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Which types of rooting material give weaner pigs most pleasure?

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ABSTRACT

Provision of rooting material as enrichment for pigs has been primarily oriented towards reducing negative affect (suffering). Information is also needed on the impact of different types of rooting materials in promoting positive affect (pleasure). We hypothesised that repeated addition of fresh rooting material, especially different types provided in combination, would stimulate positive affect in weaned pigs. We offered pigs (n = 10 weaned litters) rooting material twice daily (10 L of silage, straw or peat, or a combination ("combo") of all three), or no added rooting material (control condition, sawdust bedding only, present in all pens). Over five weeks, each litter was exposed to all five conditions for one week each (order balanced across litters), and the behaviour of two male and two female focal pigs per litter was assessed during the 30 min before and 30 min after delivery of rooting material on Days 1 and 4 each week. Behaviours indicative of positive affective states in this context (exploration, play, tail curled, tail wagging), as well as behaviours associated with harm (ear/tail manipulation, aggression, tail down), were quantified from video recordings by 1 − 0 sampling. The effect of condition (control, silage, straw, peat or comb) on positive and negative behavioural expressions was analysed using a generalised linear mixed model that also accounted for period (before vs after adding rooting material), time of day (morning vs afternoon), day of week, condition by period, condition by time of day, sex, bodyweight, litter size, and week. The peat and combo conditions resulted in higher levels of exploration, play, tail curled and tail wagging, and lower levels of ear/tail manipulation, aggression and tail down, compared to control, with the silage and straw conditions mainly giving intermediate results. Pigs showed more exploration, tail curled and tail wagging after than before adding silage, straw, peat and combo, whereas play increased only after adding peat or combo. Exploration occurred at similar levels on Day 1 and 4 of exposure to peat and combo whereas it declined across days in the other conditions, and ear/tail manipulation and aggression increased in the silage condition. Exploration, play and tail wagging declined with increasing age. Sex, bodyweight and litter size were not consistently associated with positive or negative behavioural expressions. Our results suggest that peat, and peat in combination with straw and silage, were the most consistently effective rooting materials for inducing positive (i.e. pleasurable) affective states, and reducing behaviours associated with harm, in weaned pigs.

1. Introduction

Emotional affective states are related to the behaviour, health and welfare of animals (Fraser and Duncan, 1998; Panksepp, 2011; Mellor, 2015). Emotions can be broadly defined as transient, consciously experienced (i.e. feeling) states originating in the limbic system of the brain that motivate animals to avoid harmful stimuli (suffering) and seek reward (pleasure) from valuable resources (modified from Panksepp, 1994; Cardinal et al., 2002). Emotions can be described by their valence (negative vs positive) and the animal's arousal level (low vs high). Thus, a spectrum of unpleasant and pleasant feelings may be experienced, from frustration to satisfaction and boredom to joy (Boissy et al., 2007; Mendl et al., 2010). Feelings of suffering and pleasure are important in establishing the motivational strength and priorities of behaving organisms (Cabanac, 2002). Thus, behavioural expressions have been used to describe the emotional feelings of domestic pigs (e.g. Wemelsfelder et al., 2000). Here, we evaluate exploration, play and a curled or wagging tail (positive behaviours) as expressions of pleasurable (positive) emotions in pigs such as curiosity and joy. We also report on ear/tail manipulation (a precursor of ear and tail biting), aggression, and tail down, as indicators of negative affective states related to potential or actual harm (e.g. anger, frustration or boredom in performers; fear, pain or frustration in recipients).

Pig producers in the European Economic Area are required to provide "permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay,

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wood, sawdust, mushroom compost, peat or a mixture of such" (Directive 2008/120/EC, The Council of The European Union, 2008). The provision of straw or other environmental enrichment materials is mainly driven by the value of these materials in reducing behaviours associated with economic loss, such as ear and tail biting and aggression (reviewed by Tuyttens, 2005; van de Weerd and Day, 2009; Buijs and Muns, 2019). However, to provide for animal lives worth living (FAWC, 2009), we should address not only their value in reducing these "negative" behaviours but also their role in stimulating "positive" behaviours motivated by positive emotional feelings (Lawrence et al., 2018). In a thermoneutral, predator-free environment with *ad libitum* access to feed and water, exploration and play in response to enrichment materials can be considered positive behaviours because their performance in this context appears to be pleasurable and non-urgent, facilitating the development of motor and social skills, knowledge and coping abilities that could enhance future fitness rather than addressing immediate survival needs (Špinka et al., 2001; Cabanac, 2002; McGowan et al., 2010). Tail expressions also enable assessment of affective responses to different enrichment materials given that wagging tails are often, though not exclusively, seen during exploration and play (Newberry et al., 1988; Marcet-Rius et al., 2018) while tails are more often kept down rather than curled in aversive contexts (Reimert et al., 2013) such as the threat of tail biting (Zonderland et al., 2009; Lahrmann et al., 2018).

In weaned pigs, rootable enrichment materials that are ingestible, chewable, odorous, deformable and destructible have been associated with more prolonged exploratory behaviour than simple hanging objects such as chains or tyres (Van de Weerd et al., 2003; Bracke et al., 2006; Scott et al., 2009; Van de Weerd and Day, 2009). With regards to edibility and chewability (in addition to investigation, manipulation and safety qualities), the European Commission (2016) classified straw and silage as optimal enrichment materials, and peat and sawdust as suboptimal. While straw is commonly used for enrichment, there is some indication that peat and sawdust may not be inferior to straw, with the added benefit of being easier to manage. For example, Rosvold et al. (2018) observed that farrowing sows rooted more in peat than straw, and Studnitz et al. (2007) concluded that peat, sawdust, silage, mushroom compost, sand, wood shavings, branches and beets ranked above straw for weaned pigs based on preference and operant conditioning tests. However, it is unclear whether these rankings would apply to sustained exploratory behaviour by weaned pigs under practical conditions. With regard to play behaviour, straw and peat have occasionally been reported to increase play relative to providing no material (Fraser et al., 1991; Bolhuis et al., 2005; Vanheukelom et al., 2011), and small amounts of fresh straw have been used to induce play (Donaldson et al., 2002). Apart from Jensen and Pedersen (2007), who observed differences in the frequency of scampering in pigs given different materials, reports on the relative impact of different materials in stimulating play are lacking.

With declining interest in existing material over time (Van de Weerd et al., 2003; Gifford et al., 2007), and increased soiling with manure (Bracke, 2007), pigs' curiosity can be stimulated by adding fresh (i.e. novel, clean) rooting material. Offering multiple enrichment materials simultaneously may further enhance positive affect by stimulating a diversity of pleasurable experiences. Based on a comparison of results across studies, Bracke et al. (2006) inferred that combinations of materials gave slightly better results than single materials. However, there remains a need for systematic comparison of behaviour in pigs repeatedly offered materials singly vs in combination.

In this study, we hypothesised that repeated addition of fresh rooting material, especially different types provided in combination, would stimulate positive emotions in weaned pigs. Over a 5-week period, we investigated the frequencies of positive and negative behavioural responses in pigs when given different rooting materials (silage, straw, peat) either alone or in combination (silage + straw + peat). All pens contained sawdust, which was provided as a bedding material for hygiene purposes according to standard practice in Norway. We predicted that pigs would perform more exploration and play, and less ear/tail manipulation and aggression, and that their tails would more often be curled or wagging than down, when given these rooting materials than when receiving sawdust bedding alone. We expected that these differences would be most pronounced in the 30 min after rather than the 30 min before receiving fresh rooting material, and when providing a combination of the three rooting materials. To elucidate these effects, our analysis accounted for other factors that could affect pig behaviour including sex, bodyweight, litter size, age, days of experience with the material, and time of day (e.g. see Brown et al., 2018).

2. Materials and methods

2.1. Subjects, housing and management

The study took place at the Pig Research Unit of the Norwegian University of Life Sciences (Animal Research Centre, Ås, NO) in accordance with legal requirements for the keeping of pigs (Norwegian Ministry of Agriculture and Food, 2003). Because standard pig rearing practices were followed and no potentially harmful research was performed, there was no requirement to obtain separate permission for research involving animals (Norwegian Ministry of Agriculture and Food, 2015). We used 10 litters of pigs born to crossbred Norsvin Landrace × Yorkshire sows inseminated with Duroc boar semen. Each litter was housed in a 7.7 m^2 SowComfort, farrowing pen allowing freedom of movement by the sow (Fig. 1; Andersen and Morland, 2016), with an empty pen between each occupied pen to maximise statistical independence between litters. Pens were divided into an activity/dunging area with a plastic slatted floor, two nipple drinkers and a feeder, and a nest area with a solid floor covered with a 3-cm-thick rubber mattress. The three interior walls of the nest area were sloping, with a gap at the base enabling suckling piglets to avoid the sow. To either side of the nest entrance was a solid pen partition fitted with a low piglet protection rail. Each piglet received iron orally at birth, and a veterinarian surgically castrated the males under local anaesthesia and systemic long-acting analgesia between 10 and 14 days of age. Teeth and tails were left intact.

Pigs remained in their natal farrowing pen after weaning (by removing the sow) at approximately 5 weeks of age. Litter sizes at

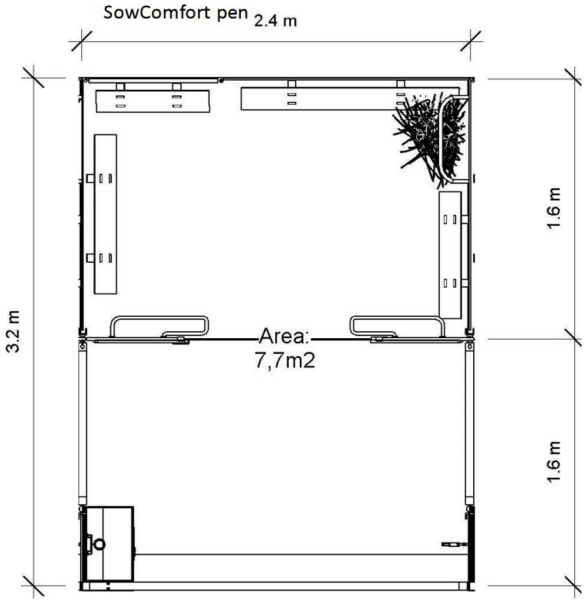

Fig. 1. Farrowing pen design, with rubber-matted nest area (containing sloping walls, piglet protection bars and straw rack), and slatted-floor activity/dunging area (containing feeder and water nipples). Contents not to scale.

weaning ranged from 12 to 15 siblings (1 litter of 12 (0.64 m^2/pig), 2 of 13 (0.59 m^2/pig), 3 of 14 (0.55 m^2/pig), and 4 of 15 (0.51 m^2/pig), for a total of 140 pigs (males, n = 71; females, n = 69). At weaning, the pigs were weighed, individually marked (using blue, red and green livestock spray in different combinations of dots and lines) and their sex was noted. They were re-marked twice weekly (on Mondays and Thursdays). Pen cleaning, and provision of sawdust (2.5 L / pen) to all pens, was performed twice daily at 08:00 and 13:00 h. Pigs were fed *ad libitum* according to the standard weaner feeding programme of the Pig Research Unit (Ideal Junior, Norgesfôr, Norway). They also had free access to water from two nipple drinkers. Ambient temperature was 22 C initially and decreased by 0.5 C weekly, in accordance with guidelines for pigs of this age (Norwegian Food Safety Authority, 2013). In addition to natural light from two windows, artificial light was provided between 06:00 and 16:00 h (in alignment with natural daylength during the study), affording a minimum of 75 lx during the day and darkness at night. No mortality occurred during the post-weaning 5-week study period.

2.2. Experimental design

We exposed each litter to the following five conditions over a 5-week period starting on the day after weaning (one week/condition): control (sawdust as bedding only; no added rooting material), silage (predominantly timothy grass), straw (long-stemmed oat straw, approximate length, 0.15 – 0.5 m), peat (*Sphagnum* (a product generally used for potting plants and gardening), with added formic, acetic acid, potassium sorbate and coal; approximately 75 % water content, 7.6 % crude fibre, and 2.4 % ash, monitored for *Salmonella* and mycotoxins, FK Pluss Avvenningstorv, Fossli a/s, Frosta, NO), or a combination of all three materials ("combo"). The order of applying the five conditions was balanced across litters (Table 1). A total of 10 L of silage, straw, peat or combo (measured in a bucket as is routine practice on commercial farms) was distributed in three similar-sized piles (triangularly arranged, 0.3 to 0.5 m apart, one pile/material in combo) on the solid floor of the nest area, twice daily at approximately 09:00 and 14:00 h, after the morning and afternoon cleaning, respectively.

2.3. Data collection

Each pen was continuously video recorded with a high-definition camera (Foscam FI9821W, 1280 × 720 P, ShenZhen Foscam Intelligent Technology Co., Ltd., Shenzhen, China) for 30 min before, and 30 min after, provision of rooting materials (08:30 – 09:30 and 13:30 – 14:30 h), on Day 1 (Tuesday) and Day 4 (Friday) each week for five weeks (5–10 weeks of age). From the recordings, we observed four focal pigs in each pen (two castrated males and two females). Of the two male-female pairs, the pigs of one pair were below, and those of the other pair above, the average bodyweight of pigs within litter at weaning. All behavioural analyses were conducted by one trained observer (MO), using Solomon Coder 17.03.22 (András Péter, https://solomon.andraspeter.com/). We used one-zero sampling of each focal pig to record the occurrence (1) or non-occurrence (0) of each behaviour in our ethogram (by variable or by element where listed, Table 2) during 10-s scans made every 6 min. Multiple behaviours could occur in the same scan and none were considered mutually exclusive within the scan period. Elements of play (mean ± SE % of scans: head toss, 0.08 ± 0.01; run, 0.13 ± 0.01; pivot, 0.08 ± 0.01; scamper, 0.06 ± 0.01; hop, 0.06 ± 0.01; flop, 0.04 ± 0.01, roll, 0.04 ± 0.01; play butt, 0.12 ± 0.01; play push, 0.19 ± 0.01) and aggression (bite, 0.03 ± 0.00; head knock, 0.02 ± 0.00; parallel knock, 0.08 ± 0.01) occurred infrequently and statistical models failed to converge. Therefore, the counts were aggregated into summed play and aggression categories prior to analysis. The tail down category combined the postures "hangs straight down" and "held tucked between the hindlegs" because the latter was rare (3.83 ± 0.23 % of scans). As recommended by Reimert et al. (2017), tail posture was only observed when pigs were active because the tail generally rests on the floor when lying down (Zonderland et al., 2009) rather than expressing varied emotional states.

Table 1
Experimental design. Litters of weaned pigs (n = 10) rotated through five conditions (control[1], silage, straw, peat, and combo[2]) over five weeks (1 week/condition) in one of five randomly assigned orders.

	Week 1	Week 2	Week 3	Week 4	Week 5
Order 1	Peat	Straw	Silage	Control	Combo
Order 2	Straw	Silage	Control	Combo	Peat
Order 3	Silage	Control	Combo	Peat	Straw
Order 4	Control	Combo	Peat	Straw	Silage
Order 5	Combo	Peat	Straw	Silage	Control

[1] No added rooting material, sawdust bedding only, present in all pens.
[2] Combination of silage, straw and peat.

2.4. Data analysis

Statistical analyses were conducted using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC, USA). The effects of condition (control, silage, straw, peat or combo) on positive (exploration, play, tail curled or wagging) and negative (ear/tail manipulation, aggression, tail down) behavioural expressions was analysed using the GLIMMIX procedure. For each behaviour variable, the (summed) count/pig/observation period was divided by the total possible count (i.e. number of scans x number of behavioural elements contributing to the variable) to produce a proportion that was modelled according to the binomial distribution. Period (30 min before vs 30 min after delivering rooting material), time of day (morning vs afternoon), day of week (1 vs 4), sex (male vs female), condition by time period and condition by day of week were included in the model as fixed effects (class variables). Starting bodyweight (kg), litter size (n) and week (1–5) were continuous variables. Pig nested within pen was specified as a random effect. Pairwise means comparisons were based on differences in least squares means with Tukey adjustment for multiple comparisons.

3. Results

3.1. Effects of different rooting materials

Condition affected the frequencies of all behaviours (Table 3). Pigs showed most exploration in the peat and combo condition, followed by the straw, silage and control conditions, respectively. Similarly, the most play behaviour was observed in the peat and combo conditions, followed by the straw condition, with the least play occurring in the silage and control conditions. Curled and wagging tails were seen least often in the control condition. Curled tails were most common in the silage, peat and combo conditions, and wagging was most commonly observed in the straw, peat and combo conditions.

Ear/tail manipulation occurred most often in the control condition and least often in the straw, peat and combo conditions, and aggression was most frequent in the control and silage conditions and least frequent in the combo condition. The control condition had the most, and combo the fewest, observations of tail down.

3.2. Effects of period, time of day and day of week

Behaviour varied with period, time of day and day of week (Table 4). Pigs showed more exploration, and tail curled and wagging, and less ear/tail manipulation and aggression, in the 30 min after than the 30 min before provision of rooting material. Exploration, play, and tail curled, and wagging occurred more often in the afternoon than the morning, as did aggression and tail down. Pigs also showed more

Table 2
Ethogram used to assess behavioural indicators of positive and negative emotional states in response to bedding material (sawdust, present in all pens) and pen enrichment with silage, straw and/or peat as rooting materials.

Behaviour variable	Element	Description
Positive		
Explore		Investigate or manipulate material on the floor by sniffing, rooting, pawing, chewing or lifting it in the mouth.
Play (sum of):	Head toss	Perform vigorous latero-rotational movements of the neck and head.
	Run	Run fast across the pen, occasionally bumping into another pig, in the absence of a clear source of alarm.
	Pivot	Jump or whirl around to face in a different direction.
	Scamper	Run with bouncy movements in a zig-zag pattern.
	Hop	Jump up with front feet or all four feet lifting off the floor and land facing in the same direction.
	Flop	Drop rapidly but in a relaxed manner from an upright posture to lying on the belly or side.
	Roll	Make rolling movements from side to side while lying on the back or the side, excluding movements made during resting/sleep.
	Play butt	Engage in mutual, mild intensity, non-harmful head butting with another pig, usually while facing in opposite directions.
	Play push	Engage in mutual, non-harmful, mild to moderate pushing against the neck and shoulders of another pig, usually while facing in opposite directions.
Tail curled		Tail coiled up. Only recorded when active (not lying down).
Tail wagging		Tail swinging from side to side or in circular movements. Only recorded when active (not lying down).
Negative		
Ear/tail manipulation		Manipulate the ears or tail of another pig with the mouth (e.g. chew, bite) or nose (e.g. root).
Aggression (sum of):	Bite	Direct single or repeated hard snaps or bites with teeth towards the head or body of another pig.
	Head knock	Make sharp, forceful movements of the head sideways towards the head of another pig.
	Parallel knock	Engage in mutual head knocks with another pig while facing in the same direction.
Tail down		Tail hangs straight down or held tucked between the hindlegs. Only recorded when active (not lying down).

Table 3
Effect of rooting material condition on mean ± SE % of observations of positive and negative behaviour.

Behaviour	Control, %	Silage, %	Straw, %	Peat, %	Combo, %	$F_{(4, 1543)}$	P-value
Positive							
Exploration	12.7 ± 1.0^{a}	45.2 ± 1.8^{b}	50.0 ± 1.9^{c}	53.8 ± 1.9^{d}	54.0 ± 2.0^{d}	151.2	< 0.001
Play	0.9 ± 0.1^{a}	1.0 ± 0.1^{a}	1.8 ± 0.2^{b}	2.8 ± 0.2^{c}	2.3 ± 0.2^{bc}	38.9	< 0.001
Tail curled	29.6 ± 1.5^{a}	53.4 ± 1.7^{b}	50.9 ± 1.8^{c}	55.8 ± 1.8^{b}	56.4 ± 1.8^{b}	81.3	< 0.001
Tail wagging	7.1 ± 0.8^{a}	11.1 ± 0.9^{b}	19.9 ± 1.3^{c}	18.4 ± 1.3^{c}	19.2 ± 1.4^{c}	32.1	< 0.001
Negative							
Ear/tail manipulation	1.9 ± 0.3^{a}	1.1 ± 0.2^{b}	0.6 ± 0.1^{c}	0.3 ± 0.1^{c}	0.4 ± 0.1^{c}	181.8	< 0.001
Aggression	1.8 ± 0.3^{a}	1.5 ± 0.2^{a}	1.0 ± 0.2^{b}	0.8 ± 0.2^{bd}	0.4 ± 0.1^{d}	8.3	< 0.001
Tail down	6.3 ± 0.9^{a}	3.2 ± 0.5^{bd}	4.5 ± 0.7^{ab}	3.1 ± 0.6^{bd}	2.2 ± 0.5^{d}	6.4	< 0.001

^{a,b,c,d}Within rows, means with different superscripts differed significantly (Tukey Honestly Significant Differences, $P < 0.05$).

Table 4
Effects of period, time of day, and day of week on mean ± SE % of observations of positive and negative behaviour.

Behaviour	Period (before vs after provision of material)				Time of day				Day of week			
	Before	After	$F_{(1, 1543)}$	P	Morning	Afternoon	$F_{(1, 1543)}$	P	Day 1	Day 4	$F_{(1, 1543)}$	P
Positive												
Exploration	24.7 ± 0.9	61.6 ± 1.2	715.9	< 0.001	41.9 ± 1.3	44.4 ± 1.2	7.2	0.007	46.1 ± 1.3	40.2 ± 1.2	39.8	< 0.001
Play	1.5 ± 0.1	2.0 ± 0.1	0.3	0.598	1.4 ± 0.1	2.1 ± 0.1	47.2	< 0.001	2.2 ± 0.1	1.3 ± 0.1	78.6	< 0.001
Tail curled	38.1 ± 1.1	60.4 ± 1.1	379.1	< 0.001	45.6 ± 1.2	52.8 ± 1.1	48.4	< 0.001	51.7 ± 1.1	46.8 ± 1.2	24.6	< 0.001
Tail wagging	9.9 ± 0.6	20.4 ± 0.9	110.8	< 0.001	13.5 ± 0.7	16.8 ± 0.8	19.8	< 0.001	18.4 ± 0.8	12.0 ± 0.7	64.1	< 0.001
Negative												
Ear/tail manipulation	1.4 ± 0.1	0.4 ± 0.1	151.0	< 0.001	0.8 ± 0.1	0.9 ± 0.1	1.5	0.226	1.0 ± 0.1	0.8 ± 01	1.9	0.174
Aggression	1.4 ± 0.2	0.8 ± 0.1	22.8	< 0.001	0.9 ± 0.1	1.3 ± 0.1	6.8	0.009	1.0 ± 0.1	1.1 ± 0.1	0.0	0.956
Tail down	4.5 ± 0.4	3.2 ± 0.4	3.2	0.070	3.4 ± 0.4	4.3 ± 0.4	3.9	0.048	4.6 ± 0.4	3.1 ± 0.4	11.5	< 0.001

Table 5
Effects of period by condition, and day of week by condition, interactions on positive and negative behaviour.

Behaviour	Period × Condition		Day × Condition	
Positive	$F_{(4, 1543)}$	P	$F_{(4, 1543)}$	P
Exploration	94.2	< 0.001	2.9	0.021
Play	33.9	< 0.001	1.2	0.320
Tail curled	56.8	< 0.001	5.5	< 0.001
Tail wagging	19.3	< 0.001	2.2	0.069
Negative				
Ear/tail manipulation	1.3	0.274	2.4	0.049
Aggression	4.5	< 0.001	3.3	0.011
Tail down	6.0	< 0.001	3.8	0.005

exploration, play, and tail curled, wagging and down on Day 1 than on Day 4.

3.3. Interaction effects

There were interactions between period and condition for all behaviours except ear/tail manipulation (Table 5). Exploration increased after provision of silage, straw, peat and combo, whereas it decreased in the control condition (Fig. 2a). Play increased after provision of peat and combo, remained at a similar level in the straw condition, and decreased in the control and silage conditions (Fig. 2b). Curled tails (Fig. 2c) and wagging tails (Fig. 2d) were seen more often after than before provision of silage, straw, peat and combo, whereas curled tails

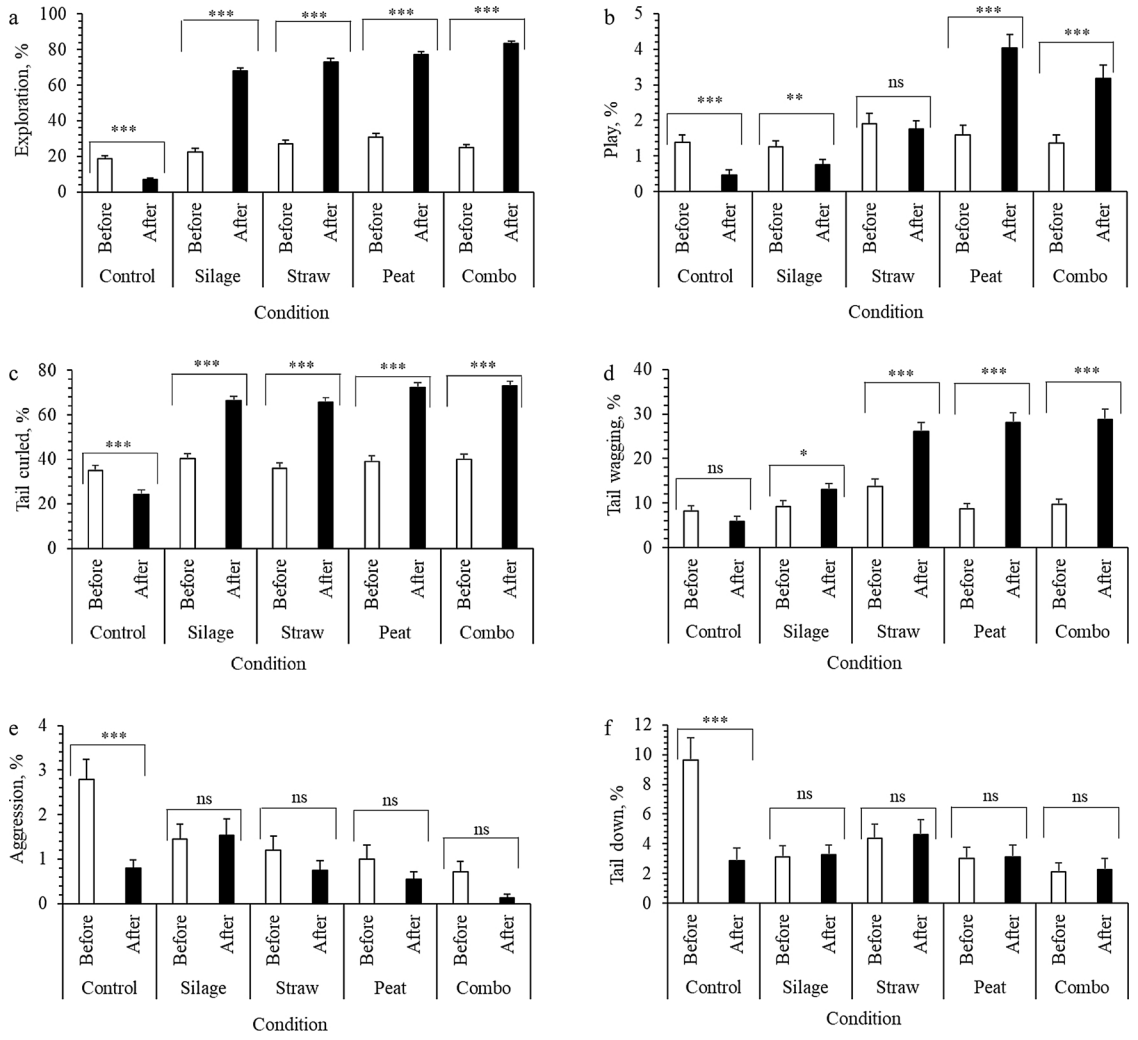

Fig. 2. Effect of interaction between period (before vs after) and condition on mean ± SE % of observations of behaviour. (a) Exploration, (b) Play, (c) Tail curled, (d) Tail wagging, (e) Aggression, (f) Tail down. Combo = silage + straw + peat. Tukey Honestly Significant Differences: $P > 0.05^{ns}$, $P < 0.01^{**}$, $P < 0.001^{***}$.

were less common in the "after" period in the control condition. Less aggression occurred in the "after" than the "before" period in the control condition, whereas aggression remained at similar levels after provision of silage, straw, peat and combo (Fig. 2e). Tail down was less frequent in the "after" than "before" period in the control condition, but did not differ between periods in the other conditions (Fig. 2f).

Considering the day of week by condition interaction (Table 5), exploration decreased from Day 1 to Day 4 in the control, silage, and straw conditions (Fig. 3a). There was a lower occurrence of curled tails on Day 4 than on Day 1 in the control and straw conditions (Fig. 2b). Manipulation of ears and tails decreased from Day 1 to Day 4 in the control, straw and peat conditions, and increased in the silage condition (Fig. 3c). There was more aggression on Day 4 than Day 1 in the silage condition (Fig. 3d). Tail down decreased from Day 1 to Day 4 in the straw condition (Fig. 3e).

3.4. Sex, bodyweight, litter size and week

Behaviour was associated with sex, bodyweight and litter size (Table 6). Tail down was observed more frequently in males than in females. Manipulation of others' ears and tails was performed more often by heavier pigs (Fig. 4a). Exploration and tail down increased with increasing litter size whereas tail wagging decreased (Fig. 4b). With increasing age (i.e. week), exploration, play and tail wagging declined (Fig. 4c).

4. Discussion

All of the provided rooting materials (silage, straw, and/or peat) increased exploration, tail curled and tail wagging, and reduced ear/tail manipulation in weaned pigs relative to the control condition (sawdust bedding only). Provision of straw, peat and combo also increased play and reduced aggression, and provision of silage, peat, or combo reduced tail down. Overall, the peat and combo conditions had the greatest impact in stimulating the behavioural indicators of positive emotions and reducing the behavioural indicators of negative emotions. These weaner pigs - based findings deviate from European Commission (2016) guidance on enrichment materials for pigs, in which straw and silage were classified as optimal materials for rooting purposes, and peat as sub-optimal.

Pigs in all conditions, including the control condition, received sawdust twice daily in accordance with Norwegian requirements for provision of bedding and rooting material (Norwegian Ministry of Agriculture and Food, 2003). In all conditions, the pigs directed much more exploratory behaviour towards material on the floor rather than manipulatory behaviour towards the ears and tail of littermates. Nevertheless, pigs in the control condition showed the lowest levels of positive behaviours and the highest levels of negative behaviours. This finding most likely reflects the lower total volume of sawdust given, coupled with provision of the sawdust half an hour earlier than the other materials. Thus, in the "after" observation period when the other

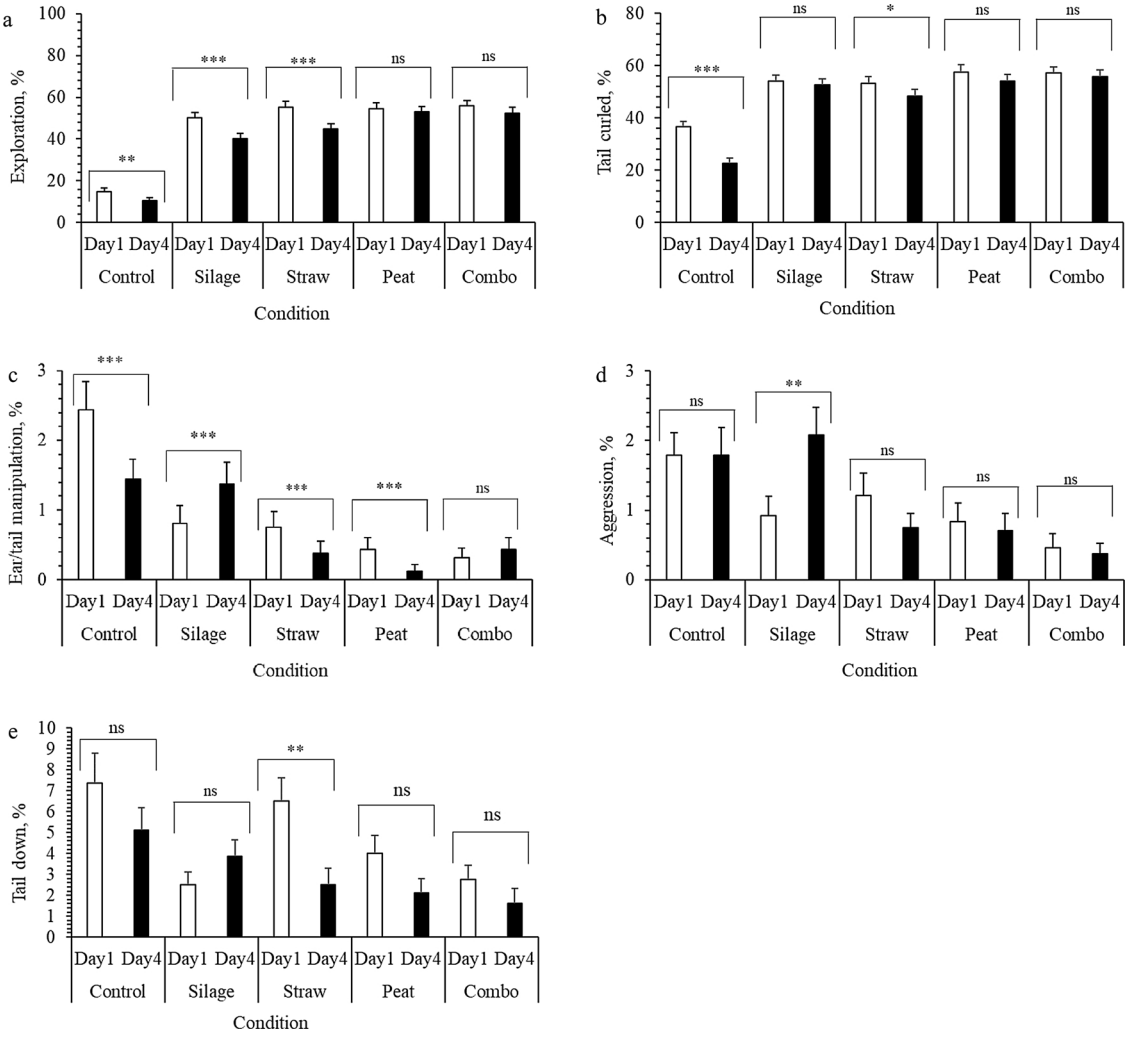

Fig. 3. Effect of interaction between day of week (1 vs 4) and condition on mean ± SE % of observations of behaviour. (a) Exploration, (b) Tail curled, (c) Ear/tail manipulation, (d) Aggression, (e) Tail down. Combo = silage + straw + peat. Tukey Honestly Significant Differences: $P > 0.05^{ns}$, $P < 0.05^{*}$, $P < 0.01^{**}$, $P < 0.001^{***}$.

Table 6
Associations of sex, bodyweight, litter size and week with positive and negative behavior.

Behaviour	Sex (mean ± SE % of observations)				Bodyweight, kg		Litter size, n		Week (1 − 5)	
Positive	♀	♂	$F_{(1, 1543)}$	P	$F_{(1, 1543)}$	P	$F_{(1, 1543)}$	P	$F_{(1, 1543)}$	P
Exploration	42.8 ± 1.2	43.5 ± 1.3	0.2	0.633	0.0	0.872	8.8	0.003	12.7	< 0.001
Play	1.9 ± 0.1	1.7 ± 0.1	1.2	0.278	0.9	0.352	0.5	0.480	129.1	< 0.001
Tail curled	51.0 ± 1.0	47.5 ± 1.2	2.1	0.148	0.0	0.905	1.1	0.298	3.4	0.649
Tail wagging	14.3 ± 0.7	16.0 ± 0.8	0.6	0.447	0.3	0.570	6.5	0.011	52.8	< 0.001
Ear/tail manipulation	0.9 ± 0.1	0.9 ± 0.1	0.0	0.982	9.9	0.002	0.0	0.965	0.0	0.888
Aggression	1.0 ± 0.1	1.1 ± 0.1	0.3	0.561	1.2	0.279	0.2	0.699	0.5	0.476
Tail down	2.8 ± 0.3	4.9 ± 0.5	5.5	0.019	0.4	0.617	8.8	0.003	0.4	0.564

pigs were being stimulated to explore by the addition of fresh rooting material, the control pigs' interest in the sawdust was waning. This is illustrated by a reduction, rather than increase, in exploration, play and curled tails in the "after" vs "before" observation period. Ear/tail manipulation was typically directed towards resting pigs (consistent with Telkänranta et al., 2014), which may explain why this behaviour persisted in the "after" period in the control condition. Aggression and tail down declined from "before" to "after" in the control condition, which probably reflects an increase in resting, as we typically observed aggression when pigs were active, and tail position was only recorded in active pigs.

Although all pens received fresh sawdust twice daily during pen cleaning, there was still a substantial effect of adding fresh rooting materials half an hour later in the other four conditions (for a total of four daily exposures to fresh material). These findings support our hypothesis that repeated stimulation with fresh material is beneficial for promoting positive welfare and minimizing undesirable behaviour. Our study design does not answer the question of whether providing additional fresh sawdust at the same volume and timing as the rooting materials investigated would have had similar beneficial effects.

We observed less exploring and tail wagging in the silage condition than in the straw, peat and combo conditions (less by 4.8 %, 8.6 % and 8.8 %, respectively), as well as more ear/tail manipulation. Furthermore, silage did not stimulate play or reduce aggression

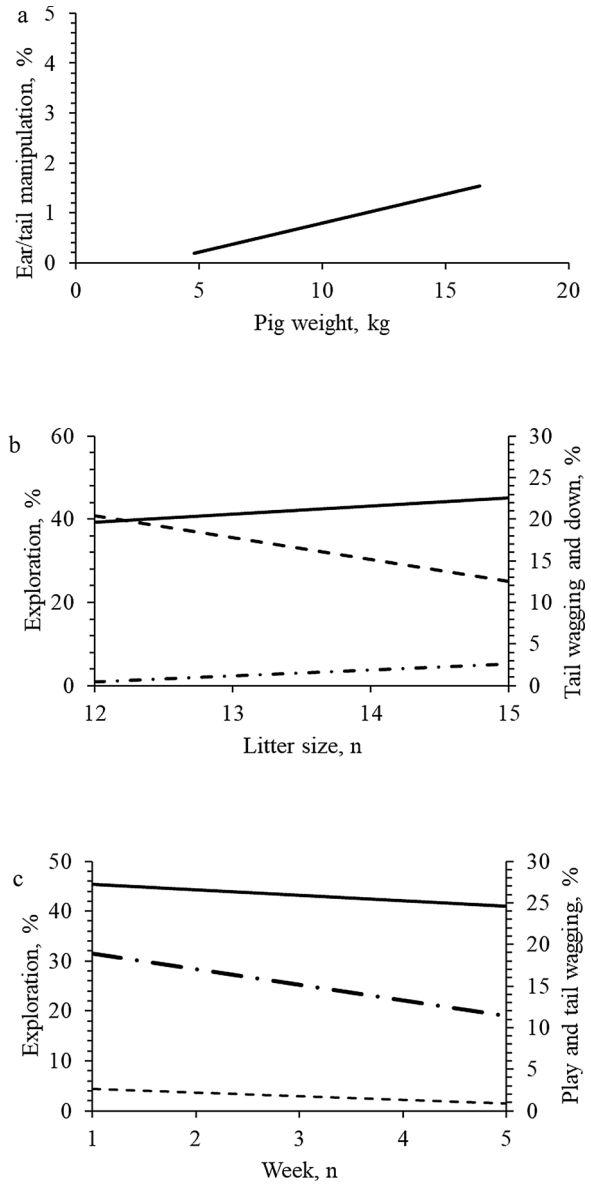

Fig. 4. Associations of bodyweight, litter size and week with mean ± SE % of observations of behaviour. (a) Bodyweight and ear/tail manipulation ($P = 0.002$). (b) Litter size and exploration (——; $P = 0.003$), tail wagging (– –; $P = 0.011$) and tail down (– · –; $P = 0.003$). (c) Week and exploration (——; $P < 0.001$), play (– –; $P < 0.001$), and tail wagging (– –; $P < 0.001$).

compared to the control condition, and it was associated with an increase in ear/tail manipulation and aggression from Day 1–4. Thus, it appears that the silage was a less effective source of rooting enrichment than the straw or peat in the current study. It is possible that the silage was eaten more than the other materials that we provided and, therefore, available for less time as a rooting material. Our findings differ from those of Jensen and Pedersen (2007), who observed more manipulation of maize silage mixed with chopped barley straw, or peat, than straw alone. Furthermore, aggression was lower in their silage condition than in their peat and straw conditions. We provided timothy rather than maize silage, and long-stemmed oat straw rather than chopped barley straw, which may explain different findings. However, their findings for scampering are comparable to those for our aggregated play category, with peat and straw being more effective in stimulating play than silage.

The straw and peat conditions were similarly effective in controlling negative behaviours, consistent with other reports (e.g. Schrøder-Petersen and Simonsen, 2001). These findings are important because, when pigs lack sufficient attractive rooting materials, such as when kept in a barren environment, given only indestructible, inedible objects such as tyres or chains, or infrequently supplied with rooting material (Bracke et al., 2006; Scott et al., 2009; Van de Weerd and Day, 2009; Statham et al., 2011), they are more likely to manipulate the ears and tails of penmates, a precursor to injurious ear and tail biting (Taylor et al., 2010). While the prevalence varies widely, tail injuries, in particular, can affect over 20 % of slaughter pigs even if tail docked (van Staaveren et al., 2017; vom Brocke et al., 2019), and have been associated with reduced weight gain (e.g. 25 % reduction after being severely bitten, Wallgren and Lindahl, 1996). Biting injuries remain a serious welfare problem as they are a source of acute pain and provide a route for infection, which can lead to long-term suffering and considerable economic loss (Sonoda et al., 2013; D'Eath et al., 2016). Given the beneficial effects detected in our study, longer-term cost-benefit analysis of repeated daily provision of rooting materials is warranted. Furthermore, while we followed best practices for pig management by avoiding the stress of mixing pigs at weaning, we recognise that it would also be useful to evaluate the effectiveness of repeated rooting material provision in buffering mixing stress.

We predicted that behavioural differences would be most pronounced when providing a combination of the three rooting materials (silage, straw, peat) by accommodating a greater variety of behavioural elements. However, our data showed no differences in behavioural frequencies between the peat and the combo conditions. Both were more effective than straw or silage alone in stimulating exploration and play, suggesting that it was the peat component of the combo condition that was most important in stimulating positive behaviours. The absence of further benefits from the combo condition is consistent with Guy et al. (2013), who found no increase in overall time spent investigating enrichment materials when presented in different paired combinations. The level of aggression detected in the combo condition did not differ significantly from that in the peat condition and was lower than that in the silage and straw conditions. This finding indicates that, although each type of material comprised only one-third of the total volume of combo material delivered, this did not stimulate aggressive competition for access to more preferred material types. Given that the continued use of peat may be curtailed in future due to environmental sustainability concerns, our results suggest that its use in combination with other materials could be one method for reducing peat use while retaining its benefits for pig welfare.

As predicted, more positive and fewer negative behaviours were observed in the 30 min period after than the 30 min period before addition of rooting material, with positive behaviours being stimulated especially when peat or combo were provided. The pigs also showed similar interest in exploring and playing on Day 1 and 4 in the peat and combo conditions, whereas these behaviours declined in the other conditions, strengthening evidence that the peat and combo materials had better qualities as rooting material than straw or silage alone. Provision of peat or peat in combination with silage and straw may, thus, result in the most pleasure for pigs as well as the lowest levels of ear/tail manipulation and aggression. A caveat to the use of organic enrichment materials, including peat, is the potential for contamination with pathogens such as *Mycobacterium avium* (Johansen et al., 2014; Wagner et al., 2018), indicating the importance of biosecurity when handling and storing enrichment materials, and regular monitoring for pathogens and other health threats (van de Weerd and Day, 2009).

There were some associations of sex, bodyweight and litter size with behaviour, but these variables were not consistently associated with positive or negative behavioural expressions. Increased bodyweight and declining free space may explain declining exploration, play and tail wagging with increasing age.

5. Conclusions

Although all pigs received fresh sawdust bedding twice daily throughout this study, we detected benefits from supplying fresh rooting materials two additional times daily, for a total of four daily exposures to fresh material. Overall, giving silage, straw, peat, or a combination of peat, straw and silage, resulted in more positive, and less negative, behaviour in weaned pigs than was observed in the control condition (no added rooting material). No conclusion can be made about sawdust, specifically, as it was present in all pens and we did not include a condition with sawdust added as a rooting material. Of the rooting materials added, the peat and combo conditions were more effective than silage and straw conditions in stimulating positive behaviours and reducing negative behaviours in the 30 min after providing the materials, and in retaining the interest of the pigs across days of exposure. Results of this study did not indicate a consistent improvement in pig welfare from simultaneously providing a combination of silage, straw and peat vs providing peat alone.

Declaration of Competing Interest

None.

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