.50; P = 0.011; means [± SEM]; F = 21.0 [± 0.8], M = 18.9 [± 0.8]). Females also used enrichment more ($F_{1,\ 449.0}$ = 9.25; P = 0.002; F = 16.6 [± 0.7], M = 14.3 [± 0.6]) and performed more tail investigation (χ^2_2 = 5.48; P < 0.019; Figure 3) and showed a tendency to perform more 'tail-directed' behaviours ($F_{1, 448.8}$ = 3.76; P = 0.053; sum of tail reaction, tail in mouth and tail investigation; Figure 3). Castrated males performed more belly-nosing than females (χ^2_2 = 6.59; P < 0.010; F = 1.2 [± 0. 2], M = 1.5 [± 0.2]).

Pig size had a number of effects on the frequency of behaviour: large and medium pigs tended to perform more 'total investigation' than small pigs ($F_{2, 442.3}$ = 2.46; P = 0.086; L = 20. 8 [± 1. 1], M = 20. 2 [± 0. 8], S = 17. 1 [± 1. 1]). The largest pigs performed the most 'tail-directed' behaviours, followed by medium-sized pigs and then the smallest pigs ($F_{2,\ 447.1}$ = 12. 96; P < 0. 001; Figure 3). When tail-directed behaviours were analysed separately, size effects were seen for each of them: larger pigs, compared to smaller pigs performed more tail reaction (χ^2_2 = 7.42; P = 0. 025), tail in mouth (χ^2_2 = 15.38; P < 0.001) and tail investigation (χ^2_2 = 22.06; P < 0.001; Figure 3). Finally, ear-chewing was not affected by tail type, sex or size.

Across the four weeks, investigation of enrichment declined (week; χ^2_3 = 28.48; P < 0.001) and this decline was more evident in intact pigs which showed a steep decline from week 5 to 6 (interaction of tail type and week; χ^2_3 = 18.25; P < 0.001). Ear-chewing also declined over time (week; χ^2_3 = 64.0; P < 0.001). Tail-directed behaviours increased over time (week; χ^2_3 = 15.49; P = 0.001), most notably this was due to an increase in tail investigation in the last week (χ^2_3 = 9.65; P = 0.022), while other behaviours showed no trend over time.

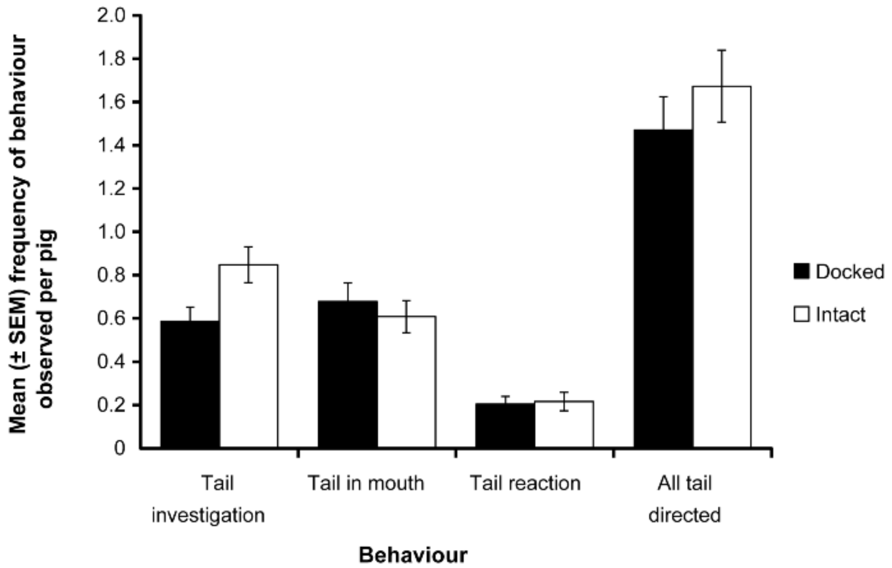
Consistency over time in investigatory behaviour

There was little evidence for consistency over time at the group or individual levels in tail-directed behaviours (overall or analysed separately). This means that certain pigs and certain groups were not consistent in showing higher levels of tail-directed behaviours than others. Correlations were either not significant, or if they were significant the correlation coefficients were low, suggesting only weak relationships (< 0.2). Investigation of enrichment objects was not

Figure 1

Investigatory behaviour of docked and intact-tailed pigs. Data shown are means (± SEM) based on individual pig data from behaviour sampling (all instances of these behaviours were recorded over 30-min sessions over 12 days; total 6 h of observation per pen). ** $P < 0.01$, * $P < 0.05$.

Figure 2



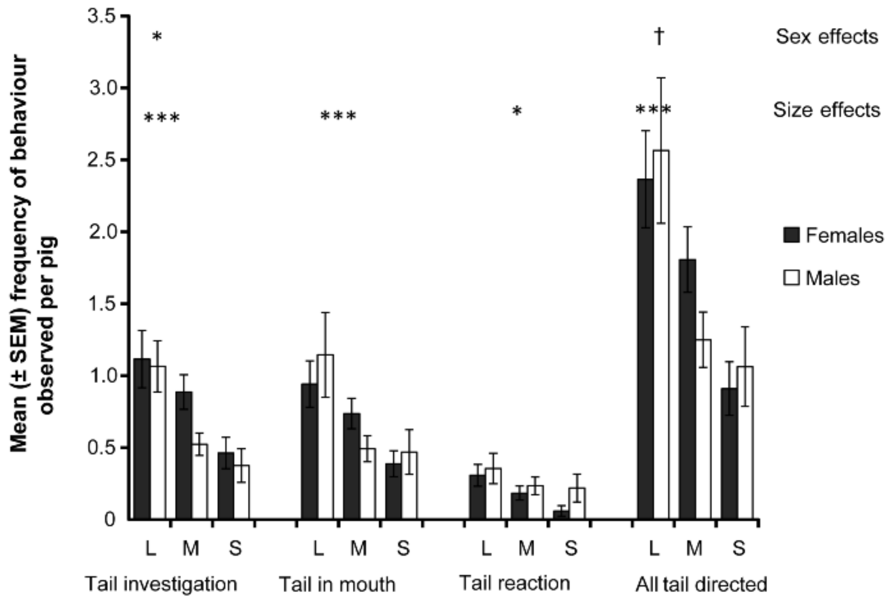
Tail-directed behaviours of docked and intact-tailed pigs. Data shown are means (± SEM) based on individual pig data from behaviour sampling (all instances of these behaviours recorded over 30-min sessions over 12 days; total 6 h of observation).

consistent at the group level, but showed a low but significant degree of consistency at the individual level (week-to-week correlations from $r = 0.13$ to 0.37, all P-values were < 0.004 or lower). Belly-nosing was consistent between weeks 4 and 5 at both the group ($r = 0.663$; $P < 0.001$) and individual ($r = 0.353$; $P < 0.001$) levels, but was not consistent at all in later weeks. Finally, ear-chewing was highly consistent over weeks at the group level ($r = 0.56$ to 0.86, all P-values lower than 0.015) and showed a lower but still always significant consistency at the individual level ($r = 0.10$ to 0.25, all P-values lower than 0.031).

Pig body posture and tail posture

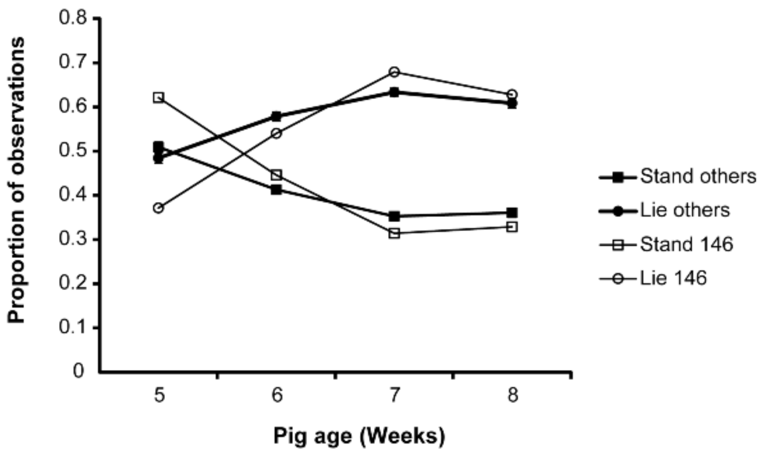
Tail type had no effect on pig posture or activity. There was an effect of time on posture. Pigs became less active over the four observation weeks. Standing declined from 51.6% of scans in week 5 to 35.9% in week 8 ($F_{11, 187} = 19.7$; $P < 0.001$) while lying increased from 47.7 to 61.0% ($F_{11, 187} = 15.9$; $P < 0.001$). Pigs were observed with tails up 35.3% of the time, tails neutral 20.6% of the time and tails down 0.8% of the time (43.3% of tails were not visible during the scan sample). Tail posture was not affected by tail-docking and did not change in a systematic way over time.

Figure 3



Tail-directed behaviours by sex and size. L = Large, M = Medium, S = Small pigs (sizes were estimated visually in comparison with pen-mates). Data shown are means (± SEM) based on individual pig data from behaviour sampling (all instances of these behaviours recorded over 30-min sessions over 12 days; total 6 h of observation). *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, † $P < 0.1$.

Figure 4



Proportion of pigs standing and lying in pen 146 (which had a tail-biting outbreak) and in other pens over the four observation weeks.

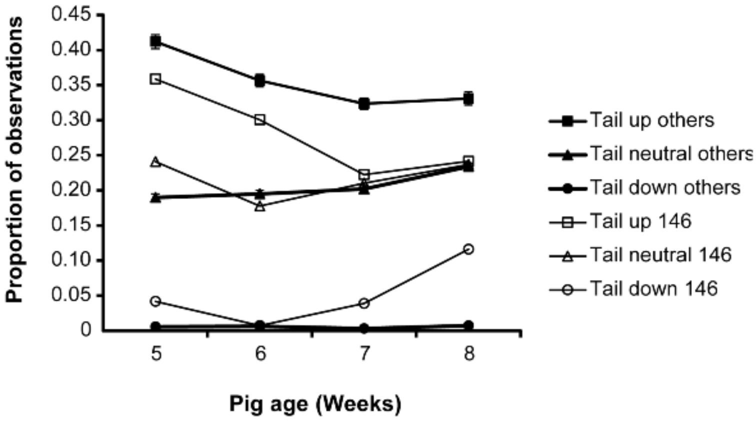
Tail-damage scores by treatment

The tail-damage scores revealed that most pigs (97.7% of docked and 85.3% of intact) had normal uninjured tails (0 scores). Only 0.5 and 1.7% of docked pigs scoring 1 and 2 and none scoring higher than this. In one pen of intact-tailed pigs (pen 146; 23 pigs), a tail-biting outbreak began in the final week of the project, resulting in eight pigs scoring 4, and five pigs scoring 3. Without this pen, the remaining intact pigs had scores as follows (0: 94.3%, 1: 0, 2: 3.3%, 3: 2.4%, 4: 0%). After this outbreak became evident at the end of the study period, the affected pigs were removed to another pen for treatment.

Although there was only one pen in which a tail-biting outbreak occurred, as we had detailed behavioural observations, we produced an anecdotal description of the behavioural changes. The development over time in activity, tail posture and all tail-directed behaviours in this pen were compared graphically to the average of the other pens in the study. Figure 4 shows that the posture (stand or lie) of pigs in pen 146 was comparable to the mean of all other pens. Figure 5 shows that tail up was lower than average, while tail down increased, particularly in the last five observations. Figure 6 shows that tail-directed behaviours appeared to increase in the last week of observation, although tail-directed behaviours appear to rise somewhat in all pens in the final week.

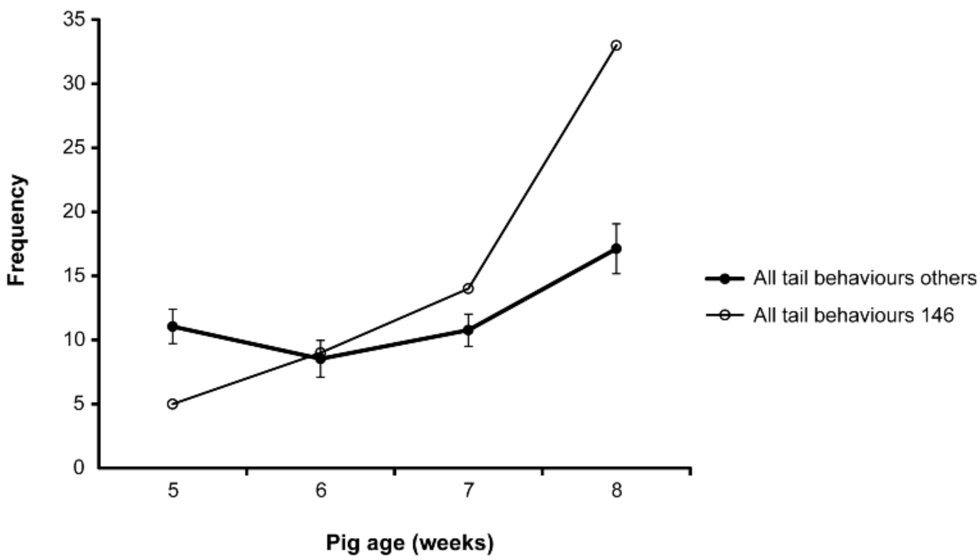
https://doi.org/10.7120/09627286.25.2.287 Published online by Cambridge University Press

Figure 5



Tail posture; proportion of tails up, neutral and tails down in pen 146 (which had a tail-biting outbreak) and in other pens over the four observation weeks.

Figure 6



Frequency of 'all tail behaviours' observed during behaviour sampling by pigs in pen 146 compared to the mean (± SEM) of all other pens.

Discussion

The main purpose of this study was to identify behavioural differences between intact and tail-docked pigs. One hypothesis (H1) for the effectiveness of tail-docking is that the physical presence of a longer, intact tail is more interesting and therefore more likely to be bitten. This study does not support this explanation, as pigs with intact tails did not perform more tail-related behaviours (tail interest, tail in mouth, tail reaction, or all three of these combined into tail-directed) than the docked-tail pigs. This could indicate that intact tails are not more attractive than docked tails. There were several forms of enrichment in the pens — ropes, wood blocks, and small amounts of straw were provided daily — which may have decreased the amount of tail-related behaviours performed by all pigs. Enrichment interaction accounted for 77.5% of the investigatory behaviours observed, suggesting the pigs found the point-source enrichments more attractive than each other's tails. In addition, pigs had chopped straw to occupy them, and this may have further reduced the tail-directed behaviours. If docked tails were less attractive to pigs (H1), we might have expected docked groups to direct more of their attention to enrichments. Instead, the reverse was found, with intact pigs performing more investigation overall, and towards enrichment objects. The reason for this remains a puzzle; perhaps the docked pigs experience some learnt or ongoing effect relating to docking itself or its after-effects that reduces their investigatory behaviour. It will be interesting to see if this result can be replicated and investigated further in other studies. The reduction of overall investigatory behaviour in tail-docked pigs (even though there was no change specifically in tail-directed behaviour) might be a possible mechanism for the effectiveness of tail-docking in reducing the 'background risk' for tail-biting.

The second hypothesis (H2) for the effectiveness of tail-docking is that docked-tail pigs are more sensitive to tail manipulation (possibly but not necessarily because it is painful) and move away from interactions more quickly, reducing the amount of tail-biting damage observed (Simonsen *et al* 1991). This explanation would indicate that there would be more tail in mouth behaviour observed in intact-tail pigs than docked-tail pigs, and more 'tail reaction' observed in docked pigs. However, our observations suggested that these behaviours were not significantly different between tail types, which does not support H2. This was unexpected, because it is known that neuromas can be present at the end of the tail stumps after the tail is docked (Simonsen *et al* 1991; Done *et al* 2003; Herskin *et al* 2010), which may (or may not) affect sensitivity. The likelihood of neuroma formation increases with the amount of tail that is docked (Herskin *et al* 2010). The pigs in this study had half-docked tails (as opposed to short-docked tails, where the tail is cut to less than 5 cm), so it could be that neuromas were not very common.

Although not the main aim of the study, differences in behaviours were seen between pigs of different sex and size. Females performed more overall investigatory behaviours compared to castrated males. Females also performed significantly more enrichment use and tail interest, and tended to perform more tail-directed behaviours overall than castrated males. Steinmetz and Pedersen (2009) reported lower tail damage in all female pens than in pens of all castrated males. Zonderland *et al* (2010) found that females were more likely to be biters than intact males. It has been speculated that the sex differences may be observed because males are typically larger and more inactive than females, making them easier targets for tail-biting (Sambraus 1985; Zonderland *et al* 2010). Tail-biters are sometimes reported to come from among the smaller pigs in a group (Sambraus 1985; Van de Weerd *et al* 2005). In our study we found that larger pigs performed more investigatory behaviours, including each of the tail-directed behaviours.

There was little evidence of consistency over time, for pens or individual pigs, performing tail-directed behaviours. Enrichment interaction and ear-chewing behaviours were both weak but consistent at the individual level over time. This study showed little support for the hypothesis that some individual pigs show consistently higher levels of tail-directed behaviours than others. Van de Weerd *et al* (2005) identified 'obsessive' tail-biters (Taylor *et al* 2010) that consistently performed higher levels of tail-biting behaviours over time. This study did not identify similar cases, but there has not been much research or report of obsessive tail-biting. It is possible that pigs may only begin to demonstrate obsessive tail-biting behaviour after a tail-biting outbreak begins. The tail-directed behaviours shown by many pigs in this study were probably the first stage of 'two-stage' tail-biting (rather than 'obsessive'; Taylor *et al* 2010). What was striking, however, was that ear-chewing was consistent over the four weeks at the group level, being more prevalent in certain groups than in others. Might ear-chewing become a 'habit' in certain groups as pigs copy others? This warrants further investigation.

Investigation of enrichment and ear-chewing both declined with age. Other studies have shown tail-directed behaviours increasing with age between 5–8 weeks of age (Schrøder-Petersen *et al* 2003). In the present study, tail-directed behaviours, especially tail investigation, increased in the last week of the period. In our study, pigs were observed from 5–8 weeks of age, which is around the age range at which some studies have seen the beginning of tail-biting behaviours (Blackshaw 1981; Penny *et al* 1981; Zonderland *et al* 2010), as we did here in one pen. However, other studies have observed increased tail-biting in older pigs between 16–20 weeks of age (Sambraus 1985; Schrøder-Petersen *et al* 2003). It is possible a longer observation period would have found an increase in tail-directed behaviours. We found a reduction in activity (standing) and an increase in lying behaviour with age (although there was no effect of tail type). This was expected, as young pigs typically become less active as they get older (eg Van der Weerd *et al* 2005).

We recorded pig body and tail posture in our study. These were not affected by tail type. If we assume that a lowered tail posture is a defensive response to unwanted tail investigation (including biting), then it is perhaps not surprising that this was not affected by tail type as there was no significant difference in the amount of tail-directed behaviours between tail types. However, we also recorded these in case tail-biting occurred, and one pen (pen 146) did have an outbreak of tail-biting right at the end of the study. Since it is only one pen, we can only present an anecdotal description, but our detailed observations mean this might be of value to other researchers. Tail-directed behaviours appeared to increase in the last week of observations as compared to the averages of the other pens (Figure 6), and pigs' tails were observed in the 'down' position more often in the affected pen (Figure 5), but there were no obvious differences in activity levels (Figure 4). McGlone *et al* (1992) and Zonderland *et al* (2009) found that more tail-directed behaviours were observed when the proportion of neutral or down tails increased. It is plausible that pigs hold their tails down or tuck them down as a defensive reaction to tail-biting (Statham *et al* 2009), or alternatively that 'up' tails are a positive welfare indicator which reduces when tail-biting is occurring. Holding the tail tucked down is known to be a behavioural measure of pain in piglets after tail-docking (Noonan *et al* 1994; Sutherland *et al* 2008). If a future study were able to record the victim's tail posture that coincides with tail-biting behaviour, it may be possible to identify which of the three tail postures is most protective from tail-biting.

Following our failure to support either of our hypotheses (H1 or H2), we suggest that tail-docking may be effective because long, intact tails are bitten with more force than short tails because a biting pig can get a better grasp on the tail, resulting in greater tail damage (Schrøder-Petersen & Simonsen 2001). Intact tails seemed more likely to be chewed and bitten with the tail crosswise in the biter's mouth, as observed by Sambraus (1985), and Sutherland *et al* (2009) found that pigs with tails docked to 5 cm had worse tail-biting damage than pigs with tails docked to 2 cm

Docked tails are not long enough to be pulled into the biter's mouth completely and usually just the distal end of the tail is chewed or bitten. Weaning/growing pigs have six incisor teeth at the front of their mouth and six premolars further back in their mouth. Anecdotally, during observations it appeared that docked tails were bitten and chewed with just the incisor teeth while intact tails are more likely to be held crosswise in the mouth, being bitten and chewed with the premolars. A future study, focusing on how the victim's tail is held in the biting pig's mouth and the damage that results could provide more insight into this hypothesis.

Animal welfare implications

Tail-biting represents a serious and unpredictable welfare and production challenge for pig producers, and the measure used by many to reduce the risk; tail-docking, is itself undesirable from a welfare standpoint and pig producers are under pressure to reduce it. Our study has provided some insight into the behavioural similarities and differences between docked and intact pigs, giving insight into how tail-docking might work to reduce tail-biting damage.

There was a single pen in which an outbreak of tail-biting occurred in the final week of our study. Anecdotally, pigs in this pen appeared to show increased tail-directed behaviour, and lowered tail posture (an increase in tails held down), but not increased activity, confirming some other reports. As suggested elsewhere (D'Eath *et al* 2014) these behaviours could be used by vigilant stockworkers as an early warning of an impending outbreak, which they could then intervene to prevent.

Conclusion

By comparing the behaviour of tail-docked and intact pigs, we hoped to identify differences to better understand why tail-docking reduces the risk of tail-biting. Because our aim was to study these 'background behavioural differences' that affect the underlying risk of tail-biting without actual tail-biting occurring, we provided enrichment including straw. Observed behavioural differences were few: intact-tailed pigs attracted no more tail-directed attention from pen-mates (H1), and docked pigs showed no signs of tail sensitivity (H2) or different tail postures. Docked pigs did show a reduction in overall investigatory behaviour, and in enrichment-directed behaviour compared to intact pigs, so it is possible that this explains the effectiveness of tail-docking: by reducing investigatory behaviour as a whole, there is a reduced background risk of tail-biting. This seems a little tenuous though, and would be a lot more convincing if the tail-directed behaviours had also been reduced. It would be valuable to repeat our study in a herd with a higher level of tail-biting, to better study the behavioural differences preceding an outbreak. However, based on the present study of 'background' differences, there was little evidence for either hypothesis, so we cautiously propose that tail-docking may be effective because pigs are able to inflict more damaging bites on intact tails because they are longer, so pigs are able to hold them across the mouth and crush them with their pre-molar teeth, which is not possible with the shorter docked tails.

An unexpected group-level consistency in ear-chewing was found which warrants further investigation. Finally, the one pen in which a tail-biting outbreak occurred (anecdotally) showed an apparent increase in tail-directed behaviours and tails held down in the days before the outbreak, supporting the suggestion that these could be useful early warning signs of an impending injurious outbreak.

Acknowledgements

This project received funding from the Danish Pig Research Centre, SEGES, and the Universities Federation for Animal Welfare (UFAW). SRUC is supported by the Rural and Environment Science and Analytical Services (RESAS) Division of the Scottish Government. The authors would like to thank the farmer Verner Nielsen and research technician Sally Balle Josefsen from the Danish Pig Research Centre for their help with this study.

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