Impact of feed, light and access to fibres on tail biting in non-tail-docked pigs

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Abstract

Background

Tail biting in pigs is a global welfare issue that has resulted in docking tails in many countries. However, tail docking by itself does not reduce the incitements for tail biting. Therefore, this study aimed to reduce tail biting in a high performing non-tail-docking pig herd with increasing incidences of tail biting.

Methods

The feed to all pigs was supplemented with amino acids, trace elements, vitamins and fibres. All pigs were also offered fibres in terms of hay silage. Thereafter four fattening stables were allotted into experimental groups as follows; I illuminated with standard fluorescent tubes with an invisible flickering of 30-40% for 14 hours per day; II illuminated with non-flickering led light for 14 hours per day; III illuminated with fluorescent tubes for 2 hours per day (this corresponded to the previous standard illumination and III served as a control group); IV similar illumination as III, but with increased access to hay silage.

Tail injuries were registered at slaughter during a period of four years prior to the trial, which was compared with the incidence of tail injuries during an adaptation period of six months and during the trial that lasted for a period of one year.

Results

The incidence of tail injuries during the four years that preceded the adaptation period was 9.2%, and the incidence of tail injuries differed significantly between the buildings as well as with season.

During the adaptation period, the incidence of tail injuries decreased significantly in all buildings and corresponded to 5.4%. The largest decrease was obtained in IV with extra access to hay silage where the incidence decreased from 11.4 to 4.3%.

During the trial, the mean incidence of tail injuries continued to decrease to 3.0%. There were no significant differences between the stables.

Conclusions

The incidence of tail biting in fast growing non-tail-docked pigs was successfully reduced by supplementation of the feed with amino acids, trace elements, vitamins and fibres. Additional manipulative material in terms of hay silage accelerated that process and non-flickering illumination may have an impact in preventing tail biting.

The results obtained argue for the un-necessity of tail docking pigs, provided that the needs of the pigs in terms of feed ingredients, stocking density and access to manipulative materials are fulfilled.
Introduction

The rear of the pig, *i.e.* behind the sacrum, is poorly drained by the lymphatic system (1) and the defence towards local infections at the rear of pigs is therefore not optimal. One type of infected wounds at the rear of the pig is tail biting from where infections risk to spread to other parts of the body. This explains why abscesses, arthritis and total condemnations at slaughter more often are identified in tail bitten pigs than in non-bitten pigs (2, 3, 4, 5). As bites always are infected, they induce a strong inflammatory acute phase response in the bitten pigs (6) and severely tail-bitten pigs need antibiotic treatment to prevent spread of the initial infections to other parts of the body (7). Despite that tail biting is a sign of reduced welfare of the biter (8), it also causes pain and ill-thrift (9) as well as decreased weight gain (10, 11, 12) in affected pigs. Consequently, apart from welfare aspects, there is also an economic incitement to prevent tail biting.

Tail injuries, presumably induced by tail biting, is a global welfare issue in pig production. To prevent tail biting, tail docking is since long effectuated in many countries, despite that invasive piglet husbandry procedures such as tail docking, teeth clipping and castration by themselves cause behavioural and physiological changes indicative of acute pain that potentially may cause long term negative consequences such as abscesses, lesions and formation of neuromas (13). Within EU, tail docking is forbidden by law unless judged as required (14). The possibility to dock tails when judged as needed has led to tail docking within the entire union (15, 16, 17, 18, 19, 20, 21, 22, 23, 24) except in countries where tail docking is prohibited by national laws like Finland and Sweden (11, 25). Tail docking has been defended by the fact that 1–3% of the pigs in non-docking countries are registered with tail injuries at slaughter (26). On the other hand, it can be concluded that the incidence of tail injuries in tail docking herds is 100%, and when viewing the problem from that aspect, tail docking appears not to be the solution to the problem (27). Thereto, tail docking does not eliminate tail biting lesions as 3.2–70% of the pigs show signs of tail biting also in tail docked populations (28, 29). Voices have therefore been raised that the pigs globally ought to be allowed to keep their tails, not the least for animal welfare reasons (30). In Sweden, several success factors for rearing pigs with intact tails has been identified such as, decreased stocking density, straw provision, high health status and increased weaning age (31). Indeed, a combination of providing straw and lower stocking density was equally effective in preventing tail biting as tail docking was under Danish conditions (32).

As indicated above, access to manipulable material such as straw reduces unwanted behaviours such as tail biting through enabling exploratory behaviour (9). Although the lack of straw has been identified as a main risk for the development of tail biting (15), tail biting is of multifactorial origin and the triggering factor is often difficult to specify (33, 34). There are different backgrounds to tail biting, covering everything from a single pig biting the rest of the pigs in a pen where the solution is to remove the deviating pig, to situations where more or less all pigs bites and are bitten (35) which may be associated with the composition of the feed (10, 36), competition (37) or ventilation errors (38). It has also been observed that especially young fatteners play with the tail of other pigs (39) and that tail biting may arise if bleeding accidently evolve due to the natural attraction pigs have to blood (40).
Regardless, the incidence of tail biting ought to be as low as possible and measures ought to be undertaken in herds with elevated incidences of tail biting. The present study scrutinised tail injuries in an integrated high health herd that reared non-tail-docked pigs for slaughter in a rearing system with improved animal welfare (Fig. 1). The fattening pens were twice the size of common Swedish fattening pens, but also housed about twice the number of pigs as a common pen. In these pens, fatteners had improved opportunities for exploratory behaviours and access to an outdoor space (41, 42). The weight gain of the growing pigs was high, but despite several attempts to optimise the feed with the aim to adapt the content of amino acids, trace elements, vitamins and fibres to the demands of the fast-growing pigs, the incidence of tail injuries registered at slaughter had increased over time. In the present study, tail injuries registered at slaughter (presumably tail biting) were scrutinised from the aspects of optimising the feed recipe even further, and at the same time investigate the impact of different illumination strategies and increased access to fibres through hay silage provision.

**Materials And Methods**

This study was carried out in a high-health farrow to finish herd with 230 sows employing an age segregated all in-all out-production system from birth to slaughter. Every 19th day, 25 sows gave birth to piglets in a previously washed and disinfected farrowing unit. The piglets were weaned and transferred to a previously washed and disinfected weaning unit at a mean age of 32 days.

At the age of 65 days, piglets with a mean weight of 26.3 kg were transferred to previously washed and disinfected units in one out of four identical buildings with fattening pens that were larger than common fattening pens (41, 42). The fattening pens were sized 19.6 m² and included a lying area, an eating area indoors (13.9 m²) and a dunging area located outdoors (5.7 m²) on a balcony (Fig. 1). Each pen initially housed 20 pigs, corresponding to 0.98 m² per pig. To harmonise with the animal welfare law of Sweden (43), the largest 1–2 pigs were slaughtered when the mean weight of the pigs reached 100 kg.

Within building, each unit with an individual mechanical ventilation system had two pens sized 19.6 m². Of these, 13.9 m² were located indoors and equipped with windows spaced 1.365 m², corresponding to 0.1 m² window area per m² of the indoor floor area, (Fig. 1). Due to the presence of windows and outdoor access, artificial illumination with fluorescent tubes was limited to care-taking time of the pigs, around two hours per day (prior to January 2021).

The pigs were offered a dry feed *ad lib* from totally four eating positions per pen. The pigs were also offered hay silage daily during the entire rearing period. In mean, pigs were slaughtered 105 days after arrival at a mean weight of around 130 kg, corresponding to a daily weight gain (DWG) of around 1000 g per day during the fattening period, which was calculated as follows: \[
\text{[slaughter weight } \times 1.34 \text{ (estimated live weight) } - 26.3 \text{ (estimated weight on arrival)}\] divided with 105 \text{ (estimated rearing period)}].

Due to the high DWG during the fattening period and the increasing incidence of tail injuries registered at slaughter, adjustments of the feed had taken place at several times, mainly focusing on trace elements.
and amino acids but also with increased levels of fibres with the aim to reduce the tail biting incidence. By September 2020, a new recipe of the premix was implemented (405651 Delta Mix P6209, Lantmännen, Malmö, Sweden), in which the levels of amino acids and trace elements were further increased. It was the third major optimising of the premix recipe since 2017. The premix was mixed with soy flour and Lipitec® piggy (NLM Vantinge A/S, Ringe, Denmark) and cereals produced on the farm (barley, wheat, oats, peas, rapeseed meal and Swedish fava beans (the minuta group of *Vicia faba*) into three different feeds with 12.74 MJ tradable energy per kg that was offered *ad lib* to all fatteners. The phase I (from 63 to 90 days of age), II (from 91 to 120 days of age) and III (from 121 days of age) feed included 18.0%, 17.4% and 14.3% protein, respectively.

**Study Design**

With the aim to validate the influence of length, quality and intensity of light, the four buildings for fatteners were allotted into four experimental groups. The following artificial illuminations were implemented from the 1st of January 2021:

**I** (Building 1): Standard artificial illumination with fluorescent tubes from 06.00 to 20.00; The invincible flickering in standard fluorescent tubes generally vary from 30 to 40% and they also may induce electromagnetic interference (EMI), especially at the interval from 104 to 1012 Hertz which may impair electric equipments and mammals negatively (44). The aim was to validate the impact of an extended illumination with standard fluorescent tubes.

**II** (Building 2): Artificial illumination free from invincible flickering (<0.3%) and not generating any EMI (Uni-light IP65T8B, Uni-light Led Ltd, Stockholm, Sweden) from 06.00 to 20.00. The aim was to extend the illumination to be long enough to decrease the melatonin production in the pigs during daytime and to create harmony in the pens (45).

**III** (Building 3): Control: Standard artificial illumination with fluorescent tubes during caretaking, approximately 2 x 1 hour per day. The aim was to create a control group with equivalent conditions as before the trial.

**IV** (Building 4): Standard artificial illumination as in the control group, i.e. two hours per day during caretaking. In this building, the pigs had access to increased amounts of hay silage initially offered in racks (Width 70 cm, Depth 28.5 cm Height 47 cm; PB 127, Siltbergs smide, Visby, Sweden) mounted on the walls with the lowest point 40 cm above the floor level. The aim was to validate the impact of increased amounts of fibres.

From the 1st of July 2021, Large (23 mm) and solid fodder pellets (406889 Time Out; Lantmännen) was offered on the floor to pens where the animal caretakers observed anxiety or signs of tail biting in most of the pigs. The pellets were a spin-off product to the premix initiated in September 2020 (405651 Delta Mix
P6209, Lantmännen) and included trace elements and fibres. The aim was to keep the pigs busy with the solid pellets and provide trace elements and thereby prevent tail biting and tail injuries.

**Assessments Made Before Initiating The Trial**

Before the trial was initiated, the overall monthly incidence of tail injuries registered at slaughter was analysed and compared with the daylength for a total period of eleven years. The daylength (sunrise to sunset) at the location of the herd was defined by the Swedish Meteorological and Hydrological Institute (SMHI, Norrköping, Sweden).

Further, the incidence of tail injuries registered at slaughter during the last four years before initiating the trial (2017–2020) was documented in detail per building, with the aim to create a background for the evaluation of the trial.

**Assessments Made During The Trial**

The adaption period, from 1st of January to the 30th of June 2021: During the first 105 days of this period, all pigs had not experienced the experimental conditions during the entire fattening period. Nor were 406889 Time Out-pellets in use during this period.

The true trial period was from July 1 in 2021 to June 30. During this period all pigs slaughtered had experienced the artificial illumination programs during the entire fattening period and 406889 Time Out-pellets were offered to all pens where anxiety or tail biting was observed on pen level.

During both periods, the number of pigs slaughtered and the number of pigs with tail injuries at slaughter was registered per building, and the incidence of tail injuries at slaughter per building was calculated.

Clinical observations were recorded in terms of number of individual fatteners treated with antimicrobials during the trial period, as well as the number of pens offered 406889 Time Out-pellets for 14 to 20 consecutive days when anxiety/tail-biting on pen level was observed.

The illuminance was quantified as LUX (1 numen per m$^2$), using a luxmeter (48882, Mini Light Meters 48882, UNI-Trend Technology, Songshan, China) at noon in all buildings following cleaning and disinfection.

The weight gain during the fattening period was calculated as described above; i.e. $[\text{slaughter weight} \times 1.34 \text{ (expected live weight)} – 26.3 \text{ (estimated weight on arrival)}] \text{divided with 105 (estimated rearing period)}$. In addition, five pens per building were also weighted repeatedly during the rearing and the daily weight gain was calculated from the weights registered.

**Statistics**
The incidence of tail injuries, as well as treatments due to tail biting are presented as total incidence, i.e. number of affected pigs divided with the number of pigs that were slaughtered, and therefore lack standard deviation. Incidences of tail injuries, individual treatments with antimicrobials and pen treatments with time out pellets in the groups were compared using χ²-tests.

When mean values were calculated, they are presented as mean values ± standard deviations. Differences in weight gains and meat percent of carcasses were analysed with student’s t-tests.

To investigate the effect of day length on tail injuries during the entire data set period of eleven years (2010–2020) prior to the study for the whole herd and for each building during the four years that preceded that trial (2017–2020), a fix effects general linear model was created with the percentage of tail biting per month as outcome and year, day length and stable (treatment) as fixed effects. The final model was created through backwards elimination.

To investigate the effect of day length on tail injuries during the trial period a fix effects model was created with the percentage of tail biting per month as outcome and day length and stable (treatment) as fixed effects. As the trial was performed for one year, year was not included in the model. In order to get the residuals normally distributed to fit the model, the data was log transformed.

When investigating the effect of day length, referred to as a generalised linear model test, least square means adjusted for multiple comparisons through Tukey-Kramer for multiple comparisons.

Results

Before initiating the trial

During the eleven years that preceded the trial (2010–2020), the mean incidence of tail injuries registered at slaughter was 7.7 ± 4.2%. The incidence of tail injuries was significantly (p < 0.0001, generalised linear model test, least square means comparisons) affected by year and also by day length in a negative way, i.e. the shorter days the higher incidence of tail injuries (Fig. 2 left). December with the shortest day length that had significantly higher incidences of tail injuries than each of the months from March to September (p < 0.05 to < 0.0001, generalised linear model test, least square means comparisons), while June with the longest day length had significantly lower incidences of tail injuries from each month from October to January (p < 0.05 to < 0.0001, generalised linear model test, least square means comparisons). When the months were compared individually by employing student t tests, December had repeatedly significantly higher incidences of tail injuries than each of the months from March to September (p < 0.05 to < 0.0001), whereas June had significantly lower incidences than each month from October to March and August (p < 0.05 to < 0.0001).

The figure to the right shows the correlation between day length (sunrise to sunset) and tail injuries registered at slaughter during the trial when the incidence of tail injuries had decreased significantly (p < 0.001, χ²-test). There was no significant (p > 0.05, generalised linear model test, least square means
comparisons) correlation to daylength. It should however be noted that the trial was carried out for one year and thereby included fewer observation points per month.

During the four years that preceded the trial (2017–2020), the overall incidence of tail injuries registered at slaughter was 9.2% (1,572 out of 17,037 pigs). However, as seen in Table 1, the incidence of tail injuries differed significantly (p < 0.05, χ²-test) between all buildings. According to the generalised linear model test, the percentage of tail biting was significantly affected by Year (p < 0.0001), Daylength (p = 0.0108) and Stable (p = 0.0134). In contrast, the meat percentage at slaughter and the weight gain (DWG) of the pigs during the fattening period was similar. The DWG ranged from 1015 to 1030 g per day. Still, the DWG of III was significantly (p < 0.05, t-test) higher than of IV.

Table 1
Tail injuries registered at slaughter and productivity in the four buildings preceding the trial calculated by a standard calculation (live weight at slaughter * 1.34–26.3) / 105

<table>
<thead>
<tr>
<th></th>
<th>I Light 14 h</th>
<th>II Led light 14 h</th>
<th>III Control</th>
<th>IV Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughtered</td>
<td>(n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With tail injury</td>
<td>(n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With tail injury</td>
<td>(%)</td>
<td>6.6 ABC</td>
<td>8.7 AD</td>
<td>9.9 BE</td>
</tr>
<tr>
<td>DWG (fattening period)</td>
<td>(g/ day)</td>
<td>1024 ± 90</td>
<td>1019 ± 74</td>
<td>1030 ± 145 F</td>
</tr>
<tr>
<td>Meat% at slaughter</td>
<td>(%)</td>
<td>58.6 ± 1.1</td>
<td>58.6 ± 1.3</td>
<td>58.7 ± 1.4</td>
</tr>
</tbody>
</table>

Within lines, columns with identical letters differ significantly [p < 0.05 (F); p < 0.01 (A and E); p < 0.001 (B, C and D)]

Light Intensity During The Adaption Period And During The Trial

When measured 1 m above floor in the middle of a pen, the light intensity corresponded to 310 LUX when the standard artificial illumination with fluorescent tubes were lightened (I), and to 180 LUX when the lights were off (III and IV, with exception for caretaking when standard artificial illumination with fluorescent tubes were lightened for two hours per day). When the non-flickering led tubes were lightened, the light intensity corresponded to 245 LUX (II). When measured outdoors, the light intensity in sunshine was 4,200 LUX.

The Adaption Period

During the adaption period (1st of January to 30th of June in 2021) the overall incidence of tail injuries decreased significantly (p < 0.05, χ²-test) from 9.2–5.4% (137 out of 2,556). As seen in Table 2, I had decreased tail injuries with 32%, from 6.6–4.5% (p < 0.05, χ²-test); II with 32%, from 8.7–5.9% (p < 0.05, χ²-
test); III with 32%, from 9.9–6.7% (p < 0.01, χ²-test), and IV with 64%, from 11.8–4.3% (p < 0.001, χ²-test). During this period there were no significant (p > 0.05, χ²-tests) differences in incidence of tail injuries registered at slaughter between buildings (Table 2).

<table>
<thead>
<tr>
<th></th>
<th>I Light 14 h</th>
<th>II Led light 14 h</th>
<th>III Control</th>
<th>IV Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughtered (n)</td>
<td>624</td>
<td>608</td>
<td>689</td>
<td>635</td>
</tr>
<tr>
<td>With tail injury (n)</td>
<td>28</td>
<td>36</td>
<td>46</td>
<td>27</td>
</tr>
<tr>
<td>With tail injury (%)</td>
<td>4.5</td>
<td>5.9</td>
<td>6.7</td>
<td>4.3</td>
</tr>
</tbody>
</table>

There were no significant differences between any groups (p > 0.05, χ²-test)

**The Trial**

During the experimental period of one year (1st of July 2021 to 30th of June 2022), the overall incidence of tail injuries registered at slaughter had decreased with 67%, from a mean of 9.2% to a mean of 3.0% when all buildings were merged (162 out of 5,345), which differed significantly (p < 0.001, χ²-test) from the four years preceding the trial (1,572 out of 17,037 pigs).

The incidence of tail injuries registered at slaughter were significantly (p < 0.001, χ²-test) lower within all buildings when compared with the period of four years that preceded the trial (Table 3). The decrease in tail injuries corresponded to 42%, 72%, 77% and 67% in I, II, III and IV, respectively (Table 1 and Table 3). As a consequence, the incidence of tail injuries during the trial was significantly (p < 0.05, χ²-test) higher in I than in II and III.

As also seen in Table 3, the DWG of 987 ± 63 gram per day in II was significantly (p < 0.05, t-test) higher than the 950 ± 92 gram per day assessed in IV when the standard formula for estimating the DWG was used. In contrast, the DWG was higher in I and IV than in II and III (p < 0.001, t-test) in the five litters that were weighted during rearing per group (Table 3).
Table 3
Tail injuries in the four experimental groups (buildings) registered at slaughter during the trial that was carried out for one year. The weight gain is showed following standard calculations (see material and methods) as well following weighting of five pens per building

<table>
<thead>
<tr>
<th></th>
<th>I Light 14 h</th>
<th>II Led light 14 h</th>
<th>III Control</th>
<th>IV Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughtered</td>
<td>1331</td>
<td>1295</td>
<td>1418</td>
<td>1301</td>
</tr>
<tr>
<td>With tail injury (n)</td>
<td>51</td>
<td>31</td>
<td>33</td>
<td>47</td>
</tr>
<tr>
<td>With tail injury (%)</td>
<td>3,8 A</td>
<td>2,4 B</td>
<td>2,3 B</td>
<td>3,9</td>
</tr>
</tbody>
</table>

Calculated weight gain

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II A</th>
<th>III B</th>
<th>IV B</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWG (fattening period) (g/day)</td>
<td>976 ± 89</td>
<td>987 ± 63 A</td>
<td>960 ± 89</td>
<td>950 ± 92 B</td>
</tr>
<tr>
<td>Meat% at slaughter (%)</td>
<td>58.1 ± 1.1</td>
<td>58.2 ± 1.3</td>
<td>58.4 ± 1.0</td>
<td>58.3 ± 0.8</td>
</tr>
</tbody>
</table>

Weighting of pigs

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II A</th>
<th>III B</th>
<th>IV B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pens (n)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of pigs (n)</td>
<td>83</td>
<td>80</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>First weighting (DPA)</td>
<td>26.0 ± 11.9</td>
<td>23.4 ± 3.7</td>
<td>22.6 ± 1.1</td>
<td>28.4 ± 7.2</td>
</tr>
<tr>
<td>Last weighting (DPA)</td>
<td>75.2 ± 6.8</td>
<td>79.6 ± 7.0</td>
<td>70.0 ± 5.8</td>
<td>78.8 ± 9.2</td>
</tr>
<tr>
<td>DWG (period) (g/day)</td>
<td>1023 ± 59</td>
<td>970 ± 51 2</td>
<td>975 ± 75 2</td>
<td>1028 ± 82 1</td>
</tr>
</tbody>
</table>

DPA = Day post arrival. Within lines, columns with different letters differ significantly (p < 0.05, \( \chi^2 \)-test/t tests); columns with different figures differ significantly (p < 0.001, t tests)

The relationship between daylight and tail injuries during the experimental period is shown in Fig. 2 (right). No significant (p > 0.05, generalised linear model test, least square means comparisons) effect of day length or stable (treatment) on tail injuries were found during the trial period.

As seen in Table 4, the merged incidence of individual treatments due to tail biting or assaults ranged from 1.1 to 2.0% and there were no significant (p > 0.05, \( \chi^2 \)-test) differences between the different buildings. The number of pens offered 406889 Time Out-pellets for up to 20 consecutive days was significantly (\( \chi^2 \)-test) lower in II than in the other buildings, (p < 0.05 compared to I and p < 0.001 compared to III and IV).
Table 4
Merged treatments of individual pigs with antibiotics due to abuse or due to tail biting in the four buildings during the trial. The table also shows the incidence for spread of time out-pellets to pens when anxiety/tail-biting on pen level was observed.

<table>
<thead>
<tr>
<th></th>
<th>I Light 14 h</th>
<th>II Led light 14 h</th>
<th>III Control</th>
<th>IV Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigs slaughtered (n)</td>
<td>1331</td>
<td>1295</td>
<td>1418</td>
<td>1301</td>
</tr>
<tr>
<td>Individually treated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tail bitten or assaulted (n)</td>
<td>27</td>
<td>22</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>Tail bitten or assaulted (%)</td>
<td>2.0</td>
<td>1.7</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Pens used (n)</td>
<td>67</td>
<td>65</td>
<td>71</td>
<td>66</td>
</tr>
<tr>
<td>Pens given time out</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated; time out) (n)</td>
<td>10</td>
<td>2</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Treated; time out) (%)</td>
<td>14.9 A</td>
<td>3.1 B</td>
<td>23.9 A</td>
<td>24.2 A</td>
</tr>
</tbody>
</table>

Within lines, columns with different letters differ significantly ($\chi^2$-tests; $p < 0.05$ II vs I; $p < 0.001$ II vs III and IV)

Discussion

Despite larger fattening pens with outdoor access and a potentially increased welfare, a high daily weight gain and a low use of antimicrobials (41, 42), the increasing occurrences of tail injuries registered at slaughter had been frustrating. Therefore, it was an exemption that the incidence of tail injuries was successfully decreased to the national mean level in all four buildings during the trial, which will be discussed below.

As the incidence of tail injuries before initiating the trial clearly was correlated to daylight (Fig. 2, left) it was important to set up the trial for a full year to avoid bias by any seasonal effects. Also, we had to consider the fact that the multi-unit buildings were populated with different ages of fatteners when the different illumination strategies were implemented by the 1st of January in 2021. As the mean rearing time in the fattening facilities was 105 days, and as the use of 406889 Time Out-pellets that was judged to have an instant effect was initiated by the 1st of July in 2021, it was natural to use the first six months of 2021 as an adaption period that also comprised the full variation in daylength over the year.

Thereafter the trial period of one full year followed (from the 1st of July 2021 to the last of June 2022). During the trial, tail injuries were not significantly correlated to the day-length, but the trend was similar as before the trial although at a significantly lower level (Fig. 2, right). Thus, the non-correlation to daylength during the trial could have been an effect of lower incidences of tail bitten pigs and to fewer observation points.
Also, the incidence of tail injuries differed between the identical buildings before the trial was initiated. As the standard operative protocols regarding care taking were equal for all buildings, the differences in tail injuries could not be explained with differences in animal husbandry. It was also notable that the incidences of tail injuries increased with proximity to the open fields, which indicated an influence from wind and weather. However, as the incidence of tail injuries decreased to approximately the same level in all buildings during the trial it appeared not to be so, at least not when feeding conditions were optimised. Therefore, we have no exact explanation to the differences between buildings before the trial. Misbehaviour may benefit from non-optimised feed that in turn may have been strengthened by an increased exposure to wind and weather, but we could not prove that.

The incidence of tail injuries was significantly reduced in all buildings (regardless of treatment) already during the adaption period. Especially in IV with access to more fibres in terms of hay silage than the other three buildings. In IV, the incidence of tail injuries was decreased with 64% already during the adaption period, which emphasised the importance of sufficient amounts of manipulating material. However, especially young fatteners had difficulties to benefit from the racks with hay silage situated on the pen wall 40 cm above floor level. As difficulties for young fatteners to capitalise fibres available from above also have been observed earlier (46) extra hay silage was therefore also offered on the floor. The true impact of racks located over the head of young fatteners ought consequently not be overestimated, but of course their efficacy may be increased by incusing piglets to stimuli above floor level through a more stimulating environment and improved spatial ability as shown in for example chicken and mice (47, 48). Still, the results obtained clearly demonstrated the potential of expanded amounts of manipulative materials such as fibres to keep pigs occupied, as also previously have been shown by others (49, 34, 12). However, allocation of manipulative materials must not interfere with the manure handling systems (49) and must also represent a novelty to the pigs as they only will occupy themselves with manipulative materials as long as they consider them as interesting (39, 41, 42). Therefore, minor amounts of manipulative materials allocated at shorter time intervals may be desirable, both from a pig and from a manure-handling point of view.

The incidence of tail injuries continued to significantly decrease during the trial in I, II and III, whereas IV with a larger decrease already during the adaption period remained at the incidence level of the adaption period. Thus, the overall incidence of tail injuries was reduced with 67%, and the overall incidence corresponded to 3.0% which in turn corresponded to the national mean of 3.2% tail injuries registered at slaughter 2018 (26). However, tail biting is known to frequently appear as concentrated outbreaks (10, 35). To visualise the effect of such outbreaks, the three consignments to slaughter with the highest incidences of tail injuries per building was withdrawn from the statistics, which decreased the incidence of tail injuries even further - down to an overall incidence of 2.3% (Fig. 3).

As the incidence of tail injuries was reduced in all buildings, including III which remained as a control that implemented an identical illumination strategy as before the trial, the influence of illumination should not be overestimated. As deficient levels of trace elements, protein and amino acids risk to induce tail biting (36), it appeared likely that the feed recipe after a large number of upgrades finally corresponded to the
demand of the fast-growing fatteners. The failure of attaining this state earlier may appear odd, but it should be remembered that pig feed generally is adapted to the mean productivity of the population where it is produced with the aim to reduce costs. Consequently, fast-growing pigs risk to attain deficient levels of trace elements and amino acids (36). However, adding trace elements and amino acids to feed is a costly process and optimising feed will therefore be effectuated in small steps. This may in turn delay accomplishment of an optimal feed recipe, as in this case.

Concluding a probable leading impact of the feed itself, the relevance of the other parameters of the trial may at a first sight appear less valuable. However, it should not be forgotten that the incidence of tail injuries decreased earlier in IV that was offered higher amounts of fibres in terms of hay silage than in the other buildings, which emphasised the impact of enough level of manipulative material. It has been found that around 400 g straw per pig and day seem to fulfil the pigs exploratory needs while increasing the straw ratio further does not reduce tail biting further (50). However, such large rations are in principle never offered to pigs. The average amount of straw per finishing pig in Sweden has been estimated to about 50 g per pig and day (49). Allocation of straw has often been kept to a minimum out of fear for errors in the manure handling systems, but at least systems with partly slatted floors and mechanical removal of the manure below the slatted floor obviously can tolerate higher amounts of straw than generally assumed. It is for instant notable that none of out of five herds that doubled the amount straw given experienced manure handling problems (31). Thereto, problems in the manure handling system due to straw occurred very seldom when questioning Swedish pig farmers (49). Nor were any problems with the manure observed in this herd that used fibres in terms of hay silage, which apart from including proteins also is tastier than straw and therefore probably more attractive to the pigs (51, 52, 53). From this perspective, it must be remembered that straw and other manipulative materials mainly are aimed to employ pigs and are not primarily to be seen as bedding material.

Nor should the illumination be neglected. The correlation to day-length observed before the trial clearly showed an effect of the daylight (Fig. 2 left). However, as the decrease of tail injuries was lower in I with long time exposure (14 h/day) to light with an expected invisible flickering of 30–40% than in the other buildings, also the quality of the light appeared important (Table 3). During the trial, the incidence of tail injuries was significantly lower in II with an equally long light exposure (14 h/day) to non-flickering light, which indicated an impact also of the quality of the light as also have been concluded by others (54, 55). Nor is sunlight, which was the main illumination in III and IV, flickering.

Sunlight decreases serum levels of melatonin, and it has also been proven that blue led-light with a wavelength of 446 to 477 nm induce plasma melatonin suppression in humans (56). The production of melatonin that induce fatigue is stimulated by darkness, and exposure to blue light ought therefore not exceed 14 h per day due the risk for insomnia induced by a lack of melatonin. However, properly managed illumination that suppress plasma melatonin in daytime accomplished by proper melatonin production during night theoretically induce tranquillity and relevant sleeping habits. Melatonin has for instance been proven effective in treating chronic insomnia in children with ADHD, although it appeared to have minimal effect on core ADHD symptoms (45). Seen from this perspective, the lower treatment
incidences at pen level due to anxious pigs and tail biting in II was interesting as it indicated an increased tranquillity in II compared to the other groups. Also, the DWG was highest in II during the trial when the standard method of calculating DWG from the market weight of the pigs was employed, which may have indicated not only tranquillity but also an increased productivity due to non-flickering light and to optimised serum levels of melatonin over day and night. Indeed, a proper use of melatonin decreasing light has been correlated to an increased milk production during the early lactation period of cows, but not over time (57) as also strengthened by the fact that melatonin treatment of dairy cattle around drying-off was ineffectual (58). Bearing these contrasting results in mind, it was interesting to observe a similar opposite relationship regarding weight gain in this study. When pigs during the trial were weighted at the interval between 22 and 80 days after arrival to the fattening enterprises, the DWG of IV was higher than in II. Further, the treatment incidence of individual pigs due to tail biting or due to aggressions were not lower in II than in the other buildings. Thus, further studies are needed to evaluate the true impact of melatonin decreasing light on tranquillity and productivity in pigs.

**Conclusions**

The incidence of tail biting in fast growing non-tail-docked pigs was successfully reduced by supplementation of the feed with amino acids, trace elements, vitamins and fibres. Additional manipulative material in terms of hay silage accelerated that process and non-flickering illumination may have an impact in preventing tail biting.

The results obtained argue for the un-necessity of tail docking pigs.

**Abbreviations**

DWG
daily weight gain
DPA
Day post arrival
g
gram

**Declarations**

**Author contribution**

SEJ, MJ and PW designed the study and also discussed feed ingredients with ZS and KS at Lantmännen. TW contributed with statistical expertise. PW was the main author of the manuscript, but all authors (MJ, TW, ZS, KS and SEJ) have read and contributed to the manuscript. They have also all approved the final version of the manuscript.

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**Availability of data materials**

Not applicable

The authors declare that they have no conflicting interests.

**Ethics approval and consent to participate**

This study was approved by an ethical permission from the Swedish Board of Agriculture, processed by the committee for ethics in Uppsala in Sweden (Dnr 5.8.18-06256/2019) entitled Scientific investigations effectuated following ordinary disease investigations in animals.

**Consent for publication**

The authors declare that the herd owners, whom also were co-authors, gave a consent for publishing the data.

**Competing interests**

The authors declare no competing interests.

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Figures
Figure 1

The four buildings for fatteners were located in a slope to the fields 15 meters apart from each other with the aim to reduce transfer of microbes between the buildings. To improve the biosecurity, an entrance for staff with possibilities to change shoes and wash hands that also stored hay silage was built on the gable to the left of each building and a space for delivering market weight pigs to slaughter was built on the gable to the right of each building (top left). Pigs had access to an outdoor area that also was used for dunging (top right). Each unit with two pens that housed 20 pigs had ventilation and manure systems that were separated from the other units. Each pen had two automatic feeders where four pigs could eat simultaneously and the door under the windows lead to the outdoor facility (bottom left). The mechanical ventilation was regulated through the windows by a bimetallic opener (bottom right). Photos by PerArne Mattsson.
The figure to the left shows the correlation between day length (sunrise to sunset) and tail injuries registered at slaughter during a period of eleven years (2010-2020) that preceded the trial. There was a negative correlation ($p<0.0001$, generalised linear model test, least square means comparisons) between daylength and tail injuries.

**Figure 2**

The figure to the left shows the correlation between day length (sunrise to sunset) and tail injuries registered at slaughter during a period of eleven years (2010-2020) that preceded the trial. There was a negative correlation ($p<0.0001$, generalised linear model test, least square means comparisons) between daylength and tail injuries.
Figure 3

Incidences of tail injuries in the four buildings merged and in the individual buildings over time (2017-2020; the adaption period; and the trial period). The figure shows the exact incidences, i.e. number of pigs with tail injuries divided with the total number of pigs slaughtered for each period. However, tail biting often arises as concentrated outbreaks. To visualise the effects of that, also the incidences when the three batches with the highest incidences of tail biting have been withdrawn is shown (Trial special).