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Turning the gaze to maize: The effects of maize kernels in straw as enrichment on exploration in pigs

Mais im Fokus: Auswirkungen von Maiskörnern in Stroh als Beschäftigungsmaterial auf die Exploration bei Schweinen

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Summary

Tail biting is one of the biggest problems in pig production systems that causes animal welfare and economic problems. Therefore, tail docking is a widely used intervention to reduce tail biting. However, appropriate enrichment material that stimulates and increases exploration behaviour of pigs also reduces the prevalence and risk of tail biting. In 288 pigs with undocked tails we investigated whether the attractiveness of chopped straw (CS) as enrichment material can be further increased when maize kernels were added (CS+MK). Further, we examined whether a higher attractiveness is accompanied by reduced tail incidents. We used material dispensers equipped with ultra-high-frequency radio-frequency identification (UHF RFID) systems to record individual exploration times of the pigs to the offered enrichment materials. Furthermore, animals were scored thrice for tail length losses and tail injuries, i.e. after the rearing period, in the middle of the fattening period and at the end of the fattening period. Both rearing and fattening pigs had higher exploration durations when housed with CS+MK compared to CS (LME: rearing, $P<0.001$, fattening, $P<0.05$). Interestingly, enrichment materials not only remained interesting but were used even more from rearing to fattening. However, when CS+MK was offered pigs showed a higher prevalence for tail biting incidents in the rearing, but not in the fattening period, compared to CS (rearing GLMM, $P<0.01$). This may have resulted from competition for the more attractive enrichment material (CS+MK). An edible additive increased the interest for straw in pigs over long term but could not improve tail status.

Keywords: nutritive additive, fattening, rearing, *Sus scrofa domesticus*, tail biting

Zusammenfassung

Eine der größten Problematiken in der kommerziellen Schweinehaltung ist das Auftreten von Schwanzbeißen, was tierschutzrelevante wie auch wirtschaftliche Probleme verursacht. Daher ist bisher das Schwanzkupieren eine weitverbreitete Maßnahme, um das Schwanzbeißen zu vermeiden. Jedoch können geeignete Beschäftigungsmaterialien, die bei den Tieren zu einem Anstieg der Explorations- und Beschäftigungszeit führen, das Risiko für Schwanzbeißen mindern. An 288 unkupierten Schweinen wurde untersucht, ob gehäckseltes Stroh mit Maiskörnern (CS+MK) im Vergleich zu gehäckseltem Stroh (CS) attraktiver ist und ob eine höhere Attraktivität zu weniger Schwanzverletzungen und Teilverlusten während der Aufzucht und Mast führt. Dafür verwendeten wir Beschäftigungsautomaten, in denen ein ultrahochfrequentes Radiofrequenz-Identifikations-System (UHF RFID) eingebaut wurde, um die individuellen Beschäftigungszeiten der Schweine für das angebotene Beschäftigungsmaterial aufzuzeichnen. Weiterhin wurden die Schwänze der Schweine dreimal bonitiert: nach der Aufzucht, zur Mitte und zum Ende der Mast. In der Aufzucht und Mast war die Beschäftigungszeit der Schweine, die CS+MK erhielten, signifikant höher, verglichen mit Schweinen, die ausschließlich CS erhielten (Aufzucht, LME, $P<0,001$, Mast, LME, $P<0,05$). Das Interesse an den eingesetzten Beschäftigungsmaterialien konnte nicht nur

aufrechterhalten werden, sondern stieg interessanterweise von der Aufzucht bis zur Mast weiter an. Jedoch zeigten Schweine, die CS+MK erhielten, in der Aufzucht mehr Schwanzlängenverluste als Schweine, die ausschließlich CS erhielten (Aufzucht GLMM, P<0,01). In der Mast gab es keinen Unterschied. Dies könnte möglicherweise daran liegen, dass durch das stark präferierte Beschäftigungsmaterial (CS+MK) in der Aufzucht eine Konkurrenz ausgelöst wurde. Ein fressbarer Zusatz steigerte langfristig das Interesse von Schweinen für Stroh, konnte den Zustand der Schwänze jedoch nicht verbessern.

Schlüsselwörter: fressbare Zusätze, Aufzucht, Mast, *Sus scrofa domesticus*, Schwanzbeißen

Introduction

Abnormal behaviours appear often in commercially housed pigs and are considered as important indicators for animal welfare problems (Beattie et al. 1995, Schouten 1986). Behavioural disorders of domestic pigs are especially manifested in tail biting (e.g. Beattie et al. 1995, Bolhuis et al. 2005, Fraser et al. 1991, Petersen et al. 1995), which mainly occur during the rearing period (Abriel and Jais 2013, Blackshaw 1981, Jans-Wenstrup 2018, Schrøder-Petersen et al. 2010, Veit et al. 2016). Indications of physiological stress were found in tail biters (Munsterhjelm et al. 2013) and it is assumed that pigs try to compensate for occurring stressors by biting the tails of their penmates (Schrøder-Petersen and Simonsen 2001). The consequences of tail biting for the victim pigs range from skin injuries, to tail losses or even to inflammation and abscesses as a late consequence (Kritas and Morrison 2007, Li et al. 2017, Valros et al. 2007). Beside these severe animal welfare and health issues, these animal-related consequences also can cause economic losses for the farmers (Kritas and Morrison 2007, Li et al. 2017, Valros et al. 2007). To reduce the occurrence of tail biting, tail docking is so far a widely used method that reduces but does not prevent the risk for tail damages (Hunter et al. 2001, Larsen et al. 2018, Li et al. 2017). Tail docking as other interventions (Veit et al. 2017) are in general legally prohibited in the European Union despite specific implemented exceptional permission (Anonymous 2008). These exceptional permissions are widely used with the consequence that 77% of the pigs in the European Union are routinely tail docked (De Briyne et al. 2018). Thus, for animal welfare reasons, which can be optimal realized when also economic considerations are taken into account, methods need to be identified that reduce the prevalence or even avoid tail biting in undocked pigs. To find solutions for preventing tail biting is rather complex as this behavioural disorder is assumed to have multifactorial causes (Brunberg et al. 2016, Schrøder-Petersen and Simonsen 2001). It is influenced by both the animal itself (e.g. genetic and breed, growth, sex, behavioural characteristics, health) and the environment (e.g. feed/feeding, space available and group size, enrichment material, climate and management) (Valros 2018). Many studies found that enrichment materials can help to prevent certain abnormal behaviours in pigs (Beattie et al. 1995, Hunter et al. 2001, Larsen et al. 2018) and can reduce tail biting (Beattie et al. 1995, EFSA 2014). However, materials that are highly preferred by pigs can lead to competition resulting in agonistic interactions and increasing risks for tail biting (Van de Perre et al. 2011). Pigs habituate to durable, non-plant-based materials quickly. Exploration times usually decreases within few days (Van de Perre et al. 2011) or even faster within hours after offering an enrichment object (Apple and Craig 1992). Plant-based materials may also trigger decreasing exploration over time, however, other studies showed that these materials sustain interest and exploration over weeks such as straw offered in different forms (Van de Weerd et al. 2006, Zwicker et al. 2013). Plant-based materials are changeable, manipulable, chewable, edible or odorous. These properties seem to be crucial for suitable enrichment materials for pigs (Fraser et al. 1991, Jensen and Pedersen 2007, Studnitz et al. 2007, Van de Perre et al. 2011, Van de Weerd et al. 2003). When given the choice pigs prefer plant-based materials to non-plant-based materials (Scott et al. 2006, 2009). Among the plant-based materials, straw is so far best investigated and it is highly recommended as enrichment material for pigs (Bolhuis et al. 2005, Fraser et al. 1991, Jensen and Pedersen 2007, Studnitz et al. 2007, Van de Perre et al. 2011, Van de Weerd et al. 2003). Materials including different mixed structures or with edible additives were even better accepted by pigs than straw (Jensen and Pedersen 2007, Zwicker et al. 2013). When pigs get a food reward the attractivity of rootable plant-based enrichment material increases (Holm et al. 2008). A possible reason is that pigs can better perform their innate foraging behaviour if they are able to search, chew and eat edible parts while exploring the enrichment material (Studnitz et al. 2007). However, from a practical point of view plant-based materials are likely to rise problems in the recent conventional pig housing systems as in pens with slatted floors they can clog the slurry pits.

We here aim to identify a practicable way to increase attractiveness of plant-based enrichment material which are feasible also later under practical conditions over the entire production period, i.e. from rearing to fattening, in order to reduce tail damages and thus avoid tail docking in pigs. For this purpose we used material dispensers with an integrated ultra-high-frequency radio-frequency identification (UHF RFID) system and investigated how chopped straw compared to chopped straw with maize kernels provided as enrichment material affect (i) exploration durations (i.e. time spent at the material dispenser), and (ii) tail status (i.e. tail length and injuries) in pigs from rearing to the end of fattening period. We hypothesize that straw enriched with a nutritive additive, i.e. maize, remains more attractive for pigs and results in higher exploration times in rearing and fattening pigs compared to straw without any additives. According to this, we expect less tail biting activities in straw with the maize supplemented groups what will be associated with a better tail status.

TABLE 1: *Dates of data collection with the corresponding times of sunrise and sunset in Germany*

Period	Replicate	Number of animals		Date	Sunrise	Sunset	Mean sunrise	Mean sunset
Rearing	1	96	Begin	14.06.2018	5:03	21:07	6:44	19:22
			End	01.08.2018	5:40	20:40		
	2	96	Begin	16.08.2018	6:14	20:42		
			End	02.10.2018	7:27	19:00		
	3	96	Begin	18.10.2018	7:53	18:25		
			End	05.12.2018	8:11	16:19		
Fattening	1	91	Begin	01.08.2018	5:40	20:40	7:30	18:06
			End	17.10.2018	7:52	18:28		
	2	93	Begin	02.10.2018	7:27	19:00		
			End	20.12.2018	8:25	16:19		
	3	93	Begin	05.12.2018	8:11	16:19		
			End	21.02.2019	7:27	17:50		

Methods

Animals and housing

We used a total of 288 pigs with randomly mixed sexes in three successive replicates (replicate 1: 55 females and 41 castrated males, replicate 2: 47 females and 49 castrated males, replicate 3: 52 females and 44 castrated males). The crossbred pigs (German Piétrain x German Hybrid) with undocked tails were housed in forced ventilated stables at the Bildungs- und Wissenszentrum Boxberg (LSZ), Germany. The study with all three identical replicates was carried out from June 2018 to February 2019 (Tab. 1). At weaning, with an age of about 28 days, the piglets were weighted and individually equipped with common ear tags that were internally equipped with an UHF RFID tag (MS Tag Round UHF, MS Schippers, Netherlands). Each piglet got two tags with the same number (one per ear) for individual identification. At the day of weaning, piglets had an average weight of 7.4 kg (±1.2 kg SD). In each of the three replicates, 96 piglets were transferred to the study stable and divided in four identical rearing pens (24 piglets each), according to their assigned treatment (see below). Each pen had 15 m^2 (5 x 3 m) floor space (Fig. 1a) with 7.5 m^2 slatted plastic floor (38.5% perforation), 3.0 m^2 slatted concrete floor (17.0% perforation), and 4.5 m^2 partly slatted concrete floor (7.0% perforation) under a heated covering. All rearing pens were equipped with a material dispenser, a scrubber bar, a wooden pole attached on a metal chain and sisal ropes. Piglets had *ad libitum* access to water from two drinking bowls (Suevia 92 R, Suevia Haiges GmbH, Kirchheim, Germany) and two additional nipple drinkers in each pen. Mashed feed was offered *ad libitum* by an automatic mash feeder (2.4:1, animal:feeding place ratio) in two phases. Feed composition changed after two weeks of rearing (detailed information on feed composition is given in the electronic supplementary material). One week before rearing ended, the piglets were additionally fed with pellet concentrate (approximately 25 kg per pen) from a single feeder to habituate them to the feed change in fattening. During the seven weeks in the rearing pens, we had to remove a total of eleven piglets in all three replicates (4 pigs with locomotion problems, 2 runts, 2 identified tail biters, 2 died without identifiable reason and 1 pig with a swollen cheek), i.e. 3.8%, resulting in 91 pigs in replicate 1 (52 females and 39 castrated males), 93 pigs in replicate 2 (46 females and 47 castrated males), and 93 pigs in replicate 3 (50 females and 43 castrated males) (Tab. 1). The pigs were distributed in eight fattening pens per replicate, respectively. The animals of each rearing pen were randomly split up in two groups for fattening pens (max. 12 pigs per pen). Thus, the pigs of each fattening group were familiar to each other. At the beginning of fattening, pigs had an average weight of 30.6 kg (±4.2 kg SD). Pigs were housed in each fattening pen (Fig. 1b) with 15 m^2 (5 x 3 m) floor space and fully slatted concrete floor (17% perforation). All fattening pens were identically equipped with a material dispenser. Pigs had *ad libitum* access to water from four nipple drinkers in each pen. Feed was offered *ad libitum* in two phases as pellet concentrate from a single feeder. When pigs reached an average weight of about 80 kg, feed composition changed (detailed information on feed composition is given in the electronic supplementary material, Supplementary

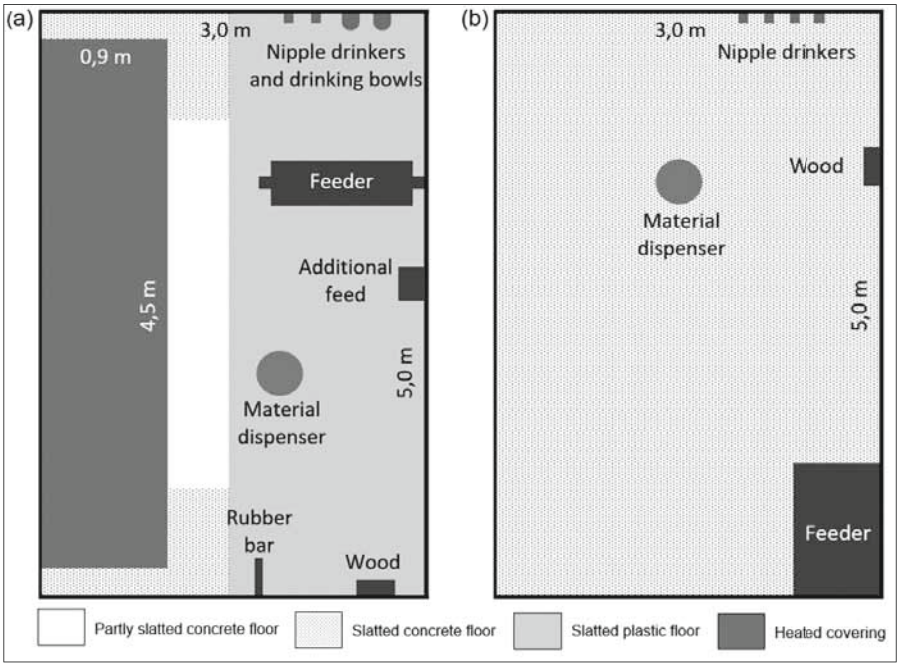

FIGURE 1: *Schematic drawing of a (a) rearing and (b) fattening pen with partly slatted concrete floor with 7% perforation (white), slatted concrete floor with 17% perforation (dotted), slatted plastic floor with 38.5% perforation (lined) and heated covering (grey). Graphic: Karen Kauselmann, FLI*

Tab. 1). The pigs were housed in the fattening pens for at least eleven weeks. Thereafter the study and, thus, the data collection ended. Pigs were fattened until reaching final mass and were then slaughtered and marketed.

With regard to the offered enrichment materials, we took up the recommendations of the European Commission (2016) and, in addition to the material dispenser, we continuously offered additional enrichment materials to the pigs during rearing (wood, sisal rope, rubber bar) and fattening (wood, sisal ropes), what exceed the minimum requirements. Furthermore, space allowance in rearing (0.58 m^2/pig) and fattening (1.14 m^2/pig) was higher than minimum requirements by the TierSchNutztV (2017).

All housing and management procedures of the animals were conducted in accordance to German legislation (TierSchNutztV) for farm animals. Animals were visually inspected daily for health issues. In case of tail biting, additional paper bags, mineral feed, squeezed oats and zeolite were offered and the pigs were further closely observed. If biters could be identified, they were removed from the group and kept in a separate pen. Bitten pigs were immediately medicated or also kept in a separate pen if necessary.

Enrichment materials and material dispenser design

At the beginning of each replicate, pens were allocated to one of the two enrichment treatments, which the animals received throughout the entire study, i.e. rearing and fattening. Pigs in the pens of treatment one (two pens in each rearing period and respectively four pens in each fattening period in each replicate) received chopped barley straw (in the following abbreviated as CS) with a length of approximately 10 to 100 mm as enrichment material. In the respective pens of the second treatment, the chopped barley straw was mixed with whole grain maize kernels from regular forage maize (CS+MK) in a weight proportion of 10% of the straw. The appropriate enrichment material was offered continuously in rearing and fattening through material dispensers to the pigs. The storage tube of the material dispenser was filled by hand daily, except on weekends. For this reason, on Fridays, the storage tube of the material dispensers were filled with a stock for the weekend.

In the middle of each pen a material dispenser was installed (Fig. 1 and Supplementary Fig. 1) and consists of a storage tube containing the enrichment material. Between the storage tube and the floor there was a gap of 2.4 cm where the pigs could root for the enrichment material by moving a 25 cm long, 5 cm wide and 0.8 cm thick plastic bolt with balls (diameter 5.5 cm) at both ends. Around the 100 cm high storage tube with a diameter of 25 cm, a 10 cm high cement ring with an inner diameter of 63 cm was installed to create a rooting area around the storage tube. According to the recommendations to calculate the animal:feeding place ratio (Averberg et al. 2018), a width of 18 cm for rearing pigs and of 33 cm for fattening pigs was used to calculate the animal:dispenser place ratio. The resulting animal:dispenser place ratio was 1.7:1 in the rearing pens and 1.5:1 in the fattening pens. Under the storage tube and the cement ring, we installed a mat that prevents the enrichment material from falling through the slatted floor.

Data collection

Each material dispenser was equipped with a dust- and waterproof UHF RFID antenna (Kathrein MiRa ETSI, KATHREIN Solutions GmbH, Ismaning, Germany) inside the storage tube. The antenna was installed horizontally at a height of 50 cm above the floor. When the pigs stay at the rooting area of the material dispenser, the UHF RFID antenna reads the UHF RFID tags in the ears of the pigs and this was recorded as exploration time. The collected data were transferred through a converter and an UHF RFID reader into a database. We used a software application (Phenobyte GmbH & Co. KG., Ludwigsburg, Germany) to assign the animals to their pens and thus to the corresponding UHF RFID antenna. This enabled us to collect the time at the material dispenser for each animal, in each of the two respective treatments, i.e. straw with or without maize. The antenna settings were taken over as described in (Kauselmann et al. submitted [a]). Accordingly, the radiated output power at the antennas was 22.4 dBm. All pigs were scored according to the "Deutscher Schweine Bonitur Schlüssel" (DSBS 2017) and weighed four times during the test: at the beginning of the rearing period (i.e. at weaning), at the end of the rearing period, after six weeks of the fattening period, and at the end of observations (i.e. after eleven weeks of fattening period). At these occasions 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 are documented, 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. We recorded tail skin injuries of the pigs' in the following four categories: (0) no injuries (1) superficial perforation of the skin, punctually or in the form of a line (2) deeper, planar perforation of the skin, maximum as large as the diameter of the tail at the respective point, and (3) deeper, planar perforation of the skin, larger than the diameter of the tail at the respective point.

Statistical analysis

We calculated the recorded time at the material dispenser per animal and week for the seven weeks of rearing period (in the following referred to as section 1), the first six weeks of fattening (section 2) and the last five weeks of fattening (section 3) for each individual. Thus, the times can be compared between the sections (with different weeks). To get the amounts of newly recorded tail length losses, for each section we calculated the difference of the scored tail length loss to the score of the previous section and used the resulting Δ tail length for further analysis. For example, if a pig had a tail length category of 0 at the beginning of rearing and a tail length category of 1 after rearing, tail length changed by 1 (1-0) category (Δ tail length = 1) during rearing (section 1). If the same pig had a tail length category of 2 after both section 2 and 3 of fattening, tail length changed by 1 (2-1) category (Δ tail length = 1) during section 2 and by 0 (2-2) categories (Δ tail length = 0) during section 3 of fattening.

The time animals spent at the material dispensers per week for each section was analyzed separately for rearing and fattening period. Normal distribution of the residuals was reached by log-transformation [log(x+1)] and was checked by visual inspection of the q-q plot.

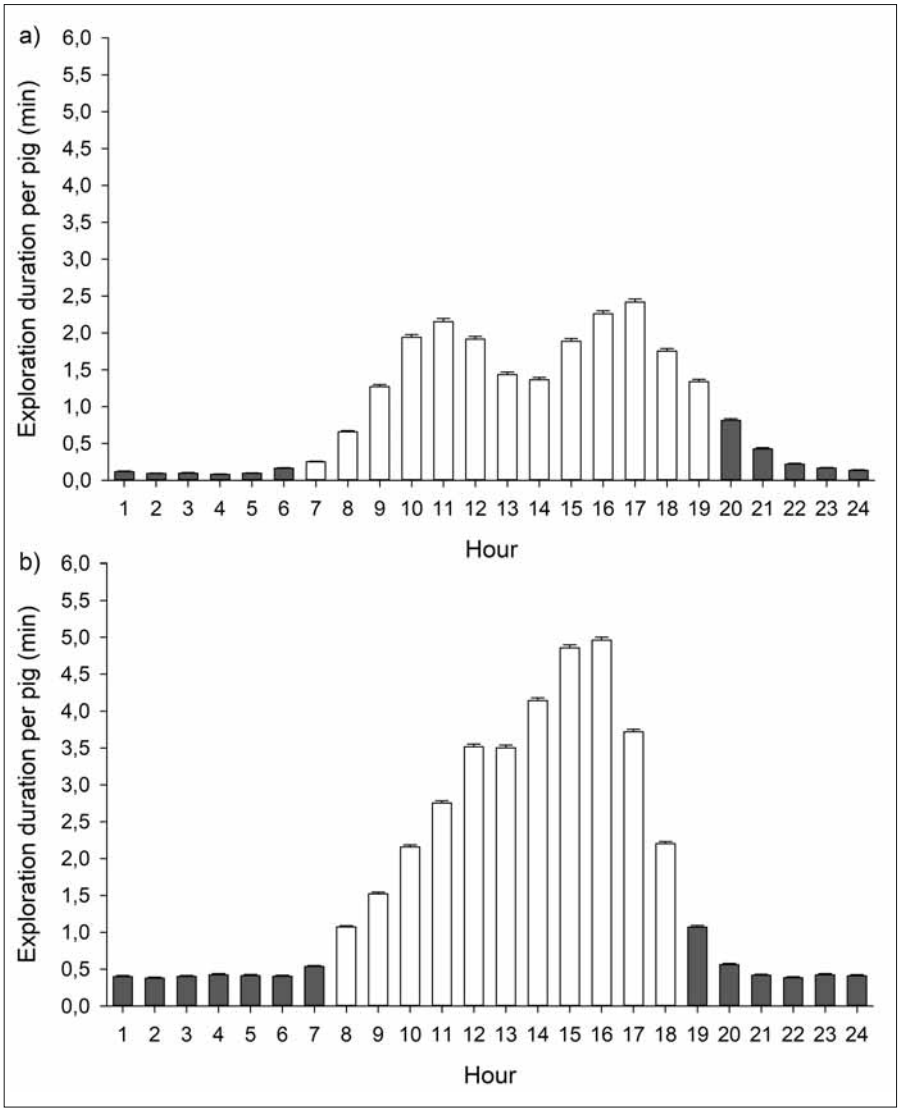

FIGURE 2: *Diurnal rhythm of mean (±SE) exploration duration in minutes per pig at the material dispenser during (a) the rearing and (b) the fattening period. White bars show the calculated mean light phase and gray bars show the mean dark phase of a 24 hour day during data collection (see Tab. 1). Graphic: Karen Kauselmann, FLI*

Linear mixed effect models (LME) with the exploratory variables (i) type of enrichment material provided in the material disperser (2-level factor, CS or CS+MK) (ii) body weight (measured at the end of each section) and (iii) two-way interactions between each exploratory variable were used. For the fattening pens section (2-level factor) was additionally considered as exploratory variable. AnimalID and PenID were considered as nesting random factors. PenID's were assigned across replicates.

To analyze the body weights of the animals at the end of the sections we used similar LMEs separately for rearing and fattening period with the same random factors and nesting random factors as described above. Here, only the type of enrichment material was used as explanatory variable in the models.

Δ tail lengths and skin injuries at the tails were also analyzed separately for rearing and fattening with generalized linear mixed models (GLMMs) with Poisson distribution. For the one section in rearing, we used the type of enrichment material as explanatory variable. As nesting random factor we used AnimalID and PenID. For the two sections in fattening, type of enrichment material, section, and the two-way interactions were used as explanatory variables. Random factors were the same as in the model for rearing. We used R version 3.3.1 (R Core Team 2019) and the packages lme4 (Bates et al. 2015) and nlme (Pinheiro et al. 2019) for the statistical analyses. To calculate the p-values for the GLMMs we used the package car (Fox and Weisberg 2019).

Results

Effects on exploration time of piglets during rearing

During rearing, a mean exploration duration of 160.4 min (±4.8 min SE) was recorded per pig and week. Within days the exploration at the material dispenser peaked about five hours after onset and about three hours before end of the light phase (Fig. 2a). During the dark phase of a 24-hour day, exploration remained at a low level.

Type of enrichment material (CS or CS+MK) had a significant effect on exploration times at the material dispenser throughout the rearing period (LME, factor material, $F_{1, 10} = 22.0$, $P<0.001$, Fig. 3a). Median exploration time was higher for chopped straw with maize kernels (177.8 min per animal and week, CS+MK) compared to chopped straw (120.6 min per animal and week, CS). The weight of the piglets had no effect on the exploration time at the material dispenser during rearing (LME, factor weight, $F_{1, 262} = 1.6$, $P = 0.2$) nor the interaction of both (LME, $F_{1, 262} = 1.6$, $P = 0.2$).

Effects on tail status during rearing period

Δ tail lengths were influenced by the offered enrichment materials (GLMM, factor material, n = 276, $\chi^2_1 = 7.9$, $P<0.01$, Fig. 4a and Supplementary Tab. 3). However, category 4 was never recorded in any of the pigs and in category 1 often only losses of a small part of the tail tip were observed. There was no effect of the treatment on injuries at the tails of the piglets (GLMM, factor material, n = 276, $\chi^2_1 = 0.7$, $P = 0.4$, Fig. 4b and Supplementary Tab. 3).

The different treatments had no effect on the weights of the piglets during the rearing period (LME, factor material, $F_{1, 10} = 2.7$, $P = 0.1$). Piglets had a daily weight gain of 476.1 g (±74.1 g SD) during rearing.

Effects on exploration time of pigs during fattening

During fattening, mean exploration duration of 296.6 min (±4.9 min SE) were recorded per pig and week. Within days exploration increased when the light phase began and reached a peak at 16:00 (Fig. 2b). Thereafter exploration duration decreased again. During the dark phase of a 24-hour day, mean exploration duration remained at a low level.

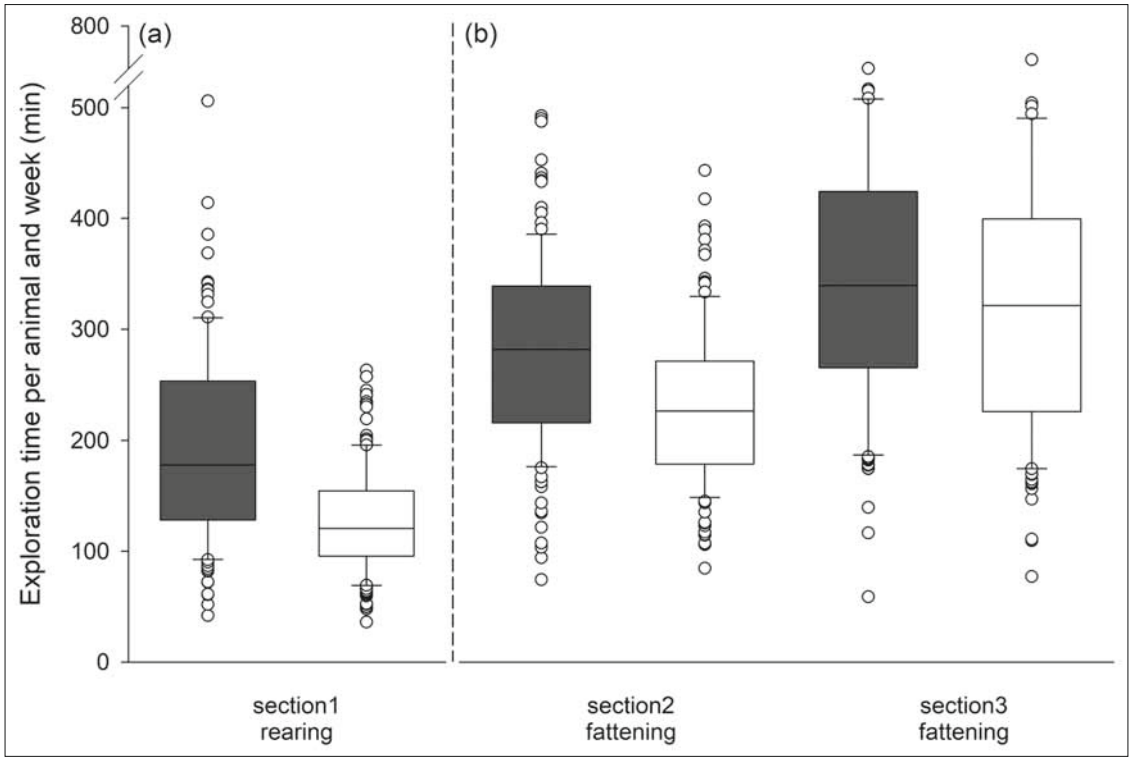

FIGURE 3: *Median and quartiles of the exploration time per animal and week at the material dispenser, filled with chopped straw (CS, white) and chopped straw with maize kernels (CS+MK, dark grey) during (a) the section in the rearing period and (b) the two sections in the fattening period. Graphic: Karen Kauselmann, FLI*

The time fattening pigs spent at the material dispenser was affected by the offered enrichment materials (LME, factor material, $F_{1, 22} = 7.0$, $P<0.05$, Fig. 3b). Animals spent more time at the material dispenser when CS+MK was offered compared to material dispensers filled with CS. Moreover, exploration duration was affected by section (section 2 and section 3) (LME, factor section, $F_{1, 254} = 226.8$, $P<0.0001$, Fig. 3b). In section 3 higher exploration durations were recorded at the material dispenser than in section 2. In addition, weight of the pigs (LME, factor weight, $F_{1, 254} = 70.9$, $P<0.0001$) affected exploration times at the material dispenser. Higher weights were negatively related to exploration. There was a significant interaction between the offered material and the section (section 2 and section 3) (LME, $F_{1, 254} = 10.7$, $P<0.01$).

Effects on tail status during fattening period

Δ tail lengths were not affected by the enrichment material during fattening (section 2 and section 3) (GLMM, factor material, n = 530, $\chi^2_1 = 0.0$, P = 1.0, Supplementary Tab. 3). The sections (section 2 and section 3) had no effect on Δ tail lengths (GLMM, factor section, n = 530, $\chi^2_1 = 2.7$, P = 0.1), whereby, in section 2 more Δ tail lengths occurred (26.9%) compared to section 3 (6.2%). As during rearing, category 4 was never recorded in any of the pigs and in category 1 often only losses of a small part of the tail tip were observed.

Tail injuries were not affected by the enrichment material during fattening (section 2 and section 3) (GLMM, factor material, n = 530, $\chi^2_1 = 2.8$, P = 0.1, Supplementary Tab. 3), however the section had a significant effect on tail injuries (GLMM, factor section, n = 530, $\chi^2_1 = 12.4$, P<0,001). With 92.3% we scored more tails without injuries in section 3 compared to section 2 (86.3%).

The offered enrichment materials (CS+MK and CS) had no effect on the weights of the pigs during fattening (LME, factor material, $F_{1, 22} = 3.6$, P = 0.1). Fattening pigs had a daily weight gain of 957.7 g (±111.5 g SD).

Discussion

As hypothesized, during both rearing and fattening period pigs showed higher interactions with chopped straw supplemented with maize kernels (CS+MK) compared to only chopped straw (CS) in a material dispenser. The duration pigs interacted with the offered enrichment materials increased from rearing to fattening and did not show any signs of habituation over time. However, in contrast to our hypothesis, increased exploration durations for CS+MK did not result in less losses of tail length although the prevalence of tail lesions did not indicate increased tail biting. Effects of the treatments on tail length were only found during rearing.

Diurnal exploration durations of rearing pigs correspond to the known diurnal activity of pigs with an activity peak in the morning and a second in the evening (Fraser et al. 1991, Lyons et al. 1995, Olsen et al. 2000, Zwicker et al. 2012). Fattening pigs, however, showed only one diurnal activity peak. Data collection in rearing was from summer to winter (June to December) while data in fattening were recorded from autumn to spring (August to February). Thus, light phase was longer during rearing compared to fattening (Tab. 1). Comparable observations of a shift of feeding activity from two activity peaks during long to one peak during shorter light phases were done

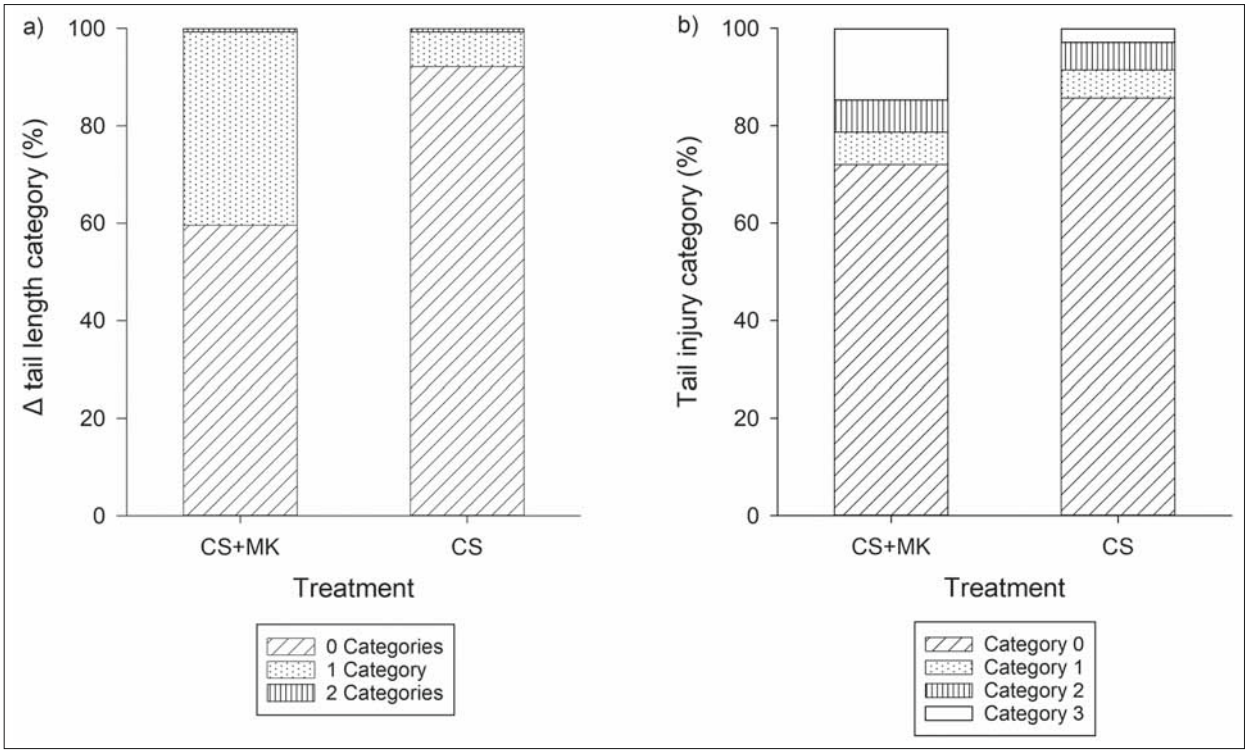

FIGURE 4: *Percentage of (a) Δ tail length during the rearing period to the previous data collection of 0 (diagonal stripes), 1 (dotted) or 2 (vertical stripes) categories and (b) tail injuries during the rearing period (category 0, diagonal stripes) no injuries (category 1, dotted) superficial perforation of the skin, punctually or in the form of a line (category 2, vertical stripes) deeper, planar perforation of the skin, maximum as large as the diameter of the tail at the respective point (category 3, white) deeper, planar perforation of the skin, larger than the diameter of the tail at the respective point) after chopped straw (CS) and chopped straw with maize kernels (CS+MK) were offered. Graphic: Karen Kauselmann, FLI*

in an earlier study on feeding behaviour of fattening pigs (Bünger et al. 2017). Thus, the differences in the diurnal pattern of exploration is likely to result from seasonal differences in day length, i.e. length of light phase.

Pigs in the rearing and fattening period explored the offered chopped straw longer when maize kernels were supplemented. These findings are in line with a short term choice test, where chopped straw with maize kernels were preferred by fattening pigs compared to chopped straw mixed with either grated carrots, squeezed oats, wheat kernels or without edible additive (Kauselmann et al. 2020). Thus, short and long-term preferences of pigs seem to reflect similar patterns of behavioural preferences, which may raise important implication for future choice experiments. Our findings, in general, are in line with several studies found that enrichment materials with edible compounds can increase the attractiveness for pigs (Haskell et al. 1996, Jensen and Pedersen 2007, Olsen et al. 2000, Studnitz et al. 2007, Young et al. 1994, Zwicker et al. 2013). It is assumed that a food reward (Haskell et al. 1996, Studnitz et al. 2007) and compound or heterogeneous materials (Jensen and Pedersen 2007, Ocepek et al. 2020) stimulate exploration behaviour in pigs. Our approach reveals that straw attractiveness can be further increased for pigs by simply adding maize kernels, thus a solution that can be easily transferred into practice. Furthermore, the pigs seem not to habituate to that stimulation.

Surprisingly, the exploration durations of pigs for the offered materials increased from rearing (section 1) to fattening (section 2 and section 3). A similar trend of increasing exploration times with the age of the animals was reported in a comparison of different plant-based enrichment materials in a two-week change (Kauselmann et al. submitted [a]). However, in the current study we continuously offered the materials (either CS+MK or CS) from rearing to fattening to the pigs. In contrast, previous studies found decreasing exploration times of pigs for enrichment materials over time: In Petersen et al. (1995) rooting the enrichment material (straw, logs and branches) decreased in pigs with an age of 18 weeks, while general activity time remained constant over the observation times (at an age of 4, 7 and 18 weeks). Also Jensen et al. (2010) found that manipulation of rooting material (maize silage and straw) decreased from 13 to 20 weeks of age and pens with maize silage had higher exploration times than pens enriched with straw. Pigs may habituate to enrichment material within one week (Trickett et al. 2009, Van de Perre et al. 2011) or even within the hour after offering (Apple and Craig 1992). Regular refreshing of small amounts of deep straw can reduce habituation (Bolhuis et al. 2005). In addition to the added maize, in our study we also refreshed the material as the material dispenser regularly was refilled with fresh material. Furthermore, the absolute number of pigs decreased from 24 in rearing pens to 12 in fattening pens. Thus, although the animal:dispenser place ratio remained similar between rearing (1.7:1) and fattening (1.5:1), at the beginning of fattening, pigs had better access to the material dispenser than at the end

of rearing, which could also have increased exploration duration of fattening pigs compared to rearing pigs.

Median exploration duration ranged from 177.8 min (CS+MK) to 120.6 min per animal and week (CS) during rearing and from 339.4 min (CS+MK) to 321.4 min per animal and week (CS) at the end of fattening (section 3). In previous studies between 0.3% and 27.4% of observation time pigs were observed exploring material. In these studies, observations were done in time sampling and observation times were restricted to the main activity phase of pigs and ranged between 8:30 and 20:30 (Lyons et al. 1995, Scott et al. 2006, 2007, Trickett et al. 2009, Van de Weerd et al. 2006). In contrast, in our study we continuously recorded exploration time of pigs for 24 h per day. The main hours of activity in our study were between 8:00 and 18:00. In this time, each pig spent 19.7 min at the material dispenser per day during rearing and 34.4 min during fattening. Thus, they explored 3.0% of the activity phase during rearing and 5.2% during fattening, what is within the lower range found in the previous studies mentioned above. However, in our study pigs had access to additional enrichment material (sisal ropes and wood) and exploration of these materials are not included in our data.

Although the straw supplemented with maize was more attractive, however, in the rearing period more partial losses of tail length were recorded in the treatment with CS+MK compared to the treatment with only CS. This finding was in contrast to our hypothesis, because higher exploration of enrichment material supporting foraging behaviour should lead to a reduction of penmate manipulation (Beattie et al. 1995, Fraser et al. 1991, Petersen et al. 1995) and, thus, should reduce the risk for tail biting. In line with this, we assumed that high exploration times would reduce penmate manipulation more than less explored materials. However, it might be that CS+MK was so highly attractive for the piglets that it triggered competitive social behaviour. Although aggressive interactions due to limited access to resources does not directly lead to tail biting (Prunier et al. 2020), an increased stress level of pigs resulting from the competition for resources increases the risk for tail biting (Munsterhjelm et al. 2013, Schrøder-Petersen and Simonsen 2001). The pigs' preference for CS+MK was noticeable in the quantities consumed (details on consumed enrichment materials were given in the supplementary material, Supplementary Tab. 2). Thus, material dispensers in pens where CS+MK was offered were used up faster compared to CS. However, the material dispensers were not refilled at weekends. Perhaps the pigs developed an expectation to have constant access to the material, which turned into frustration, and thus stress, when the material dispensers remained empty. Thus, it is crucial to better investigate the amount of enrichment material and how many animals should have access to the materials simultaneously.

In the fattening period, there were neither differences in partial losses of tail length between the treatments (CS+MK and CS) nor over time (section 2 and section 3). It is well known that tail biting is influenced by age and weight of the pigs (Schrøder-Petersen and Simonsen 2001) and occurs mainly during rearing. Most tail-in-mouth behaviour (Schrøder-Petersen et al. 2010) and most tail biting behaviour (Jans-Wenstrup 2018) had been observed at an age between 4 and 8 weeks of life. Tail biting seems to start in the first weeks after weaning (Abriel and Jais 2013, Blackshaw 1981, Veit et al. 2016). Due to partial losses of tail length during the rearing period, some tails were already short when pigs were moved to the fattening pens. Short bitten tails can be compared with docked tails that reduce tail biting (Hunter et al. 2001, Larsen et al. 2018, Li et al. 2017). In our study, reduced tail length often just affected the tip of the tail. However, even if only the tail tip is affected, injured nerves can lead to neuropathic pain (Devor and Rappaport 1990). An increased sensitivity to pain is a proposed reason for reduced tail biting of docked tails (Simonsen et al. 1991) and could also be considered in bitten pigs.

Reduced tail biting behaviour also resulted in reduced tail injuries during the fattening period (section 2 and section 3) compared to the rearing period (section 1). Tail injuries decreased over time during fattening, i.e. from section 2 to section 3, what is in line with Larsen et al. (2018), who found that tail damages occur first mainly in the first week and first half of the finishing period. As well as for Δ tail lengths the material had no effect on the tail injuries of the pigs during fattening. Preferences of pigs for enrichment materials change with age (Docking et al. 2008) and from rearing to fattening (Kauselmann et al. submitted [a]), what could lead to a better satisfaction of behavioural preferences and, therefore, to reduced tail biting activities during the fattening period compared to the rearing period. Furthermore, as mentioned above, in our test it has to be considered that the absolute number of animals was halved in fattening pens and the animal:dispenser place ratio was comparable in the rearing and the fattening pens. According to Schmolke et al. (2003) group size has no effect on tail biting. However, due to a reduced group size, pigs in our study had more place at the material dispenser in the beginning of the fattening period compared to the end of the rearing period. As competition for enrichment material can trigger biting penmates (Van de Perre et al. 2011), reduced competition for the enrichment material could have led to reduced tail damages in fattening pigs.

Although straw is recommended as enrichment material for pigs (Bolhuis et al. 2005, Fraser et al. 1991, Jensen and Pedersen 2007, Studnitz et al. 2007, Van de Perre et al. 2011, Van de Weerd et al. 2003) and maize kernels have the additional property of being edible, increased exploration durations when offering CS+MK could not reduce tail biting compared to CS. In a review, Godyń et al. (2019) showed to the contrary that even enrichment materials classified as of marginal interest for pigs (Anonymous 2016) can achieve a welfare benefit. Thus, by using enrichment materials, much more factors affecting the pigs have to be taken into account than recommendations, i.e. the Commission Recommendation (EU) 2016/336. An effect on welfare can be influenced by numerus factors due to the multifactorial problem of tail biting. Enrichment material can improve welfare, however, there are other factors that should be considered in reducing tail biting. Several enrichment materials, i.e. chopped straw on the floor of the pen or ryegrass haylage offered in a wired spherical rack, can be used as an early intervention when the first signs of tail biting were recorded (Lahrmann et al. 2018). Thus, in the present study a greater effect possibly might have been achieved if straw had been permanently offered to the pigs and maize kernels had been used to increase exploration duration at the first signs of tail biting.

The different treatments (CS+MK and CS) had no effect on the weights of the animals. The exploration times and enrichment consumption was higher for CS+MK than for CS. Since parts of the material fell through the slatted floor, we cannot estimate which material was actually eaten by pigs. However, the intake of CS+MK does not seem to have led to an additional weight gain. Either the additional intake of nutrients by the maize (average usage of 5.1 g per pig and day) was rather low or the pigs reduced feed intake, which was not recorded in our study.

Conclusion

Our approach to provide chopped straw enriched with maize kernels as enrichment material in commercial housing systems can be recommended to increase exploration duration and, thus, probably facilitate the natural behaviour of the animals from rearing to fattening. However, probably limited access to the highly preferred enrichment material could have led to competitive behavior and losses of tail length. Future studies are needed to assess what quantities of enrichment material must be offered and how many pigs must have access to the material simultaneously in order to provide highly preferred enrichment materials without triggering competitive behaviour among piglets. As for feeding data, there were seasonal changes in exploration behavior of pigs. These findings should be further investigated to better understand exploration behavior in pigs and to adapt provision of enrichment material.

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Conflicts of Interest

The authors declare no conflict of interest.

Ethical statement

The data acquisition was performed in accordance with the laws of Germany at that time and did not require specific approval. We provided additional enrichment materials to commercially housed pigs. All data were recorded at a licensed farm that produces, rears, fattens and markets pigs (VVVO-Number: 08 128 0140 538). Pigs from the study were marketed at the end of the study. Housing, management and data acquisition was conducted under farm conditions and in accordance to German legislation (TierSchNutztV) for farm animals. Furthermore, space allowance in rearing (0.58 m^2/pig) and fattening (1.14 m^2/pig) exceeded the minimum requirements by the German legislation, i.e. TierSchNutztV (2017).

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Providing resources: H.S.
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