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Rooting for feed: Mixing corn pellets into rooting material tends to increase the presence of grower and finisher pigs in the rooting area but not its cleanliness

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A R T I C L E I N F O

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A B S T R A C T

Exploratory behaviour is an essential part of the behavioural repertoire of pigs. Providing pigs with a rooting area filled with appropriate material enables such behaviour and is therefore considered to improve animal welfare. Managing the hygiene of a rooting area, however, is often challenging when pigs use it also for elimination. Mixing corn pellets into the rooting material could increase use and exploration while reducing elimination behaviour. To investigate this hypothesis, we constructed rooting areas filled with compost produced from garden waste in four pens on a commercial organic farm. We compared two experimental pens (E) with rooting areas filled with compost, in which we mixed 2 kg of corn pellets every morning, with two control pens (C, rooting areas filled with compost only). The experiment started in October 2019 and lasted 34 weeks with seven replicates in total. Group size ranged between 21–35 pigs (N = 386). We registered behaviour once a week through direct observations of the complete outdoor area and additional video recordings of the rooting area. Behavioural variables of interest were activity status (*i.e.* standing/sitting or lying), rooting, agonistic and play behaviour. We assessed cleanliness of the rooting material *via* visual scoring and chemical analysis of compost samples. The latter included tests on dry matter content, conductivity, and ammonium concentration. Data were analysed with linear mixed-effects models. Results showed that there was a tendency for a higher total number of pigs in the rooting area in E than in C ($p = 0.06$). In E, more pigs were lying in the rooting area than in C ($p = 0.04$). There was no difference between treatments in rooting behaviour. In addition, the overall use of the outdoor run did not differ between treatments. Time of day influenced all recorded behaviours in the rooting area ($p < 0.001$). With increasing temperature, more pigs were present in the outdoor run ($p < 0.001$) and in the rooting area ($p < 0.01$) for both treatments. Conductivity and ammonium concentration in the compost increased the longer the compost remained in the rooting area ($p < 0.001$), but there was no difference between the two treatments. We conclude that mixing corn pellets into rooting material increases the use of the rooting area by heightening the overall presence of pigs in it but not its cleanliness.

1. Introduction

Exploration is an intrinsic behavioural need in pigs involving rooting, sniffing, chewing and manipulation of numerous items (reviewed by Studnitz et al., 2007). Rooting is characterised by digging, grubbing and scooping with the snout, raking with the forelegs and chewing or gnawing items turned up by these activities (Stolba and Wood-Gush, 1989). The goal of rooting behaviour is to find feed resources and to explore novelties (reviewed by Studnitz et al., 2007). Providing pigs with rooting material enables them to perform species-specific

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behaviours such as rooting, foraging or resting. Conversely, when pigs cannot perform rooting behaviour in a satisfying way, for example due to a barren environment, the risk of damaging behaviours, for instance ear and tail biting or manipulation of pen structure, increases (Jensen et al., 2010). Therefore, an environment that allows pigs to root in appropriate material is expected to enable species-specific behaviour and thereby improve their welfare.

The EU-regulation Council Directive 2018/848/EC for organic agriculture obligates farmers to provide pigs with permanent access to an outdoor area. However, it only specifies minimum space requirements and that the exercise area permits dunging and rooting without specific details regarding the overall design. In practice, a typical outdoor area for organic growing-finishing pigs often consists of a barren area with partially slatted floors, which is mainly used for elimination, therefore meeting only one of the two requirements according to the EU regulation (Früh et al., 2014; Olsson et al., 2014). Although some straw might be present, generally, no specific rooting area is demarcated in the outdoor run.

According to Studnitz et al. (2007) rooting material should be "complex, changeable, destructible, manipulable, and contain sparsely distributed edible parts" to keep the pigs interested. Straw, which is often provided indoors as bedding material in organic pig production, contributes to fulfilling the pigs' need for rooting (van de Weerd and Day, 2009). However, soil-like materials such as compost or peat are clearly preferred by pigs to root in if given the choice (Beattie et al., 1998; Pedersen et al., 2005; Jensen et al., 2008). To make the rooting area even more attractive, Olsson et al. (2016b) scattered feed pellets on top of peat in the rooting area, but this did not affect pigs' general activity (not lying (standing /sitting/walking) or lying). On that basis we hypothesize that instead of distributing corn pellets on top of the surface, it might be better to mix them into the rooting material to stimulate rooting behaviour of pigs.

While it has been shown that rooting areas make the outdoor run more attractive to pigs and contribute to overall cleanliness of the outdoor area (Vermeer et al., 2015; Olsson et al., 2016a), knowledge is lacking on the design of such areas to ensure "good functioning" *i.e.*, being used by the pigs for exploratory but not for elimination behaviour. This is important since a soiled area is positively correlated to higher ammonia emissions (Aarnink et al., 1996) and could result in health problems (*e.g.* endoparasite accumulation). Previously identified factors for a "good functioning" rooting area are the height of surrounding walls, size of the area and type of rooting material. Olsson et al. (2016a) concluded that one wall of 1.0 m high, coupled with walls of 0.3 m high in combination with an area of 0.525 m^2/pig (compared to 0.33 m^2/pig) resulted in the lowest soiling scores. In addition, the authors mentioned the importance of a roof to prevent rain from entering the area.

Olsson et al. (2016b) described, that properties of the rooting material, such as pH and moisture level, influence ammonia emissions from rooting areas and therefore concluded that peat is suitable and wood shavings are not suitable as rooting material. Although peat appears to be a good rooting material due to its high ammonia-binding capacity (Kemppainen, 1987), it has some disadvantages. Peat excavation is associated with large negative environmental impacts, *e.g.* on water systems (Winkler and DeWitt, 1985) and emission of greenhouse-gases (Boldrin et al., 2010). Locally produced compost from short-term crops and vegetation is more favourable regarding emissions (Boldrin et al., 2010) and has similar earth-like characteristics as peat. It therefore seems to be a valid alternative to peat. Mixing feed into the compost may additionally raise the attractiveness for pigs ensuring a "good functioning" of the rooting area.

The main objective was to study the effects of mixing corn pellets into rooting material on the use and cleanliness of the rooting area in organic growing-finishing pigs under commercial organic conditions.

2. Animals, materials and methods

2.1. Farm and housing

We conducted the experiment on a commercial pig farm certified under the organic label Bio Suisse (2020) in the Swiss canton of Aargau. Within this farm, we used four pens with pigs born and raised on this farm. The pig barn was an uninsulated building with natural ventilation. All pens had the same dimensions with an indoor (42.90 m^2) and an outdoor area (31.75 m^2). The indoor area consisted of a feeding area (20 % of indoor area) with partially slatted floor (25 % of the feeding area) for elimination behaviour, a straw-bedded lying area (70 % of indoor area), another slatted area which could be opened to remove manure (5% of indoor area) and a solid area close to the openings to the outdoor area (5% of indoor area). Each outdoor area had a partially slatted floor at the opening to the indoor area (12 % of the area) and at the far end of the outdoor area (18 % of the outdoor area), both for elimination. A roof covered 50 % of the outdoor surface (Fig. 1).

In all four pens, we constructed rooting areas on solid floors under the roofed part of the outdoor run with a total area of 9.2 m^2 (3.4 × 2.7 m, length × width), covering about 30 % of the outdoor area. We used the pen partition as one wall (1 m high). Together with the two sides of the rooting area (50 cm high), it prevented displacement of rooting material while one side (25 cm high) functioned as the entrance to the rooting area. We filled all rooting areas with 2 m^3 compost from a regional source, that was produced by composting green waste, grass and branches from private households and horticultural companies for eight weeks, heated to 65 °C as part of the composting process, and sieved. Every two weeks, we added 0.240 m^3 of fresh compost to each rooting area. Throughout the experiment, we completely replaced the compost three times in all pens when it was too dirty (score 3 for three consecutive weeks; see below) and considered not suitable for rooting anymore. The compost remained in the pen for 12 weeks on average (range 8–14 weeks). Compost was replaced in all pens approximately at the same time within a range of two weeks.

2.2. Pigs, feeding and treatment

In total, 386 pigs (Swiss Large White and Swiss Large White x Duroc crosses, barrows and gilts) took part in the experiment in groups of 21–35 animals ($\tilde{x} = 29$). Group size was balanced for experimental and control groups and depended on the availability of weaners from the breeding unit. Feeding was identical for both treatments and consisted of dry feed provided *ad libitum via* dispensers indoors, at which eight pigs could eat at the same time. The crumbled feed in the finishing period consisted of wheat, triticale, barley, field beans, peas, potato protein and soy cake (order according to decreasing percentages). Four nipple drinkers per pen, located indoor close to the lying area, provided water *ad libitum*. Every morning, the farmer provided fresh straw and hay indoors and cleaned the outdoor area. The experimental treatment consisted of the daily provision of corn pellets mixed into the rooting material. The pellets consisted of whole-plant silage with a diameter of about 0.5 cm and a length of 2 cm. We chose to investigate this type of feed as it was locally available on the farm but not too expensive and therefore suitable for future use. Two pens (pen 1 and 3, Experimental: E), where the farmer distributed 2 kg of corn pellets in the rooting area every morning, were compared with two pens (pen 2 and 4, Control: C) without provision of corn pellets. In the experimental pens, the farmer scattered and mixed the corn pellets into the rooting material during cleaning using a hoe at around 09:30 h. In the control pens, the rooting material was also raked to provide the same stimulus for all groups. The corn pellets were provided to pigs before the start of the trial, and it had been observed that pigs searched for the pellets and consumed them.

Growing pigs were housed in pens 1 and 2 ("grower pens") from a live weight of approximately 35–60 kg and were then moved to pens 3 and 4 ("finishing pens") for the finishing period (60–105 kg). To keep

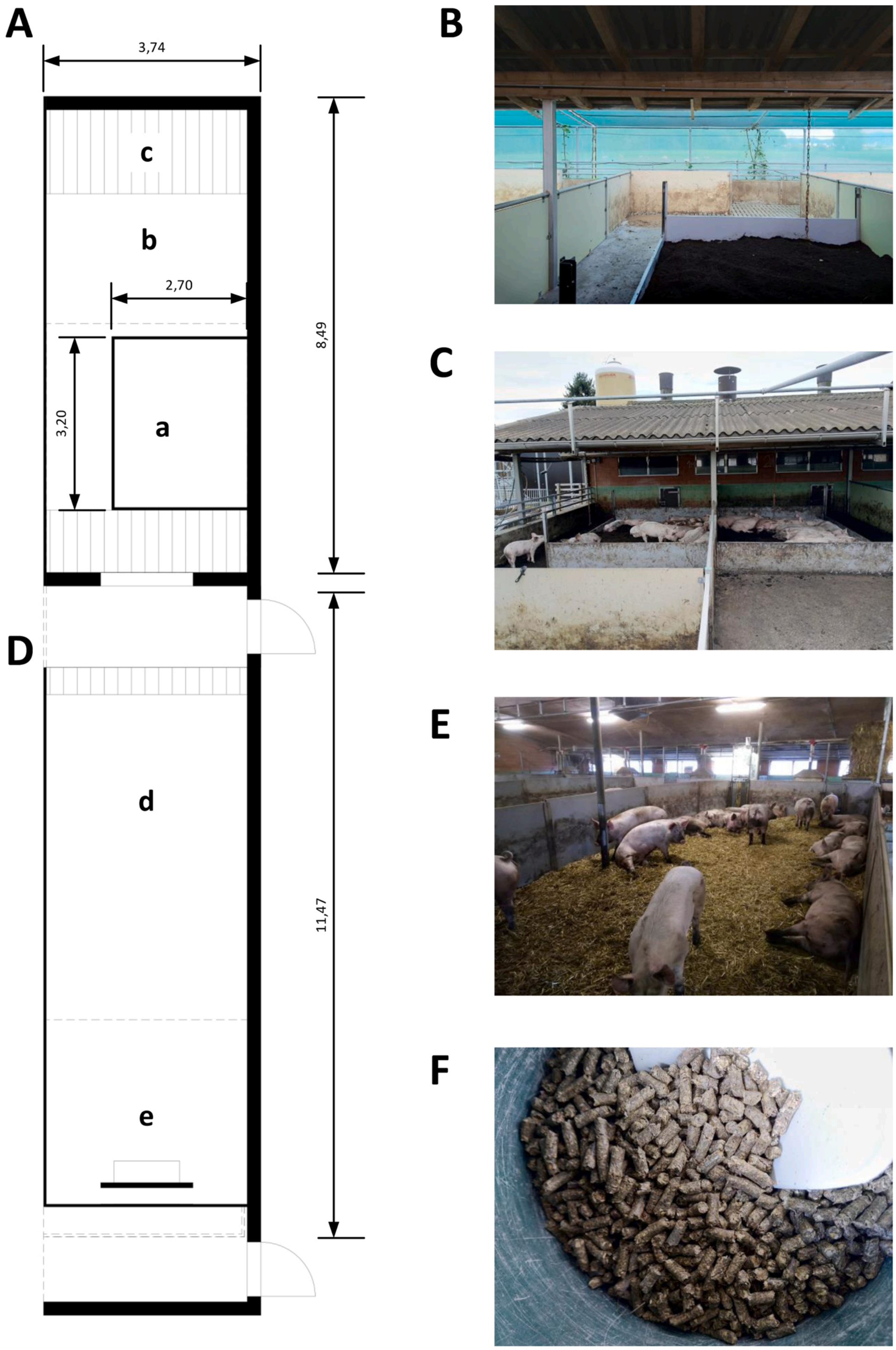

Fig. 1. Illustrations of pen design: Layout of the outdoor run (A) with roofed rooting area (a), solid floor (b) and slatted floor (c). View of the general structure of the outdoor area (B) and the perspective of the observer when assessing two pens simultaneously (C). Layout of the indoor area (D), with lying (d) and feeding area (e), and view of the indoor lying area (E). Corn pellets used as treatment in the experiment (F).

the treatment consistent, animals of pen 1 were relocated to pen 3 and groups of pen 2 were moved to pen 4. On average, each group stayed in the experiment for 10 weeks. Four groups were in the experiment only during half of their fattening time: The two finishing groups at the start were only assessed during their finishing period and the two growing groups at the end of the experiment only during their growing period. The experiment started in October 2019 with four groups of both weight categories. In total 14 groups were included in the experiment over 34 weeks, resulting in seven replicates per treatment. The pigs were slaughtered between 100−110 kg live weight. The pigs did not receive anthelmintics as the farm had no problems with endoparasites.

2.3. Data collection

2.3.1. Pig behaviour and location

For the first half of the experiment, two alternating observers conducted direct behavioural observations in the outdoor area once a week from approximately 10:00 h (after the pens had been cleaned) to 15:00 h to record location and activity status of the animals. After 14 weeks, we conducted an interim analysis after which we decided to reduce direct observations to a biweekly rhythm. The observers were trained through live and video observations before the start of the experiment. They performed two inter-observer-reliability tests from video material prepared for this purpose. The overall intraclass correlation for behavioural observations was 0.68 and the observer agreement with a tolerance of one was 89 %. After the tests, the agreement was further trained and improved on the farm and repeatedly verified by observing simultaneously during the assessment period. Due to the Covid-19 pandemic, we had to stop direct observations for 1.5 months so that four weeks of direct observations of four groups are missing.

For direct observation, we divided the outdoor run into three different zones according to floor type and assumed functional areas (Fig. 1, A). This included the rooting area (a), activity area (solid floor; b) and elimination area (slatted floor; c). We will refer to activity and elimination area combined as concrete area. Before starting a round of direct observation, the observer waited for two minutes in front of the two pens giving the animals a moment to realise, that the observer is there and thus to standardize the human influence. One observation round started with one scan sample for two neighbouring pens (grower pens, or finishing pens, respectively (Fig. 1, C), followed by ten minutes of continuous observation of the focal pen, and ended with another scan sampling for both pens. The sequence of focus pen observations was randomized prior to a specific observation day. Within a scan sample, the outdoor area was scanned successively for three classes of behavioural states within a minute as presented in Table 1. In a first step, the number of active and lying animals in each zone was recorded, followed by counting the number of animals rooting in the rooting area. Finally, numbers of pigs showing oral manipulations towards pen structure, floor, substrate manipulation outside rooting area and nosing of pen mates were registered. A pig was considered to be in either the rooting, activity or elimination area, if at least the head and front legs were within one of these areas. The 10 min continuous observation was focused on different behavioural events. We recorded the following behaviours: locomotor (hop, pivot, run, toss head) and object play (shake and carry object), agonistic (fight, head knock, bite, displacement from rooting area) and manipulation of pen mates (manipulation of feed, legs, ears or tails). We counted the frequency of events. A new event from the same pig was only counted if the behaviour was not shown for at least 30 s. Per observation day and pen, three continuous behavioural observations (total 30 min) and twelve scan samples were taken. Pigs were not individually marked.

Additionally, behaviour of the pigs in the rooting area was recorded by one camera in each pen once a week for 14 h from 6:00 h to 20:00 h. Video recordings solely focussed on the rooting area while direct observations had the objective to assess the use of the complete outdoor run by pigs. The video recordings were analysed manually by one observer only for twenty seconds every ten minutes using the ethogram presented in Table 1.

Table 1
Ethogram for scan sampling. Within a scan sample, the outdoor area was scanned successively for three classes of behavioural states.

Behaviour	Description
Activity status (all pigs visible in the outdoor run)	
Active	Standing, walking, or running = Body supported by three or more legs Sitting = Body supported by one or two front legs (Ekkel et al., 2003).
Lying	Lying (active or inactive) on side or belly, body not supported by any of the legs, position not changed (Ekkel et al., 2003).
Rooting area related behaviour (active pigs in the rooting area)	
Rooting in the rooting area	Digging with snout or chewing on parts of the material provided in the rooting area
Oral manipulation behaviour	
Pen structure manipulation (active pigs)	Nose or mouth in contact (sniffing, touching, sucking, rubbing or chewing) with pen structure: walls, bars (Beattie et al., 2000; van de Weerd et al., 2006).
Floor directed manipulation outside the rooting area (active pigs)	Nose or mouth in contact (sniffing, touching, sucking or rubbing) with the floor.
Substrate manipulation outside rooting area (active pigs)	Rooting, nosing, or displacing the compost spread on the concrete floor with the snout close to the substrate; with circular movements or movements along the substrate.
Nosing pen mate (all visible pigs)	Rubbing the body of pen mate with the snout, directed to back, shoulders belly of flank and around the soft tissue between the limbs in an active or lying position (van de Weerd et al., 2006; Trickett et al., 2009)

2.3.2. Pen soiling

The observers assessed pen soiling visually three times per farm visit (morning, noon, afternoon) from outside the pen. We ensured inter-observer reliability through training using comprehensive photo material. The calculated PABAK (prevalence-adjusted and bias-adjusted kappa) was on average 0.82. For the pen soiling score, we assessed the same zones in the outdoor run as for the behavioural observations. We applied a 3-point-scale for soiling of the rooting area considering wet and moist surface soiled with manure (score 1: $< 1/10$, score 2: $\geq 1/10$ & $< 2/3$, score 3: $\geq 2/3$ of the surface). For the concrete area (solid and slatted floor), we applied a 4-point scale considering the surface soiled with wet or dry manure (1= $< 1/3$ of the surface, 2= $\geq 1/3$ of the surface, 3= $\geq 2/3$ of the surface, 4= complete area heavily soiled with accumulation of manure that covers openings in slats).

2.3.3. Dry matter content, conductivity, and ammonium concentration of the rooting material

Every four weeks after the direct behavioural observations, we took 20 compost samples: one in each of the four corners and one in the middle of the rooting area from each pen. We conducted chemical analysis of the rooting material following the manual of 'educompost', a Swiss training institute for the recycling of organic materials (Fuchs et al., 2010). All measurements were related to the dry weight of the sample. We determined the dry weight by drying 200 g of the 20 fresh samples in a drying chamber for 24 h at 105 °C until the weight was constant. To get comparative values, we took three samples of fresh compost, each before changing the rooting material. The fresh compost had an average dry matter (DM) content of 59 % (CI = 56–61), conductivity of 1.14 mS/cm (CI = 0.89–1.42) and ammonium concentration of 2.25 ppm/l (CI = 1.33–3.18). The pH was only measured for the fresh compost and was on average 7.5 (CI = 6.78–8.2). One litre of each sample was taken for chemical analysis to determine conductivity from a water extract (1:10) and ammonium concentration from a 0.01 M $CaCl_2$ extraction (1:10). Conductivity is a measure for salt content in a solution whereby more salt means higher conductivity. We used it as an indicator for urine in the rooting material. The conductivity of the water extract was determined after filtration using a conductivity meter (FiveGo Cond meter F3, Mettler Toledo Switzerland, 8606 Greifensee, CH). After filtration of the 0.01 M $CaCl_2$ extraction, ammonium concentration was determined with an automated discrete analyser based on a modified Berthelot reaction (Smartchem 450 Discrete Analyser, AMS France, 95740 Frepillon, FR).

2.3.4. Additional measurements

Air temperature outdoors was continuously recorded every hour using a data logger located under the roof above the rooting area of Pen 2 (TinyTag Ultra 2, TGU-4500, Gemini Data Loggers, West Sussex, United Kingdom).

At every farm visit, we assessed the number of pigs with clinical indicators of tail biting like tail lesions (considerable swelling and/or fresh bloody tail lesions or dry crusts) and tail length (Short tail = more than 2/3 of the original length left but hairless tail tips; “Stumpy” tail = less than 2/3 of the original length left).

To assess the level of endoparasite burden throughout the trial, we took six incremental faecal samples for each group of pigs after introduction and just before leaving the pen and tested for endoparasites. We carried out the parasitological diagnosis of the samples through a quantitative egg count using a modified McMaster method. We used a $ZnCl_2$ solution (density 1.45 g/cm^3) as flotation solution and recorded *Ascaris suum*, *Trichuris suis*, *Strongyloides* spp, and *Eimeria scabra*.

Two animals died during the experiment before reaching slaughter weight: One in November, one in May, both four weeks into the fattening period. The cause of death could not be determined as no autopsy was performed.

2.4. Statistical analysis

We carried out statistical calculations with the statistical software R (version 4.0.2, R Core Team, 2020). We computed linear mixed-effects models with the command “lmer” of the package “lme4” (Bates et al., 2015). Fixed and random effects for each model are presented in Table 2. “Week” refers to week of the fattening period per group (1–14). Time of day was included as continuous variable for data from video observations (06:00 h – 20:00 h). For direct observations, we did not include time of day as the timeframe for data collection was shorter (10:00 h – 15:00 h). Temperature refers to the temperature measured at each observation. The chosen random effects reflected repeated measurements and dependency within group, pen, and date. We assessed assumptions of the models visually with respect to homogeneity of variance (Tukey Anscombe Plot), normality of residuals and random effects (Q-Q plots), and equal distribution of the residuals of each level of random effects (boxplots). If model assumptions were not met, we transformed outcome variables with square root, log or orderNorm transformation. For the variable “lying pigs in the concrete area” (direct observations) none of these transformations was successful. The variable was thus coded as binary and analysed using a generalized linear mixed model.

Table 2
Specification of statistical models with the used transformation as well as fixed and random effects of the final model. Treatment was a fixed effect in all models.

Outcome variables	Transformation	Fixed effects additional to treatment	Nested random effects	Crossed random effects
Video observations, scan samples (in proportion of all pigs in the group)				
Pigs in the rooting area	None	Week[a], time of day, temperature, treatment x week[a], treatment x temperature	Observation in week[a] in group	Pen and observation day
Active pigs in the rooting area	Square root			
Lying pigs in the rooting area	Square root			
Pigs rooting	Square root			
Direct observation, scan samples (in proportion of all pigs in the group)				
Pigs in the outdoor area	None	Week[a], temperature, treatment x week[a], treatment x temperature	Observation in week[a] in group	Pen and observation day
Direct observation, scan samples (in proportion of all pigs in outdoor area)				
Pigs in the rooting area	Square root	Week[a], temperature, treatment x week[a], treatment x temperature	Observation in week[a] in group	Pen and observation day
Active pigs in concrete area	Square root			
Lying pigs in concrete area	Binary			
Chemical analysis of the rooting material				
Dry matter content (%)	Ordered Quantile normalization	Sampling location, sample per compost period[b]	Sample in pen in compost period[b]	Pen
Conductivity (mS/cm)	Log-normal			
NH_4^+ (ppm/l)	Log-normal			

[a] Week of fattening period per group.
[b] Time the compost remained in the rooting area until exchange (three periods).

For model comparisons we used the function “PBmodcomp” from the package “pbkrtest”, which is a bootstrapping approach, since we considered the commonly used likelihood ratio tests as not suitable for the small sample sizes (Halekoh and Højsgaard, 2014). First, we compared the full model including all fixed effects to the zero model that contained merely the intercept. We only carried out further steps if this comparison resulted in a p-value of <0.05. To obtain single p-values for fixed effects or interactions, we compared models that were reduced by the effect or interaction of interest to the full model. We used dummy variables encoded as sum contrasts for factorial fixed effects. Using sum contrasts when comparing reduced models with the full model provides interpretable main effects, even in the presence of a significant interaction. We attained model estimates and corresponding confidence intervals through 1000 parametric bootstrap simulations with the function “bootMer” in “lme4” (Bates et al., 2015). Model estimates and confidence intervals are presented for the full models including all fixed effects and interactions.

For analysis of the behavioural data, we removed the first two weeks of Groups 3 and 4 due to faulty pen gates resulting in unstable group sizes during this time. From the video observations, we also removed the last two weeks of April of Group 11 in Pen 3 as it was unclear how many animals were in the pen due to miscommunications during the observation stop caused by the Covid-19 pandemic. For the chemical analysis, we removed two outliers for the analysis of DM content (91.7 and 41.6 % DM) and two for conductivity (2.7 and 2.3 mS/cm) because of their distorting influence on the residuals.

Behavioural variables from continuous direct observations were analysed descriptively because of their low occurrence. We categorized the variables locomotor play and object play into one variable “play” as well as fights, head knocks and displacement into one variable “agonistic”. Scores for pen soiling were analysed separately for each of the three zones with Chi-Square tests. We set significance level to $P < 0.05$. For concrete areas we transformed the 4- to a 3-point scale during data processing as score 4 was not recorded during the experiment.

2.5. Ethical considerations

This research was conducted in compliance with the Swiss animal welfare act, the animal welfare ordinance, and the animal experimentation ordinance. The responsible authority (Cantonal Veterinary Office, Aargau, Switzerland; permission No. 75732) has given its approval to the present study.

3. Results

3.1. Pig behaviour and location

Results from video and direct observations can be found in Table 3 and show that there was a tendency for a higher total number of pigs in the rooting area in E than in C. In E, more pigs were lying in the rooting area than in C. There was no difference between treatments in active animals and rooting behaviour in the rooting areas. Also, there were no differences between treatments regarding the overall use of the outdoor run, except for a tendency for more active pigs on the concrete area in E

Table 3
Model estimates and confidence intervals [in brackets] of analysed variables for the two treatments "experiment (E)" and "control (C)" as well as p-values for fixed effects and interactions. Total pigs refer to all pigs in the pen.

Variable	Model estimates [± CI]		P-values					
	C	E	Treatment	Week	Time of day	Temperature	Treatment x Week	Treatment x Temp
Video observations								
Proportion of pigs in the rooting area / total pigs	0.23 [0.15–0.30]	0.31 [0.23–0.38]	0.06	0.49	<0.001	<0.01	0.23	0.08
Proportion of active pigs in the rooting area / total pigs	0.04 [0.03–0.05]	0.04 [0.03–0.05]	1.00	0.02	<0.001	<0.001	0.26	0.68
Proportion of lying pigs in the rooting area / total pigs	0.10 [0.05–0.17]	0.18 [0.11–0.26]	0.04	0.32	<0.001	0.20	0.11	0.71
Proportion of rooting pigs in the rooting area / total pigs	0.03 [0.03–0.04]	0.03 [0.03–0.04]	1.00	0.11	<0.001	<0.001	0.50	0.32
Direct observations								
Proportion of pigs in the outdoor run / total pigs	0.39 [0.28–0.50]	0.39 [0.28–0.50]	1.00	0.23	–	<0.001	1.00	0.50
Proportion of pigs in the rooting area / pigs in the outdoor run	0.70 [0.58-0.83]	0.65 [0.53-0.78]	0.89	1.00	–	0.13	0.50	0.09
Proportion of active pigs on concrete / pigs in the outdoor run	0.05 [0.04–0.07]	0.07 [0.05–0.09]	0.07	0.02	–	<0.01	0.28	0.08
Proportion of observations with at least one lying pig on concrete	0.16 [0.07–0.30]	0.36 [0.21–0.56]	0.12	0.87	–	<0.001	0.24	0.14

than in C.

The pigs used the rooting areas throughout the whole experiment in both treatments; however, time of day had an effect on behaviour (active, lying, rooting) in the rooting area. Activity in general and specifically rooting behaviour was highest between 8:00h-12:00 h and 14:00h-18:00 h and lowest in the morning between 6:00h-7:00 h and in the evening between 19:00h-20:00 h (Fig. 2).

The average temperature in the outdoor run across the whole experiment was 9.3 °C (minimum: -3.5 °C, maximum: 29.7 °C). With increasing temperature, there were more pigs in the rooting area, irrespective of treatment. However, pigs were less active when it was warmer and showed less rooting behaviour (Table 3, Fig. 3). Overall, during the direct observations there were more pigs in the outdoor run, more active pigs on concrete, and more lying pigs on concrete in both treatments when temperature was high compared to lower temperatures (Table 3, Fig. 4).

The behaviours manipulation and play and agonistic behaviour during direct observations occurred infrequently in both treatments throughout the experiment and were therefore not analysed in a model. The median and maximum proportion of pigs per group showing the respective behaviour per scan were: Pen structure manipulation (E: Median 0, Maximum 0.1, C: Median 0, Maximum 0.1); Floor directed manipulation (E: 0; 0.2 C: 0; 0.1); Bedding / litter manipulation (E: 0; 0.1, C: 0; 0.2); Nosing pen mate (E: 0; 0, C: 0; 0.04). The median and maximum proportion of pigs per group showing the respective behaviour per 10-minute continuous observation were: Play (E: 0; 0.1, C: 0;

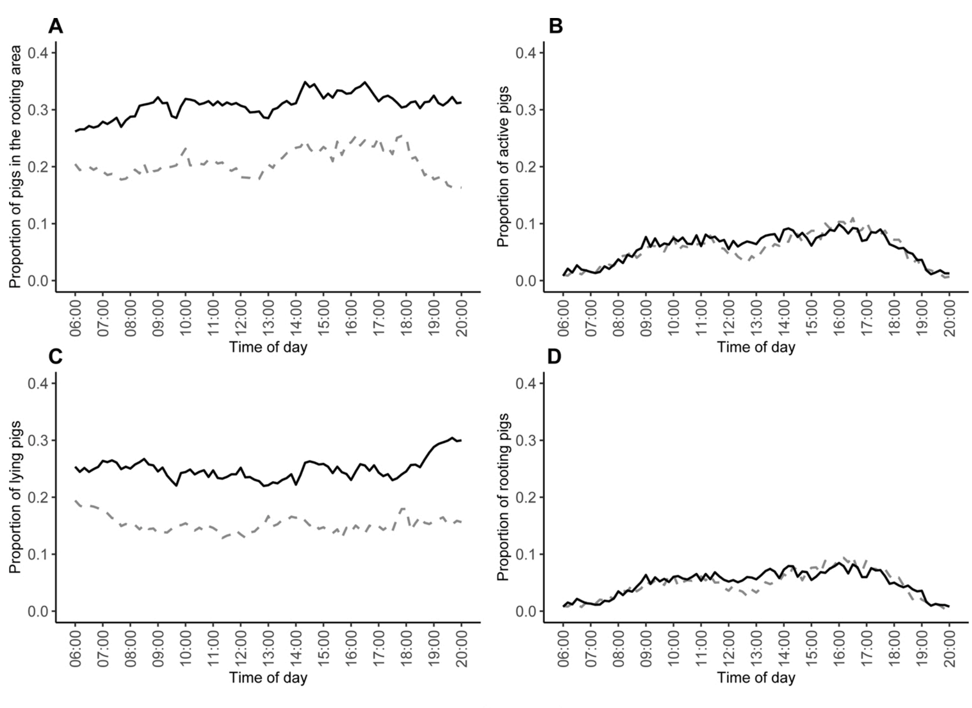

Fig. 2. Average proportion of total (A), active (B), lying (C) and rooting (D) pigs in the rooting area in intervals of 10 min assessed through video observations. Data is presented as proportion of total group size.

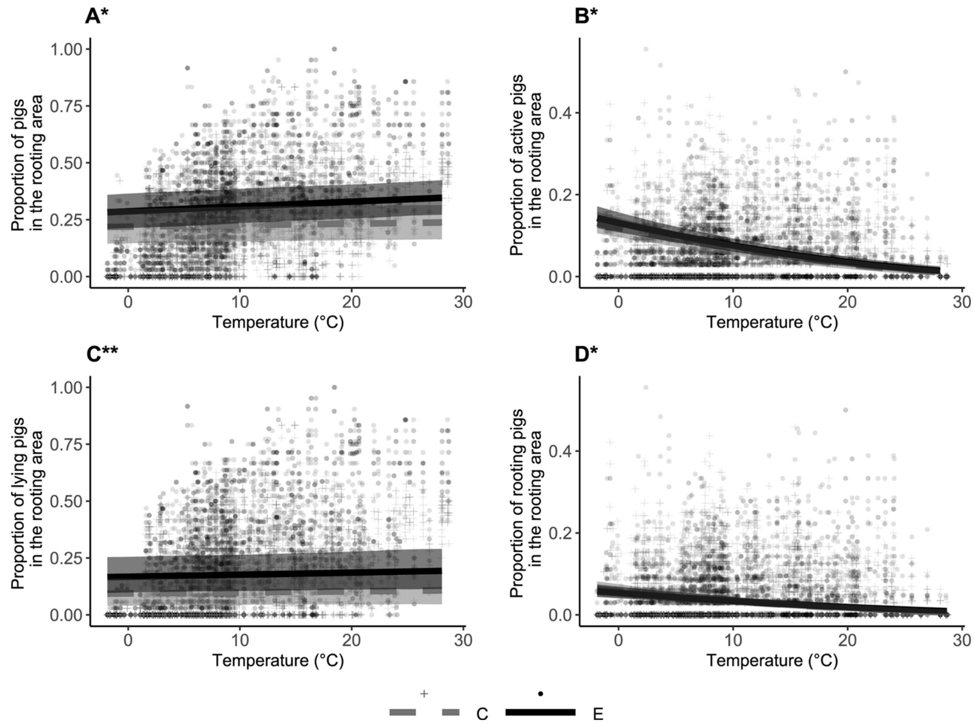

Fig. 3. Model estimates and confidence intervals for proportions of total (A), active (B), lying (C), and rooting (D) pigs in the rooting area in relation to temperature, as assessed by video observations between 6:00 and 20:00. Significance ($p < 0.05$) of only treatment (**) or only temperature (*) are marked. Interaction treatment x temperature was not significant. Data is presented as proportion of total group size.

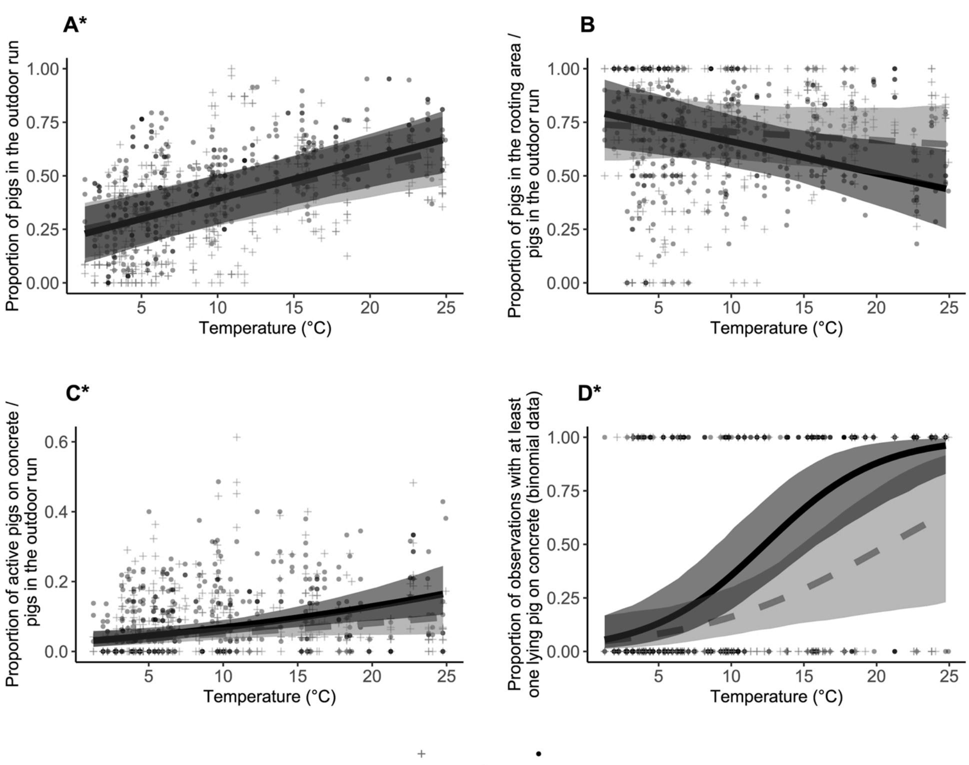

Fig. 4. Model estimates and confidence intervals from the scan samples of direct observations (assessed between 10:00 and 15:00) in relation to temperature for: proportion of pigs in the outdoor run (A); proportion of pigs in the rooting area (B); proportion of active pigs on concrete (C); proportion of observations with at least one lying pig on concrete (D). (A) refers to the number of pigs in the group, (B)-(D) to pigs in the outdoor area only. In (D), the lines represent the estimation of the logit-model, which interpolates a continuous distribution for the binomial variable. Significant influence ($p < 0.05$) of temperature is marked with *. Treatment and interaction treatment x temperature were not significant.

0.1); Agonistic (E: 0; 0.2, C: 0; 0.2); Manipulation of pen mates (E: 0; 0.2, C: 0; 0.1).

3.2. Pen soiling

Pen soiling differed between treatments for solid floor ($\chi 2_{\mathbf{solid}}$ (2) = 8.04, $p = 0.01$) but not for slatted floor ($\chi 2_{\mathbf{slatted}}$ (2) = 0.56, $p = 0.76$) and rooting area ($\chi 2_{\mathbf{rooting}}$ (2) = 7.4, $p = 0.26$).

Frequencies for scores for E pens were as follows: rooting: 1 (77.8 %), 2 (5.5 %), 3 (16.7 %); solid: 1 (94.7 %), 2 (4.4 %), 3 (0.9 %), slatted: 1 (63.2 %), 2 (28.1 %), 3 (8.7 %). Frequencies for scores for C pens were: rooting: 1 (61.3 %), 2 (13.2 %), 3 (25.5 %); solid: 1 (82.9 %), 2 (13.5 %), 3 (3.6 %), slatted: 1 (62.2 %), 2 (26.1 %), 3 (11.7 %).

3.3. Dry matter content, conductivity, and ammonium concentration of the rooting material

DM content of the compost did not differ between the two treatments (Table 4). With increasing time, the rooting material remained in the rooting area (sampling number within compost period), conductivity and ammonium concentration increased but there was no difference between the two treatments (Table 4). Location in the rooting area had a significant effect regarding conductivity and ammonium concentration, indicating that the corners which were closer to the indoor area, were preferred for elimination behaviour (data not shown).

3.4. Additional measurements

Tail biting occurred in one group in E and one group in C, respectively) with all pigs of these groups showing tail lesions and short or stumpy tails. We removed one animal identified as a biter from Group 1 and excluded it from the trial. We recorded no other incidences of tail biting.

Throughout the whole experiment, we did not detect any endoparasites in the faecal samples of all groups.

4. Discussion

The main objective of the experiment was to study the effects of mixing corn pellets into rooting material on the use and cleanliness of the rooting area in organic grower and-finisher pigs under commercial organic conditions. The results showed that the treatment increased the overall use of a rooting area, but mainly as lying area, while time of day and temperature influenced the behaviour of pigs in a rooting area. The treatment had no effect on the cleanliness of the rooting area.

4.1. The effect of the feed item provided

Considering suggestions of prior studies (Jensen and Pedersen, 2007; Studnitz et al., 2007; Holm et al., 2008), we expected to stimulate exploratory behaviour by adding edible parts to the compost as pigs clearly prefer a rewarding rooting material. Yet, while in our study there was a tendency for a higher total proportion of pigs and a higher proportion of pigs lying in the rooting area in E than C, rooting behaviour did not increase by adding corn pellets. This partially confirms findings of Olsson et al. (2016b) in whose study scattering of feed pellets on top of peat had also no effect on activity in rooting areas. It is interesting, however, that even mixing the pellets in the compost as we did had no effect on rooting behaviour. Some of the pellets were still visible in the late afternoon during direct observations, suggesting the corn pellets were not interesting enough, presumably because the pigs could obtain *ad libitum* feed indoors. It is possible that a novel feed such as carrots, larvae or insects might have stimulated the pigs more. For the use of pelleted feed, palatability should be considered.

Another aspect is Houpt's (2018) argument that pigs that are not hungry do not root much. As in our study pigs were fed *ad libitum* and provided with straw and hay daily, curiosity was probably the main driver for rooting behaviour. Curiosity motivates pigs to seek novelty even if all acute needs are met (inquisitive exploration) and to investigate novel environments and resources (intrinsic exploration) (Wood-Gush and Vestergaard, 1989; Studnitz et al., 2007). This would explain why pigs perform rooting behaviour even without any food reward. Moreover, since we observed only little damaging behaviour during our study, the need for exploration was assumingly satisfied in both treatments due to the generally high level of enrichment.

While the provision of corn pellets did not affect rooting behaviour, it unexpectedly increased lying behaviour in the rooting area. Normally pigs use separate areas in their pen for feeding, lying and elimination behaviour (Nannoni et al., 2020). The treatment in our study caused pigs to perceive the rooting area more frequently as lying area. Possibly the perceived differentiation between lying and feeding area was not very pronounced in this case, as pigs were also often observed to feed compost or pellets in a lying rather than an upright position.

With the rooting areas we added an additional attractive, albeit spatially limited, space to the pen, potentially creating a competitive environment that could lead to aggression and social stress. By mixing corn pellets into the compost, we further exacerbated the situation with a limited feed resource. Aggressive behaviours can even occur when a certain resource, such as a bedded area and feed indoors in our case, are sufficient (McGlone, 1986). However, during our experiment we rarely observed agonistic behaviours, indicating the size of the rooting area was sufficient and the additional feed resource did not foster competitive behaviours.

4.2. Influence of temperature on use of rooting area and outdoor run

As demonstrated with our results and reviewed by Olszak et al. (2015), temperature influences rooting behaviour. High temperatures result in a smaller proportion of active pigs in the rooting area. Temperature also seems to have an influence on the general use of the outdoor area by organic growing-finishing pigs. With increasing temperature, a higher proportion of pigs used the outdoor area, which is in line with previous findings (Olsen, 2001; Vermeer et al., 2006; Olsson et al., 2016a). Nevertheless, while there were more total pigs in the outdoor run, the proportion of pigs in the rooting area decreased with higher temperatures. Instead, they chose the concrete area more often for lying behaviour, assumingly because concrete has a better cooling effect by conduction for thermoregulation. Fraser (1985) suggested that pigs seek bedded areas for resting mainly at temperatures below 25 °C. Another possibility could be that the available space in the rooting area became a limited factor with increasing numbers of pigs in the outdoor run. Even if the number of pigs in the rooting area remained constant or increased slightly, the proportion still decreased because there were also more pigs in the outdoor run overall. This limitation is also reflected in the effect of "week" on proportion of pigs in the rooting area (Table 3) with a lower proportion at increasing age.

Table 4
Model estimates and confidence intervals [in brackets] for the two treatments at the last sampling and p-values for treatment, sampling location and sampling number with respect to dry matter content, conductivity, and ammonium.

	Model estimates at the last sampling [± CI]		P-values		
Variable	C	E	Treatment	Location	Sampling number
DM content (%)	58.9 [38.0–83.4]	63.8 [38.6–86.0]	n.s[a]	n.s	n.s.
Conductivity (mS/cm)	4.0 [3.1–5.1]	4.6 [3.5–5.9]	0.29	<0.001	<0.001
NH_4^+ (ppm/L)	27.6 [15.8–49.3]	50.4 [28.5–89.3]	0.16	<0.001	<0.001

[a] n.s.= not significant. In this case, the model comparison between full and zero model resulted in a p-value of 0.19. Therefore, we did not carry out further tests.

4.3. Cleanliness of rooting areas

By adding feed to the rooting material, we introduced additional resources in the outdoor run. Based on the assumption by Andersen et al. (2020) that pigs avoid elimination close to resources (food and water), we expected that rooting areas would remain cleaner but we observed no differences between treatments. More specifically, the rooting areas were assessed mostly clean during the experiment for both treatments.

Scores to assess pen soiling including rooting areas, as applied in numerous other studies (Vermeer et al., 2015; Olsson et al., 2016b, 2016a), accounted for obvious soiling solely, which was only sometimes the case in our study as reflected in the low average scores. Chemical analyses on the other hand yielded more precise results. The chemical analysis of the rooting material showed that ammonium concentrations and conductivity increased over time. Treatments did not differ, which might be due to a high variation in soiling throughout the experiment and among pens. Chemical analysis allowed for testing of different sampling locations in the rooting area to assess if the pigs selected the corners of the rooting area for elimination. Such behaviour was reported by Olsson et al. (2016a) and was partially confirmed during the current experiment as pigs preferred the corners close to the building for elimination.

4.4. Influences of weather on elimination behaviour

In week nine of the experiment, the rooting area in Pen 1 (E), which was located on the far end of the barn, was heavily soiled. Rooting areas in other pens became soiled as well in the subsequent weeks and remained that way until weather conditions changed. Reason for the increased soiling could be foggy weather in the mornings as well as lots of rain and few sunshine starting at week eight of the experiment, likely causing the compost to absorb water and becoming moist. Olsen et al. (2001) reported that half of the elimination behaviour occurred in the installed wallow, giving support to the theory, that pigs favour wet places for elimination. However, for outdoor pigs it has not been found that they defecate near the mud wallow (Salomon et al., 2007) and Vermeer et al. (2006) reported that pigs avoided elimination near the water cup in the outdoor run.

4.5. Influence of draught and management of the rooting material on elimination behaviour

During the experiment in some cases the same compost was used by several successive groups of pigs as it was only completely replaced when heavily soiled. However, before we relocated a group from the growing to the finishing pen, we topped up the rooting areas with fresh rooting material to minimise the effect on rooting or elimination behaviour. Apparently, however, other influences besides the management of the rooting material were of importance. Interestingly, when moved from Pen 1 (grower pen) with heavily soiled rooting area to Pen 3 (finishing pen), with new and clean rooting material, Group 6 did not transfer their acquired elimination behaviour but kept the new rooting area clean. Therefore, their elimination behaviour seems to have been influenced by factors present in Pen 1 located on the far-left side exposed to wind (Fig. 1). One explanation could be draughts caused by the open pen side. The avoidance of the rooting area for sleeping due to draught possibly resulted in localized elimination as described by Randall et al. (1983). A solution could be to use wind-blocking nets on open pen sides in the outdoor run.

4.6. Freshness of compost and novelty of corn pellets

The freshness aspect of the compost seemed to be highly important, as it was obvious that pigs became very active when fresh compost was added to the rooting areas. One explanation could be that the fresh compost contained more changeable parts compared to the already "used" compost and was therefore more rewarding for the pigs. Similarly, pigs became active for a few minutes after corn pellets were mixed into the rooting material but for a shorter amount of time. This raises the question whether the pigs perceived the feed pellets as novel even though they were exposed to them every day. While habituation to objects such as pig "toys" happens quickly (Apple and Craig, 1992), feed items might be a greater stimulus for exploration. To incorporate novelty in a targeted way into the provision of feed items to the rooting areas, it might be useful to distribute small amounts of feed throughout the whole day into the rooting areas, possibly at random points in time and possibly with a variation in the feed. Technical solutions for automated feed distribution are available on the market. Positive effects of such repeated food provision in rooting areas should be the subject of future studies.

5. Conclusions

We conclude that mixing corn pellets into rooting material tends to increase the presence of growing and finishing pigs in a rooting area but not its cleanliness. Generally, we found that pigs used a rooting area filled with compost a lot, regardless of additional feed. Therefore, the areas seem to be very attractive for the pigs.

Declaration of Competing Interest

The authors report no declarations of interest.

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