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Use of space and behavior of weaned piglets kept in enriched two-level housing system

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ABSTRACT

In this study, the possibility of introducing an elevated platform to a piglet pen was explored as a way of increasing available space and creating functional areas. On the platform, nine different manipulable materials were offered. In four batches, 40 weaned piglets were kept for five weeks in the two-level pen. Video recordings were taken two days per week. In the afternoon, more piglets were on the platform than in the morning or at night (7.2 ± 0.1 vs. 4.9 ± 0.1 vs. 0.6 ± 0.1 piglets/5 minutes; $p < .05$). The area under the platform was preferred more in the morning and at night than in the afternoon (18.5 ± 0.1 vs. 21.6 ± 0.2 vs. 12.5 ± 0.1 piglets/5 minutes; $p < .05$). Up to 36 piglets were counted there simultaneously, mainly in the recumbent position. On and under the platform, air velocity and ammonia concentration were within the recommended ranges. The study concluded that a two-level pen is a feasible option to increase space allowance and to create functional areas in a piglet pen.

KEYWORDS

Two-level pen; piglet; environmental enrichment; space allowance; functional areas

Introduction

Modern pig production systems providing hygienic and economic benefits are frequently characterized by a barren environment for the nonhuman animals with few opportunities for playing or exploring, and thus, they often do not fulfill some natural behavioral needs of pigs. Pigs require stimulation in their pens to utilize their cognitive abilities (Broom, Sena, & Moynihan, 2009; Gieling, Nordquist, & Van Der Staay, 2011; McLeman, Mendl, Jones, White, & Wathes, 2005) and to carry out highly motivated behaviors such as exploration (Studnitz, Jensen, & Pedersen, 2007). With little space allowance and few opportunities for physical or mental stimulation, pigs can develop abnormal behaviors such as stereotypies or carry out injurious behaviors to each other, such as tail and ear biting (Beattie, Walker, & Sneddon, 1995; Kittawornrat & Zimmermann, 2011; Stafford, 2010).

Enrichment materials such as straw or simple objects made of chains, wood, plastic, or rubber are known to be suitable to enhance animal welfare in intensive housing systems (Beattie, O'Connell, Kilpatrick, & Moss, 2000; D'Eath et al., 2014; Fraser, Phillips, Thompson, & Tennessen, 1991; Schaefer, Salomons, Tong, Sather, & Lepage, 1990; Stubbe, 2000). It is well known that conventional housing conditions cause negative mental states like fear, stress, or boredom; and behavioral disorders like stereotypies or tail biting can be reduced by environmental enrichment (Newberry, 1995; Young, 2013). However, often only few materials are offered on commercial farms, which are frequently not suitable for manipulation and rooting.

Besides environmental enrichment, the minimum amount of space that a pig is required to have when being reared has been heavily discussed in the pig husbandry sector. According to current

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recommendations in various countries, the minimum spatial requirements for the maintenance of good pig welfare are tailored to the weight of the pig being raised to ensure that pigs have sufficient space to be able to move without major stress being incurred (Anonymous (2008a, 2008b, 2014)). However, it is becoming increasingly prevalent within the scientific literature that giving pigs some additional space to carry out their desired behaviors improves their welfare (Cox & Cooper, 2001; Edwards, Armsby, & Spechter, 1988; Fritschen & Muehling, 1987).

Pigs are also motivated to divide their living areas into regions for specific activities—typically eating, sleeping, and dunging (Geers, 2007; Simonsen, 1990)—and it has been suggested that, like play, pigs show division of the pen into functional areas only if the living arrangements are suitable. Vermeer, Altena, Vereijken, and Bracke (2015) noted that if functional areas are provided and are compatible with the pigs' behavioral needs, these areas will be utilized and the pigs will also dung in the expected location. Therefore, pen design can be used to encourage pigs to use the space in a way that is beneficial for the handlers and the animals.

For agricultural practice, there is a need to develop housing systems that meet the natural behavior needs of the pigs but also take into account economic aspects. A possibility for increasing space allowance for pigs in existing farm buildings is the construction of two-level pens—that is, pens equipped with an elevated platform that pigs can reach via a ramp. First, studies focusing on two-level pens for growing and fattening pigs were carried out in the late 1980s (Fraser & Phillips, 1989; Fraser, Phillips, & Thompson, 1986; Phillips & Fraser, 1987; Phillips, Thompson, & Fraser, 1989). The idea of increasing space allowance for pigs by introducing an elevated platform to a pen is currently very topical as a result of intensifying debate about animal welfare in livestock production. Pig farmers are currently showing increasing interest in such systems to allow for the provision of more space for their animals, and two-level pens have already been installed on commercial farms (Van Dooren, 2014). However, new scientific data about the behavior of animals in such housing systems are lacking. Furthermore, the question of whether the additional area on the platform may be accepted for legal space requirements has arisen.

In the present study, an elevated platform was introduced to a piglet pen and was also used to create an enriched area and to support the creation of functional areas by piglets. Objectives in this context were an increase in the available space per animal, a particularly enriched environment with numerous manipulable materials that were offered on the platform, and the division of space into different functional areas. Thus, three important basic needs of pigs should be fulfilled in this housing system, potentially increasing animal welfare. Behavioral observations clarified to what extent the different areas in the pen, particularly the elevated platform, were accepted and used by the animals. Additionally, the piglets' acceptance of different functional areas was revealed, and possible effects on the barn microclimate were analyzed. Finally, the suitability of the housing system for piglet rearing was ascertained.

Materials and methods

Nonhuman animals and housing

The study was carried out at the research farm of the University for Veterinary Medicine Hannover, Foundation in Germany. The research farm kept a total of 90 sows, and every two weeks, five to six sows gave birth to piglets. The piglets were hybrids (Bundeshybridzuchtprogramm/BHZP (BHZP), db Victoria × db 77 Pietrain). Before weaning, piglets were kept in farrowing pens (2.30 m × 2.00 m) with a partially slatted floor and a heated creep area available to them; the sows were kept in farrowing crates. Each piglet was marked with an ear tag during the first week of life, and male piglets were castrated. Piglets were weaned at 35 days of age and moved to the rearing unit.

Before starting the experiment, two compartments for rearing weaned piglets were equipped with one two-level pen, respectively, where an elevated platform could be reached by the piglets via a ramp (slope angle of 22°). Thus, there were two compartments, and in each compartment, there was

one two-level pen available for 40 piglets. The elevated platform was placed adjacent to two sides of the wall of the compartment and was installed 60 cm above the ground and secured laterally toward the open side of the pen by 76-cm-high fence elements (Figure 1). The floor of the ramp and the elevated platform consisted of fully slatted plastic floor elements. The floor of the base level of the pen was partially slatted and consisted of slatted plastic floor elements and a nonperforated concrete surface. The area under the elevated platform as well as the expected dunging area and parts of the walking area were slatted. The feeding area and part of the walking area had a nonperforated concrete floor. In relation to the whole pen area including the elevated platform, the proportion of nonperforated floor was 33%.

For the present study, in each of the four batches, an experimental group of 40 piglets was formed at weaning. Piglets were balanced by weight and sex as much as possible and were moved to the experimental two-level pen. Per batch, one pen was studied in one of the two compartments. The animals were kept in this pen for 33 days before being sold for fattening. The average initial weight of all piglets was 10.2 ± 2.0 kg; the average final weight was 29.4 ± 5.5 kg. For each Batches 1 and 2, piglets from five different litters were mixed in the experimental pen, whereas for each Batches 3 and 4, groups of piglets were formed from four different origin litters. For barn climate measurements, two additional batches were available on the research farm.

The space allowance in the experimental two-level pen was 0.6 m^2 per piglet, including the area on and under the ramp. The floor area of the elevated platform covered a total space of 5 m^2, and the platform was supported by stainless steel stanchions, which were affixed to plastic fiberglass beams. The floor space on the ramp was 2.6 m^2. The entire area of the experimental pen including the floor area of the elevated platform covered 24 m^2. Piglets had ad-libitum access to dry feed and water, which were offered on the base level of the pen. The animal-to-feeding place ratio was 1.7:1. Due to the modification of the former pen, two nipple drinkers were located in the area under the platform and two were located in front of the ramp.

The installation of an elevated platform should support the development of functional areas and help create a structured housing environment. To create an activity area on the platform, different enrichment materials were offered there. The piglet resting area was intended to be under the platform—an area providing protection from above; the walking area was more than half the body length of a pig from the feeding trough; the feeding area was immediately in front of the feeders; and

Figure 1. Enriched two-level pen for weaned piglets.

the dunging area was next to the pen's door in front of the ramp. To prevent the piglets from having dunging areas in the corners of the pen at the base level, grid elements were placed there obliquely.

Environmental enrichment on the elevated platform

In its function as an activity area, the platform was equipped with nine different manipulable materials, most of which were filled with organic materials such as straw, sugar beet pulp, or pressed molasses (Table 1, Figure 2). The availability of various manipulable materials on the elevated platform aimed to meet the exploratory behavior of the piglets and to keep them occupied. For this purpose, we selected materials that animals could move or eat. The "activity cone," which is commonly used as a feed cone for wild boar hunting, and the "Mik toy" (MIK INTERNATIONAL GmbH & Co. KG, Ransbach-Baumbach, Germany) are commercially available materials that were purchased for the study. The other manipulable materials were produced by technical staff for the research project and were made of materials that were not harmful to the animals and that the animals could not destroy to avoid oral ingestion and to ensure durability of the materials.

The "activity cone," the "play rail," the "lifting tube," and the "Mik toy" were fastened to the wall on the left side of the elevated platform. For stabilizing the fence elements on the right side of the

Table 1. Manipulable materials offered on the elevated platform.

Enrichment	Material	Filling
1 Activity cone	plastics (PA)	sugar beet pulp
2 Play rail	iron (galvanized)	
2.1 Rotating element for play rail	plastics (PP)	sugar beet pulp and straw
2.2 Hard rubber ball for play rail	natural rubber	
3 Lifting tube	plastics (PP)	
4 Mik toy	V2A-stainless steel	pressed molasses
5 Canister, perforated	plastics (HM-HDPE)	sugar beet pulp and straw
6 Bucket	plastics (HDPE)	sugar beet pulp
7 Pipe swing	plastics (PP)	sugar beet pulp and straw
8 Cross of chains	softwood, plastic, iron	
9 Biting sausage	polyester yarn, EPDM-natural rubber, iron inside	

Note. PA: polyamide, PP: polypropylene, HM-HDPE: high-molecular-high-density polyethylene, HDPE: high-density polyethylene, EPDM: ethylene propylene diene monomers.

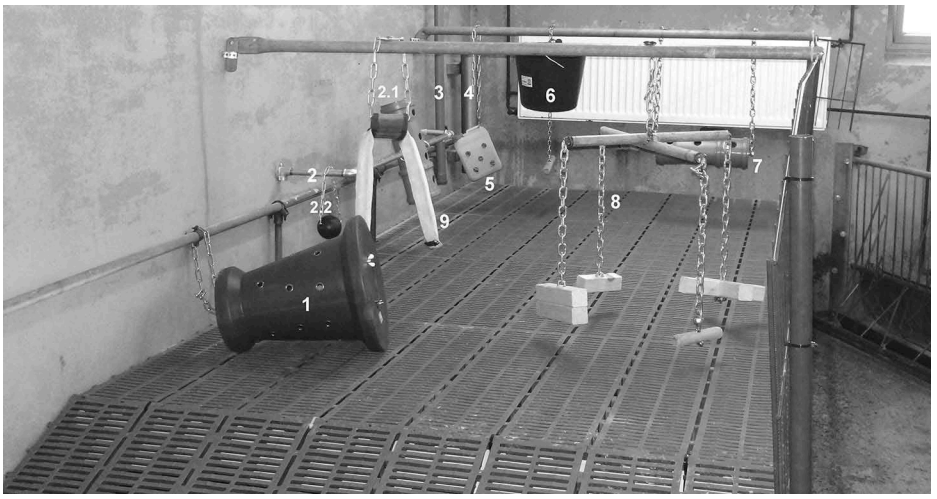

Figure 2. Arrangement of manipulable materials on the elevated platform. For a description of the materials on the basis of their numbers, please see Table 1.

elevated platform, two iron bars each 165 cm in length were mounted between the left wall and the fence elements. Those iron bars were also used for hanging a "perforated canister," a "bucket," a "pipe swing," a "cross of chains," and a "biting sausage," which were fastened by iron chains to the iron bars. During the experimental period, the fillable enrichment materials were regularly refilled with organic materials so that they were never empty, and at the end of the investigations, they were emptied, cleaned, and disinfected.

Behavioral analysis

Above each of the two experimental pens, three cameras (Everfocus, EQ550T, New Taipei, Taiwan) were installed and connected with a digital video recorder (Everfocus, ECOR 264-9X1, New Taipei, Taiwan), which recorded onto the hard drives. Twenty-five images were captured per second. Immediately after weaning and forming the experimental group of 40 piglets, video recording started to capture and observe the behavior of the animals during the first 48 hours in the experimental pen. During the total experimental period of 33 days, additional 48-hour recordings were carried out at intervals of 7 days and were subsequently analyzed. The compartments were illuminated 10 hours a day, with the lights being turned on in the morning at 06:00 and turned off in the afternoon at 16:00.

Video-based behavioral analyses were performed using the Everfocus Player Application (EFPlayer) version 1.0.8.4 Everfocus, New Taipei, Taiwan) on a commercially available personal computer. For this purpose, the video files had to be exported from the hard disk of the digital video recorder to an external hard drive, which was connected to a computer for analyzing the recorded video files. Three observation periods were chosen. For Batches 1 and 2, Observation Period 1 was defined from 07:00 to 11:00, Observation Period 2 was 14:00 to 18:00, and Observation Period 3 was 00:00 to 03:00. In Batches 3 and 4, Observation Period 2 was set at 13:00 to 17:00, as the first results of the analysis revealed that from 13:00, increased animal activity was observed, whereas at 17:00, animal activity decreased.

Behavioral analysis was carried out using the scan-sampling method. Within each observation period, every five minutes, the video was stopped and the number of standing/sitting and lying piglets in the different functional areas was counted. Animals who were observed in the dunging area were assigned to the walking area, because the location of the dunging area could slightly vary between the batches. "Lying" was defined as contact of the piglet's cranial and caudal body portion with the floor and comprised inactive behavior. "Standing" meant that all four limbs came in contact with the floor, while "sitting" meant that the piglet's body was supported by the two front legs. The more active behaviors of "standing" and "sitting" were summarized for analysis, and the results of lying and standing/sitting piglets will be presented. Furthermore, piglets using the manipulable materials (contact for at least two seconds) on the elevated platform were counted separately every five minutes.

Floor-soiling analysis

The dunging behavior of piglets in the experimental pen was recorded using a floor-soiling score from 0 (no floor soiling) to 3 (high floor soiling). In each batch, floor soiling was determined five times during the housing period (Day 5, Day 15, Day 22, Day 29, and Day 33). For soiling analysis, the pen was separated into the following areas: on the platform, under the platform, on the ramp, under the ramp, in the walking area, and in the expected dunging area (Figure 3). A soiling score was assigned for each area every day of the observation, and mean values for the different areas were calculated.

Barn climate measurements

In six batches, barn climate measurements were carried out on the 15th and 29th days after piglets entered the experimental two-level pen. Measurements were taken on the elevated platform, under the elevated platform, and in the walking area. At the animals' body height, ammonia (ppm) and air

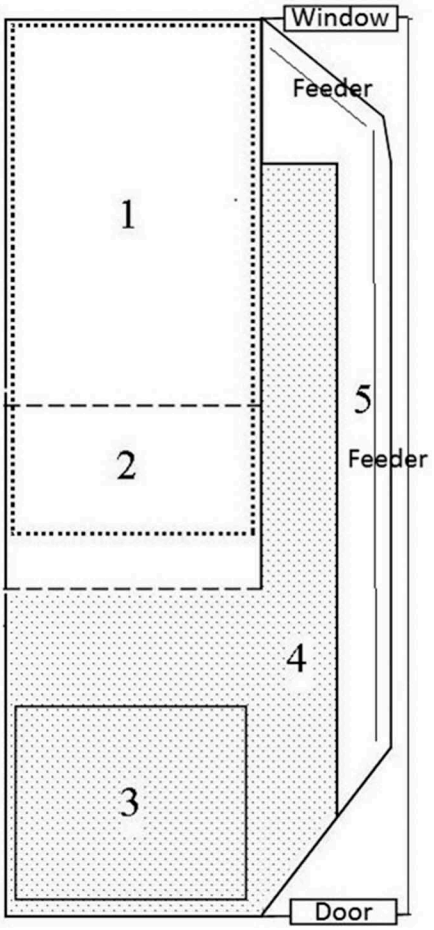

Figure 3. Different areas of the experimental pen for behavioral and floor-soiling analysis.

Note. 1 = platform (area on and under the platform); 2 = ramp (area on the ramp and smaller usable area under the ramp); 3 = expected dunging area (for behavioral analysis, part of 4 = walking area); 4 = walking area; 5 = feeding area (for floor-soiling analysis, part of 4 = walking area).

velocity (m/second) were measured. For measuring air velocity, a hot-wire anemometer was used (PCE-423, PCE Instruments, Meschede, Germany). Ammonia in the barn air was determined using a Dräger pump, model Accuro (Drägerwerk AG & Co. KG, Lübeck, Germany) and Dräger Short Term Tubes (DR Ammoniak 2/A, Drägerwerk AG & Co. KG, Lübeck, Germany).

Statistics

Statistical analysis was carried out using the software IBM SPSS Statistics Version 23. First, all data concerning animal behavior obtained in the present study (i.e., number of piglets using different pen areas per five minutes, number of standing/sitting and lying piglets in different pen areas per five minutes, and number of piglets using the enrichment materials per five minutes) and data for the soiling score were tested for normal distribution using histograms and the Kolmogorov-Smirnov test. Because data were not normally distributed, nonparametric statistical tests were conducted. For data on ammonia concentration and air velocity, descriptive statistics were calculated using mean values for each batch (ammonia) or mean values and standard deviations for all batches (ammonia, air velocity).

For behavioral analysis, we determined the total number of pigs and the number of standing/sitting and lying pigs in different areas of the experimental pen every five minutes in each group. Each group was recorded for two days per week during three observation periods (morning, afternoon, and night) for a total period of five weeks. Per batch, one group of 40 pigs was studied, and consequently, in a total of four batches, four groups were analyzed. For statistical analysis, each group was considered separately, and afterward, data from the two days studied per week were pooled and averaged for all groups. Data are presented as means ± standard error of the mean (SEM). Because data from different observation periods within a group and data from different groups in the same environment and with the same management are not independent, Friedman tests followed by pairwise comparisons using the Wilcoxon test were carried out for:

(1) detection of significant differences between observation periods (morning, afternoon, and night = independent variable) for the total number of (standing/sitting and lying) piglets per five minutes in different areas of the experimental pen;
(2) detection of significant differences between the number of standing/sitting and lying piglets per five minutes in different pen areas during all observation periods (average);
(3) detection of significant differences between observation periods (morning, afternoon, and night) and between weeks for the use of manipulable materials with observation period or week as the independent variable; and
(4) detection of significant differences between floor-soiling scores in different areas of the experimental pen with week as the independent variable.

Results

Use of space, activity, and resting behavior

The piglets used the elevated platform during the entire housing period (Figure 4). On average, five piglets were observed per five minutes on the platform during all observation periods within a day (Table 2). The total number of piglets observed per five minutes on and under the elevated platform differed between the batches. In Batches 3 and 4, more piglets were counted on the platform and fewer animals were observed under the platform compared with Batches 1 and 2 (Table 3). In Batches 3 and 4, the period of observations started one hour earlier, with the goal of better covering the animals' activity phase. The highest proportion of lying piglets was counted under the platform.

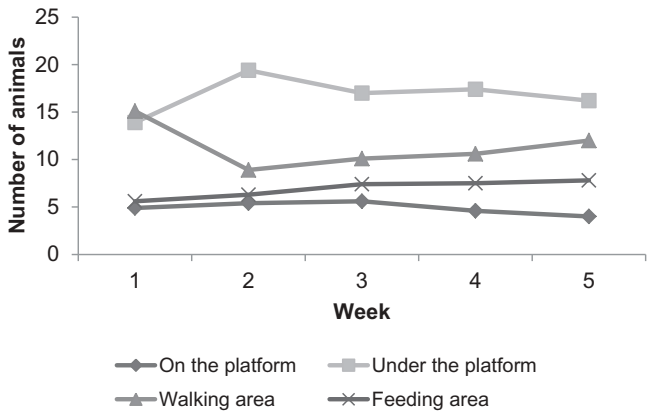

Figure 4. Mean number of animals per five minutes in the different pen areas during Week 1 to Week 5 after entering the experimental two-level pen.

Table 2. Number of piglets per five minutes in different areas of the experimental two-level pen at different times of day.

		Piglets on the platform Mean ± SEM (Median)	Piglets under the platform Mean ± SEM (Median)	Piglets in the walking area Mean ± SEM (Median)	Piglets in the feeding area Mean ± SEM (Median)
Morning	Total	4.9 ± 0.1 (5) a	18.5 ± 0.1 (19) a*	10.2 ± 0.1 (10) a	6.5 ± 0.1 (6) a
	Standing/Sitting	1.6 ± 0.1 (1) *a*	2.0 ± 0.0 (2) *a*	3.4 ± 0.1 (3) *a*	3.3 ± 0.1 (3) *a*
	Lying	3.3 ± 0.1 (3) **a**	12.8 ± 0.1 (13) **a**	6.8 ± 01 (6) **a**	3.2 ± 0.1 (3) **a**
Afternoon	Total	7.2 ± 0.1 (7) b	12.6 ± 0.1 (12) b*	12.4 ± 0.1 (12) b	7.6 ± 0.1 (7) b
	Standing/Sitting	3.8 ± 0.1 (3) *b*	2.5 ± 0.0 (2) *b*	5.7 ± 0.1 (5) *b*	5.4 ± 0.1 (5) *b*
	Lying	3.4 ± 0.1 (3) **a**	7.1 ± 0.1 (6) **b**	6.7 ± 0.1 (6) **a**	2.2 ± 0.1 (2) **b**
Night	Total	0.6 ± 0.1 (0) c	21.5 ± 0.2 (22) c*	11.6 ± 0.2 (11) c	6.2 ± 0.1 (6) a
	Standing/Sitting	0.0 ± 0.0 (0) *c*	1.3 ± 0.1 (1) *a*	0.7 ± 0.0 (0) *c*	1.2 ± 0.1 (0) *c*
	Lying	0.6 ± 0.1 (0) **b**	9.2 ± 0.3 (8) **c**	10.9 ± 0.2 (10) **b**	5.0 ± 0.1 (5) **c**
Average	**Total**	**4.9 ± 0.1 (4)**	**16.8 ± 0.2 (17)***	**11.4 ± 0.2 (11)**	**6.9 ± 0.1 (7)**
	Standing/Sitting	**2.1 ± 0.0 (1) a**	**2.2 ± 0.0 (2) a**	**3.7 ± 0.1 (3) a**	**3.7 ± 0.1 (3) a**
	Lying	**2.8 ± 0.0 (2) b**	**10.0 ± 0.1 (9) b**	**7.6 ± 0.1 (7) b**	**3.2 ± 0.0 (3) a**

Note. Significant differences within a column ($p < .05$) are indicated by different letters (i.e., between morning, afternoon, and night for total [Roman letter], standing/sitting [italic letter], and lying piglets [bold letter]). Significant differences between standing/sitting and lying (average) are indicated by different bold, underlined letters ($p < .05$). $n = 1900$ observations per time of day in four batches.

*Deviations from the sum of lying and standing/sitting piglets were caused by the fact that for technical reasons, the exact position of the piglets under the platform was not always identifiable on the recorded video material.

SEM = standard error of the mean.

Table 3. Number of piglets per five minutes in different areas of the experimental two-level pen.

Batch	Parameter	Piglets on platform	Piglets under platform	Piglets in walking area	Piglets in feeding area
Average	Mean ± SEM	4.9 ± 0.1	16.8 ± 0.2	11.4 ± 0.2	6.9 ± 0.1
	Median	4	17	11	7
	Min	0	0	0	0
	Max	20	36	32	25
Batch 1	Mean ± SEM	3.4 ± 0.1	15.3 ± 0.2	13.9 ± 0.1	7.4 ± 0.1
	Median	2	15	14	7
	Min	0	1	2	0
	Max	19	35	32	20
Batch 2	Mean ± SEM	3.8 ± 0.1	20.1 ± 0.2	10.2 ± 0.1	6.3 ± 0.1
	Median	3	21	10	6
	Min	0	0	1	0
	Max	17	36	25	22
Batch 3	Mean ± SEM	7.3 ± 0.1	13.8 ± 0.1	11.4 ± 0.1	7.3 ± 0.1
	Median	8	13	11	7
	Min	0	2	2	0
	Max	20	30	26	25
Batch 4	Mean ± SEM	5.3 ± 0.1	17.9 ± 0.2	10.1 ± 0.1	6.7 ± 0.1
	Median	5	18	10	6
	Min	0	4	0	0
	Max	18	33	24	23

Note. SEM = standard error of the mean.

Under the platform and in the walking area, throughout all time periods of observation (morning, afternoon, and night), more piglets were counted in a lying position than in a standing/sitting position. On the elevated platform, the proportion of piglets in a lying and standing/sitting position was almost the same in the afternoon (Table 2).

The use of various areas of the pen differed significantly between the times of day (Table 2). Most animals were counted on the elevated platform in the afternoon, while at night, there were fewer animals on the platform (7.2 ± 0.1 animals per five minutes vs. 0.6 ± 0.1 animals per five minutes, $p < .05$). Compared with night, the number of piglets observed on the platform increased significantly ($p < .05$) in the morning (4.9 ± 0.1 animals per five minutes). However, the number of piglets on the platform in the morning was significantly lower compared with the afternoon ($p < .05$). The highest number of animals

was counted under the platform. On average, 16.8 ± 0.2 piglets per five minutes used this area during the total housing period. The area under the platform was used as a resting area, and piglets were observed there mainly at night and in the morning in a lying position. At night, the number of animals under the platform was significantly ($p < .05$) higher than in the afternoon and in the morning.

Concerning the number of animals counted in the walking area, there were also significant differences between the times of day. In the walking area, most animals were counted in the afternoon followed by night and morning (12.4 ± 0.1 vs. 11.6 ± 0.2 vs. 10.2 ± 0.1 pigs per five minutes; $p < .05$). The feeding area was mainly used in the afternoon, with 7.6 ± 0.1 piglets being there every five minutes mainly in a standing/sitting position. At night, the number of standing/sitting piglets in the feeding area was significantly lower, while the number of lying piglets was higher than in the morning and in the afternoon. Other than the feeding area, significantly more piglets were observed lying than standing or sitting ($p < .05$) in all areas of the experimental pen. In the feeding area, significantly more piglets were recorded standing/sitting than lying ($p < .05$).

Use of manipulable materials on the elevated platform

Piglets used the different manipulable materials offered on the elevated platform during the entire housing period. The significantly highest mean values compared with all other weeks were reached during Weeks 2 and 3, with 1 ± 0.05 piglets per five minutes on average using a manipulable material on the platform each week ($p < .05$). After Week 3, the mean number of animals using the enrichment materials decreased to 0.9 ± 0.04 per five minutes in Week 4, and in Week 5, the same number of piglets as in Week 1 was counted (0.7 ± 0.03 piglets). There was also a significant difference between Week 4 and Weeks 1 and 5 ($p < .05$).

The manipulable materials were mostly used in the afternoon (1.5 ± 0.04 piglets per five minutes), whereas at night, hardly any animals were observed with the different materials (0.01 ± 0.0 piglets per five minutes, $p < .05$). In the morning, 0.7 ± 0.03 animals per five minutes were detected, and this number differed significantly from afternoon and night ($p < .05$). A varying number of piglets, ranging from 0 to 9, using the manipulable materials at the same time was detected, showing a temporarily strong interest in environmental enrichment. Preferred materials were the "activity cone" (frequency of use related to other materials = 24%) and the "cross of chains" (22%), followed by the canister (11%) and the bucket (11%), whereas the piglets showed the lowest interest in the "Mik toy" (3%) and the "lifting tube" (3%). Moderate interest was shown in the "play rail" (10%), the "pipe swing" (8%), and the "biting sausage" (8%).

Dunging behavior of piglets

Dunging behavior of piglets was recorded using a floor-soiling score from 0 (no floor soiling) to 3 (high floor soiling) for the different areas of the experimental pen in a total of four batches. There were significant differences between different pen areas ($p < .05$), with the most soiling found in the expected dunging area in front of the ramp and the lowest soiling scores detected on and under the ramp. Mean soiling scores on the platform and in the walking area did not differ significantly ($p > .05$) but were significantly higher than those on and under the ramp and significantly lower than the scores in the expected dunging area and under the platform ($p < .05$). The mean soiling score under the elevated platform was not significantly different from the score detected in the expected dunging area (Figure 5).

Barn climate

Air velocity was measured on Days 15 and 29 of the experiment in a total of six batches. Measurements were done on the elevated platform, under the elevated platform, and in the walking area at the animals' body height. Air velocity did not differ between the different areas within the experimental pen. Even under the platform, the air velocity was only slightly slower than on the elevated platform and in the walking area (Table 4).

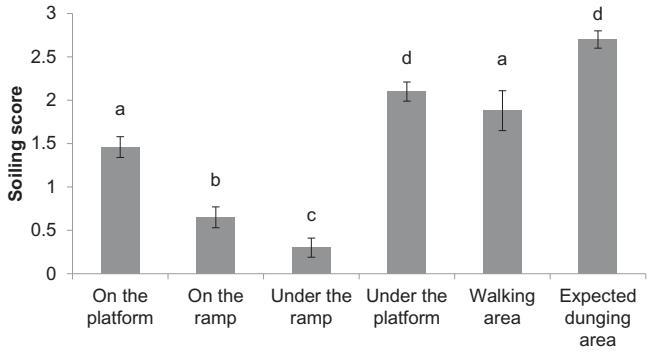

Figure 5. Means and standard errors of the means (SEM) of the floor-soiling score for different areas in the experimental pen for all batches and all weeks. Significant differences are indicated by different letters ($p < .05$).

Table 4. Air velocity data for three different areas of the experimental two-level pen, measured in six batches.

Parameter	On the platform	Under the platform	Walking area
Mean (m/second)	0.1	0.08	0.1
SD (m/second)	0.03	0.02	0.02
Min (m/second)	0.04	0.03	0.08
Max (m/second)	0.15	0.11	0.15

Note. *SD* = standard deviation.

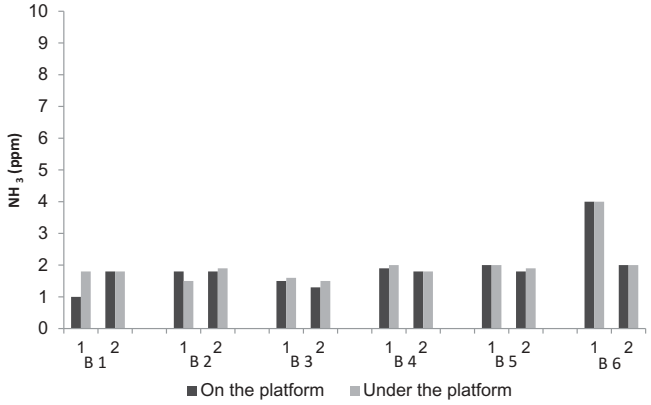

Figure 6. Concentration (ppm) of ammonia (NH_3) in the air on the platform and under the platform measured on the 15th day (1) and on the 29th day (2) of the housing period in six batches (B1–B6).

Ammonia was measured on Days 15 and 29 of the experiment in a total of six batches on the elevated platform and under the platform at the piglets' body height, respectively. The measured values were far less than the defined limit of 20 ppm (Figure 6). There were no differences between the ammonia concentrations in the air measured on the platform and under the elevated platform. On the platform, an ammonia concentration of 1.9 ± 0.7 ppm was measured on average, while under the elevated platform, the ammonia concentration was 2.0 ± 0.6 ppm on average. On Day 15 in Batch 6, the highest ammonia concentration was detected compared with all other measurements (4 ppm).

Discussion

Use of elevated platform

The aim of this study was to develop and test a new housing system for weaned piglets that was fulfilling important natural behavioral needs, such as creating functional areas for activity and resting, performing exploratory behavior, and living with an enhanced space allowance. For this purpose, a two-level pen was constructed to provide a special area for activity and playing on an elevated platform. The first scientific studies of two-level pens for grower pigs at eight weeks of age (Phillips, Thompson, & Fraser, 1988, 1989) and for fattening pigs (Fraser et al., 1986; Phillips & Fraser, 1987) were carried out almost 30 years ago. In those studies, with the building of an elevated platform, the pen provided extra space for running, resting, and engaging in social activities with the possibility of avoiding other pigs. Although in those earlier studies there were minor issues concerning some pigs' motivation and comfort using the ramp, in general, the additional space was utilized.

A study with grower pigs showed that more than 90% of the pigs used the elevated platform within the first 24 hours. The slope of the ramp was 30° (Fraser & Phillips, 1989). Phillips et al. (1989) recommended a ramp design with a 22° or 28° slope for 7- to 8-week-old pigs and narrowly spaced cleats, which can compensate for steepness of a slope, in particular for the 28° ramp design. In our study, we used a ramp with a slope of 22° without cleat spacing. The 5- to 10-week-old pigs consistently used the ramp, and the plastic slatted floor elements provided a secure nonslip surface.

Thus, fattening pigs as well as younger growing pigs can be successfully kept in pens with elevated platforms, which was confirmed by the results of the present study as well. In our study, piglets entered the experimental two-level housing system immediately after weaning at the age of 35 days, and thus, they were younger than pigs in all previous studies that have focused on the growing and finishing phase. Based on the results of Fraser and Phillips (1989) showing that not every pig was able to use the ramp within the first few days and therefore some pigs could not reach the elevated platform, in the present study, feed was offered on the base level. As a consequence, each animal had access to feed immediately after entering the experimental pen. On the first day of the experiment, piglets were brought to the base level of the experimental pen and could then voluntarily decide whether they wanted to use the ramp and reach the elevated platform.

An innovative aspect of our research project was providing a structurally separate area for activity on the elevated platform where nine different manipulable materials were offered. Thus, the elevated platform not only increased the space available per piglet (as it did in earlier studies), but it was also intended to provide environmental enrichment within the piglets' pen—an aspect that had not been previously investigated. Piglets in the present study used the elevated platform during the entire housing period. After Week 3, the number of piglets counted on the platform began to decrease with the lowest number of piglets being on the platform during Week 5; this finding could be attributed to the increase in size of the animals while the space allowance remained the same.

A similar decrease in the number of animals was also detected under the platform, probably due to the same reason. Our observations concerning the use of the elevated platform by weaned piglets in the course of the housing period were contradictory to the results of other studies, which have revealed that the use of an elevated platform by fattening pigs increased with the increasing fattening stage (Bulens, Van Beirendonck, Van Thielen, Buys, & Driessen, 2015; Vermeij, Hoofs, Enting, Hopster, & Ruesink, 2003). However, it has to be emphasized that in those studies, the elevated platform was only intended to increase the available space. Thus, it can be assumed that pigs who were grown up during the fattening period needed more space and consequently used the space on the platform to a greater extent. In the present study, on the platform, some additional space was provided for the piglets, while at the base level, the (legally) stipulated space allowance was already fulfilled. Therefore, no piglet was forced to use the elevated platform because of space restrictions.

Functional areas

During the activity period in the afternoon, most piglets were observed on the platform, and there were the most detected contacts with the manipulable materials during this period. In Batches 3 and 4, the observation period in the afternoon changed from 14:00 to 18:00 to 13:00 to 17:00, resulting in even higher numbers of animals observed on the elevated platform (3.4 piglets in Batch 1 vs. 7.3 piglets in Batch 3). This finding was probably due to consideration of the start of the activity phase. These observations showed the success of the intention to create an activity area on the elevated platform. When the pigs were more active, more animals were also observed on the platform.

At night, piglets lay under the platform with close body contact. During resting at night, piglets preferred to lay in close body contact with each other (Ekkel, Spoolder, Hulsegge, & Hopster, 2003; Hillmann, Mayer, & Schrader, 2004). Occasionally, a maximum number of 36 piglets—that is, almost the entire group—was observed under the platform, indicating that a resting area was established there. Consequently, during the activity period in the afternoon, under the platform, significantly fewer animals were observed than in the morning and at night. Because the area under the platform did not provide sufficient space for all piglets to lie simultaneously during the entire rearing period, the walking area was also used to rest in a lying position in the morning and at night, while in the afternoon, the number of standing/sitting and lying animals in that area was almost the same.

The feeding area was mostly frequented during the afternoon, whereas the fewest animals were counted there at night, showing that this area was used particularly during the activity phase for eating; at night, hardly any piglets were observed there in the standing/sitting position at the feeder while some piglets were lying there. Thus, behavioral observation revealed that functional areas for activity and resting were created in the experimental two-level pen, and the use of these areas by the piglets differed depending on the time of day.

Behavior of piglets and use of manipulable materials

Except for the feeding area, in all areas of the two-level pen, significantly more piglets were recorded lying than standing/sitting (Table 2). This result corresponds to the results of other studies, which have shown that pigs spent the greater part of the day in a recumbent position. In those studies, the proportion of lying was 80% for the animals for the day (Bea, 2004; Elkmann, 2007; Rohrmann, 2004), and the results were similar for nonslatted and slatted floors (Averós et al., 2010). Even on the elevated platform, on average, more piglets were observed in a lying position than in a standing/sitting position. However, the proportion of standing/sitting and lying piglets on the platform was almost the same in the afternoon, indicating the function of the platform as an area for activity and playing.

On the platform, nine different manipulable materials were offered. Play and exploratory behavior requires space. It was therefore not surprising that on average, significantly fewer animals were counted on the elevated platform than under the platform where the animals lie close together, even when both areas were of equal size (4.9 piglets on the platform vs. 16.8 piglets under the platform). Nevertheless, sometimes a maximum of 20 piglets was observed on the 5-m^2 elevated platform, indicating the high attractiveness of the enriched platform. According to our findings concerning the activity period, most piglets used the manipulable materials in the afternoon.

In total, relatively few piglets were counted with the materials. On average, 1.5 piglets used the different materials in the afternoon during the times of observation. The use of manipulable materials by pigs in conventional housing systems generally seems to have only a small impact on the entire daily activity period. According to Elkmann (2007), individual pigs in a conventional fattening pen without litter used manipulable materials for 1 minute to 29 minutes per 24 hours, with the highest frequency in the afternoon. Nevertheless, the high importance of enrichment to reduce negative behaviors such as tail biting or aggression and to increase animal welfare is supported by numerous scientific studies (Van De Weerd & Day, 2009). Play itself can be used as a welfare indicator (Dawkins, 1990; Newberry, Wood-Gush, & Hall, 1988), and environmental

enrichment can have positive effects by promoting play and reducing stress and tension (Held & Spinka, 2011).

Even if the use of enrichment in the two-level pen was similar to the use of enrichment materials in conventional systems, our enriched platform was considered to be beneficial for pig welfare. The enrichment on the elevated platform was suitable to create an activity area and thus to separate functional areas in the piglets' pen. Moreover, by installing the elevated platform, the available space was increased and could be used for play and activity. However, further studies may clarify whether the number of manipulable materials could be reduced to successfully establish an activity area.

Manipulable materials for weaning and grower pigs should be ingestible, odorous, chewable, deformable, and destructible (Van De Weerd & Day, 2009; Van De Weerd, Docking, Day, Avery, & Edwards, 2003). All materials offered on the elevated platform met at least one of these criteria. Some of them were filled with organic material such as straw or sugar beet pulp, and others were partly made of wood, which should ensure continuous interest from the animals. Piglets preferred the "activity cone," which could be rolled over the ground with sugar beet pulp dropping out of the holes. The second most popular material was the "cross of chains" consisting of four iron chains with wood or plastic at their ends.

Elkmann and Hoy (2009) found the high attractiveness of such a material and attributed it to the movability, the clinking of the chains, and the chewable material. The least attractive materials were the commercially available "Mik toy" and the "lifting tube." Both were wall-mounted pipes. The lifting tube offered only limited play value, as the animals were only able to move it upward. This activity was obviously not sufficient to maintain the interest of the piglets. All other materials were used almost to the same extent. Thus, the results of our study confirmed that the piglets preferred organic, deformable, movable, and chewable materials.

Floor soiling and environment

During the housing period, floor soiling was detected in all areas of the experimental pen. The highest soiling scores were found in the expected dunging area and under the platform, particularly in the corners. The floor soiling on the platform was slightly lower than that in the walking area. Nevertheless, both areas were significantly less soiled than the expected dunging area and the area under the platform. Especially on the elevated platform, defecation should be avoided, as it could affect the use of manipulable materials; this effect is also often a concern for pig farmers trying to offer environmental enrichment in common pens. In our study, piglets defecated at different places in the pen, though they established a main dunging area located largely at the expected location. This place was expected because it was neither a lying or feeding area nor an activity area or a running path.

Nevertheless, piglets also used parts of the area under the elevated platform as a dunging area. This area was intended to be a lying area, and behavioral analysis revealed that piglets used this area mainly for lying during the resting periods. However, this area was also used for defecating. Nonetheless, the piglets continued to rest under the platform during the entire housing period. Hillmann et al. (2004) observed that pigs only lie in the dung area when thermal adaptation by lying without contact did not suffice. However, in our study, many piglets lie in close body contact under the platform, indicating that no thermoregulative behavior was performed.

In general, pigs prefer cooler places for defecating (Olsen, Dybkjær, & Simonsen, 2001), and Ekesbo (2011) noted that pigs also have a tendency to defecate in isolation, which is linked to the vulnerability of the defecation position. The short side of the platform was located on an outer wall of the building. Thus, it may be that this area was slightly cooler than elsewhere in the pen. In addition, the corners under the platform provided some protection for the piglets, both from the sides and from above, and the piglets could defecate there largely insulated. In contrast, the expected dunging area in front of the ramp was located next to the door of the compartment, and although there was a corner of the pen as well, this place was not as protected as the space under the platform. In particular, piglets going up and down the ramp may have disturbed other piglets defecating there.

Whatson (1985) suggested that a piglet looks for an adequate space for each elimination anew, and it cannot be predicted where a piglet will defecate from the knowledge of where the animal last eliminated. Thus, it is possible that piglets chose different areas for defecating depending on the situation; for instance, they chose more protected areas during the activity period and areas away from the resting place during the resting periods.

Furthermore, pigs prefer to excrete in wet areas. Therefore, it was suggested that the water spout should be placed well away from the lying area because the pigs would be likely to defecate next to it shortly after drinking (Olsen et al., 2001). Because the former pen was converted to a two-level pen, drinkers being under the platform was unavoidable, which could also be a reason why some piglets used that area for defecation.

In the experimental pen, the creation of a dunging area did not work optimally, probably mainly because of the structural prerequisites in the former conventional pen. For future planning of two-level pens, it would therefore be important to provide a separated, protected, and if possible, cooler area for defecation. Nevertheless, the concentration of ammonia in the pen was very low on the platform as well as under the platform, and there was also no difference in air velocity between different pen areas. Thus, there was no negative effect of the construction of a two-level pen on microclimate (harmful gas and draft) in the piglets' pen.

Conclusion

An elevated platform within a piglets' pen was readily accepted by the animals after weaning and was used during the entire housing period of five weeks. It is therefore considered to be a feasible option to enrich the environment and to increase the available space in intensive piglet rearing. A two-level pen was shown to be suitable for providing functional areas for activity, resting, feeding, and partly dunging; it therefore has the potential to increase animal welfare in piglet rearing. To fulfill the piglets' need to carry out exploratory behavior, the elevated platform was successfully designed as an enriched area where different manipulable materials were offered. The animals largely used the different areas as expected. To enhance the acceptance of a certain dunging area by piglets, a separate, protected, and cool dunging area should be provided. To clarify whether a pen can be kept clean in this way, further research is needed.

Disclosure Statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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