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How do different amounts of straw as well as compost in the home pen affect the rooting motivation of growing-finishing pigs?

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A B S T R A C T

Rooting is a strongly motivated, species-specific behaviour of pigs. Most housing systems do not provide appropriate materials that enable the full expression of this behaviour, and it remains unclear whether straw is suitable to entirely fulfil the rooting motivation of pigs. We therefore investigated the suitability of small (minimal) and large (deep) amounts of straw as well as large amounts of compost to satisfy rooting motivation in pigs. Fifty-seven growing-finishing pigs were housed in three pens, each providing permanent access to one of the three treatment substrates. Eight pigs per group were tested individually in a classical preference test (**PT**) and another eight pigs in a conditioned place preference test (**CPPT**). In the tests, pigs could show their preference to consume freely available feed (“feed”) or feed hidden in sawdust (“root”). In the CPPT, feed was only present during training but not during testing. Pigs were exposed to the test situation twice, with approximately 72 kg and 115 kg BW. In both tests, the following variables were measured and used as outcome variables in linear mixed effect models: first decision to choose one of the two stimuli (“feed” or “root”), duration of time spent in proximity to “root”, number of changes between stimuli, and latency to the first decision. Overall, the pigs’ first decision (by tendency; $P = 0.076$) and the duration in proximity to “root” ($P = 0.034$) varied among treatments: Pigs housed with minimal straw tended to be more likely to choose “root” first (posthoc comparison; $P = 0.090$) and spent more time in proximity to “root” ($P = 0.030$) than pigs housed with compost, whereas pigs housed with deep straw were intermediate. Interestingly, the patterns of response to the treatment differed depending on the behavioural tests for both, first decision (interaction; $P = 0.032$) and duration in proximity to “root” (interaction; by tendency; $P = 0.006$). In addition, pigs in the PT changed more often between stimuli than pigs in the CPPT ($P < 0.001$). There was a tendency for an interactive effect between test and treatment for latency to first decision (interaction; $P = 0.082$), though pairwise comparisons did not reveal any differences. We concluded that in this study housing with permanent access to compost satisfied rooting motivation in pigs more than housing with minimal amounts of straw.

Implications

Pigs are highly motivated to root, but in most housing systems, they do not have access to suitable rooting materials. We investigated how much pigs’ rooting motivation is reduced when they are housed with permanent access to small (minimal) or large (deep) amounts of straw or to large amounts of compost. In two different test approaches, pigs’ behaviour indicated that compost is better suitable to satisfy their rooting motivation compared to minimal straw, while deep straw had intermediate effects. More research is needed to evaluate our findings in a broader context to ameliorate the environmental enrichment in pig housing systems and thus, improve animal welfare.

Introduction

Pigs living in a natural or semi-natural habitat spend up to around 60% of the time during daylight performing foraging behaviour (Stolba and Wood-Gush, 1989). Foraging behaviour includes a variety of behavioural components such as exploration, manipulation, grazing or chewing, as well as rooting. While foraging behaviour represents the appetitive part of this behavioural complex, feeding - effectively ingesting feed components - represents the

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consummatory part. Rooting is shown during about 20% of the active time and makes up around 40% of the total foraging behaviour (Stolba and Wood-Gush, 1989). Rooting is a species-specific behaviour pigs are highly motivated to perform (Day et al., 1995; Studnitz et al., 2003). The behaviour consists of searching and digging in the ground with the snout. It not only fulfils feeding purposes but is an important way of exploring the environment (Studnitz et al., 2007). Studies have shown that pigs root even if fed *ad libitum* and with a diet covering their nutritional needs (Beattie and O'Connell, 2002; Knoll et al., 2021). These results indicate that their behavioural need for rooting should be satisfied by providing them with suitable material, eliciting such behaviour irrespective of the time spent eating (Beattie and O'Connell, 2002).

In intensive housing, growing-finishing pigs are kept in a low-stimulus environment, without the possibility to perform natural foraging behaviour. They often show behavioural problems such as chewing and biting on bars and other metal objects as well as the ears and tails of pen-mates (Terlouw and Lawrence, 1993; Van de Weerd et al., 2005). The provision of rooting materials has been shown to be effective to provide an opportunity to perform rooting behaviour and to reduce redirected exploratory and foraging behaviour, which are among the causes for tail biting in pigs (e.g., Beattie et al., 2001; Day et al., 2002; Larsen et al., 2018; Henry et al., 2021).

An appropriate rooting material should be "complex, changeable, destructible, manipulable and should contain sparsely distributed edible parts" (Studnitz et al., 2007). For instance, straw provided in sufficient quality and quantity enables pigs not only to root but also to manipulate, chew, and eat (Tuyttens, 2005). However, it is not clear which quantity of straw is necessary to satisfy the pigs' rooting motivation. The amount of straw needed to significantly decrease oral manipulations of pen mates has been investigated by Pedersen et al. (2014), without looking into the potentially underlying rooting motivation. Additionally, it remains unknown how suitable straw is in this respect in comparison with other materials. For example, an earth-like substrate such as compost might better meet the pigs' behavioural needs (Jensen and Pedersen, 2007; Studnitz et al., 2007; Ocepek et al., 2020) as it is moist, heavy and consists of various organic components and is thus more similar to the pigs' natural rooting substrate.

Our objective was to study whether permanent access to a pen area filled with deep straw or compost satisfies growing-finishing pigs' rooting motivation to a higher extent compared to permanent access to a minimal amount of straw. To do so, we assessed the rooting motivation of individual pigs in either a classical preference test (**PT**; e.g. Jensen et al., 2008) or a conditioned place preference test (**CPPT**; e.g. de Jonge et al., 2008). In PT, stimuli are presented simultaneously and thus, the animals might be influenced by the presence of the stimuli. In contrast, CPPT aims to train animals to associate a stimulus with a place, as indicated by e.g., a colour, pattern, side, or a combination. During the test itself, the animal then has to choose between the associated places without the presence of the stimulus. Given that the two tests are evaluating the pig's preference in presence versus in absence of a stimulus, we aimed to target both, appetitive and consummatory aspects of rooting motivation by using both PT and CPPT in our study.

We hypothesised that pigs with permanent access to compost would have the opportunity to satisfy their motivation to root and therefore, both in the PT and the CPPT, prefer freely accessible feed over the same feed hidden in sawdust (i.e., available only after performing rooting behaviour). In contrast, pigs provided with minimal amounts of straw in the home pen may not have sufficient opportunity to root and would therefore show a preference for hidden feed during the behavioural tests, allowing them to fulfil their need for rooting and exploration. We thus hypothesised that permanent access to compost (as well as *ad libitum* concentrate feed) would be better suitable to fulfil both the appetitive and consummatory aspects of foraging and feeding behaviour, whereas minimal amounts of straw (as well as *ad libitum* concentrate feed) would only satisfy the consummatory aspect. Assuming that pigs provided with deep straw would have the opportunity to root, though not in a preferred substrate, we expected that permanent access to deep straw would have an intermediate effect on rooting motivation. In addition, we evaluated whether PT and CPPT would lead to comparable results as both tests are used to evaluate preference but are likely to target different aspects of motivation. The main difference between those tests is the potential interference of reinforcers.

Material and methods

Animals and housing

We conducted an experiment from October to December 2021 at the Centre for Proper Housing of Ruminants and Pigs (ZTHT) in Tänikon, Switzerland. We used 57 pigs (purebred Swiss Edelschwein) from eight different litters. All male piglets were castrated at 7 (± 1) days of age with isoflurane anaesthesia and pain medication. Tails and teeth were left intact. When pigs aged on average 75.6 days (min–max: 57–77 days) and weighed on average 29.6 kg (min–max: 21–37 kg), they were transferred to three growing-finishing pens with an indoor and a permanently accessible outdoor area. One of the pens was smaller than the other pens. To keep stocking density identical across treatments, two pens housed twenty pigs each and the third pen housed seventeen pigs. This resulted in a space allowance of 1.51 m^2 per pig indoors and 0.88 m^2 per pig outdoors in all three pens. Both indoor and outdoor areas consisted of solid concrete flooring, with one–third of the area equipped with concrete slats. Sex was balanced within the three groups (26 males and 31 females in total). All pigs received an individual ear tag and were individually marked with spray–painted patterns on their back. The ambient temperature in the pens was kept between 20 and 22 °C. The pigs were fed with the same dry feed (crumbles) throughout the entire fattening period. Feed (indoors in the activity/feeding area), water (indoors and outdoors), and roughage (hay in a rack; indoors in the activity/feeding area) were provided *ad libitum*. Pigs were weighed individually three times during the study period (at day 0, day 35, and day 70 of the study, Fig. 1).

Treatments

In a given pen, a rooting area (0.5 m^2 per pig) was filled with either a thin layer of unchopped, long straw (treatment "minimal straw"), a thick layer of unchopped, long straw (treatment "deep straw") or a thick layer of compost (treatment "compost"; Fig. 2). Given that one–third of the rooting area consisted of slatted concrete, a wooden board was installed to cover the slats. In the first pen ("minimal straw"), the straw was distributed sparsely on the ground of the rooting area, not covering it completely. In the second pen ("deep straw"), the rooting area was filled with a straw layer of approximately 20 cm. In the third pen ("compost"), we provided green waste compost with a depth of 20 cm in the rooting area. The green waste was obtained from a conventional composting plant and consisted of garden and forest waste (no domestic waste or kitchen scraps). The rooting area was refilled regularly (approximately once per week) in order to keep the amount of material constant. As the pigs kept the rooting area clean and mostly used the outdoor area to defecate, no cleaning of the pens was necessary throughout the experiment. The compost rooting area dried out quickly; therefore, we watered the compost rooting

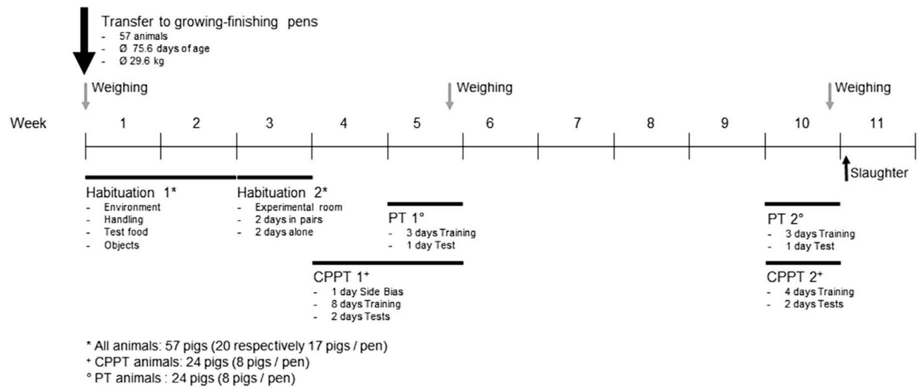

Fig. 1. Timeline showing the experimental procedures during the study period including weighing of pigs, habituation phase and test sessions. CPPT = Conditioned place preference test, PT = preference test.

Fig. 2. Picture of the indoor area including the rooting area of the three experimental pens for growing-finishing pigs. The material in the rooting area was either a minimal layer of straw (picture A), deep straw (picture B), or compost (picture C). Concentrate feed was provided *ad libitum* outside of the rooting area.

area with a hose approximately once per week. The pigs used the rooting area also as a lying area, and additional unperforated flooring was available to meet the Swiss minimum requirements regarding space allowance in the lying area up to the end of the experiment (0.6 m^2 per pig up to 110 kg live weight). Overall, the pens provided 0.5 m^2 rooting area, 0.6 m^2 solid concrete, and 0.4 m^2 slatted concrete per pig indoors and 0.88 m^2 per pig outdoors.

Behavioural tests

Habituation

During the 1st 2 weeks after placement in the growing-finishing pens, the pigs stayed in their home pens to adapt to the new environment, the trainers, and the pen mates (Habituation 1; Fig. 1). The trainer entered all three pens on a daily basis, approaching the pigs with the voice first and then with hand contact on the back. Gradually, objects like a wooden board or feed troughs were introduced to the animals to prepare them for training and testing. In this phase, several feed items were given to the pigs to determine which one was suitable to be used for the training for the behavioural tests. Hay pellets, apple slices, corn pellets, and dry pasta were offered to the pigs at different times of day, and observations were made regarding the animals' interactions with these feed items. Hay pellets, apple slices, and dry pasta seemed to be most attractive, whereas the pigs' interest in corn pellets was ambiguous. We first decided to use the hay pellets due to ease of provision, but had to replace them after 4 days of training in session 1 with apple slices, as hay pellets turned out not to be attractive enough to motivate pigs to participate in the tests. Hence, for the remaining training days and all test days in session 1 as well as during training and test days in session 2, apple slices were used as feed.

In the following week, 16 pigs per group were trained to be moved to the experimental room and the test setting (Habituation 2; Fig. 1). The pigs were led from the home pens to the experimental room with the help of a wooden board, which they were previously accustomed to, and were then led back to their pen. This procedure was first conducted with pairs of pigs on 2 days, and then with single pigs on 2 consecutive days. The habituation procedure was performed before session 1 only.

General test settings

We conducted two different types of tests: PT with eight pigs per pen and CPPT with eight other pigs per pen. When moved to the experimental pens, all pigs were numbered and the first 16 pigs were used for the experiment. The remaining pigs stayed in the pens and were not used for the experiments. Testing was conducted with individual pigs. Each test was conducted twice with the same eight pigs for PT and other eight pigs for CPPT at a 5−week interval (Fig. 1). The first test session took place in weeks 4–5 (session 1; growing period) and the second session in week 10 (session 2; finishing period). The tests were carried out in an experimental room adjacent to the room with the three home pens. Both tests were conducted during the same weeks, CPPT being done in the morning and PT in the afternoon.

The experimental room consisted of an anteroom (95 × 386 cm), which gave access to two side-by-side test chambers (425 × 193 cm each). The total floor area consisted of slatted floor and was cleaned up after every pig to avoid visual or olfactory influence. A camera was installed in the experimental room (directly above the anteroom and entrance to the chambers) so that the pigs could be observed without disturbance on a screen from an adjacent room. All observations were performed directly by the same observer, and all pigs were moved into the experimental room by the same helper.

In both test approaches, pigs had to choose between two stimuli: feed freely accessible (“feed”) or feed hidden in sawdust (“root”). The stimuli were provided in wooden feed troughs (50 cm long × 50 cm wide × 12 cm high). We chose sawdust as material to hide the feed items because it was unfamiliar to all pigs.

Conditioned place preference test

The duration of the first training and testing session for the CPPT was 11 days: 1 day to test side bias, 8 days of training, and 2 days of repeated testing. Each pig was trained and tested (side bias, CPPT) on each day. To assess a possible side bias (Fig. 3, top left drawing), each pig was observed in the experimental room for 5 min, with both test chambers being freely accessible and no stimuli present (based on the procedure in de Jonge et al. (2008)). The first decision for one side was recorded.

On days 2–9, the pigs were moved through the anteroom and into one of the two test chambers for 3 min per day, while the other chamber remained closed (Fig. 3, top middle drawing). On these days, the pigs were trained to associate a side (left or right) in combination with a colour (blue or yellow) with one of the two stimuli (“feed” or “root”). The feed troughs were painted (i.e. labelled for the pigs) according to the assigned colour. In addition, the animals had to step across a metal board painted in the corresponding colour when entering one of the chambers. The side / colour / stimulus combinations were balanced among the pigs (two pigs per combination per treatment). Each side / colour / stimulus combination was presented on 2 consecutive days.

On days 10 and 11, the CPPT was carried out with each pig being tested on each test day. On test days, both test chambers including the coloured metal boards were accessible for 3 min (Fig. 3, top right drawing), but no stimuli were present in the feed troughs.

The second CPPT training and testing session was conducted similarly, although the side bias test was not repeated. As the CPPT was done twice on the same animals and the pigs were expected to still associate the side / colour with a given stimulus, the training phase for the second CPPT was shortened (4 days of training with each side / colour / stimulus combination presented on 1 day, 2 days of repeated testing; Fig. 1).

The observer was blind to the test situation as no stimulus was present in the chambers, but not to the treatment of the pig taking a test. The first chamber entered was considered to be the pig’s first decision. The latency to decision was measured from the moment the entire body of the animal was inside the anteroom until both forelimbs were in one of the chambers. The time spent in the respective chamber (“feed” or “root”) was recorded and considered as duration spent in proximity of a given stimulus to make it comparable across tests. A change between stimuli was recorded when the pig left one chamber, went through the anteroom, and entered the opposite chamber.

Preference test

For the PT, pigs were moved into the experimental room individually, where they had access to both stimuli (feed freely accessible and feed hidden in sawdust) simultaneously. Feed troughs were placed in the anteroom, next to each other with a gap of 50 cm without visual or physical barrier (Fig. 3, bottom drawings). To enhance association, feed troughs were painted blue or yellow and placed left or right consistently for each pig (side / colour / stimulus combinations balanced between pigs). Side bias was not tested for PT pigs as we assumed that the feeders were too close and the presence of the stimuli would overcome a potential bias. The two PT training and testing sessions were set up identically and had a total duration of 4 days each. Each pig was trained and tested on each day. For each session, the 1st 3 days were considered as training phase and the last day as test day. On this last day, pigs had – as during training days – access to both stimuli for 3 min and all four parameters were recorded similarly to the CPPT, i.e., the first decision, the latency to decision, the duration of stay at each trough and the number of changes from one trough to the other. Latency to the first decision was measured from the moment the pig entered the experimental room until its snout was over or in one of the troughs. Duration of time spent in proximity of a given stimulus (“feed” or “root”) was equal to the time the pig’s snout was over or in the respective trough. A change between troughs was recorded when the pig left one trough and positioned its snout over or in the other trough.

Statistical analyses

All statistical analyses were performed with the software R (R Version 4.2.2; R Core Team, 2022). Side bias and colour bias were tested with a binomial test on group level using the function “binom.test” from the package “stats”. Because participation in the side bias test at the beginning of the training phase for the CPPT was low (15 out of 24 pigs did not take a decision), we included all decisions taken during CPPT sessions for the analysis of the side bias. Colour bias was tested separately for CPPT and PT, including all decisions taken by the pigs during the tests. We then assessed for the CPPT whether participation (decision vs no decision) was affected by treatment, session, and test day using a generalised linear model with decision (yes / no) as outcome variable (binomial distribution with logit link function). Fixed effects were treatment (“minimal straw”, “deep straw”, “compost”), session (session 1: week 4–5, session 2: week 10), and test day (day 1, day 2). Based on the outcome, data points without a decision as well as data from test day 2 (where only a few pigs participated) were excluded for all further analyses.

The outcome variables of interest were: First decision (“root” or “feed”), duration in proximity to “root” and “feed” (i.e., the duration within a chamber or with the stimuli), number of changes between chambers (CPPT) or between stimuli (PT) and latency to first decision. As the duration in proximity to “root” was inversely related to the duration in proximity to “feed”, only the duration in proximity to “root” was further considered. Latency to the first decision was standardised to make it better comparable between the two types of test approaches. Models were calculated using the functions “blmer” or “bglmer” from the package “blme” (Chung et al., 2013). The fixed effects of the models were test (CPPT or PT), session, and treatment, including the two-way interactions between test and session and between test and treatment. Pig was included as random effect. Model assumptions (normal distribution of residuals, homoscedasticity) were checked and confirmed

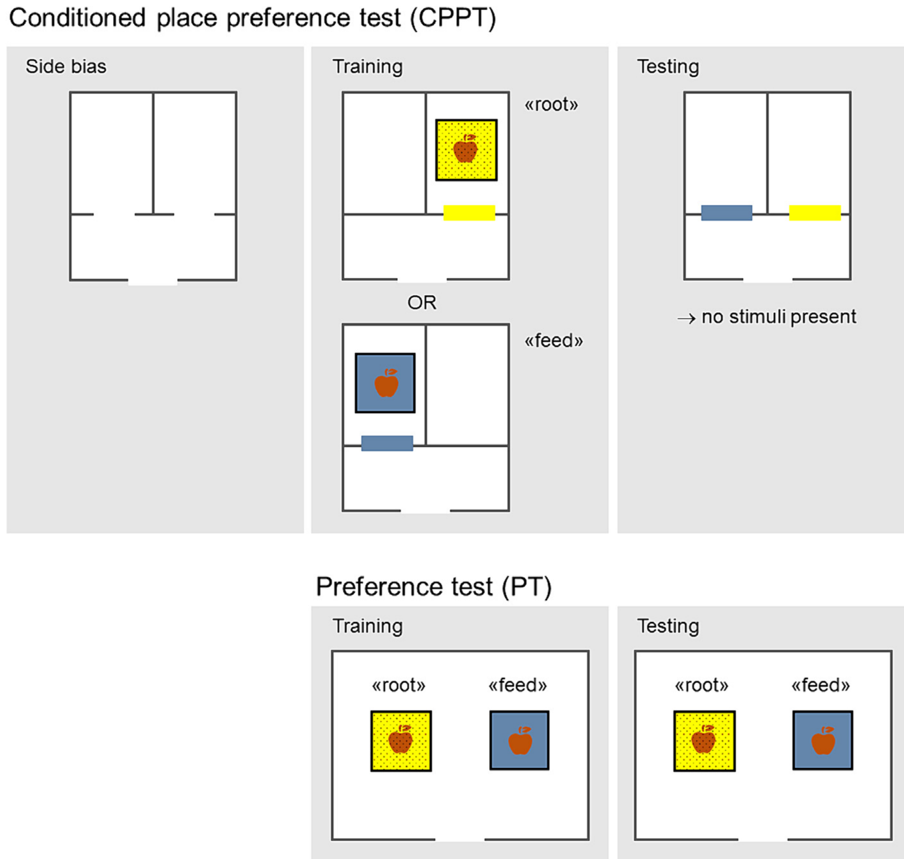

Fig. 3. Test setting used to assess a possible side bias, for training and in the testing phase of the Conditioned Place Preference Test (CPPT; above) as well as for training and in the testing phase of the Preference Test (PT; below). Stimuli were either apple slices provided directly in a trough ("feed") or hidden in sawdust ("root"). Colours (blue or yellow) and side allocation for stimuli are shown exemplarily and have been balanced across pigs.

through graphical analysis of residuals. The variable latency to first decision had to be log-transformed to meet model assumptions. We used dummy variables with sum contrasts for the tested factors and interactions. *P*-values were obtained by comparing the full model including all main effects and their interactions to models each reduced by one main effect or interaction. This procedure provides interpretable main effects, even in the presence of a significant interaction (Singmann and Kellen, 2019; Schad et al., 2020). The model comparison was performed using a parametric bootstrap approach with the function "mixed" from the "afex" package (Singmann et al., 2023). Model estimates and confidence intervals (CIs) for the full model were obtained with parametric bootstrap simulations (function "bootMer" in the package "lme4"; Bates et al., 2015). Posthoc tests were carried out if the model comparison revealed *P*-values < 0.1 for either a main effect or an interaction with more than two–factor levels. *P*-values for pairwise comparisons were adjusted using the Tukey method (function "emmeans" in the package "emmeans"; Lenth, 2023). We chose a significance level of α = 0.05 and interpreted *P*-values < 0.1 as tendencies (Wasserstein and Lazar, 2016).

Results

After the first and second test sessions, pigs weighed on average 72.2 kg (minimum–maximum: 51–86 kg) and 114.7 kg (minimum–maximum: 85–127 kg), respectively. No obvious side bias could be detected for the CPPT on group level (*P* = 0.165). Also, no colour bias was detected (*P* = 0.111 for PT; *P* = 0.652 for CPPT). Fewer pigs took a decision for one of the two test chambers within the 3–min test period of CPPT on day 2 compared to day 1 (*P* = 0.011). Across both sessions, in 4 out of 48 test situations (24 pigs tested twice: in sessions 1 and 2), pigs did not take a decision on day 1, while this was the case in 13 out of 48 test situations on day 2. As the number of pigs taking a decision in the CPPT was obviously reduced on the second test day, we decided to ignore day 2 in all further analyses. Slightly fewer pigs took a decision in session 2 compared to session 1 (36 decisions versus 43 per 48 test situations each; *P* = 0.046). In session 1 on day 1, 23 (out of 24) pigs took a decision, in session 2 on day 1 it was 21 pigs. Treatment did not influence the likelihood that pigs took a decision (*P* = 0.203). In PT, all pigs in both sessions took a decision for one of the two stimuli.

Overall, treatment tended to affect the pigs' first decision (*P* = 0.076; Table 1; Fig. 4): Pigs housed with minimal straw were more likely to choose "root" first than pigs housed with compost (posthoc comparison; *P* = 0.090). In addition, pigs showed different patterns of responses to the treatment depending on the test (interaction treatment * test; *P* = 0.032; Fig. 5). In the PT, pigs housed with minimal straw were by tendency more likely to choose "root" first than pigs housed with deep straw (posthoc comparison; *P* = 0.065).

The duration in proximity to "root" varied by treatment (*P* = 0.034; Table 1; Fig. 4). More specifically, pigs housed with minimal straw spent more time in proximity to "root" than pigs housed with compost (posthoc comparison; *P* = 0.030). However, an interactive effect of treatment and test indicated that different patterns between treatments emerged among tests (*P* = 0.006; Fig. 6). Whereas in the PT, pigs housed with compost spent less

Table 1
Results of mixed effect models and pairwise comparisons for outcome variables proportion of first decision to "root" vs "feed", duration in proximity to "root", number of changes between chambers or stimuli, and latency to first decision. N=8 pigs per treatment (minimal straw, deep straw, compost) and test (CPPT, PT). Overall n = 48 pigs, tested twice each. Contrasts are shown between treatments and for the interaction of treatment and test.

	First decision			Duration in proximity to "root"			Number of changes			Latency to first decision		
Overall effect	P[1]			P[1]			P[1]			P[1]		
Treatment	0.076			0.034								
Treatment * Test	0.032			0.006						0.082		
Pairwise comparison	Est.[2]	SE	P	Est.	SE	P	Est.	SE	P	Est.[3]	SE	P
Treatment												
Compost – deep straw	−1.30	0.96		−26.1	14.2		0.07	0.37		−0.19	0.20	
Compost – minimal straw	−2.26	1.07	0.090	−36.8	14.1	0.030	−0.07	0.37		−0.01	0.20	
Deep straw – minimal straw	−0.96	0.97		−10.7	14.2		−0.15	0.37		0.18	0.20	
Treatment * Test												
CPPT: Compost – deep straw	0.86	1.32		17.1	20.4		0.08	0.54		−0.44	0.29	
CPPT: Compost – minimal straw	−2.30	1.45		−30.9	20.2		−0.09	0.53		−0.45	0.29	
CPPT: Deep straw – minimal straw	−3.17	1.60		−47.9	20.4	0.057	−0.16	0.54		−0.01	0.29	
PT: Compost – deep straw	−3.46	1.55	0.065	−69.3	19.7	0.003	0.06	0.52		0.06	0.28	
PT: Compost – minimal straw	−2.22	1.41		−42.8	19.7	0.086	−0.06	0.52		0.43	0.28	
PT: Deep straw – minimal straw	1.24	1.30		26.6	19.7		−0.12	0.52		0.37	0.28	

Abbreviations: Est. = Estimate, CPPT=Conditioned place preference test, PT=Preference test.
[1] P-values for the main effects test and session as well as their interaction are not presented here. P-values are only presented for $P < 0.10$.
[2] Estimates for the variable first decision are shown as log odds.
[3] Estimates for latency are based on standardised values on a logarithmic scale.

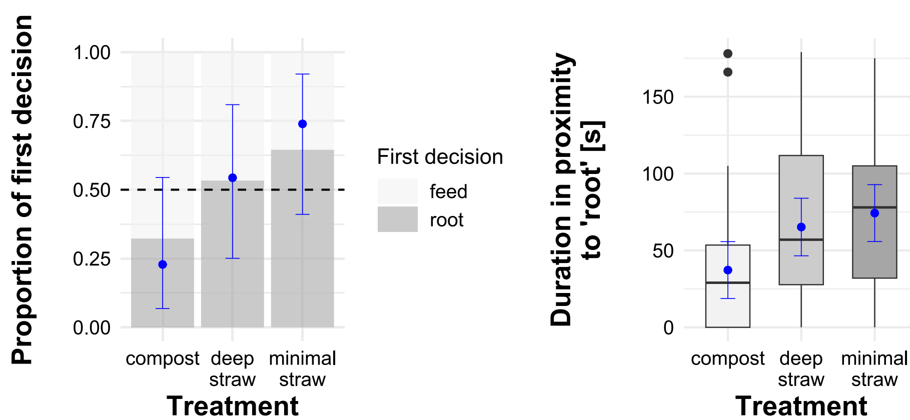

Fig. 4. Left: Proportion of first decision to "root" (dark grey) and "feed" (light grey) for pigs housed with compost, deep straw, and minimal straw. Blue dots and whiskers indicate estimated means and estimated 95% confidence intervals. The horizontal, dotted line indicates the proportion of first decision to "root" vs "feed" that would be expected by chance. Right: Duration of time spent in proximity to "root" (s). Boxplots show medians, interquartile, and absolute ranges. Blue dots and whiskers indicate estimated means and estimated 95% confidence intervals. Each boxplot comprises 32 data points: n = 16 pigs per treatment covering both tests, tested twice each.

time in proximity to "root" than pigs housed with deep straw (posthoc comparison; $P = 0.003$) and pigs housed with minimal straw ($P = 0.086$), in the CPPT, "minimal straw" pigs spent more time in proximity to "root" than "deep straw" pigs ($P = 0.057$).

Pigs in the PT changed between stimuli more often than pigs in the CPPT, irrespective of treatment, and thus had a higher number of changes (test; $P < 0.001$; Fig. 7).

Latency to the first decision tended to vary among tests and treatments (interaction treatment * test; $P = 0.082$; Table 1; Fig. 8). Nevertheless, no differences in pairwise comparisons could be shown.

Discussion

In this study, we aimed to assess the rooting motivation of growing-finishing pigs housed with permanent access to different rooting substrates using two behavioural tests. Overall, we found a pattern indicating that pigs housed with compost had the lowest preference for rooting as expressed as a lower proportion of pigs with first decision "root" and the shortest duration in proximity to "root". In contrast, pigs' preference for rooting (first decision, duration in proximity to root) was higher when housed with minimal straw. In addition, the PT and the CPPT did not yield identical though potentially complementary results.

Rooting motivation

The finding that "compost" pigs had a lower preference to root than "minimal straw" pigs is according to our hypothesis that pigs housed with compost could satisfy their behavioural need to root in their home pens appropriately and thus, would prefer freely accessible feed during the behavioural tests. Multiple underlying mechanisms could be involved and should be discussed in this context.

First, our findings could have been influenced by treatment differences in the pigs' motivation to feed. This would have been the case if pigs with access to straw had ingested larger amounts of this material compared to pigs with access to compost, resulting in a larger satiety and thus a lower motivation to feed compared to the motivation to root. However, all pigs were fed *ad libitum*

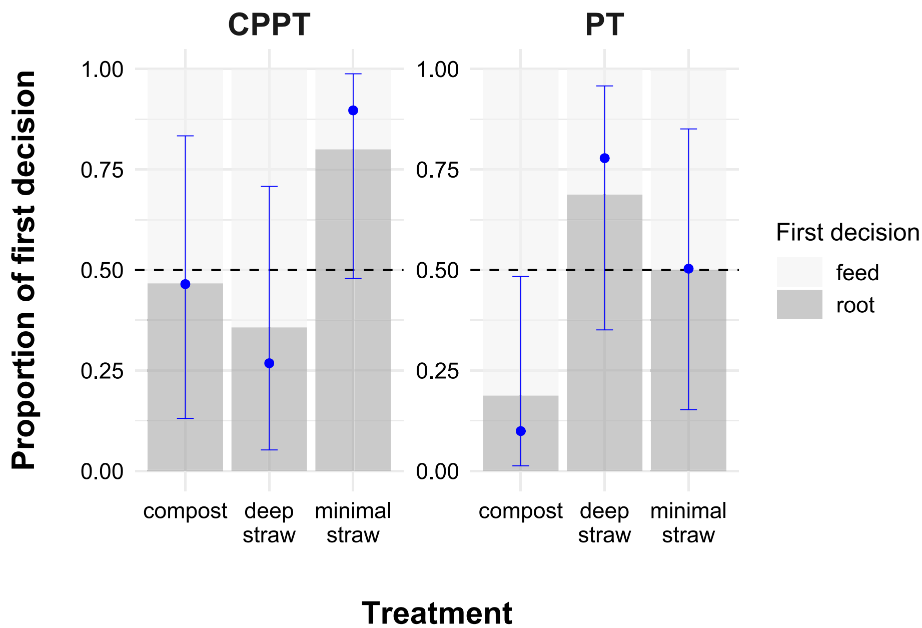

Fig. 5. Proportion of first decision to "root" (dark grey) and "feed" (light grey) in the Conditioned Place Preference test (CPPT) and the Preference Test (PT) for pigs housed with compost, deep straw, and minimal straw. Blue dots and whiskers indicate estimated means and estimated 95% confidence intervals. The horizontal, dotted line indicates the proportion of first decision to "root" vs "feed" that would be expected by chance. Each boxplot comprises 16 data points: n = 8 pigs per treatment, tested twice each.

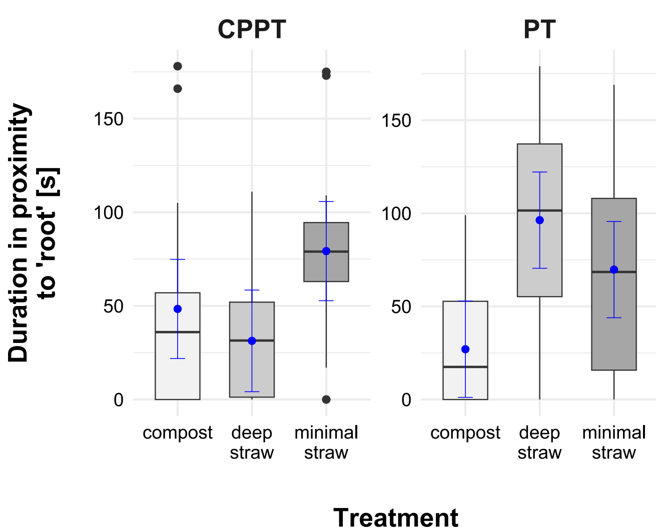

Fig. 6. Duration of time spent in proximity to "root" (sec) in the Conditioned Place Preference test (CPPT) and the Preference Test (PT) for pigs housed with compost, deep straw, and minimal straw. Boxplots show medians, interquartile, and absolute ranges. Blue dots and whiskers indicate estimated means and estimated 95% confidence intervals. Each boxplot comprises 16 data points: n = 8 pigs per treatment, tested twice each.

with concentrate feed and hay in a rack, leading to the assumption that the satiety level was comparable across treatments.

Second, the phenomenon of contrafreeloading has been discussed in pigs previously (Young and Lawrence, 2003; de Jonge et al., 2008). Animals performing contrafreeloading prefer a resource that requires effort over the identical, but freely accessible resource. For instance, rats choose to press a lever to obtain feed even if the identical feed is provided in an open dish simultaneously (see Inglis et al. (1997) for a review). In the context of our study and given that rooting is a strongly motivated behaviour in pigs, rooting should be considered rewarding rather than effort or work and thus, contrafreeloading was assumingly not the underlying mechanism explaining our results. Instead, an experimental set-up where pigs must perform a task which is considered physical work without a rewarding component, e.g., opening a weighted gate or a push door, would be better suited to demonstrate contrafreeloading in pigs.

Third, in our experimental set-up, we aimed to distinguish between preference for rooting and preference for feeding. We treated these options as if rooting and feeding were behaviours that would occur in an isolated way. Nevertheless, rooting and feeding are behavioural components of foraging behaviour (Stolba and Wood-Gush, 1989; Studnitz et al., 2007) that occur in sequence, and thus cannot be regarded separately. Given that "root" in our experiment involved hidden feed rather than just the rooting material, rooting eventually resulted in feeding. Hence, when pigs chose "root" over "feed", they did not necessarily prefer one behaviour over another, but rather the opportunity to perform a behavioural sequence (rooting and feeding) over a single component (feeding) of foraging behaviour. Future studies including a stimulus where pigs can root only (e.g., sawdust without feed) could contribute to a better understanding of rooting motivation as a single component of foraging behaviour.

Fourth, foraging is a behavioural complex involving both, appetitive and consummatory behaviours (Toates, 1998). In our behavioural tests, feeding gave the opportunity to satisfy the consummatory aspect of foraging. In contrast, rooting is an appetitive behaviour which ultimately leads to the consummatory behaviour of feeding, i.e., the goal state. As a result, while feeding elicits positive feedback such as "liking" (or not), rooting with its appetitive nature represents "wanting" (or not) and thus, the motivation to reach the goal state (see Gygax (2017) for a detailed evaluation of "wanting" and "liking" to understand proximate behavioural control). Nevertheless, as pigs also root in the absence of nutritive feedback (Beattie and O'Connell, 2002), rooting itself may represent the goal state and thus, elicit the positive feedback of "liking".

Overall, the motivation to root as a component of foraging behaviour is high in pigs, and providing compost seems to have satisfied the pig's behavioural need for rooting better than minimal straw, while the treatment "deep straw" was ambiguous. In addition to

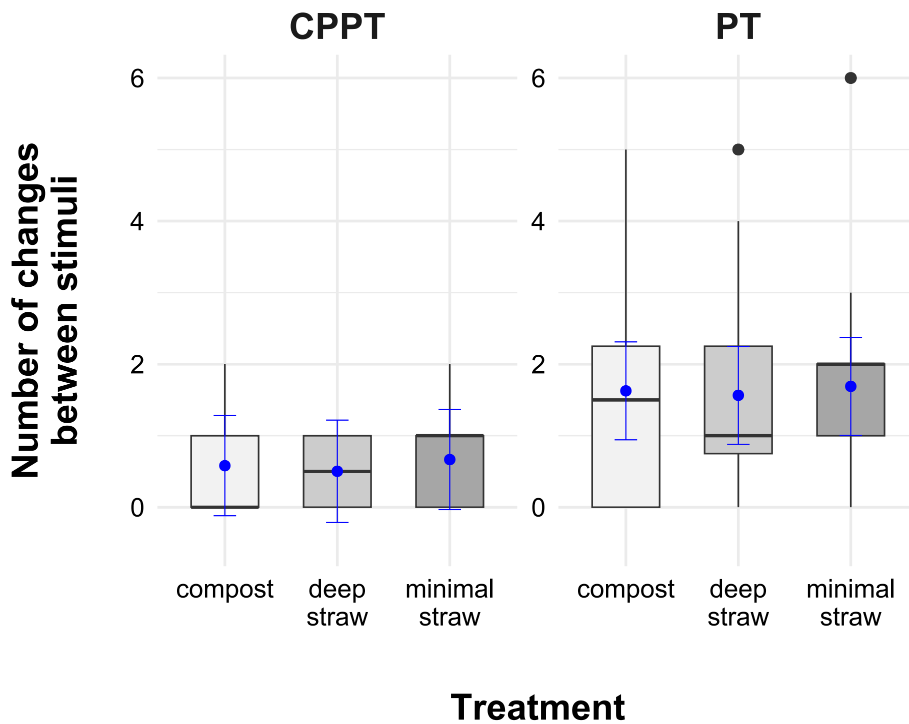

Fig. 7. Number of changes between chambers or stimuli in the Conditioned Place Preference test (CPPT) and the Preference Test (PT) for pigs housed with compost, deep straw, and minimal straw. Boxplots show medians, interquartile, and absolute ranges. Blue dots and whiskers indicate estimated means and estimated 95% confidence intervals. Each boxplot comprises 16 data points: n = 8 pigs per treatment, tested twice each.

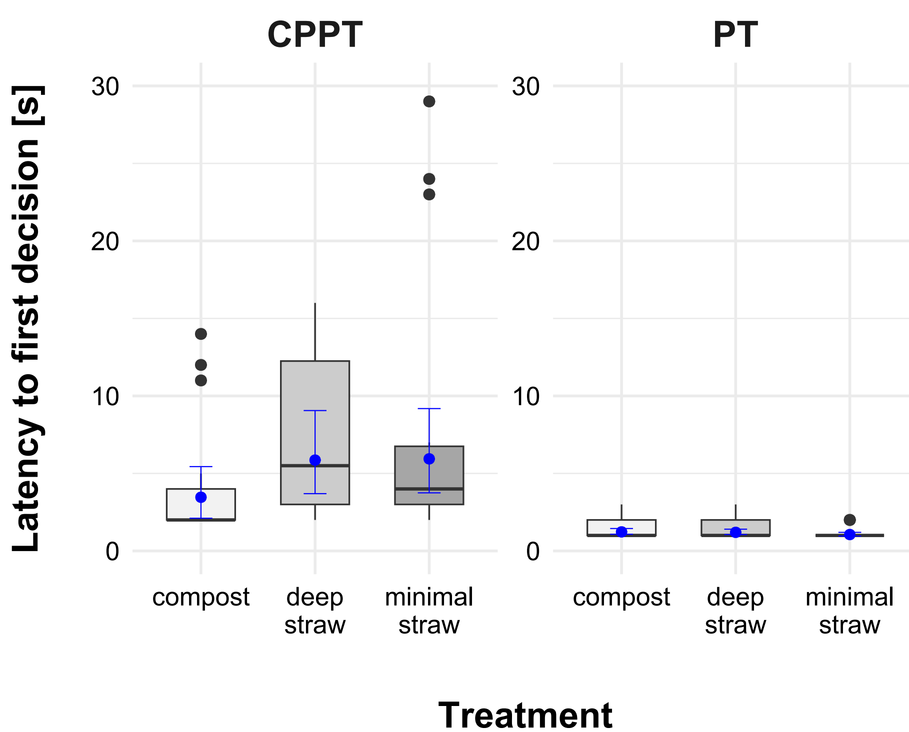

Fig. 8. Latency to first decision (s) in the Conditioned Place Preference test (CPPT) and the Preference Test (PT) for pigs housed with compost, deep straw, and minimal straw. Boxplots show medians, interquartile, and absolute ranges. Blue dots and whiskers indicate estimated means and estimated 95% confidence intervals. Each boxplot comprises 16 data points: n = 8 pigs per treatment, tested twice each.

conducting behavioural tests, assessing behaviour in the home environment might help gaining a better understanding of the motivation to perform foraging behaviours, because the presence of a given resource such as a rooting area does not necessarily imply that the target behaviours (here: rooting) were expressed in the home pen. As an example, providing rooting material could serve as environmental enrichment resulting in better cognitive performance (Sneddon et al., 2000) rather than satisfying rooting motivation, which could have affected test outcomes.

Behavioural tests

When discussing rooting and feeding as components of foraging behaviour, it is important to mention that the two applied behavioural tests are likely to measure different aspects of motivation or preference, too. While pigs in the PT had direct access to both stimuli during training and tests, pigs in the CPPT were trained to associate a location with a stimulus and were tested for their expectancy of a stimulus during the test day. Given that the expression of rooting and feeding is likely to be affected through reinforcers such as feed, the PT might rather test the preference for performing a specific behaviour (resulting in the goal state, i.e., "liking") rather than the motivation to do so (performing a behaviour towards the goal state, i.e., "wanting"). In contrast, the CPPT is a concept initially used to assess affective properties and motivational effects in drugs (Bardo and Bevins, 2000; Tzschentke, 2007; Prus et al., 2009) or reinforcing events (White and Carr, 1985). Hence, it is possible that we assessed "wanting", i.e., the motivation to root as expressed by the first decision for one of the stimuli and the duration in proximity to the stimulus, in both tests but "liking", i.e., the preferred occupation, only in the PT.

Pigs of the same treatments responded to the tests differently in our study. Whereas the shorter latency and the higher number of changes between stimuli for PT pigs could be explained with proximity of the feed troughs (no anteroom) and easy changes between "root" and "feed", the different patterns for the first decision and duration of proximity to "root" among treatments in the CPPT versus PT are more difficult to explain. Overall, pigs housed with compost showed a lower rooting preference than pigs housed with minimal straw across both tests, but the ambiguous results for pigs housed with deep straw seem inconclusive and need further study.

Thus, regarding the suitability of the behavioural tests to capture motivation, a validation would be necessary, especially for the CPPT. It would be crucial to evaluate whether the pigs have actually learned the association of colour, side and stimuli. It can be assumed that sides (right / left) are more easily associated with a stimulus than colours. In a next step, pigs could be trained, for example, to associate colours with stimuli while changing sides during training days. If pigs repeatedly choose the same stimulus and this choice remains consistent even after reversal learning, it can be assumed that there is indeed a preference (repeated same choice), and that the association has been learned successfully (reversal learning). Regarding repetitive test scenarios for recording the consistency of decisions, it should be considered that participation in the CPPT decreased on the second test day without stimuli. Huston et al. (2013) have previously described this extinction effect in the context of repeated CPPT. Intermittent training days or the use of partial reinforcement could avoid frustration and reduce the extinction effect (Bouton et al., 2014).

Preference tests in general give an indication of the relative preference between two or more choices. In our case, both PT and CPPT were supposed to reflect the relative motivation to display rooting or feeding behaviour. However, both tests neither allow for an assessment of absolute motivation for these behaviours nor for the strength of the motivation because both options or stimuli were freely available. In order to assess the strength of motivation, so−called consumer demand tasks may be applied. In these tests, animals learn to work for a specific resource, e.g. by pressing a lever or pushing a door open. By varying the costs of access for one or multiple resources in comparison, a demand function can be obtained (Dawkins 1983, 1988). Future studies could apply such tests to assess the strength of motivation pigs display to gain access to either feed or a rooting substrate with feed.

Applicability & implementation

Overall, we found indications that pigs housed with compost showed the lowest preference for rooting, whereas pigs' preference for rooting was highest in "minimal straw" and intermediate in "deep straw". Assuming that unsatisfied rooting motivation can be redirected to pen mates and barn furnishings, this finding is in accordance with Pedersen et al. (2014), who found that pigs manipulated pen mates less the more straw was provided. Similarly, Beattie et al. (2001) have shown that pigs with access to mushroom compost displayed less pen mate−directed behaviours and less pigs had tail lesions. Hence, providing compost (or possibly deep straw) could better satisfy rooting motivation compared to only small amounts of straw and thus, prevent redirected exploratory and foraging behaviours such as tail biting.

Nevertheless, we cannot conclude whether compost could completely satisfy rooting motivation. For this purpose, observations in the home pens (e.g., time budget analysis) and a comparison with the behaviour of pigs in semi-natural environments would be needed. Furthermore, our study has low external validity due to missing replicates and thus, results can only be interpreted within the context of our experimental setup. We cannot exclude that specific factors in the pigs' social environment such as dominant individuals might have affected our results. The chosen approach as well as the results may be the basis for future studies investigating appropriate enrichment materials for pigs.

Ethics approval

An ethical approval for the experiment was obtained from the Veterinary Office of the Canton of Thurgau in Switzerland (approval number TG06/2021, national number 33930). All procedures were in compliance with the Swiss regulations regarding the treatment of experimental animals.

Data and model availability statement

Data and R-script used for the analyses are publicly available here: https://zenodo.org/records/10001336.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) did not use any AI and AI-assisted technologies.

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Declaration of interest

None.

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