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Enrichment use in finishing pigs and its relationship with damaging behaviours: Comparing three wood species and a rubber floor toy

Jen-Yun Chou[a,b,c,*], Rick B. D'Eath[b], Dale A. Sandercock[b], Keelin O'Driscoll[a]

[a] Teagasc, Pig Development Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland
[b] Scotland's Rural College (SRUC), Animal & Veterinary Sciences Research Group, Roslin Institute Building, Easter Bush, EH25 9RG, Midlothian, UK
[c] University of Edinburgh, Royal (Dick) School of Veterinary Studies, Easter Bush, EH25 9RG, Midlothian, UK

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ABSTRACT

Environmental enrichment in pig housing is a legal requirement under current EU legislation, but some recommended loose materials may cause obstructions in fully-slatted systems. Wood is an organic material that could be compatible with slatted systems. This study investigated enrichment use in finishing pigs (three wood species and a rubber floor toy) and explored the relationship between use and damaging behaviours, and physiological and physical measures of stress and injury. Individual variation in enrichment use within pen was also investigated. Pigs (12 weeks old; week 0) were housed in 40 pens of seven pigs (n = 280). One of four different enrichment items (one spruce, larch, or beech wooden post, or rubber floor toy) was randomly assigned to each pen (10 pens/treatment). The behaviour of each individually marked pig was observed continuously from video recordings taken on six different occasions (twice during week 2, 4 and 7; 1 h per occasion). Individual tail/ear lesion and tear staining scores were recorded every 2 weeks. Saliva samples for cortisol analysis were obtained from three focal pigs per pen every 2 weeks. These focal pigs were selected based on the latency to approach the experimenter on the first sampling day and classified as 'Approach', 'Neutral' or 'Avoid'. Carcasses were inspected for tail lesions and potential oral damage. Time spent using enrichment was higher in pigs with spruce and rubber toy than with larch and beech ($P < 0.001$). Spruce was used up the most quickly and was the softest of the wood species ($P < 0.001$). High use of spruce was not due to consistent high use by certain pigs. No treatment effect on any other behaviour was recorded, but enrichment use was positively correlated with damaging behaviours at pen level ($P < 0.001$). Spruce pigs had slightly more severe tail lesion scores than Beech ($P < 0.05$). Salivary cortisol did not differ between treatments but was higher in 'Avoid' than 'Approach' pigs ($P = 0.04$). No clear oral damage that could be attributed to using wood was found. By investigating enrichment use at both pen and individual level, a more complete picture was obtained of how pigs used the enrichment. Wood appears to be a safe material to use as environmental enrichment for pigs and a softer wood species was preferred by pigs with equal preference for the rubber floor toy.

1. Introduction

In the EU it is mandatory to provide pigs with suitable materials to explore and manipulate, regardless of the housing system (European Commission, 2009). However, on fully-slatted floors the choice of environmental enrichment is limited, since loose materials can be wasted as they fall through the slats quickly, or may block the slats or potentially disrupt the slurry removal system beneath, which depends on an unobstructed flow of drainage of liquid manure. A survey of expert opinion suggested that suitable enrichment for pigs should provide occupation and allow exploration, and the materials used should be rootable, manipulable, and chewable (Bracke, 2006), which agrees with the latest recommendations by the European Commission (European Commission, 2016a). Wood is an organic option that could potentially satisfy these criteria, depending on the characteristics and presentation of the wood (Barbari et al., 2017). It is acceptable to producers in Ireland due to its convenience and durability, which means it is economically advantageous (Haigh and O'Driscoll, 2016). However, concerns were also raised as to whether dried wood could cause splinters and become unsafe for pig to use (European Commission, 2016b), which requires further investigation.

Recently wood has gained increasing attention in research as a point-source enrichment material for pigs, especially in relation to damaging behaviours such as tail biting. Previously, we have found that

* Corresponding author at: University of Edinburgh, Royal (Dick) School of Veterinary Studies, Easter Bush, EH25 9RG, Midlothian, UK
E-mail address: jenyun.chou@ed.ac.uk (J.-Y. Chou).

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softer wood species used as enrichment material generated higher levels of interaction, and a higher rate of wear than harder species did, from docked finishing pigs (Chou et al., 2018). At the same time, however, tail lesion scores and damaging behaviours were similar across treatments. Telkänranta et al. (2014) reported that undocked finishing pigs interacted more with fresh branches of birch (*Betula pendula* and *Betula pubescens*) compared to chains, and wood also reduced the prevalence of tail injuries, albeit with no difference in tail biting behaviour. However, Nannoni et al. (2018) compared undocked finisher pigs given three poplar (*Populus*) wood posts to those given a steel chain, and they found less interaction with the enrichment, no difference in tail biting behaviour, and higher tail lesion scores in pigs given wood. In that study, the wood was provided horizontally in an elevated rack. A more recent study showed poplar logs were more effective than hanging chains in attracting interaction from finishing pigs, but only reduced tail biting when suspended by chains but not when presented loose on the floor (Giuliotti et al., 2019). However, the authors did not specify if the pigs they used were docked or undocked.

Enrichment use is affected by the presentation and location of the device. Rooting with snout movement is an important behavioural repertoire for pigs and enrichment provided should allow this rooting behaviour (Studnitz et al., 2007). However, the drawback is that floor items can be soiled easily. Giuliotti et al. (2019) found that providing a piece of wood directly on the floor decreased pigs' interest compared to hanging due to excessive soiling. In order to balance between fulfilling the pigs' need to root and preventing the enrichment item from getting dirty, this study provided wood in a fixed dispenser which allowed the wooden posts to drop down on the floor (Fig. 1). This enabled pigs to root the wood but at the same time maintain its cleanliness. In addition, a commercially available inorganic rubber floor toy was provided directly on the floor as its design prevents it from soiling. A study found similar levels of interaction between a hanging rubber chew toy in the centre of the pen and a pine post presented vertically through a plastic dispenser attached to the fence (Horback et al., 2016). The current study can further compare the level of interaction when organic and inorganic items both facilitate rooting behaviour from pigs.

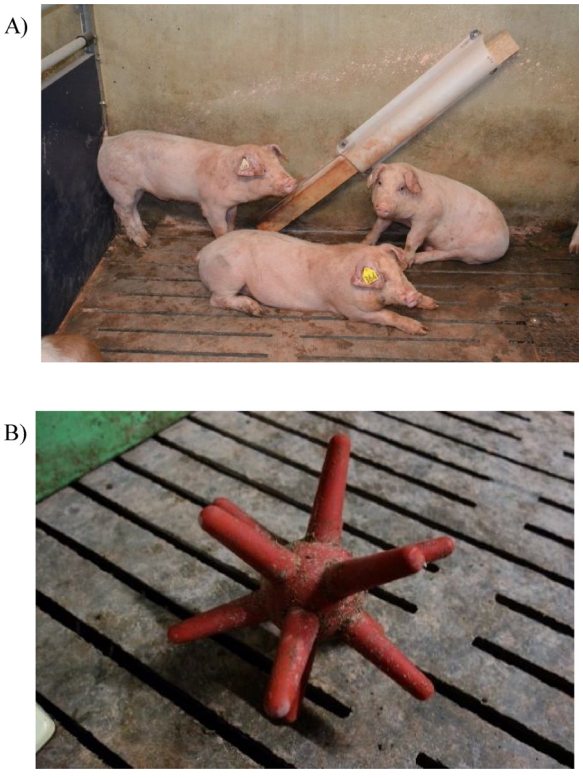

Fig. 1. Picture of A) Wood dispenser as located in the pen and B) Rubber floor toy.

Salivary cortisol is a non-invasive and efficient method to assess the stress response in animals, and can be used as a basic physiological measure to supplement behavioural observation and physical scores (Casal et al., 2016; Merlot et al., 2012; Scollo et al., 2014; Smulders et al., 2006). Some studies have found enriched housing increased salivary cortisol concentration in pigs (de Groot et al., 2000; de Jong et al., 2000, 1998; Morrison et al., 2007). However, factors such as activity level, rearing background and social competition can also influence salivary cortisol concentration (Casal et al., 2016; Merlot et al., 2012). It is not certain if point-source enrichment items would affect cortisol concentration, or if organic and inorganic item would differ in this regard.

Most of the enrichment studies mentioned above used group level comparisons of enrichment use, as is the case in the majority of enrichment studies. More recently, Larsen et al. (2019) used behaviour observation at different levels (pen *vs* focal animal) and with various sampling methods (continuous, one-zero and instantaneous) to investigate in more detail the length of an interaction bout, and the proportion of individuals within a pen that interacted with the enrichment. Indeed, there has been growing interest in how individual differences in farm animals can affect their behaviour and welfare (Finkemeier et al., 2018). Although recent research has investigated how environmental enrichment can affect farm animals' emotional state (Boissy and Erhard, 2014), how their individuality may influence their enrichment use is less discussed.

This study investigated enrichment interaction in tail-docked finishing pigs provided with one point-source enrichment item per pen. It builds upon a previous study, which was the first to report differences in use in terms of wood species when provided to finishing pigs as enrichment on a commercial farm (Chou et al., 2018). In the current study, three wood species and an inorganic rubber floor toy were compared, with regard to performance of damaging behaviours, and selected physical outcomes. As a secondary aim, this study further explored the within-pen variation in pigs' interaction with the enrichment.

2. Materials and methods

The experiment was conducted at the Pig Research Facility in Teagasc, Moorepark, Ireland and approved by the Teagasc Animal Ethics Committee (TAEC110/2016).

2.1. Animals and housing

A total of 280 finisher pigs (Maxgrow × Landrace × Large White, Hermitage Genetics, Ireland) arrived at the research farm over two batches, with the second batch arriving two weeks after the first batch was sent for slaughter. All pigs arrived at 12 weeks of age. Pigs had been tail-docked and teeth-clipped at the breeding farm and male pigs were not castrated. On arrival at the research facility, pigs were individually tagged, weighed and their tails checked for lesions and blood. The experiment lasted for 10 weeks, after which time the pigs were sent to the slaughterhouse for post-mortem carcass inspection.

The finisher pens measured 2.37 × 2.36 m and had a fully-slatted floor, except for a 1.21 × 0.77 m area around the feeding trough (1.00 m L × 0.32 m W × 0.21 m H) which was covered by a rubber mat to prevent food waste. The temperature was maintained at around 20 °C by passive ventilation with three main inlets on the ceiling and smaller inlets along the wall, and the room was artificially lit at around 130 lx for 12/24 h. Pigs were fed a standard liquid diet *ad-libitum* by sensor feeding (9.56 MJ/kg net energy, 15.97 % protein and 4.26 % crude fibre). A nipple drinker was located near the trough at 0.3 m above ground to provide *ad libitum* access to fresh water.

Table 1
Ethogram for video observation. All behaviours were recorded continuously as duration of time and frequency.

Behaviours	Description
Tail biting	Performing tail in the mouth behaviour on another pig: ranges from tail being gently manipulated to tail being chewed/bitten (Distinguished between performing while standing up or sitting/lying down)
Ear biting	Performing ear in the mouth behaviour on another pig: ranges from ear being gently manipulated to being chewed/bitten (Distinguished between performing while standing up or sitting/lying down)
Play	Individual play behaviour, including scampering, jumping/running around
Enrichment use	Any forms of oral/nasal manipulation on the enrichment (for the wood posts, only the wood itself was included, not the dispenser)
Aggression over enrichment	Hostile encounter for the access of enrichment including aggressive biting, head knocking and parallel pressing

2.2. Experimental treatments

After pigs were weighed individually, they were assigned to blocks on the basis of sex and weight (10 blocks of 4 pens: 4 blocks in batch 1 and 6 blocks in batch 2); each pen housing 7 pigs. Within a block, the differences between body weights and pen locations were kept at minimum between pens (Supplementary I). There were 7 pigs per pen, so half of the pens had 4 males and 3 females, and the other half had 4 females and 3 males. Pigs whose tails had inflammation, infection or fresh blood recorded on arrival were not used. The average starting weight was 35.82 ± 0.16 kg for batch 1 and 31.91 ± 0.34 kg for batch 2.

Within a block of 4 pens, each pen was randomly assigned to one of 4 different treatments (10 pens per treatment) based on the enrichment item in the pen: one rubber floor toy (Easyfix, Ballinasloe, Ireland, average starting weight 2.18 kg), one spruce (*Picea sitchensis*) wooden post (average starting length 1.097 m, weight 1.366 kg, perimeter 0.231 m), one larch (*Larix decidua*) post (average starting length 1.216 m, weight 3.167 kg, perimeter 0.267 m), or one beech (*Fagus sylvatica*) post (average starting length 1.214 m, weight 2.858 kg, perimeter 0.237 m). All wooden posts were cuboid in shape. The enrichment to pig ratio was 1:7 in all pens.

All wooden posts were standardised and sourced from a local sawmill (Glennon Bros. Cork Ltd., Fermoy, Ireland) and were kiln dried but not treated with any chemicals. The posts were dispensed in the pens using a 0.65 m L × 0.18 m W × 0.11 m D white plastic Funbar wood holder (Jetwash Ltd., Carrigallen, Ireland), mounted on the wall at around a 45° diagonal angle (top-right to bottom left), with the bottom of the holder at 0.25 m above ground (Fig. 1A). The position of the wood dispenser was based on a previous pilot study suggesting that pigs used wood more when it was provided in a diagonally installed dispenser than when presented vertically. The wood posts were placed into the dispenser and the base touched the floor. The pigs were able to access ~0.35 m of wood below the holder and ~0.21 m above, although they primarily made use of the lower part. The rubber floor toy was made of soft rubber (food grade natural rubber compound) with a spiked shape (in the form of a sphere in the middle with a diameter of 0.12 m, and 12 arms each with a length of 0.12 m, Fig. 1B) and placed on the floor in the pen. The toy was movable and the pigs could pick it up and carry it in their mouth by the spiked arms. All items were chewable and rootable.

2.3. Enrichment measurements

Before each wood post was provided, the following measurements were taken: 1) Length (m), 2) Weight (kg), 3) Perimeter (m), taken at 0 m, 0.1 m, 0.2 m, and 0.4 m from the bottom of the post), 4) Hardness (shore D scale, measured by a durometer AD-300, Checkline Europe, Enschede, the Netherlands), taken at three randomly selected spots at 0 m, 0.1 m, 0.2 m, 0.4 m, and 0.6 m from the base of the post (15 readings/post), 5) Moisture level (%, using Hydromette BL-H-40, Gann, Germany), taken at 0 m, 0.1 m, 0.2 m, 0.4 m, and 0.6 m from the base of the post. Subsequently all measurements were taken every week. Whenever a wood post was shortened to the extent that it could no longer stay in the dispenser and slid on the ground, a new post was measured and replaced the old one. The weight of the remains was also recorded. The rubber floor toys were weighed before the start of the trial and again at the end.

2.4. Animal-based measures

2.4.1. Behaviour recordings

In experimental week 2, 4 and 7, the pens were continuously video-recorded (QVIS HDAP400 CCTV cameras and a Pioneer-16 digital recorder case, CCTV Ireland, Kildare, Ireland) for 24 h/day on 3 consecutive days. Due to the layout of the house, only half of the pens (2 blocks of pens in batch 1 and 3 blocks in batch 2, detailed blocking plan see Supplementary I) could be covered at one time. After the first half of the pens were recorded, the cameras were then switched to video record the other half of the pens over a 24 -h period for another 3 consecutive days. Before recording commenced, each pig in a pen was marked with a distinct colour on their back by animal marker sprays (Coyle Vet, Galway, Ireland) for individual identification, and the colour was reapplied whenever necessary. This was the case except for batch 1 in week 2, where no individual markings were made due to technical issues and therefore only pen-level data were available for analysis.

In order to identify when most activities occurred, six randomly selected 24 -h video clips were scanned every 3 min by counting the number of pigs standing up and lying down. The hour of day when the most pigs were standing up was from 12:00 h to 13:00 h, and therefore this time was selected for subsequent behaviour sampling. All pens were observed continuously during this period on two different days during each of the recording weeks (6 h of recording/pen in total), using the ethogram in Table 1. The video observations were completed using the Observer XT (Ver. 14, Noldus, Wageningen, the Netherlands), with the duration and frequency of all behaviours recorded at the pig level when individual identification was available.

2.4.2. Saliva sampling

In week 2, 4, 6, 8, and 10, saliva samples were collected on the same day between 1000–1200 h from 3 focal pigs in each pen. A stratified randomisation method was used to select the focal pigs based on the latency to approach the experimenter when collecting the first sample in order to obtain a good representation of the pigs within a pen. One pig which approached the experimenter voluntarily (“Approach”), one pig which stayed at the back of the pen showing avoidance (“Avoid”), and one pig in between the two (“Neutral”) were selected for the subsequent saliva samplings. All samples were taken using a biocompatible synthetic swab (Salivette, Sarstedt, Wexford, Ireland) presented on tweezers for the pigs to chew on. The salivary samples taken (approximately 0.5 ml) were preserved in the swab storage tubes (Salivette, Sarstedt, Wexford, Ireland) and were then centrifuged at 1,500 rpm and frozen at -20 °C. The samples were later analysed using ELISA (Enzyme-linked immunosorbent assay, Salimetrics, Carlsbad, CA, USA; 96-well plate with assay sensitivity of 0.007 μg/dL and assay range between 0.012–3.000 μg/dL) to determine the cortisol concentration in the saliva. The inter-assay CV based on the control

samples was 3.0 % and the intra-assay CV was 16.6 %.

2.4.3. Physical scores

Pigs were scored individually every two weeks for the following measures: Tail lesions were recorded using two different systems: the scoring system adapted from Hunter et al. (1999) (0: no damage, 1: mild, 2: moderate, 3: severe) and the system developed by the Fare-WellDock consortium, which consisted of separate scores for damage (0: no lesion, 1: bite marks, 2: open wound, 3: swollen bite wounds) and presence of blood (0: no blood, 1: black scar, 2: older red blood, 3: fresh blood) (Chou et al., 2019b). Ear lesions were recorded on a 0–4 scale (0: no lesion, 1: superficial scratches, 2: evidence of recent bleeding, 3: substantial cuts and bleeding, 4: part of ear amputated; modified from Telkänranta et al., 2014). Tear staining was evaluated with the DeBoer-Marchant-Forde Scale (0: no visible stains, 1: barely detectable stains not extending below eyelid, 2: visible stain about < 50 % in ratio to the eye, 3: visible stain about 50–100 % in ratio to the eyes, 4: visible stain > 100 % in ratio to the eye but not extending below the mouth line, 5: visible stain extending below the mouth line; DeBoer et al., 2015). Left and right eyes were scored separately.

2.4.4. Carcass data

All pigs were tattooed with individual identification before being sent for slaughter. In the slaughterhouse, tail lesions visible on the carcass were recorded (0–4 scale, 0: no lesion, 1: healed/mild lesions, 2: evidence of chewing and puncture wounds, 3: signs of swelling and infection, 4: partial/total loss of tail; Harley et al., 2012). In addition, the inside of the mouth was examined for the presence or absence of possible damage to the gums and tongues caused by oral manipulation of wood.

2.5. Data analysis

Data were analysed using Statistical Analyses System (SAS, version 9.1.3, 1989, SAS Institute Inc., Cary, NC, USA). Linear mixed models (PROC MIXED) were used to analyse continuous data such as wood measures, duration of behaviour and salivary cortisol. Differences between least square means were investigated using the t-test, followed by the Tukey-Kramer adjustment for multiple comparisons. Residuals were checked for normality and the data were transformed using logarithms where necessary.

For analyses of wood measures, treatment, week, batch and the interaction between week and treatment were included as fixed effects, week as a repeated effect and block within batch as a random effect. As moisture and hardness measures were taken at different positions on the wooden posts, position was also included as a fixed effect. The perimeter was analysed as the variation of the values between measures at different positions on the wooden posts, so the position was included as a fixed effect as well.

Data from behaviour observations on the two different days within an observation week were averaged. In order to include the data for batch 1 in week 2 (when individual pig identification was not available), behaviour data were analysed at both pen-level and individual level; the pen-level data were mainly used to compare differences between treatments, whereas the individual-level data were used to explore the within-pen variation. For pen-level analyses, the response variable was the duration of a behaviour per hour per pig. Fixed effects included treatment, week, batch, and the interaction between week and treatment. Week was considered a repeated effect and block within batch as a random effect. The relationship between enrichment interaction and damaging behaviours (tail biting, ear biting and the two combined) were examined using Pearson's correlation, using the log-transformed data of pen-level average duration on each observation day.

For individual-level analyses, the duration of each behaviour per hour for each pig was the response variable. Treatment, week, batch, sex and the interaction between week and treatment were included as fixed effects, week a repeated effect and block within batch as a random effect. To further compare the differences between types ("Approach", "Neutral" or "Avoid") of focal pigs, their data was analysed separately by adding the "type" as a fixed effect. Kendall's coefficient of concordance was calculated for individual pigs in each treatment to test the level of agreement in each pig's enrichment use between recording occasions. For enrichment interactions, the bout length and the proportion of pigs per pen that interacted with the enrichment was also calculated and analysed similarly to the total duration of interaction during the recording period.

Salivary cortisol was right-skewed due to 4 extremely high outliers, but the residuals were normally distributed following removal of these outliers. Treatment, week, batch, sex, and the type of pig were used as fixed effects, week was a repeated effect, and block within batch, and the plate on which the ELISA was performed, as random effects.

Physical scores were analysed using generalised linear mixed models (PROC GLIMMIX), with a Poisson distribution and a log link function. Treatment, week and batch were included as fixed effects, week as a repeated effect and block within batch as a random effect. When analysing tear staining scores, the eye (left or right) from which the score was taken was also included as a fixed effect. The damage recorded on the tongue and gum of the carcass was processed as binary data and analysed using GLIMMIX with a binary distribution and a logit link function for comparison between all treatments, and Chi-square to compare between pigs with wood and a rubber toy.

3. Results

3.1. Enrichment measurement

There was an effect of wood species on the deterioration of the wooden posts. The reduction in length and weight was greater in Spruce than Larch and Beech (Table 2), as was the variation in perimeter at the same position higher in Spruce than Larch and Beech (Table 2). No post was replaced in Larch and Beech pens, but only 2 out of 10 Spruce pens did not have posts replaced (average length of spruce post upon replacement was 84.62 ± 2.79 cm, and the average frequency of replacement for these posts was 5.53 ± 0.45 d). Spruce also had the highest moisture content and was the softest of the three wood species

Table 2
Measurements taken on the wood species used in the study. Data are presented as least squares means ± SEM for moisture and hardness. Length and weight reduction and perimeter variation since the preceding measurement were log-transformed for analysis, and with the raw LSMeans indicated in the brackets. Different letters indicate significant differences after Tukey-Kramer adjustment.

	Wood species			*F*-value	*P*-value
	Spruce	Larch	Beech		
Length reduction (mm/day)	1.09 ± 0.05 (3.53)[a]	0.59 ± 0.04 (-0.08)[b]	0.60 ± 0.04 (-0.07)[b]	33.3	< 0.001
Weight reduction (g/day)	3.57 ± 0.06 (22.05)[a]	3.15 ± 0.08 (3.91)[b]	3.03 ± 0.08 (1.10)[b]	16.83	< 0.001
Perimeter variation (mm)	2.79 ± 0.10 (30.36)[a]	1.38 ± 0.12 (4.97)[b]	1.09 ± 0.12 (3.39)[b]	74.44	< 0.001
Moisture (%)	31.36 ± 0.89[a]	26.40 ± 1.02[b]	26.79 ± 1.02[b]	8.74	< 0.01
Hardness (Shore D scale)	27.92 ± 0.70[a]	41.85 ± 1.15[b]	46.23 ± 1.15[c]	1.49	< 0.001

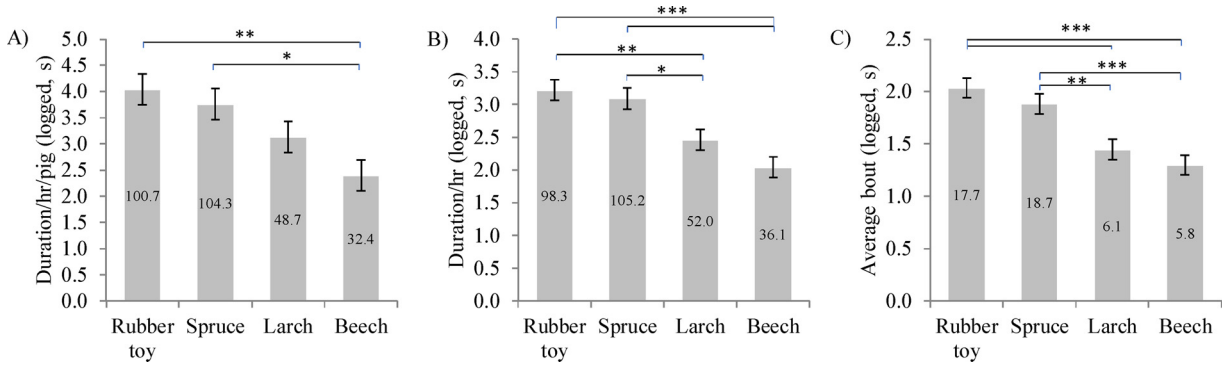

Fig. 2. Average duration (logged) of interaction with the enrichment item between treatments (LSM of the original data as indicated on each bar). **A)** Total duration at pen level; duration was averaged between 2 days of observations per pen per pig ($F_{(3,\ 33.6)} = 6.19$), **B)** Total duration at individual level, duration was averaged between 2 days ($F_{(3,\ 257)} = 12.36$), and **C)** Bout lengths ($F_{(3,\ 254)} = 13.33$). Significant differences after the Tukey-Kramer adjustment are indicated by * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

(Table 2). The interaction between week and treatment was only significant for spruce; weeks 7 and 8 had the highest weight reduction compared to weeks 1–4 ($P < 0.001$). The average decrease in weight of the rubber toy was 5.34 ± 0.45 g/day.

3.2. Behaviour

3.2.1. Enrichment interaction

At the pen level, the average duration of interaction with the enrichment was higher when pigs had the Rubber toy or Spruce ($P < 0.01$, Fig. 2A). There was a tendency for pigs to interact with the enrichment more during week 2 compared to week 4 ($P = 0.07$).

When analysed at the individual level, pigs interacted with the Rubber toy and Spruce more than Larch and Beech, both in terms of total duration ($P < 0.001$, Fig. 2B), and average bout length ($P < 0.001$, Fig. 2C). Kendall's coefficient of concordance comparing pigs' behaviour over different observation sessions was only significant for Beech ($W = 0.27$, $P < 0.01$) and Larch ($W = 0.25$, $P < 0.05$), and not for Spruce or Rubber toy, suggesting that there was a greater consistency in the amount of interaction that each pig had with the enrichment in pens with Beech and Larch. No sex difference was found in enrichment use, nor was there an effect of pig 'type' among the focal pigs.

During each observation session, about half of the pigs in the pen interacted with the enrichment (48.58 ± 2.37 %), but there was no difference between treatments (Fig. 3A); moreover, a higher proportion of pigs in the pen interacted with the enrichment in week 2 compared to week 4 and 7 (Fig. 3B, $P < 0.001$). Only one out of ten Spruce pens had one or more pigs that did not interact with the enrichment at all during six recording sessions, whereas there were three in Rubber toy pens, and four each in the Larch and Beech pens.

3.2.2. Other behaviours

There was no difference between treatments in tail or ear biting behaviour, both of these behaviours combined together, or play behaviour. On average, more ear biting (19.37 ± 1.53 s/hr/pig) was recorded than tail biting (3.54 ± 0.33 s/hr/pig). Pigs with spruce had more frequent aggressive encounters when interacting with the enrichment compared to beech (1.80 ± 0.36 v's 0.52 ± 0.35, $F = 3.26_{(27.4,3)}$, $P < 0.05$). There was a positive correlation between enrichment use and tail and ear biting combined at the pen level ($r_p = 0.45$, $P < 0.001$). No difference in behaviours between the types of focal pigs was found.

3.3. Salivary cortisol

No difference was found in salivary cortisol concentrations between treatments, however "Avoid" pigs' exhibited slightly higher salivary cortisol concentrations than "Approach" pigs (0.16 ± 0.02 v's 0.13 ± 0.02 µg/dL, $F = 3.24_{(111,2)}$, $P = 0.04$), with "Neutral" intermediate.

3.4. Physical scores

Pigs enriched with Spruce had higher tail lesions on the Hunter scale than Beech (Fig. 4, $P < 0.05$), and similarly higher tail damage

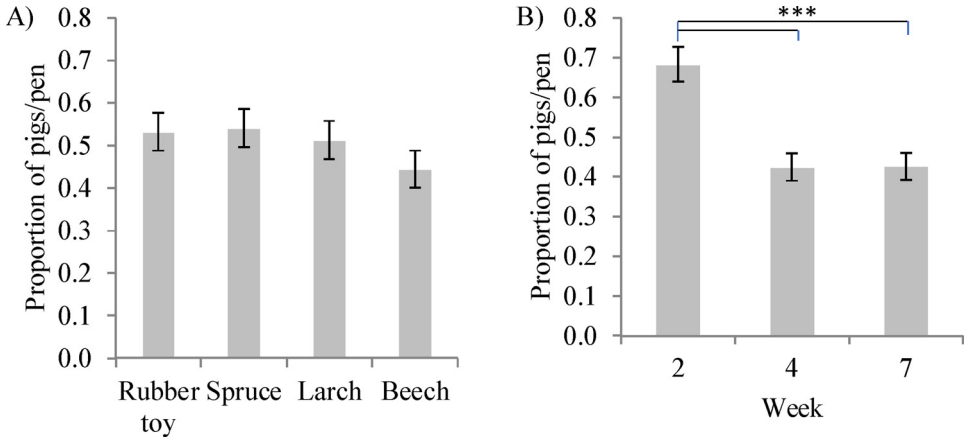

Fig. 3. Proportion of pigs in a pen that interacted with the enrichment across **A)** Different treatments and **B)** Experimental weeks, Significant differences after the Tukey-Kramer adjustment are indicated by *** $P < 0.001$.

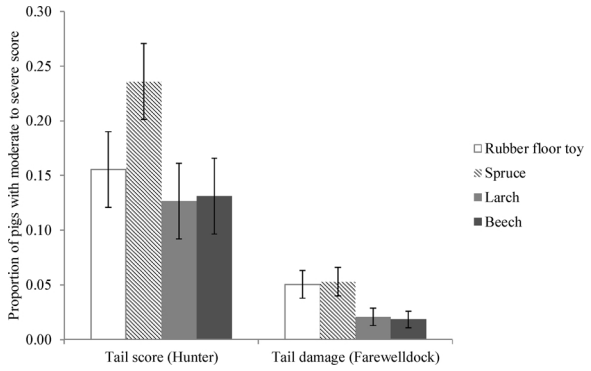

Fig. 4. Proportion of pigs with moderate to severe tail lesion scores (score 2–3) in different enrichment treatments. Pigs with spruce had higher tail lesion scores ($P < 0.05$). Hunter tail lesion scale: 0-no damage, 1-mild, 2-moderate, 3-severe. Tail damage: 0-no lesion, 1-bite marks, 2-open wound, 3-swollen bite wounds.

scores using the FareWellDock system (Fig. 4, $P < 0.05$). However, there was no difference in the presence of blood on the tail. There was no difference in ear lesion scores and tear staining scores between any of the treatments.

3.5. Carcass data

The post-mortem tail lesion scores did not differ between treatments, and neither did the presence of possible damage recorded in the tongue and gum area on the carcasses. Chi-square analysis also showed no difference between pigs using wood or rubber toy in terms of the oral damage ($X^2_{(1,\ n\ =\ 280)} = 1.202$, $P = 0.27$, Fig. 5).

4. Discussion

In the current study, pigs spent a longer time interacting with the spruce post and the rubber floor toy compared to larch and beech posts. Within the wood species investigated, the longer time that pigs spent interacting with Spruce compared to the other species, was also reflected in the longest bouts of interaction. Moreover, spruce posts also had the highest weight loss per day compared to larch and beech, which agrees with our previous study (Chou et al., 2018), comparing spruce with larch, beech and Scots pine (*Pinus sylvestris L.*). Spruce was the softest wood, and this quality probably attracted more use from the pigs and led to depletion more quickly, and consequently a more frequent replacement rate. Being destructible and deformable are the qualities of enrichment preferred by pigs (van de Weerd et al., 2003). Moreover, the frequent replacement and the higher reduction in length and variation in perimeter likely led to more morphological changes and

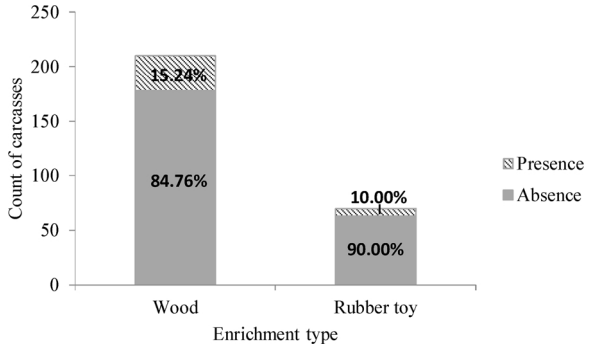

Fig. 5. Presence or absence of damage to the tongue and gum area recorded on the carcasses. No difference between pigs with wood or rubber floor toy was found by Chi-square test ($X^2_{(1,\ n\ =\ 280)} = 1.202$, $P = 0.27$).

increased novelty due to replenishment, compared to the other wood types. This may mean use of spruce posts was more appealing over time compared to the other two types of wood (Chou et al., 2018).

Pigs interacted with the rubber floor toy at a similar level to the spruce post in the present study. Rubber materials are not considered more suitable as enrichment than organic ones (European Commission, 2016b). Nevertheless, previous studies have also found that when provided as a point-source enrichment item, soft rubber items did not necessarily generate fewer interactions from pigs than organic items (Horback et al., 2016; Telkänranta et al., 2014), albeit they are not as attractive as loose materials (Scott et al., 2009; van de Weerd et al., 2006). The rubber floor toy used in the current study is very easily accessed not only because it can be placed in the centre of the pen, but also because it is moveable and can therefore stimulate reciprocal actions between pigs. Although sometimes floor items can be soiled easily, the device used in the present study was designed so that there was minimal contact surface with the ground. When presented in this way, floor items can generate more frequent interactions than hanging organic items (Chou et al., 2019b). Considering the wood posts provided more limited access due to their fixed location inside the pen, they could potentially have attracted more interaction if accessibility had been improved.

A further aim of the study was to understand the variation within pens between individual pigs in terms of enrichment use and other behaviours. The analysis showed that the high use of spruce posts was not a result of a few consistent high users. This may also suggest that pigs interacted more equally among groups when the quality of the enrichment was more attractive, as they were observed to interact more with the spruce post and the rubber floor toy on average. A positive finding was that there was no difference in enrichment use between sexes or types of pigs that showed different responses to human approach, indicating again that a particular pig type did not dominate enrichment access or use. However, during each observation session only approximately half of the pigs in the pen interacted with the enrichment item in all treatments, and in some pens (even one Spruce pen) there were pigs that did not once use the enrichment during all 6 sessions. Larsen et al. (2019) compared pigs' use of pine posts with a previous study which used similar methodologies with small amounts (10 g/pig/day) of loose straw (Jensen et al., 2015). These authors found that the highest usage of pine posts (22 s/hr/pig) in their study was only similar to straw use 3–8 hours after provision (15 s/hr/pig), when the straw was possibly already depleted. The authors concluded that provision of wood as enrichment at a 1:4.5 ratio may not be sufficient to satisfy pigs' exploratory needs. In the current study, Spruce attracted around 100 s/hr of interaction per pig, which was higher than in Larsen et al. (2019) and could be due to a different presentation and a smaller pen size (Apple and Craig, 1992). Nevertheless, this is still much lower than when 10 g/pig/day of straw was freshly provided (501 s/hr/pig, Jensen et al., 2015). Straw has commonly been regarded as the gold standard in enrichment provision for pigs (Studnitz et al., 2007; van de Weerd et al., 2006), and the much lower interaction with the spruce post in the current study, than that with a small amount of straw was provided, could indicate that wood is not as biologically relevant for pigs.

Furthermore, the proportion of pigs interacting with the enrichment decreased in all treatments over time, even though the deterioration of the spruce post accelerated. This suggests that as the pigs matured, they were increasingly more capable of destroying the posts, without a higher rate of use. In fact, pigs provided with spruce had slightly higher tail lesion scores, and the positive correlation between enrichment use and damaging behaviours showed that the enrichment provided in the current study did not prevent damaging behaviours. Indeed if environmental enrichment stimulates pigs' exploratory instinct, but fails to satisfy their behavioural need, it could potentially induce frustration and in turn generate more manipulative behaviours towards pen mates (van de Weerd and Ison, 2019). The spruce post might have stimulated

pigs' appetitive behaviour to forage but was not enough to help them reach the consummatory phase, leading to the higher rate of biting in this treatment (Duncan, 1998). Even under an *ad libitum* feeding regime, where pigs' nutritional need may be satisfied, their behavioural need for foraging and exploration still may not be satiated (Studnitz et al., 2007). Nevertheless, the overall occurrence of damaging behaviours, especially tail biting, was quite low in this study. This may however, be a result of tail docking, as Chou et al. (2019a) found that a spruce post and a rubber floor toy were ineffective in preventing tail biting in undocked pigs at a 1:14 ratio.

There was no difference in salivary cortisol concentrations observed between treatments in the current study, which may suggest the organic enrichment and the inorganic counterpart did not contribute to alterations in different physiological responses that affect cortisol homeostasis. Compared to other studies which adopted a similar method of saliva collection, Giuliotti et al. (2019) found that finishers enriched with only a metal chain had the similar salivary cortisol concentrations as pigs enriched with both wood and chain. Similarly, Casal et al. (2016) compared pigs housed in a barren or enriched (sawdust, hemp ropes and rubber balls) environment, and only found in the barren pigs higher hair cortisol and salivary Chromogranin A, but not salivary cortisol. Another possible explanation for not finding differences between treatments could be that simply varying the type of enrichment, when provided at a rate of one item per 7 pigs (or as in Giuliotti et al. (2019), 3 wood logs per 25 pigs) does not generate enough of a difference in environment to induce different physiological responses. Moreover, compared to previous studies which used a similar breed of finisher pigs at resembling ages, the pigs' salivary cortisol concentrations quantified in the current study appeared to be similar or lower (Bradshaw et al., 1996; Casal et al., 2016; Coutellier et al., 2007; de Jong et al., 2000; Escribano et al., 2015; Nzolo, 2014; Scollo et al., 2014). Even for the "Avoid" pigs, which had marginally higher salivary cortisol concentrations compared to the "Approach" pigs, the cortisol concentration was not outside the normal range compared to previous studies. Although this higher cortisol concentration in "Avoid" pigs may suggest that they might be slightly more aroused during sample collections than "Approach" ones, the different types of pigs were only defined by the latency to voluntarily approach the experimenter when taking the first saliva sample. It should be noted that no further behavioural tests or repeated measures were conducted to validate these categorisations (Boissy and Erhard, 2014).

Post-mortem inspection of the tongues and gums revealed no obvious ante-mortem oral damage was sustained in pigs which had any specific type of enrichment during the trial. To the best of our knowledge, this is the first attempt to conduct post-mortem examination on the oral cavity of finishing pigs. Due to a lack of knowledge on pigs' oral health in general, we attempted to record any visible damage. Some examples of the damage observed can be found in supplementary material II. Although there are concerns that dried wood can present a risk of splintering and consequent damage to pigs' health (European Commission, 2016b), currently no evidence supports these concerns. The amount of oral damage recorded in the current study was not significantly higher in pigs with a specific wood species, or all wood species combined, compared to the rubber toy. This suggests that the damage observed could be caused by factors other than the enrichment materials provided, and common to all pens (e.g. oral manipulation of other pen fixtures). Another possible explanation is the damage was incurred post-mortem, during the carcass processing. Pigs are opportunistic omnivores by nature and do ingest a variety of organic substances during foraging (D'Eath and Turner, 2009; Held et al., 2009); as such, it is unlikely wooden materials would be unsafe for them, and the results are therefore unsurprising. Further toxicological studies should investigate whether there are other substances in some wood species that could be harmful to pigs.

5. Conclusions

Spruce posts and the rubber floor toy attracted more interaction from pigs more than larch and beech, although no difference in damaging behaviours and salivary cortisol concentration was found, and pigs with spruce had slightly higher tail lesion scores. The higher usage of spruce and the rubber toy was not attributable to consistent high users, but the overall duration of interaction was still quite low in comparison to previously reported data for small quantities of straw. No clear damage to the carcass was found caused by using wood; hence standardised dried wood appears to be safe as environmental enrichment for pigs. Based on the current results, the spruce post appears to be a safe and preferred wood species to be used as an enrichment item and so does the rubber floor toy. However, due to the low level of tail biting recorded and higher tail lesions in pigs with Spruce, further work is needed to assess the efficacy of using suitable point-source items along with other enrichment provision to prevent pigs from tail biting when the pigs' tails are not docked.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.applanim.2020.104944.

References

Apple, J.K., Craig, J.V., 1992. The influence of pen size on toy preference of growing pigs. Appl. Anim. Behav. Sci. 35, 149–155. https://doi.org/10.1016/0168-1591(92)90005-V.

Barbari, M., Conti, L., Rossi, G., Simonini, S., 2017. Supply of wood as environmental enrichment material to post-weaning piglets. Agron. Res. 15, 313–321.

Boissy, A., Erhard, H.W., 2014. How studying interactions between animal emotions, cognition, and personality can contribute to improve Farm animal welfare. In: Grandin, T., Deesing, M.J. (Eds.), Genetics and the Behavior of Domestic Animals. Elsevier, pp. 81–113. https://doi.org/10.1016/B978-0-12-394586-0.00003-2.

Bracke, M., 2006. Expert opinion regarding environmental enrichment materials for pigs. Anim. Welf. 15, 67–70.

Bradshaw, R.H., Parrott, R.F., Goode, J.A., Lloyd, D.M., Rodway, R.G., Broom, D.M., 1996. Behavioural and hormonal responses of pigs during transport: effect of mixing and duration of journey. Anim. Sci. 62, 547–554. https://doi.org/10.1017/S1357729800015095.

Casal, N., Manteca, X., Escribano, D., Cerón, J.J., Fàbrega, E., 2016. Effect of environmental enrichment and herbal compound supplementation on physiological stress indicators (chromogranin A, cortisol and tumour necrosis factor-a) in growing pigs. Animal 11, 1228–1236. https://doi.org/10.1017/s1751731116002561.

Chou, J.-Y., D'Eath, R.B., Sandercock, D.A., Waran, N., Haigh, A., O'Driscoll, K., 2018. Use of different wood types as environmental enrichment to manage tail biting in docked pigs in a commercial fully-slatted system. Livest. Sci. 213, 19–27. https://doi.org/10.1016/j.livsci.2018.04.004.

Chou, J.-Y., D'Eath, R.B., Sandercock, D.A., O'Driscoll, K., 2019a. Can dietary fibre level and a single enrichment type reduce the risk of tail biting in undocked pigs? In: Proceedings of the 11th European Symposium on Porcine Health Management. Presented at the the 11th European Symposium on Porcine Health Management. Utrecht, the Netherlands..

Chou, J.-Y., Drique, C., Sandercock, D., D'Eath, R., O'Driscoll, K., 2019b. Rearing

undocked pigs on fully slatted floors using multiple types and variations of enrichment. Animals 9, 139. https://doi.org/10.3390/ani9040139.
Coutellier, L., Arnould, C., Boissy, A., Orgeur, P., Prunier, A., Veissier, I., Meunier-Salaün, M.-C., 2007. Pig's responses to repeated social regrouping and relocation during the growing-finishing period. Appl. Anim. Behav. Sci. 105, 102–114. https://doi.org/10.1016/j.applanim.2006.05.007.
D'Eath, R.B., Turner, S.P., 2009. The natural behaviour of the pig. In: Marchant-Forde, J.N. (Ed.), The Welfare of Pigs, Animal Welfare. Springer, Netherlands, Dordrecht.
de Groot, J., de Jong, I.C., Prelle, I.T., Koolhaas, J.M., 2000. Immunity in barren and enriched housed pigs differing in baseline cortisol concentration. Physiol. Behav. 71, 217–223. https://doi.org/10.1016/S0031-9384(00)00336-X.
de Jong, I.C., Ekkel, E.D., van de Burgwal, J.A., Lambooij, E., Korte, S.M., Ruis, M.A.W., Koolhaas, J.M., Blokhuis, H.J., 1998. Effects of strawbedding on physiological responses to stressors and behavior in growing pigs. Physiol. Behav. 64, 303–310. https://doi.org/10.1016/S0031-9384(98)00066-3.
de Jong, I., Prelle, I., Vandeburgwal, J., Lambooij, E., Korte, S., Blokhuis, H., Koolhaas, J., 2000. Effects of environmental enrichment on behavioral responses to novelty, learning, and memory, and the circadian rhythm in cortisol in growing pigs. Physiol. Behav. 68, 571–578. https://doi.org/10.1016/S0031-9384(99)00212-7.
DeBoer, S., Garner, J., McCain, R., Lay Jr, D., Eicher, S., Marchant-Forde, J., 2015. An initial investigation into the effects of isolation and enrichment on the welfare of laboratory pigs housed in the PigTurn < SUP > ® < /SUP > system, assessed using tear staining, behaviour, physiology and haematology. Anim. Welf. 24, 15–27. https://doi.org/10.7120/09627286.24.1.015.
Duncan, I.J., 1998. Behavior and behavioral needs. Poult. Sci. 77, 1766–1772. https://doi.org/10.1093/ps/77.12.1766.
Escribano, D., Gutiérrez, A.M., Tecles, F., Cerón, J.J., 2015. Changes in saliva biomarkers of stress and immunity in domestic pigs exposed to a psychosocial stressor. Res. Vet. Sci. 102, 38–44. https://doi.org/10.1016/j.rvsc.2015.07.013.
European Commission, 2009. Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (codified version). Off. J. Europ Union.
European Commission, 2016a. Commission Recommendation (EU) 2016/336 of 8 March 2016 on the application of Council Directive 2008/120/EC laying down minimum standards for the protection of pigs as regards measures to reduce the need for tail-docking. Off. J. Europ Union.
European Commission, 2016b. Commission Staff Working Document on Best Practices With a View to the Prevention of Routine Tail-docking and the Provision of Enrichment Materials to Pigs Accompanying the Document Commission Recommendation on the Application of Council Directive 2008/120/EC Laying Down Minimum Standards for the Protection of Pigs As Regards Measures to Reduce the Need for Tail-docking.
Finkemeier, M.-A., Langbein, J., Puppe, B., 2018. Personality research in mammalian farm animals: concepts, measures, and relationship to welfare. Front. Vet. Sci. 5. https://doi.org/10.3389/fvets.2018.00131.
Giuliotti, L., Benvenuti, M.N., Giannarelli, A., Mariti, C., Gazzano, A., 2019. Effect of different environment enrichments on behaviour and social interactions in growing pigs. Animals 9, 101. https://doi.org/10.3390/ani9030101.
Haigh, A., O'Driscoll, K., 2016. The long and short of it: Irish farmers' experiences of tail biting. Teagasc Pig Research Dissemination Day 2016. Presented at the Teagasc Pig Research Dissemination Day 2016. Cavan, Ireland.
Harley, S., More, S.J., O'Connell, N.E., Hanlon, A., Teixeira, D., Boyle, L., 2012. Evaluating the prevalence of tail biting and carcase condemnations in slaughter pigs in the Republic and Northern Ireland, and the potential of abattoir meat inspection as a welfare surveillance tool. Vet. Rec. 171https://doi.org/10.1136/vr.100986. 621–621.
Held, S., Cooper, J.J., Mendl, M.T., 2009. Advances in the study of cognition, behavioural priorities and emotions. In: Marchant-Forde, J.N. (Ed.), The Welfare of Pigs, Animal Welfare. Springer, Netherlands, Dordrecht.
Horback, K.M., Pierdon, M.K., Parsons, T.D., 2016. Behavioral preference for different enrichment objects in a commercial sow herd. Appl. Anim. Behav. Sci. 184, 7–15. https://doi.org/10.1016/j.applanim.2016.09.002.
Hunter, E.J., Jones, T.A., Guise, H.J., Penny, R.H.C., Hoste, S., 1999. Tail biting in pigs 1: the prevalence at six UK abattoirs and the relationship of tail biting with docking, sex and other carcass damage. The Pig Journal 43, 18–32.
Jensen, M.B., Herskin, M.S., Forkman, B., Pedersen, L.J., 2015. Effect of increasing amounts of straw on pigs' explorative behaviour. Appl. Anim. Behav. Sci. 171, 58–63. https://doi.org/10.1016/j.applanim.2015.08.035.
Larsen, M.L.V., Jensen, M.B., Pedersen, L.J., 2019. Increasing the number of wooden beams from two to four increases the exploratory behaviour of finisher pigs. Appl. Anim. Behav. Sci. https://doi.org/10.1016/j.applanim.2019.04.010.
Merlot, E., Vincent, A., Thomas, F., Meunier-Salaün, M.-C., Damon, M., Robert, F., Dourmad, J.-Y., Lebret, B., Prunier, A., 2012. Health and immune traits of Basque and Large White pigs housed in a conventional or enriched environment. Animal 6, 1290–1299. https://doi.org/10.1017/s1751731112000080.
Morrison, R.S., Johnston, L.J., Hilbrands, A.M., 2007. The behaviour, welfare, growth performance and meat quality of pigs housed in a deep-litter, large group housing system compared to a conventional confinement system. Appl. Anim. Behav. Sci. 103, 12–24. https://doi.org/10.1016/j.applanim.2006.04.002.
Nannoni, E., Sardi, L., Vitali, M., Trevisi, E., Ferrari, A., Ferri, M.E., Bacci, M.L., Govoni, N., Barbieri, S., Martelli, G., 2018. Enrichment devices for undocked heavy pigs: effects on animal welfare, blood parameters and production traits. Ital. J. Anim. Sci. 18, 45–56. https://doi.org/10.1080/1828051x.2018.1472531.
Nzolo, J., 2014. Effect of Pre-slaughter Stress of Pigs on the Levels of Cortisol, Creatine Kinase and Their Subsequent Relationship With Pork Quality. PhD Thesis. University of Fort Hare, South Africa.
Scollo, A., Gottardo, F., Contiero, B., Edwards, S.A., 2014. Does stocking density modify affective state in pigs as assessed by cognitive bias, behavioural and physiological parameters? Appl. Anim. Behav. Sci. 153, 26–35. https://doi.org/10.1016/j.applanim.2014.01.006.
Scott, K., Taylor, L., Gill, B.P., Edwards, S.A., 2009. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems 3. Hanging toy versus rootable toy of the same material. Appl. Anim. Behav. Sci. 116, 186–190. https://doi.org/10.1016/j.applanim.2008.07.002.
Smulders, D., Verbeke, G., Mormede, P., Geers, R., 2006. Validation of a behavioral observation tool to assess pig welfare. Physiol. Behav. 89, 438–447. https://doi.org/10.1016/j.physbeh.2006.07.002.
Studnitz, M., Jensen, M.B., Pedersen, L.J., 2007. Why do pigs root and in what will they root? Appl. Anim. Behav. Sci. 107, 183–197. https://doi.org/10.1016/j.applanim.2006.11.013.
Telkänranta, H., Bracke, M.B.M., Valros, A., 2014. Fresh wood reduces tail and ear biting and increases exploratory behaviour in finishing pigs. Appl. Anim. Behav. Sci. 161, 51–59. https://doi.org/10.1016/j.applanim.2014.09.007.
van de Weerd, H., Ison, S., 2019. Providing Effective Environmental Enrichment to Pigs: How Far Have We Come? Animals 9, 254. https://doi.org/10.3390/ani9050254.
van de Weerd, H.A., Docking, C.M., Day, J.E.L., Avery, P.J., Edwards, S.A., 2003. A systematic approach towards developing environmental enrichment for pigs. Appl. Anim. Behav. Sci. 84, 101–118. https://doi.org/10.1016/s0168-1591(03)00150-3.
van de Weerd, H.A., Docking, C.M., Day, J.E.L., Breuer, K., Edwards, S.A., 2006. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl. Anim. Behav. Sci. 99, 230–247. https://doi.org/10.1016/j.applanim.2005.10.014.