frontiers in Animal Science

ORIGINAL RESEARCH
published: 06 December 2021
doi: 10.3389/fanim.2021.749583

The Effects of Refilling Additional Rooting Material on Exploration Duration and Tail Damages in Rearing and Fattening Pigs

Karen Kauselmann[1], Lars Schrader[1], Hansjörg Schrade[2] and E. Tobias Krause[1]*

[1] Institute of Animal Welfare and Animal Husbandry, Friedrich-Loeffler-Institut, Celle, Germany, [2] Bildungs- und Wissenszentrum Boxberg (LSZ), Boxberg, Germany

Pigs housed in commercial barns with slatted floors cannot fully perform their natural behavioral needs such as rooting or exploring. Enrichment materials can stimulate these behaviors in pigs. Here, we investigated whether exploration can be stimulated by offering additional enrichment material, i.e., chopped straw, once compared to four times daily. In two replicates each with four rearing and eight fattening pens, a total of 192 pigs with undocked tails continuously received chopped straw from a dispenser, while a stimulus to explore was given by filling the rooting area of the dispenser either once (R1) or four times (R4) daily with additional chopped straw. The dispensers were equipped with an ultra-high-frequency radio-frequency-identification (UHF-RFID) system in order to record the exploration durations of each individual pig at the dispenser. At four times throughout rearing and fattening, pigs were weighted and tail injuries and length losses were assessed. This resulted in three temporal sections within each replicate, for each of which the difference in tail length to the previous section (Δ-tail length) was calculated. Exploration durations did not change in long-term but increased from rearing throughout fattening. The refillings in which additional chopped straw was offered (R1 vs. R4) did not affect the overall exploration duration during rearing (linear mixed effects model (LME), $P = 0.85$) or fattening (LME, $P = 0.66$). However, descriptive evaluations showed that exploration durations decreased within the first 10-min sequences within the hour after refilling the rooting area with additional chopped straw in both treatments (R1 and R4). Exploration durations were affected by week, day, and hour within day during rearing (LME, all factors, $P < 0.0001$) and fattening (LME, all factors, $P < 0.0001$). Neither tail injuries nor length losses were affected by the refilling treatment (R1 vs. R4) during rearing (GLMM, both $P > 0.1$) or fattening (GLMM, both $P > 0.1$). Offering additional straw four times compared to once a day had no advantage in the present setting with regard to exploration duration and tail damages of pigs. However, refilling the rooting area with additional chopped straw triggered a short-term increase of exploration that decreased within 1 h, thus, exploration was more spread over the day.

Keywords: enrichment material, chopped straw, tail biting, habituation, exploration, UHF RFID, *Sus scrofa* domesticus

Edited by:
Rafael Freire,
Charles Sturt University, Australia

Reviewed by:
Sebastien Goumon,
ETH Zürich, Switzerland
Yi-Chun Lin,
National Chung Hsing University, Taiwan

****Correspondence:***
Karen Kauselmann
karen.kauselmann@fli.de

Specialty section:
This article was submitted to Animal Welfare and Policy, a section of the journal Frontiers in Animal Science

Received: *29 July 2021*
Accepted: *10 November 2021*
Published: *06 December 2021*

Citation:
Kauselmann K, Schrader L, Schrade H and Krause ET (2021) The Effects of Refilling Additional Rooting Material on Exploration Duration and Tail Damages in Rearing and Fattening Pigs. Front. Anim. Sci. 2:749583. doi: 10.3389/fanim.2021.749583

INTRODUCTION

Most rearing and fattening pigs in the European Union are kept in commercial housing systems with slatted floors and barren pens (EFSA, 2007; Früh et al., 2013), where behavioral needs such as rooting, chewing and exploring often cannot adequately be satisfied. Enrichment material is highly recommended to facilitate exploration behavior in pigs (e.g., Van de Weerd et al., 2003; Studnitz et al., 2007). If pigs cannot perform exploration and foraging behavior with suitable enrichment material, manipulative behavior against pen mates like tail biting can occur (Lawrence et al., 1993; Beattie et al., 1995). Tail biting can cause injuries, inflammations or tail losses, which affects reduced welfare in pigs (Valros et al., 2007). However, it can also lead to reduced weight gains (Marques et al., 2012; Sinisalo et al., 2012) or even death of pigs, which means an economic loss for the farmer (Kritas and Morrison, 2007; Valros et al., 2007; Li et al., 2017). Enrichment materials that are changeable, chewable, edible, manipulable, novel, and/or odorous are especially recommended for pigs (Van de Weerd et al., 2003; Jensen and Pedersen, 2007; Studnitz et al., 2007; Van de Perre et al., 2011). Plant-based enrichment materials possess these properties. Among them, the exploration increasing effect of straw is well-investigated and recommended for pigs in commercial housings (Fraser et al., 1991; Peeters et al., 2006; Jensen et al., 2015). However, due to the risk of clogging the manure pipes of the slurry system, farmers often avoid the use of long straw in barns with slatted floors. As pigs explore both long and chopped straw with similar intensities (Lahrmann et al., 2015), the use of chopped straw offers an enrichment possibility for housing systems with slatted floors. Enrichment materials, however, have often been considered to lead to habituation in pigs already hours after first provisioning (Apple and Craig, 1992). Habituation can be prevented by a regular change of materials (Trickett et al., 2009; Kauselmann et al., 2021a) or by regular refilling (Docking et al., 2008; Kauselmann et al., 2020, 2021b). Although suitable plant-based enrichment material can lead to increased exploration durations, this does not necessarily result in a reduction of manipulative behaviors such as tail damages (Kauselmann et al., 2020, 2021b). Highly preferred enrichment materials can even lead to an increase of tail biting behavior, probably by triggering competitive behavior for the preferred resources (Van de Perre et al., 2011; Kauselmann et al., 2020). Thus, proper enrichment material should always be available in sufficient quantity allowing access to the material for all pigs motivated to root.

In this study, we investigated whether exploration durations of rearing and fattening pigs can be stimulated by offering additional chopped straw multiple times per day at the rooting area of a dispenser filled with a stock of chopped straw. Therefore, we provisioned an additional amount of fresh chopped straw either (i) once or (ii) four times daily in the rooting area of a dispenser already filled with chopped straw in order to enhance attractiveness of the material. We hypothesized that higher exploration durations will be reached throughout rearing and fattening by providing additional chopped straw four times per day at regular refillings (R4) compared to only a single daily additional straw stimulus (R1). We also assumed higher exploration durations to be linked with fewer tail damages. Furthermore, we expected short-term increases in exploration durations immediately after each additional straw stimulus.

Abbreviations: DSBS, Deutscher Schweine Bonitur-Schlüssel; GLMM, generalized linear mixed models; R1, refilling treatment in which pigs received additional chopped straw once per day; R4, refilling treatment in which pigs received additional chopped straw four times per day; LME, linear mixed effect models; LSZ, Bildungs- und Wissenszentrum (Landesanstalt für Schweinezucht) Boxberg; RFID, radio-frequency identification; UHF, ultra-high-frequency.

METHODS

Animals and Housing

In this study, we conducted two identical replicates each with four rearing (8 groups in total with 24 piglets each) and eight fattening pens (16 groups in total with 12 pigs each). Groups were composed of both sexes and in total 192 undocked crossbred pigs (German Piétrain × German Hybrid) were used (replicate 1: 52 females and 44 castrated males, replicate 2: 57 females and 39 castrated males). The study was carried out from February 2019 to August 2019 in forced ventilated barns at the Bildungs- und Wissenszentrum Boxberg (LSZ), Germany. At weaning at an age of about 4 weeks, piglets weighted on average 7.9 kg (±1.7 kg SD) and were individually equipped with one UHF RFID tag per ear (MS Tag Round UHF, MS Schippers, Netherlands) that we used for data collection during the study. The 96 piglets per replicate were randomly assigned to four rearing pens with 24 piglets each. Rearing pens were continuously numbered across replicates (8 PenIDs in rearing in total) and had 15 m^2 (5 m × 3 m) floor space. The floors consisted of slatted plastic floor (7.5 m^2, 38.5% perforation), slatted concrete floor (3.0 m^2, 17.0% perforation) and partly slatted concrete floor (4.5 m^2, 7.0% perforation) under a heated covering (**Figure 1A**). All rearing pens were equipped at any time with a rubber bar, two sisal ropes, a piece of wood hanging on metal chains and a self-constructed dispenser (see below). Mashed feed was offered *ad libitum* to the piglets in two phases by automatic feeders (animal:feeding place ratio 2.4:1). After 2 weeks of rearing, feed composition changed (detailed information is given in the **Supplementary Table 1**). Due to upcoming feed change in fattening, piglets were fed pellet concentrate (25 kg per pen) in addition to the *ad libitum* offered mashed feed during the last week of rearing. Piglets had *ad libitum* access to water from two nipple drinkers and two drinking bowls (Suevia 92 R, Suevia Haiges GmbH, Kirchheim, Germany) during rearing. Three piglets had to be excluded (one loss due to a disease and two identified tail biters were separated), resulting in 95 pigs in replicate 1 (51 females and 44 castrated males) and 94 pigs in replicate 2 (56 females and 38 castrated males).

After 7 weeks of rearing, piglets weighted on average 30.0 kg (±5.5 kg SD). As in rearing, the floor space of the fattening pens was 15 m^2 (3 m × 5 m) and consequently the group size had to be reduced. Thus, pigs were divided in eight fattening pens per replicate (**Figure 1B**) by randomly assigning piglets of each rearing pen to two groups, respectively (12 pigs per fattening pen). By that, pigs of a given fattening pen had the same

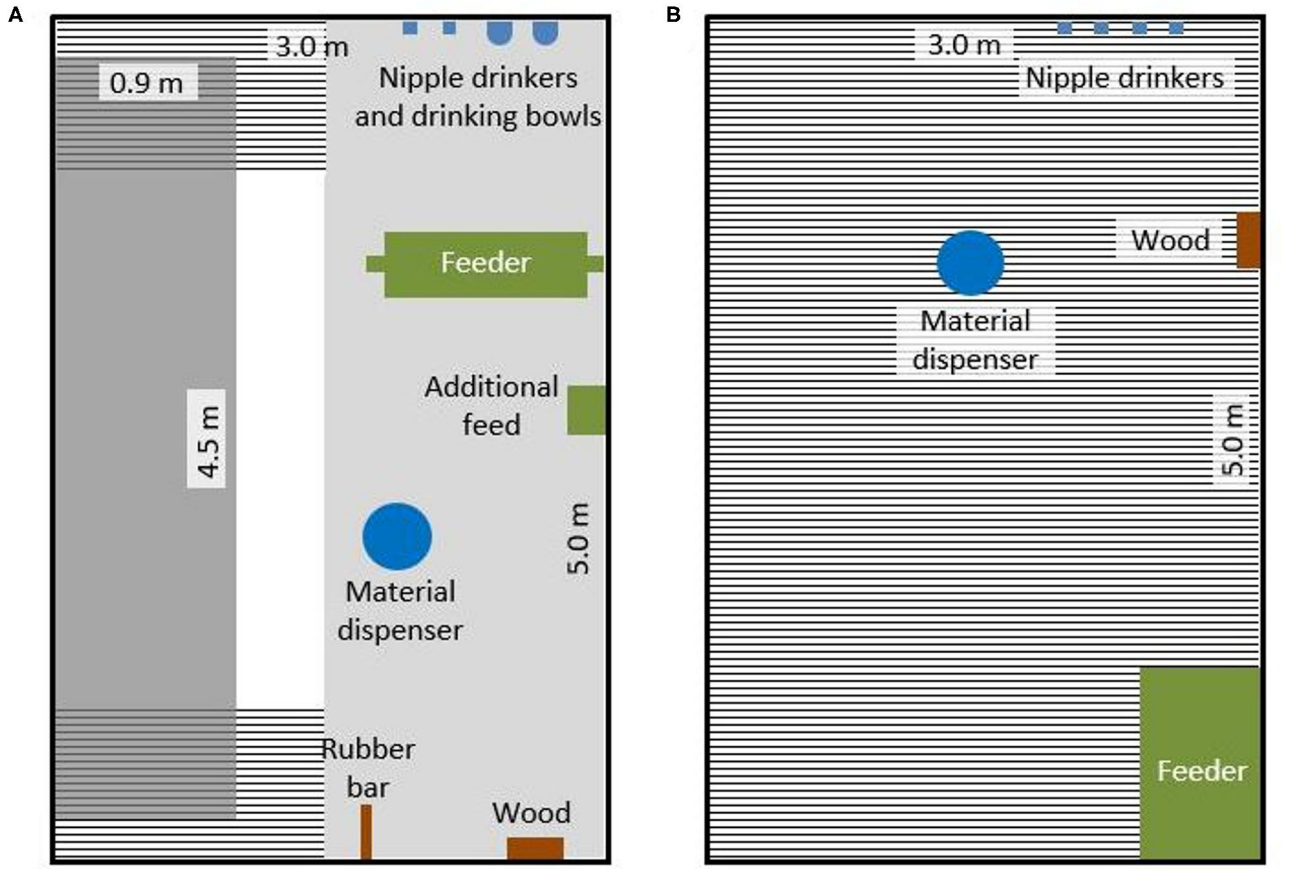

FIGURE 1 | Schematic drawing of a **(A)** rearing and **(B)** fattening pen with partly slatted concrete floor with 7% perforation (white), slatted concrete floor with 17% perforation (striped), slatted plastic floor with 38.5% perforation (light gray) and heated covering (dark gray).

experience and treatment during rearing and were familiar to each other. Fattening pens were continuously numbered across replicates (16 PenIDs in fattening in total) and were equipped with slatted floor (17% perforation). In each fattening pen pigs had access to two sisal ropes, a piece of wood hanging on metal chains and a self-constructed dispenser (see below) at any time. Fattening pigs had *ad libitum* access to water from four nipple drinkers in each pen. Pellet concentrate was offered *ad libitum* from a single feeder to the pigs. Feed composition changed when pigs reached an average weight of about 80 kg (detailed information is given in the **Supplementary Table 1**). Data collection ended after 11 weeks of fattening, when the first pigs were removed for slaughter.

Enrichment Refilling Treatment

Throughout the whole observation period, a stock of chopped barley straw with a length of ∼10–100 mm was *ad libitum* provided to all pigs in all pens by a dispenser. At least every second day the straw was manually filled into the storage tube of the dispensers (if necessary, also on weekends).

In addition, at the beginning of rearing, pens were assigned to one of two treatments. Piglets in half of the rearing pens additionally received once per day (1 refilling = R1) chopped barley straw (i.e., the same material as permanently available in the storage tube) into the rooting area of the dispenser. Piglets in the other half of the pens received this additional rooting material four times per day (4 refillings = R4) (**Supplementary Figure 1**). Provision of this additional chopped straw was done automatically (see **Supplementary Video 1**) and continued during fattening (four pens per treatment, as mentioned above). In treatment R1 additional chopped straw was daily provided at 0800 (first refilling). In treatment R4 the rooting areas of the dispensers were filled at 0800 (first refilling), 1000 (second refilling), 1400 (third refilling), and 1600 (fourth refilling) each day. Filling times were chosen based on previous evaluations of the activity of pigs in order to avoid disturbing of resting phases around noon (e.g., Kauselmann et al., 2020, 2021b). In a previous study we found that fattening pigs consumed higher amounts of chopped straw from the dispenser compared to weaned piglets (Kauselmann et al., 2021a). Thus, at each provision, additional chopped straw was delivered for 15 s in rearing and 20 s in fattening resulting in ∼80 g straw/refilling in rearing and ∼110 g straw/refilling in fattening. Thus, in treatment R1 pigs got only a quarter of the additional amount of

chopped straw compared to the pigs of treatment R4. However, at any time pigs still had *ad libitum* access to the chopped straw in the dispenser and the additional provision of straw was intended to trigger/enhance rooting behavior.

The self-constructed dispensers (Kauselmann et al., 2021a) were installed in the middle of each pen (**Figure 1**) and consist of a 100 cm high storage tube with a diameter of 25 cm (**Supplementary Figure 2**). Around the base of the storage tube a 10 cm high cement ring with an inner diameter of 63 cm was installed to create a rooting area. The chopped straw could be rooted into the rooting area through a 2.4 cm wide gap between the storage tube and the floor by moving a plastic bolt. According to Averberg et al. (2018) a width of 18 cm per pig at the dispenser was used to calculate the animal:dispenser place ratio for rearing pigs and 33 cm per pig was used for fattening pigs. Thus, we obtained an animal:dispenser place ratio of 1.7:1 in rearing and 1.5:1 in fattening pens.

In the storage tube of the dispenser, we installed a dust- and waterproof UHF RFID antenna (Kathrein MiRa ETSI, KATHREIN Solutions GmbH, Ismaning, Germany) at a height of 50 cm above the floor (**Supplementary Figure 2C**). The UHF RFID antenna read the UHF RFID tags in the ears of the pigs when they stayed at the rooting area of the dispenser. Data were collected in a database *via* a converter and an UHF RFID reader. Pigs were assigned to the corresponding UHF RFID antenna and, thus, to their pen and the respective treatment by a software application (Phenobyte GmbH & Co. KG., Ludwigsburg, Germany). As described in Kauselmann et al. (2021a) the antenna output power was set to 22.4 dBm and UHF RFID recordings with a maximum pause of 30 s between two readings were summarized to obtain optimal sensitivity (70.7% in rearing and 79.3% in fattening) and specificity (99.4% in rearing and 99.5% in fattening). With the UHF RFID system, we recorded for each individual pig the exploration times that were summed up to exploration durations per pig and hour, which we used for further statistical analysis.

Four times during the test period (at the beginning of rearing, at the beginning of fattening, after 6 weeks of fattening and at the end of fattening; see **Supplementary Figure 3**), the pigs were scored according to a scoring scheme developed to assess tail and ear damages of, i.e., the Deutscher Schweine Bonitur-Schlüssel (2017) to evaluate the length of the tails and skin lesions at the tails. Tail length was scored in five categories: (0) full/natural length, (1) length loss up to one-third, i.e., here we also include individuals with only minimal losses at the tassel, (2) distinct damages, i.e., length losses from at least one third up to two-thirds, (3) length loss more than two-thirds, and (4) total loss with a maximum of 1 cm leftover for piglets in the rearing and 2 cm leftover for pigs in the fattening. However, score 4 was never recorded and score 1 often concerned a small part of the tail tip rather than one-third of the tail. Injuries at the skin of the tails were scored in four categories: (0) no injuries, (1) superficial perforation of the skin, punctually or in the form of a line, (2) deeper perforation of the skin, maximum as large as the diameter of the tail at the respective point, and (3) deeper perforation of the skin, larger than the diameter of the tail at the respective point.

Ethical Note

Ethical approval was not required for the study because the animals were not isolated from conspecifics, not restricted from any resources, remained in their familiar environment and were not manipulated in accordance to the study protocol. Furthermore pigs were housed and managed according to the German legislation for farm animals (TierSchNutztV, 2017) and in accordance to Council Directive 2008/120/EC. The different numbers of refillings with rooting material per day, i.e., once vs. four times, were provided in addition to the rooting material available *ad libitum*. These additional refillings represented additional environmental enrichment and were the only change in the housing environment with respect to the data collection. The additionally provided rooting materials at the refillings (R1 vs. R4), thus, represented no limited resource which might have triggered competitive behavioral patterns, but rooting material was *ad libitum* available at any time in the dispersers regardless of the refillings (R1 vs. R4). All data were recorded at a licensed farm that produces, rears, fattens, and markets pigs (VVVO-Number: 08 128 0140 538). Thus, pigs from the study were marketed after the study. Beyond minimum German legal requirements, space allotment per pig in the present study was higher and pigs were offered additional enrichment material on a daily basis (as R1 and R4 treatment), which is usually expected to have a positive effect on pigs' welfare, as additional stimulation of explorative behavior is regarded to reduce potential welfare issues such as tail biting. Data on exploration were automatically recorded *via* an UHF RFID system which was integrated into the dispenser. Scoring of tail damages was conducted carefully and non-invasively using the Deutscher Schweine Bonitur-Schlüssel (2017). Pigs remained with their peers at any time. Pigs were visually inspected on a daily basis. In case of tail biting, additional enrichment materials (paper bags, mineral feed, squeezed oats, and zeolite) were offered and in case biters were identified (two piglets during rearing) they were separated from the group and housed in a separate pen.

Statistical Analysis

All statistical analyses were calculated separately for rearing and fattening using R version 3.3.1 (R Core Team, 2019) and the packages lme4 (Bates et al., 2015), nlme (Pinheiro et al., 2019), and car (Fox and Weisberg, 2019).

We summed up the recorded exploration duration per pig for each hour. Weeks were consecutively numbered in rearing (7 weeks) and fattening (11 weeks) and days within weeks were additionally considered (7 days). The 7 weeks of rearing were assigned to temporal section 1 and for fattening two temporal sections were considered (section 2: first 6 weeks of fattening and section 3: last 5 weeks of fattening; see **Supplementary Figure 3**), which corresponded to the intervals between the scorings, as in Kauselmann et al. (2020). Although data were log-transformed [log(x+1)], q-q plots showed minor deviations from normal distribution of the residuals. We used linear mixed effect models (LME) that are robust to such minor deviations (Schielzeth et al., 2020). The LME used for analyses of exploration duration per hour included the exploratory variables (i) refilling treatment (2-level factor: R1 and R4), (ii) week of rearing/fattening (rearing: 7-level factor; fattening: 11-level factor) (iii) day within week,

(iv) hour (v) two-way interactions between refilling treatment and hour and between refilling treatment and week. As animals within pen were not independent from each other, AnimalID, PenID, and week were considered as nesting random factors in the model for rearing and fattening, respectively. The hierarchical structure of the statistical model is exemplarily shown in the **Supplementary Figure 4**. In case of significant differences ($P < 0.05$), pairwise *t*-tests were used to calculate *post-hoc* comparisons.

As we found significant interactions between refilling treatment and hour within day on exploration durations in the above mentioned LME's, during both rearing and fattening we further examined this effect and did a more detailed descriptive analyses of exploration duration in 10-min sequences focusing on the hours after refilling the rooting area (0800–0900, 1000–1100, 1400–1500, and 1600–1700) independent from whether refilling was done four times (R4) or only once (R1) per day. All days during rearing and fattening were considered.

In order to relate the changes in tail length to exploration durations during the three sections, we calculated Δ-tail lengths by subtracting for each pig its tail length score at the end of a section from the score at the beginning of the respective section. For example, if a pig had an intact tail (score 0) at the beginning of rearing (beginning of section 1) and a tail length score of 1 after rearing (after section 1), Δ-tail length was 1 (1–0 = 1) for section 1. If the same pig still had a tail length score of 1 after 6 weeks of fattening (after section 2), Δ-tail length was 0 (1–1 = 0) for section 2. When the score was 2 after a total of 11 weeks of fattening (after section 3), Δ-tail length was 1 (2–1 = 1) for section 3. To analyze Δ-tail lengths and skin injuries at the tails we used generalized linear mixed models (GLMMs) with Poisson distribution separately for rearing and fattening. We used (i) the refilling treatment (2-level factor: R1 and R4) and sex (2-level factor: female or castrated male) as explanatory variable and AnimalID as well as PenID as nesting random factors for the one section in rearing. For fattening we considered the explanatory variables (i) section (2-level factor: section 2 and 3), (ii) refilling treatment (2-level factor: R1 and R4), and (iii) sex (2-level factor: female or castrated male). Two-way interactions between all variables were considered, however, due to convergence problems in the model for skin injuries during fattening, we only considered interactions between refilling and section (sex was not considered as there was no significant effect on tail injuries; see section Effects of Refillings of Additional Rooting Material on Tail Damages During Fattening). For fattening the nesting random factors AnimalID and PenID were considered.

RESULTS

Effects of Refillings of Additional Rooting Material on Exploration Duration During Rearing

The refilling treatment (i.e., R1 vs. R4) at which the chopped straw was additionally distributed into the rooting area of the dispensers did not affect the exploration durations of the piglets during rearing (LME, factor refilling, $F_{(1, 6)} = 0.039$, $P = 0.85$). Mean exploration durations per pig and hour were 0.56 min (i.e., summing up to 13.4 min per pig and day) when the rooting areas were additionally filled once daily (R1) and 0.54 min (12.8 min per pig and day) when they were additionally filled four times a day (R4). However, the weeks within rearing had a significantly but not systematic effect on exploration durations of the piglets (LME, factor week, $F_{(6, 1131)} = 17.19$, $P < 0.0001$; **Supplementary Table 2**). Piglets spent most time at the dispenser in week 7 (0.62 min/pig and hour) followed by week 1 (0.60 min/pig and hour). Lowest mean exploration durations were recorded in week 2 (0.44 min/pig and hour). The days within week significantly affected exploration duration of the piglets (LME, factor day, $F_{(6, 222677)} = 99.53$, $P < 0.0001$; **Supplementary Table 3**) but also did not show any consistent pattern. The exploration duration of piglets was also affected by the hours within day (LME, factor hour, $F_{(23, 222677)} = 1005.93$, $P < 0.0001$) and showed one peak in the morning and one higher peak in the afternoon. There was a significant interaction between refilling and hour (LME, factor refilling*hour, $F_{(23, 222677)} = 8.39$, $P < 0.0001$; **Figures 2A**, **3A**). Exploration duration of piglets in treatment R1 and R4 increased after refilling the rooting area at 0800, while exploration duration of piglets in treatment R4 also increased after refilling at 1000, 1400 and 1600. Furthermore, between 0800 and 0900, piglets from treatment R1 showed more exploration (0.84 min/pig) compared to pigs from treatment R4 (0.64 min/pig). However, compared to R1 treatment, piglets in treatment R4 showed more exploration within the hours after refilling at 1000 (R1: 0.70 min/pig; R4: 0.80 min/pig) and 1600 (R1: 0.92 min/pig; R4: 1.07 min/pig). The interaction between refilling and week was not significant (LME, factor refilling*week, $F_{(6, 1131)} = 0.66$, $P = 0.69$).

When having a closer descriptive look on the 10-min sequences within the hours after refilling (i.e., 0800–0900, 1000–1100, 1400–1500, and 1600–1700), no clear differences in the course of exploration duration could be found between the refilling treatments during rearing (**Figures 2B–E**, **3B–E**).

Effects of Refillings of Additional Rooting Material on Tail Damages During Rearing

There was neither an effect of the refilling treatments (GLMM, factor refilling, $X^2_{(1)} = 0.94$, $P = 0.33$; **Figure 4A**), of sex, nor of the interaction (GLMM, factor sex, $X^2_{(1)} = 0.23$, $P = 0.63$; factor refilling*sex $X^2_{(1)} = 0.20$, $P = 0.65$) on Δ-tail lengths. Likewise, skin injuries of tails were neither affected by refilling treatment (GLMM, factor refilling, $X^2_{(1)} = 0.13$, $P = 0.72$), by sex, nor by the interaction (GLMM, factor sex, $X^2_{(1)} = 1.65$, $P = 0.20$; factor refilling*sex $X^2_{(1)} = 0.49$, $P = 0.49$) during rearing. After rearing, 57.8% of the piglets had intact tails without length losses (category 0).

Effects of Refillings of Additional Rooting Material on Exploration Duration During Fattening

The refilling treatment of additional rooting material provision did not affect exploration durations of fattening pigs at the

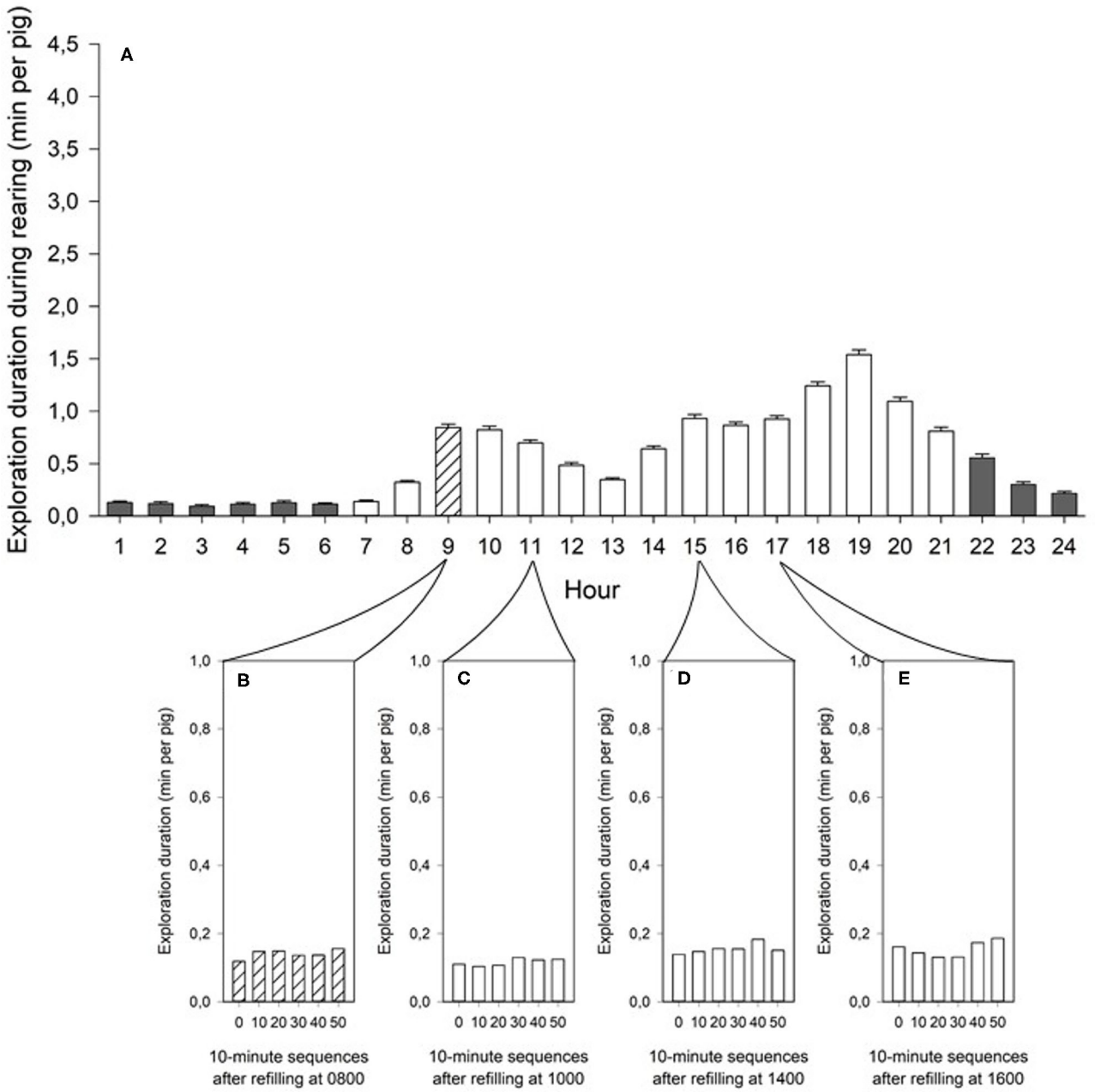

FIGURE 2 | (A) Diurnal pattern of exploration duration (mean ± SE minutes per piglet) at the dispenser filled with chopped straw in treatment R1 (one additional offer of chopped straw at 0800) during rearing. **(B)** Exploration durations in 10-min sequences within the hour after refilling the rooting area (striped bars). **(C–E)** Exploration durations within the hours at which in treatment R4 (see **Figure 3**) chopped straw was additionally offered. Light bars indicate light phase and dark bars indicate dark phase.

dispenser (LME, factor refilling, $F_{(1,\ 14)} = 0.20$, $P = 0.66$). Mean exploration duration at the dispensers per pig and hour was 1.28 min (i.e., summing up to 29.7 min per pig and day) when they received additional chopped straw in the rooting area once a day (R1) and 1.22 min (27.9 min per pig and day) when they were additionally filled four times a day (R4). There was a significant interaction between refilling treatment and week (LME, factor refilling*week, $F_{(10,\ 1804)} = 3.54$, $P = 0.0001$). The week affected exploration duration of the pigs (LME, factor week, $F_{(10,\ 1804)} = 84.06$, $P < 0.0001$; **Supplementary Table 2**) but showed no consistent pattern over the 11 weeks of fattening. Highest exploration durations per pig and hour were recorded in week 9 (1.76 min) and lowest in week 1 (0.76 min). Exploration duration was also affected by day of week (LME, factor day, $F_{(6,\ 334465)} =$

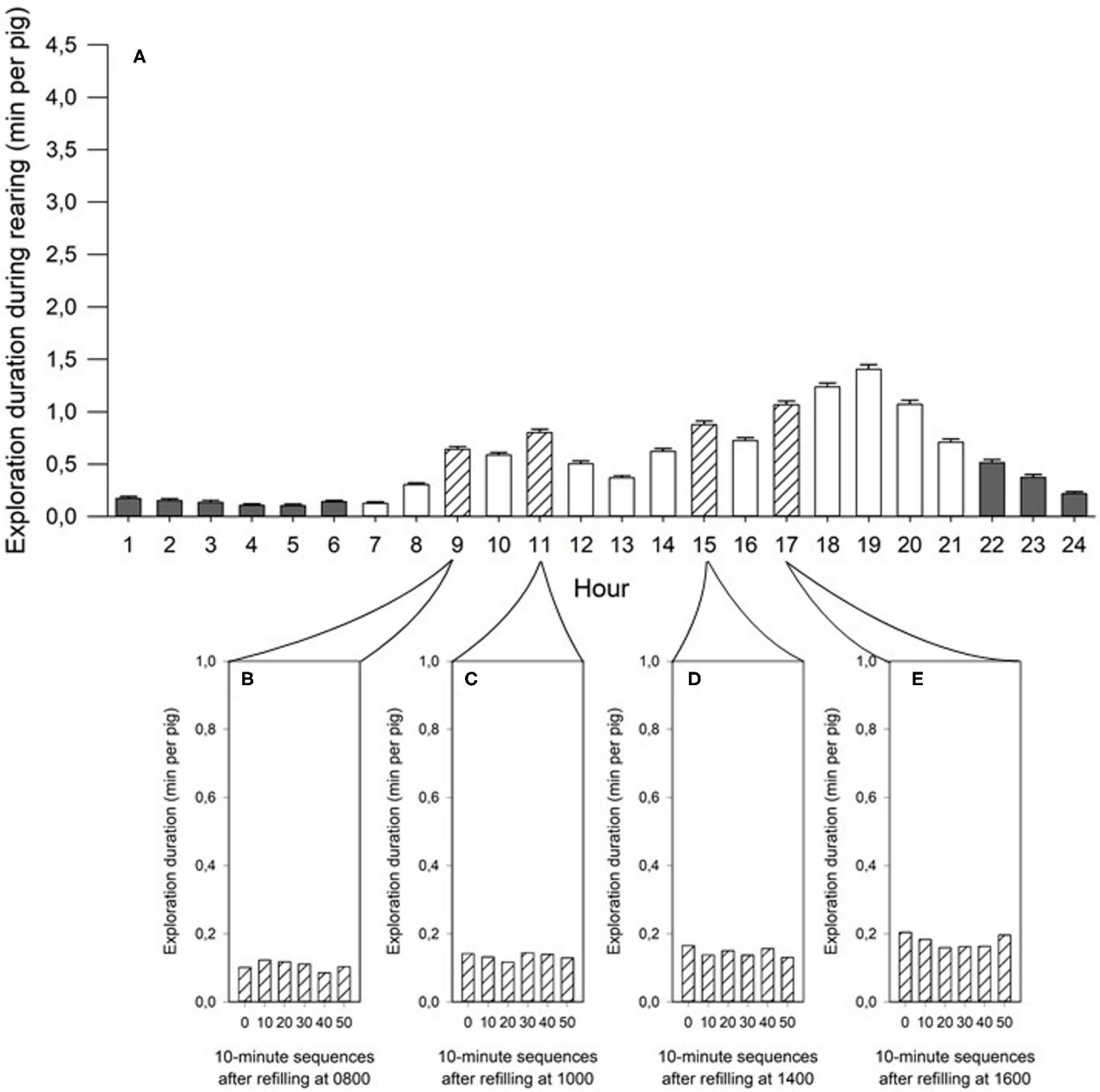

FIGURE 3 | (A) Diurnal pattern of exploration duration (mean ± SE minutes per piglet) at the dispenser filled with chopped straw in treatment R4 (four additional offers of chopped straw at 0800, 1000, 1400, and 1600) during rearing. **(B–E)** Exploration durations in 10-min sequences within the hours after refilling the rooting area (striped bars). Light bars indicate light phase and dark bars indicate dark phase.

16.96, $P < 0.0001$; **Supplementary Table 3**) but again showed no consistent pattern. Highest exploration durations at the dispenser were recorded on day 2 (1.33 min/pig and hour) and lowest on day 4 (1.19 min/pig and hour) and day 6 (1.17 min/pig and hour). The hours within day also affected exploration duration of the pigs (LME, factor hour, $F_{(23,\ 334465)} = 4594.53$, $P < 0.0001$). Exploration within day showed two peaks, i.e., one peak in the morning and one higher peak in the afternoon. During night time, exploration duration remained at a low level. There was also a significant interaction between refilling and hour within day (LME, factor refilling*hour, $F_{(23,\ 334465)} = 53.73$, $P < 0.0001$; **Figures 5A,B**). Exploration duration of pigs that received additional chopped straw once per day (R1) showed a peak within the hour after refilling the rooting area at 0800 and showed more exploration within the hour after refilling at 0800 (1.55 min/pig) compared to pigs in treatment R4 (1.36 min/pig). Pigs

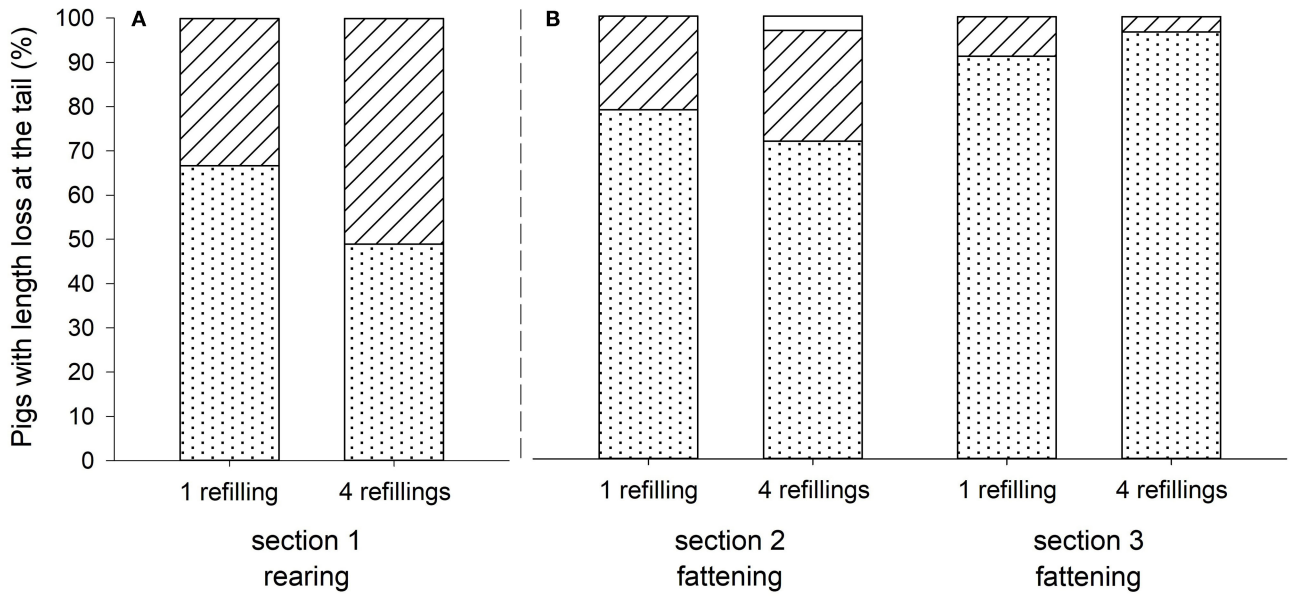

FIGURE 4 | Percentage of pigs without changes (dotted) in length losses (Δ-tail length), with changes by one score (lined), or by two scores (white) during **(A)** section 1 in rearing, **(B)** section 2 and section 3 in fattening. Δ-tail length losses indicate changes in tail length scores within section 1 (rearing), section 2 (first to sixth week of fattening), and section 3 (seventh to eleventh week of fattening).

that received additional chopped straw four times daily (R4) showed peaks within the hour after all four additional fillings, i.e., after 0800, 1000, 1400, and 1600. Compared to R1 treatment, pigs in treatment R4 showed more exploration within the hours after refilling at 1000 (R1: 1.09 min/pig; R4: 1.63 min/pig), 1400 (R1: 2.03 min/pig; R4: 2.57 min/pig), and 1600 (R1: 3.16 min/pig; R4: 3.45 min/pig).

A descriptive exploration of the 10-min sequences showed that after refilling the rooting area at 0800 (R1 and R4 received additional chopped straw), exploration duration decreased within the first three 10-min sequences and remained at a constant level thereafter in both, R1 and R4 (**Figures 5B**, **6B**). However, pigs of R1 showed higher exploration durations during the first two 10-min sequences compared to R4 pigs. During the hours after refilling the rooting areas only in R4 (i.e., 1000–1100, 1400–1500, and 1600–1700), R4 pigs had higher exploration durations in the first two 10-min sequences (**Figures 6C–E**), while R1 pigs did not show clear changes in exploration durations (**Figures 5C–E**) and remained at a low level.

Effects of Refillings of Additional Rooting Material on Tail Damages During Fattening

During fattening neither refilling treatment (GLMM, factor refilling, $X^2_{(1)} = 1.65$, $P = 0.20$; **Figure 4B**) nor sex (GLMM, factor sex, $X^2_{(1)} = 0.07$, $P = 0.79$) affected Δ-tail lengths. However, there was an effect of section on Δ-tail lengths (GLMM, factor section, $X^2_{(1)} = 4.75$, $P = 0.029$). After section 2 Δ-tail lengths of 0 occurred less often (75.3% of pigs) compared to after section 3 (93.6% of pigs), i.e., most losses of tail length occurred in the first weeks of fattening. In total, 31.2% of the pigs had intact tails without losses of tail length after fattening. None of the interaction between the factors significantly affected Δ-tail lengths (GLMM, factor refilling*section, $X^2_{(1)} = 3.02$, $P = 0.08$; factor refilling*sex, $X^2_{(1)} = 0.53$, $P = 0.47$, factor section*sex, $X^2_{(1)} = 1.26$, $P = 0.26$).

Injuries at the tails of the pigs were neither affected by refilling treatment (GLMM, factor refilling, $X^2_{(1)} = 0.48$, $P = 0.49$), by section (GLMM, factor section, $X^2_{(1)} = 0.40$, $P = 0.53$), nor by sex (GLMM, factor sex, $X^2_{(1)} = 0.14$, $P = 0.71$). The interaction of refilling treatment and section also did not significantly affect tail injuries (GLMM, factor refilling*section, $X^2_{(1)} = 0.22$, $P = 0.64$).

DISCUSSION

Our results show that the provision of additional straw at different refilling treatments (either once or four times per day) did not affect the exploration durations of pigs at the rooting area of a dispenser during rearing and fattening. However, within the hour after additional straw was offered in the rooting area exploration duration increased. Furthermore, exploration durations increased from rearing to fattening and showed no signs of habituation toward the rooting material in long-term. Tail damages (skin injuries at the tails and length losses of the tails) did not differ between the two refilling treatments.

Although there was a short-term increase in exploration duration within the hour after refilling the rooting area of the dispensers, no difference was found in overall exploration duration of pigs that received additional chopped straw once (R1) compared to four times per day (R4). These results were unexpected and against our initial hypothesis as we expected

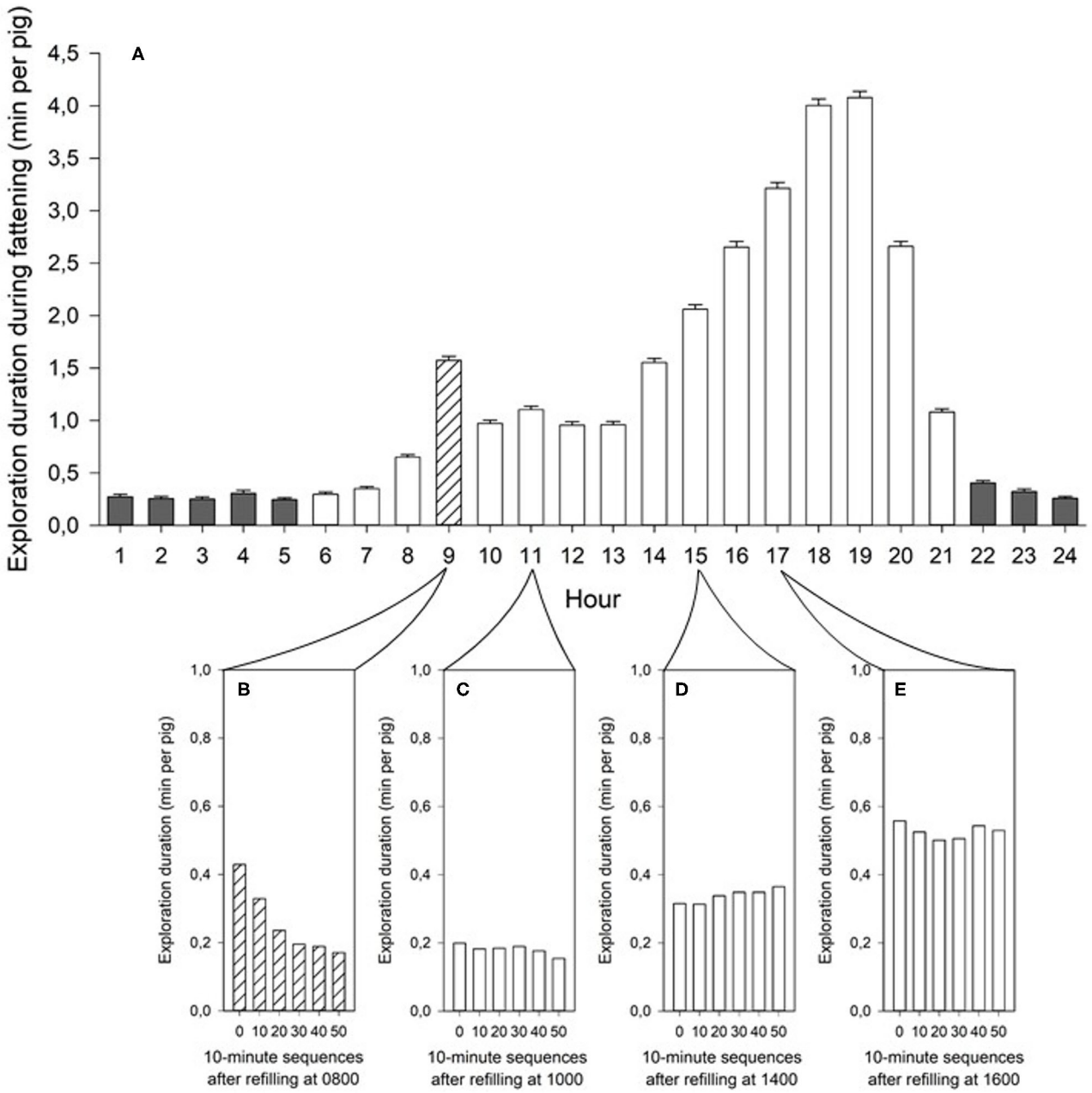

FIGURE 5 | (A) Diurnal pattern of exploration duration (mean ± SE minutes per pig) at the dispenser filled with chopped straw in treatment R1 (one additional offer of chopped straw at 0800) during fattening. **(B)** Exploration durations in 10-min sequences within the hour after refilling the rooting area (striped bars). **(C–E)** Exploration durations within the hours at which in treatment R4 (see **Figure 6**) chopped straw was additionally offered. Light bars indicate light phase and dark bars indicate dark phase.

a more frequent incentive to explore chopped straw when it was additionally delivered four times. Pedersen et al. (2014) found that pigs were more active when the amounts of chopped straw were increased. In our study, R4 pigs got the four-fold additional amount of chopped straw compared to R1 pigs but this did not affect exploration duration. Pigs synchronize their behavior especially when using limited resources (Docking et al., 2008) indicating that pigs can estimate the availability of resources. Resources can be limited by offering a limited amount or limited space. In our study, a stock of chopped straw was available for the pigs during the whole time and, therefore, the amount of straw represented no limited resource for the pigs. This may have led to similar exploration durations in both treatments and, thus, reduced or even fully eliminated the expected effect of the additional stimulation. These results do not mean that enrichment material should be offered as limited

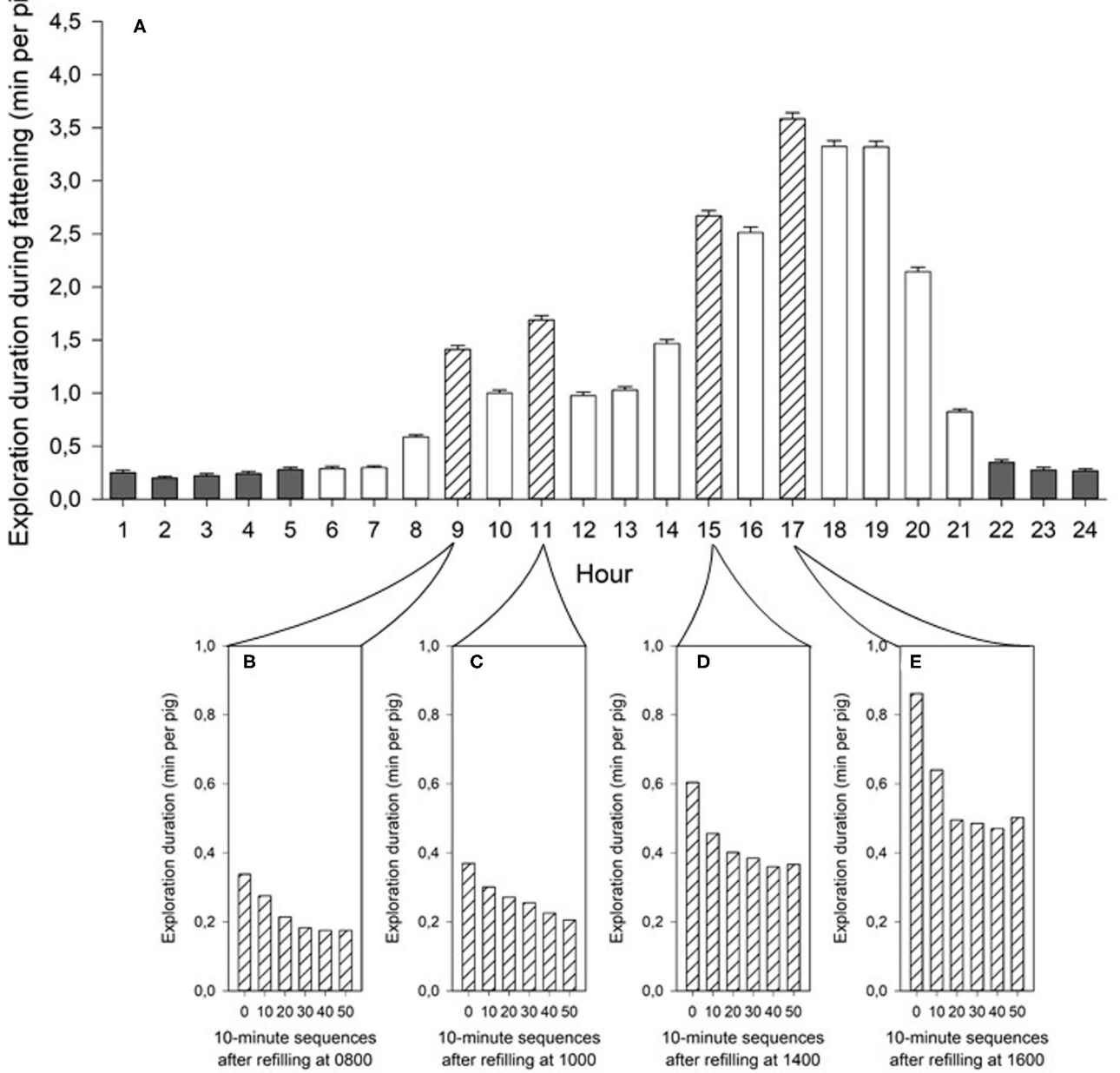

FIGURE 6 | (A) Diurnal pattern of exploration duration (mean ± SE minutes per pig) at the dispenser filled with chopped straw in treatment R4 (four additional offers of chopped straw at 0800, 1000, 1400, and 1600) during fattening. **(B–E)** Exploration durations in 10-min sequences within the hour after refilling the rooting area (striped bars). Light bars indicate light phase and dark bars indicate dark phase.

resource. If the access to the enrichment material is limited, competition for the materials can arise, that may lead to an increase of manipulative behaviors such as tail biting (Van de Perre et al., 2011; Kauselmann et al., 2020). Thus, it seems to be necessary to ensure continuous and sufficient access to the provided enrichment materials, especially during rearing, when tail biting is often observed (Blackshaw, 1981; Schrøder-Petersen et al., 2010; Abriel and Jais, 2013; Veit et al., 2016). However, it seems that multiple provisioning events in combination with material available *ad libitum* has no additional benefit for the pigs and a single *ad libitum* refilling (R1) per day is sufficient to stimulate similar exploration durations compared to R4, which may be important for farmers as work load can be better balanced. Providing the material at more than one additional refilling does not increase overall exploration duration, but rather led to subtle shifts, as indicated in our study by small and short-term increases of exploration after additionally providing material.

In our study, rearing piglets on average spent between 13.4 min (additional chopped straw once per day, R1) and 12.8 min (additional chopped straw four times per day, R4) per pig and day at the dispenser. In comparable previous studies with the similar dispensers and test conditions, piglets explored on average 23.2 min per pig and day when the flavor of straw pellets (including control without flavor) was changed weekly (Kauselmann et al., 2021b) and 25.4 min per pig and day when maize kernels were added to chopped straw (Kauselmann et al., 2020). This may be related to the fact that flavored pellets and maize kernels in straw can be chewed by the piglets. Such a possibility to manipulate the material seems to be an important property of enrichment materials during rearing (Kauselmann et al., 2021a). Thus, offering further chewable materials, changing the flavor of enrichment materials or adding edible additives to chopped straw may be a more effective way to increase exploration duration in piglets during rearing than continuously providing straw or repeatedly offering a stimulus for exploration throughout the day.

Compared to rearing piglets, fattening pigs in this study showed higher exploration durations per pig and day (R1: 29.7; R4: 27.9 min), which are comparable with exploration durations of fattening pigs in previous studies where different flavored straw pellets were changed weekly (23.7 min per pig and day; Kauselmann et al., 2021b). The preferences of pigs for enrichment materials change with age (Docking et al., 2008; Kauselmann et al., 2021a) and therefore enrichment materials should be adapted to the age-related needs of the pigs. Fattening pigs have been found to explore chopped materials to a higher or a comparable frequency as pelletized materials (depending on the material) when these materials were changed biweekly (Kauselmann et al., 2021a). Thus, in fattening pigs chopped straw offered in daily refillings seems to have the same effect as changing the flavor of pelletized enrichment materials weekly.

Exploration durations varied somehow randomly between and within weeks of rearing and fattening period. However, an increase in exploration duration was recorded from rearing to fattening. Thus, there are no signs of long-term habituation. As mentioned above, pigs are highly motivated to synchronize their behavior (Hsia and Wood-Gush, 1983; Zwicker et al., 2015) and synchronization of object directed behavior even increases with age (Docking et al., 2008). Furthermore, it has to be considered that after rearing, the total number of pigs per pen was reduced from 24 to 12 in the fattening pens. Thus, higher exploration durations in fattening probably were affected by both the increased motivation to synchronize exploration behavior of fattening pigs and the smaller group size, resulting in better simultaneous access to the dispenser. Further research would be needed to investigate whether better simultaneous access to the rooting material or additional dispensers could further increase exploration duration and reduce tail damages especially during rearing.

Depending on the refilling treatment, i.e., one or four times daily, exploration durations briefly increased after providing additional chopped straw. However, overall exploration duration per day remained unaffected. Independent from treatment, exploration duration of rearing and fattening pigs at the dispenser within days showed one peak in the morning and one higher peak in the afternoon, which is a typical temporal pattern for exploration behavior in pigs (Olsen et al., 2000; Kauselmann et al., 2020, 2021b). Thus, refilling of additional chopped straw does not seem to affect the daily pattern of exploration.

In fattening pigs, the highest increase of exploration duration occurred within the first 10-min sequence after provision of additional straw. Thereafter exploration duration decreased and remained at a constant level. Previous studies found also reduced exploration of pigs over time and within a day after providing enrichment materials (Apple and Craig, 1992; Van de Perre et al., 2011) caused by habituation. By use of the UHF RFID system we were able to show that such a habituation can happen very quickly within an hour. However, as in our study we tested the effect of chopped straw that was offered in addition to *ad libitum* accessible chopped straw in the dispenser, this probably increased the speed of habituation. As previous studies suggest, offering enrichment materials with different structures (Kauselmann et al., 2021a), edible additives (Kauselmann et al., 2020), or flavors (Kauselmann et al., 2021b) in intervals may have longer lasting effects. Compared to fattening, rearing piglets showed constant exploration durations within the 10-min sequences after refilling the rooting area of the dispenser with additional chopped straw. Probably, fattening pigs habituate faster to the already known straw than rearing piglets that did not had access to straw until start of rearing. Both in rearing and fattening, there was an increase in exploration duration after refilling the rooting area of the dispenser compared to the hour previous to the refilling. This short-term effect on exploration duration was low but could be an opportunity to occupy and distract pigs by regularly offering additional plant-based enrichment material when tail biting occurs. Although regarding exploration duration no long-term effect of multiple refillings was found compared to a single refilling, it might be worth to investigate in future studies whether multiple refillings can be used as an immediate intervention after the occurrence of tail biting in a group of pigs, to reduce the consequences of tail biting, i.e., injuries or length losses at the tail.

There was no effect of the refilling treatments on Δ-tail length in rearing and fattening. It is known that offering enrichment material can increase exploration (Studnitz et al., 2007; Jensen et al., 2010, 2015) and reduce manipulative behavior (Jensen et al., 2010; Pedersen et al., 2014; Larsen et al., 2018) in pigs. In our study exploration durations did not differ between refilling treatments, which could explain the missing effect on tail length. Nevertheless, more tail length losses occurred during rearing than during the fattening period, where higher exploration durations were recorded. Since rearing poses an increased risk for tail biting (Blackshaw, 1981; Schrøder-Petersen and Simonsen, 2001; Veit et al., 2016), enrichment material should be offered especially during this period, to further increase exploration duration and reduce tail damages in rearing pigs.

CONCLUSION

This study provides new insights in refilling rooting materials as additional plant-based enrichment material at different

frequencies per day. Regarding exploration duration and tail damages an offer of additional straw four times per day had no advantage or disadvantage compared to offering straw once a day, when pigs have *ad libitum* access to straw. However, even though the additional straw provision does not affect the daily pattern of exploration duration, there is a small short-term effect of the additional provided straw as a stimulus for exploration, which may be further examined in the future with regard whether multiple refillings may represent an immediate intervention at the occurrence of tail biting.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the animal study because the animals were not isolated from conspecifics, not restricted from any resources, remained in their familiar environment and were not manipulated in accordance to the study protocol. Furthermore pigs were housed and managed according to the German legislation for farm animals (TierSchNutztV, 2017) and in accordance to Council Directive 2008/120/EC. The different numbers of refillings with rooting material per day, i.e., once vs. four times, were provided in addition to the rooting material available *ad libitum*. These additional refillings represented additional environmental enrichment and were the only change in the housing environment with respect to the data collection. The additionally provided rooting materials at the refillings (R1 vs. R4), thus, represented no limited resource which might have triggered competitive behavioral patterns, but rooting material was *ad libitum* available at any time in the dispersers regardless of the refillings (R1 vs. R4). All data were recorded at a licensed farm that produces, rears, fattens, and markets pigs (VVVO-Number: 08 128 0140 538). Thus, pigs from the study were marketed after the study. Beyond minimum German legal requirements, space allotment per pig in the present study was higher and pigs were offered additional enrichment material on a daily basis (as R1 and R4 treatment), which is usually expected to have a positive effect on pigs' welfare, as additional stimulation of explorative behavior is regarded to reduce potential welfare issues such as tail biting. Data on exploration were automatically recorded *via* an UHF RFID system which was integrated into the dispenser. Scoring of tail damages was conducted carefully and non-invasively using the Deutscher Schweine Bonitur-Schlüssel (2017). Pigs remained with their peers at any time. Pigs were visually inspected on a daily basis. In case of tail biting, additional enrichment materials (paper bags, mineral feed, squeezed oats, and zeolite) were offered and in case biters were identified (two piglets during rearing) they were separated from the group and housed in a separate pen.

AUTHOR CONTRIBUTIONS

LS and HS: idea and funding. EK, LS, and HS: project administration and supervision. KK, EK, and LS: conceptualization and methodology, writing, review, and editing manuscript. KK: investigation, data curation, writing original draft, and creating figures. KK and EK: statistical analysis. HS: providing resources. All authors contributed to the article and approved the submitted version.

FUNDING

This project was funded by the Federal Ministry of Food and Agriculture (BMEL) by a decision of the Parliament of the Federal Republic of Germany *via* the Federal Office for Agriculture and Food (BLE; FKZ: 2819200615).

ACKNOWLEDGMENTS

We thank two reviewers for helpful comments on our manuscript. Furthermore, we thank the staff from the Bildungs- und Wissenszentrum Boxberg (LSZ) for supporting the study, as well as the project partners, the partner from the Deutscher Tierschutzbund and Eva Gallmann, Bastian Kolb and Svenja Opderbeck from the University of Hohenheim, in the collaborative project Label-Fit for discussion on the project and the results.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fanim.2021.749583/full#supplementary-material

REFERENCES

Abriel, M., and Jais, C. (2013). Einfluss der Haltungsbedingungen auf das Auftreten von Kannibalismus bei Aufzuchtferkeln. *Landtechnik* 68, 389–394. doi: 10.15150/lt.2013.254

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

Averberg, U., Scholz, T., and Ziron, M. (2018). *Futtervorlage bei Mastschweinen*. DLG Merkblatt, 360, 1–12.

Bates, D., Maechler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67, 1–48. doi: 10.18637/jss.v067.i01

Beattie, V. E., Walker, N., and Sneddon, I. A. (1995). Effects of environmental enrichment on behaviour and productivity of growing pigs. *Anim. Welfare* 4, 207–220.

Blackshaw, J. K. (1981). Some behavioural deviations in weaned domestic pigs. Persistent inguinal nose thrusting, and tail and ear biting. *J. Anim. Sci.* 33, 325–332. doi: 10.1017/S00033561000 3172X

Deutscher Schweine Bonitur-Schlüssel (2017). *Deutscher Schweine-Boniturschlüssel.* Available online at: https://www.fli.de/fileadmin/FLI/ITT/Deutscher_Schweine_Boniturschluessel_2017-06-30_de.pdf

Docking, C. M., Van de Weerd, H. A., Day, J. E. L., and Edwards, S. A. (2008). The influence of age on the use of potential enrichment objects and

synchronisation of behaviour of pigs. *Appl. Anim. Behav. Sci.* 110, 244–257. doi: 10.1016/j.applanim.2007.05.004

EFSA (2007). Scientific opinion of the panel on animal health and welfare on a request from commission on the risk associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. *EFSA J.* 611, 1–13. doi: 10.2903/j.efsa.2007.611

Fox, J., and Weisberg, S. (2019). *An {R} Companion to Applied Regression, 3rd Edn*. Thousand Oaks, CA: SAGE Publications Inc.

Fraser, D., Phillips, P. A., Thompson, B. K., and Tennessen, T. (1991). Effect of straw on the behaviour of growing pigs. *Appl. Anim. Behav. Sci.* 30, 307–318. doi: 10.1016/0168-1591(91)90135-K

Früh, B., Bochicchio, D., Edwards, S., Hegelund, L., Leeb, C., Sundrum, A., et al. (2013). Description of organic pig production in Europe. *Organic Agric.* 4, 83–92. doi: 10.1007/s13165-013-0056-9

Hsia, L. C., and Wood-Gush, D. G. M. (1983). The temporal patterns of food intake and allelomimetic feeding by pigs of different ages. *Appl. Anim. Behav. Sci.* 11, 271–282. doi: 10.1016/0304-3762(84)90034-8

Jensen, M. B., Herskin, M. S., Forkman, B., and Pedersen, L. J. (2015). Effect of increasing amounts of straw on pigs' explorative behaviour. *Appl. Anim. Behav. Sci.* 171, 58–63. doi: 10.1016/j.applanim.2015.08.035

Jensen, M. B., and Pedersen, L. J. (2007). The value assigned to six different rooting materials by growing pigs. *Appl. Anim. Behav. Sci.* 108, 31–44. doi: 10.1016/j.applanim.2006.10.014

Jensen, M. B., Studnitz, M., and Pedersen, L. J. (2010). The effect of type of rooting material and space allowance on exploration and abnormal behaviour in growing pigs. *Appl. Anim. Behav. Sci.* 123, 87–92. doi: 10.1016/j.applanim.2010.01.002

Kauselmann, K., Krause, E. T., Glitz, B., Gallmann, E., Schrade, H., and Schrader, L. (2021a). Effect of plant-based enrichment materials on exploration in rearing and fattening pigs (*Sus scrofa domesticus*). *Appl. Anim. Behav. Sci.* 236:105261. doi: 10.1016/j.applanim.2021.105261

Kauselmann, K., Schrader, L., Glitz, B., Gallmann, E., Schrade, H., and Krause, E. T. (2020). Turning the gaze to maize: the effects of maize kernels in straw as enrichment on exploration and tail status in pigs. *Berliner und Münchener Tierärztliche Wochenschrift* 133. doi: 10.2376/1439-0299-2020-24

Kauselmann, K., Schrader, L., Glitz, B., Gallmann, E., Schrade, H., and Krause, E. T. (2021b). Tasty straw pellets – exploration of flavoured rooting material by pigs. *Animal* 15:100239. doi: 10.1016/j.animal.2021.100239

Kritas, S. K., and Morrison, R. B. (2007). Relationship between tail biting in pigs and disease lesions and condemnations at slaughter. *Vet. Rec.* 160, 149–152. doi: 10.1136/vr.160.5.149

Lahrmann, H. P., Oxholm, L. C., Steinmetz, H., Nielsen, M. B., and D'Eath, R. B. (2015). The effect of long or chopped straw on pig behaviour. *Animal* 9, 862–870. doi: 10.1017/S1751731114003024

Larsen, M. L. V., Andersen, H. M., and Pedersen, L. J. (2018). Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? *Animal* 12, 1260–1267. doi: 10.1017/S175173111700249X

Lawrence, A. B., Terlouw, E. M., and Kyriazakis, I. (1993). The behavioural effects of undernutrition in confined farm animals. *Proc. Nutr. Soc.* 52, 219–229. doi: 10.1079/PNS19930054

Li, Y. Z., Zhang, H. F., Johnston, L. J., Martin, W., Peterson, J. D., and Coetzee, J. F. (2017). Effects of tail docking and tail biting on performance and welfare of growing-finishing pigs in a confinement housing system. *J. Anim. Sci.* 95, 4835–4845. doi: 10.2527/jas2017.1571

Marques, B. M. F. P. P., Bernardi, M. L., Coelho, C. F., Almeida, M., Morales, O. E., Mores, T. J., et al. (2012). Influence of tail biting on weight gain, lesions and condemnations at slaughter of finishing pigs. *Pesq. Vet. Bras.* 32, 967–974. doi: 10.1590/S0100-736X2012001000003

Olsen, A. W., Vestergaard, E. M., and Dybkjaer, L. (2000). Roughage as additional rooting substrates for pigs. *Anim. Sci.* 70, 541–456. doi: 10.1017/S1357729800051808

Pedersen, L. J., Herskin, M. S., Forkman, B., Halekoh, U., Kristensen, K. M., and Jensen, M. B. (2014). How much is enough? The amount of straw necessary to satisfy pigs' need to perform exploratory behaviour. *Appl. Anim. Behav. Sci.* 160, 46–55. doi: 10.1016/j.applanim.2014.08.008

Peeters, E., Driessen, B., Moons, C. P. H., Ödberg, F. O., and Geers, R. (2006). Effect of temporary straw bedding on pigs' behaviour, performance, cortisol and meat quality. *Appl. Anim. Behav. Sci.* 98, 234–248. doi: 10.1016/j.applanim.2005.10.002

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., and R Core Team (2019). *nlme:Linear and Nonlinear Mixed Effects Models*. R package version 3.1-141. Available online at: https://CRAN.R-project.org/package=nlme

R Core Team (2019). *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.

Schielzeth, H., Dingemanse, N. J., Nakagawa, S., Westneat, D. F., Allegue, H., Teplitsky, C., et al. (2020). Robustness of linear mixed-effects models to violations of distributional assumptions. *Methods Ecol. Evol.* 11, 1141–1152. doi: 10.1111/2041-210X.13434

Schrøder-Petersen, D. L., and Simonsen, H. B. (2001). Tail biting in pigs. *Vet. J.* 162, 196–210. doi: 10.1053/tvjl.2001.0605

Schrøder-Petersen, D. L., Simonsen, H. B., and Lawson, L. G. (2010). Tail-in-mouth behaviour among weaner pigs in relation to age, gender and group composition regarding gender. *Anim. Sci.* 53, 29–34. doi: 10.1080/09064700310002017

Sinisalo, A., Niemi, J. K., Heinonen, M., and Valros, A. (2012). Tail biting and production performance in fattening pigs. *Livest. Sci.* 143, 220–225. doi: 10.1016/j.livsci.2011.09.019

Studnitz, M., Jensen, M. B., and Pedersen, L. J. (2007). Why do pigs root and in what will they root? *Appl. Anim. Behav. Sci.* 107, 183–197. doi: 10.1016/j.applanim.2006.11.013

TierSchNutztV (2017). *Tierschutz-Nutztierhaltungsverordnung in the Version Published on 22. August 2006 (BGBl. I S. 2043), Last Amended by Article 3(2) of the Act of 30*. June 2017 (BGBl. I p. 2147). Available online at: https://www.gesetze-im-internet.de/tierschnutztv/BJNR275800001.html

Trickett, S. L., Guy, J. H., and Edwards, S. A. (2009). The role of novelty in environmental enrichment for the weaned pig. *Appl. Anim. Behav. Sci.* 116, 45–51. doi: 10.1016/j.applanim.2008.07.007

Valros, A., Ahlström, S., Rintala, H., Häkkinen, T., and Saloniemi, H. (2007). The prevalence of tail damage in slaughter pigs in Finland and associations to carcass condemnations. *Acta Agric. Scand. Sec. A Anim. Sci.* 54, 213–219. doi: 10.1080/09064700510009234

Van de Perre, V., Driessen, B., Van Thielen, J., Verbeke, G., and Geers, R. (2011). Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. *Anim. Welfare* 20, 641–649.

Van de Weerd, H. A., Docking, C. M., Day, J. E. L., Avery, P. J., and Edwards, S. A. (2003). A systematic approach towards developing environmental enrichment for pigs. *Appl. Anim. Behav. Sci.* 84, 101–118. doi: 10.1016/S0168-1591(03)00150-3

Veit, C., Traulsen, I., Hasler, M., Tölle, K.-H., Burfeind, O., Beilage, E. G., et al. (2016). Influence of raw material on the occurrence of tail-biting in undocked pigs. *Livest. Sci.* 191, 125–131. doi: 10.1016/j.livsci.2016.07.009

Zwicker, B., Weber, R., Wechsler, B., and Gygax, L. (2015). Degree of synchrony based on individual observations underlines the importance of concurrent access to enrichment materials in finishing pigs. *Appl. Anim. Behav. Sci.* 172, 26–32. doi: 10.1016/j.applanim.2015.08.037

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.