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Behaviour and Skin Injuries of Piglets Originating from a Novel Group Farrowing System Before and After Weaning

Lilith Schrey *, Nicole Kemper and Michaela Fels

Institute for Animal Hygiene, Animal Welfare and Farm Animal Behaviour, University of Veterinary Medicine Hannover, Foundation, Bischofsholer Damm 15, D-30173 Hannover, Germany; nicole.kemper@tiho-hannover.de (N.K.); michaela.fels@tiho-hannover.de (M.F.)

* Correspondence: lilith.schrey@tiho-hannover.de; Fax: +49-511-8568998

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Abstract: The aim of this study was to analyse a novel group farrowing system (GH) concerning piglets' behaviour, skin injuries and body weight gain, to test its animal friendliness. Skin injuries and weight gain were compared to piglets originating from conventional individual housing (IH) before and after weaning. The GH system had five farrowing pens without crates, a common area and an area only available for piglets. In total, 34 litters were studied. Four days after the GH-piglets had left the pens during lactation, the lesion score of piglets in GH was higher than in IH. However, piglets from the GH sustained fewer injuries after mixing at weaning, compared to the piglets from IH and had higher daily weight gains, during the early nursery phase. The common area in GH was intensively used for active behaviour, since standing/walking and playing were observed there, most frequently, whereas lying occurred most frequently inside the pens. Immediately after the piglets had left the pens in the GH, the piglets preferred proximity to the sow, compared to the pens where they were born. The GH system enabled social enrichment, offered increased space for activity and led to fewer skin lesions, after weaning; thus, potentially increasing animal welfare.

Keywords: pre-weaning group housing; piglets; weight gain; skin lesions; activity

1. Introduction

In conventional pig production, sows and their litters are often kept in individual housing systems with farrowing crates, until the end of lactation. Confining the sow to crates leads to a restriction of her natural behaviour since, for instance, nest-building behaviour or leaving the nest for eliminative and foraging behaviour are strongly affected [1,2]. Additionally, the piglets' natural behaviour can be impaired, since opportunities to interact with the sow are restricted [3]. Under semi-natural conditions, piglets follow the sow on foraging excursions from their second week of life [4,5], investigating the environment [4] and learning how to forage and to eat, from the sow [3]. In conventional farrowing pens, the sow is not able to leave the crate and there are only few opportunities for the animals to explore. According to Oostindjer et al. [6], enrichment in the farrowing pen (wood shavings, peat, branches, straw and increased pen size) resulted in an increase in the piglets' foraging and play behaviour. Furthermore, the authors found that piglets from loose-housed sows showed less belly nosing and manipulative behaviour, after weaning.

One of the most critical stages in the piglets' early life is the weaning process, commonly performed on pig farms between three and five weeks of age. Weaning exposes piglets to various stressors, due to the dramatic environmental changes—abrupt separation from the sow, a change of diet and mixing with unacquainted piglets, accompanied by intensive fighting, can reduce growth performance and increase

the frequency of diarrhoea [3,7–9]. Under semi-natural conditions, weaning is a gradual process and is completed between 14 weeks and 17 weeks [10,11]. Nest leaving, joining the herd and meeting unfamiliar piglets from foreign litters, occurs about 10 days post-partum [10]. Thereafter, a period of social integration follows where social relationships between unknown piglets are established, through mainly non-aggressive, playful interaction [12]. According to Jensen [13] and Pitts et al. [14], mixing of young suckling piglets, results in less aggressive behaviour, compared to the older piglets.

Hence, several studies have already been conducted on investigating the effects of early contact between piglets originating from different litters, during lactation. These studies were performed either in conventional single housing systems by opening piglet doors between adjacent pens [15], by removing the partitions between adjacent pens [16–20] and by providing access to an additional piglet area while the sows were still confined to the crates [21–23]; or in group housing systems, where both, sows and piglets could co-mingle by removing a barrier at the entrance of the farrowing pen [15,24,25] and by removing the farrowing pens themselves [26], or even by transferring sows and piglets from single housing in the early lactation to group housing in the later lactation [27]. Most of these studies revealed that giving piglets the opportunity to socialise before weaning, can reduce aggressive behaviour and injuries when piglets are re-mixed after weaning, since social hierarchies have already been established. Some authors have also observed a conspicuous positive effect on the body weight gain after weaning [15,19,24]; whereas other authors did not find a significant difference, but also did not find any negative effect [17,21–23,25]. Consequently, group farrowing systems might have positive effects on the piglets' development, due to enabling of contact between several sows and piglets and providing an environment with more space and complexity [28]. Such piglets might be better prepared for social and non-social challenges at weaning [29]. Furthermore, the housing conditions during the first weeks of life have important long-lasting effects on the piglets' welfare, since behaviour, cognitive and social skills, as well as stress regulation in future life are affected by early life experiences [30].

In previous studies, the point in time when piglets were first allowed to co-mingle with non-littermates, was fixed; partitions and barriers were removed or piglet doors were opened at various time-points, ranging from 5 days post-partum [25] to 16 days post-partum [22], while most studies practised co-mingling at 10–11 days post-partum [15–18,21,23,26].

Although positive effects of pre-weaning group housing on aggressive interactions and weight gain after weaning have already been found in earlier studies, there are hardly any commercially available systems for group housing of sows and their piglets in agricultural practice. In the present study, data were obtained from a novel group housing system for five lactating sows, which was designed to be easily installed on commercial farms. This system was constructed as a prototype on a research farm. Information on the effects of this housing system, on the sows kept therein, could be found in the study by Schrey et al. [31]. In contrast to earlier studies, the piglets were given the opportunity to freely choose the moment of nest-leaving and co-mingling with foreign piglets and sows, since apertures in the pens' board were not opened until the first piglets started leaving the pens via flexible steps. To test the practicability of this housing system with regard to animal-friendly piglet rearing, behavioural analyses during lactation were conducted, to verify the hypothesis that piglets utilised the additional space offered in the group housing system. Furthermore, the piglets' weight gain and skin injuries in group housing were analysed during the suckling period and after mixing at weaning, as well as being compared to the piglets originating from the conventional individual housing.

2. Materials and Methods

2.1. Animals and Housing during the Suckling Period

The study was conducted on the research farm of the University of Veterinary Medicine Hannover, Foundation, Germany, from November 2013 to February 2015. A total of 34 litters (German National Breeding Program BHZP) housed in two types of farrowing accommodation, group housing (GH) and

conventional individual housing (IH) with crates for the sow, were observed in five batches (Table 1). Sows from first–ninth parity were transferred to the farrowing systems, seven days before farrowing.

In the GH system, five sows were kept together with their piglets. Therefore, the system consisted of five single pens for farrowing (ca. 5 m^2) and a central common area (11.6 m^2, Figure 1). The pens were equipped with flexible iron bars and rubber bollards, to prevent the piglets from being crushed by the sow. The sow could turn around inside the pen, leave it and meet other sows in the common area. An area (1.75 m^2) only available for the piglets (piglet area) was located between two farrowing pens with access from the common area. Creep areas with water heated plastic flooring (0.3 m × 2.4 m) were installed in each pen, along the pen's board and were equipped with transparent plastic cover panels and infrared heat lamps. Similarly, the piglet area was partly fitted with water-heated plastic flooring.

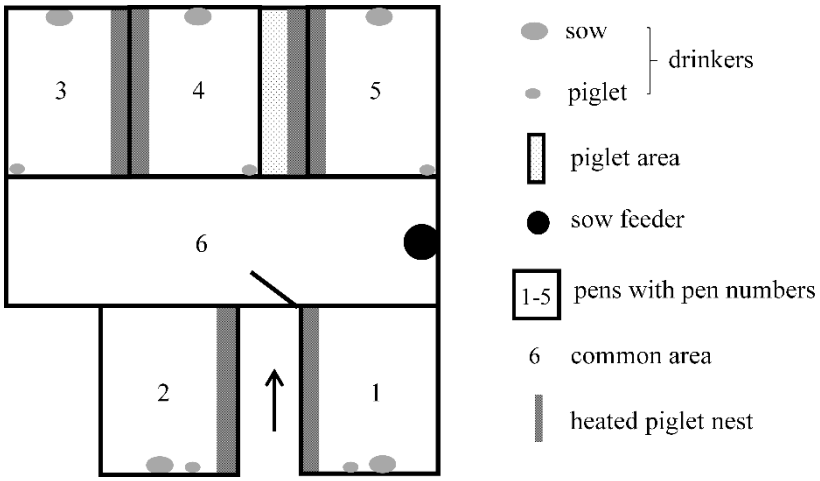

Figure 1. Group housing system layout with five farrowing pens and a central common area (published in Schrey et al. [31]).

To prevent the piglets from leaving the pens during the first days of life, the entrance of the pens was equipped with flexible steps (Figure 2). When the first piglets started leaving the pens by passing the steps, apertures in the pens' board were opened, to ensure that all piglets (including the weaker ones) could leave the pens. The floor design included plastic slats (29% perforation) in the common area and in two farrowing pens (with a central lying area). The other three pens were equipped with less perforated (0.7%) plastic flooring. Hence, about 10 litres of loose, long straw could be provided, once a day, in these pens. Sows were fed ad libitum in the common area; piglets were given solid food in the piglet area, since they could leave the pens. Water was available inside the pens in the drinking bowls for the sows and the piglets.

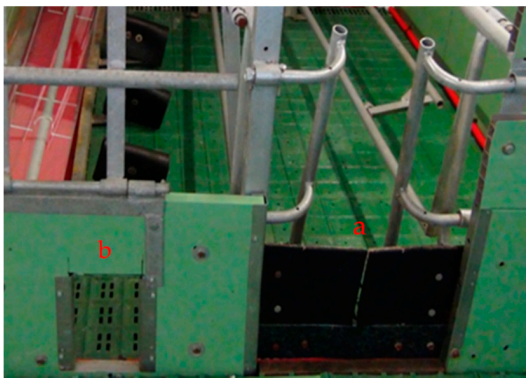

Figure 2. Farrowing pen with flexible steps at the entrance (**a**) and closable apertures in the pens' board (**b**) to prevent the piglets from leaving the pens during the first post-partum days (Photo: Schrey).

The IH system was located in another compartment of the same building. Studies on sows and their litters were carried out at the same time in both systems. Each pen (ca. 4.6 m^2) was equipped with a diagonally arranged farrowing crate, a partially slatted floor and a creep area with water heated flooring, cover panels and an infrared heat lamp. Piglets were kept separate from foreign litters. Solid food was given to the piglets at the same age as in the GH system. In both farrowing systems, the maximum litter size was balanced at 14 piglets per litter, within the first 24 h after farrowing. Boars were castrated and the piglets received individual ear tags, five days post-partum, on average. The average weaning age of the piglets was 35 days, in both housing systems. In group housing, one sow (first parity) had to leave the system due to difficulties during birth on the eighth day after entering the system. Another sow (eighth parity) had to leave the system on the fourteenth day because of lactation problems, thus, the litter could be investigated only at the first scoring. Due to a limited number of litters born simultaneously (maximum seven to nine sows gave birth to piglets every two weeks), the number of piglets available for the study varied slightly between the group and individual housing (Table 1).

Table 1. Overview of the recorded parameters for group housing (GH) and individual housing (IH).

	Farrowing System	Number of Batches	Number of Litters	Number of Piglets
Suckling period				
Skin lesions & body weight	GH	N = 5	N = 24	N = 274
	IH	N = 3	N = 10	N = 126
Behavioural observations	GH	N = 3	N = 15	N = 164
After weaning				
Skin lesions & body weight	GH	N = 4	N = 8	N = 40
	IH	N = 3	N = 6	N = 30

2.2. Recorded Traits during the Suckling Period

Skin lesions were assessed in both housing systems by one trained observer in the first week of life (before the piglets had left the pens in the GH system, which occurred with 10.6 days post-partum on average), in the second or third week of life (four days after the piglets had left the pens in GH) and in the fifth week of life (at weaning). The skin was scored at several parts of the body—head, ears, shoulder/neck, side, ham, back (right and left side, respectively) and tail. Each part was scored by a scoring system from 0–3 [22]. Score 0 was given for a body part, if no scratches were found. Score 1 was given if fewer than five superficial scratches were observed, and Score 2 was given if five–ten superficial scratches or fewer than five deep scratches were detected. Score 3 described a body area with more than ten superficial scratches or more than five deep scratches. For each piglet, a cumulative lesion score (minimum: 0 or maximum: 39) was calculated as the sum of the scores for the different body parts. Furthermore, each piglet was weighed individually, on the days of scoring.

In GH, the piglets' behaviour was continuously video-recorded to analyse how the space was used in GH and how the piglets spread throughout the system. Cameras were placed above each pen and above the common area (a total of seven cameras, Everfocus EQ550, lens EVF-2810DC, Everfocus, Taipei, Taiwan) and connected with a digital video recorder (Everfocus ECOR264-9x1, Everfocus, Taipei, Taiwan). The videos were analysed by one trained person for one day, during the third and fifth week post-partum, respectively from 06:00 h–10:00 h, 13:00 h–17:00 h and 00:00 h–04:00 h, using time sampling (instantaneous sampling). Every ten minutes, the piglets' location and activity were analysed, counting the number of piglets observed in the different areas of the housing system (pens, common area and piglet area) and determining their activities. The piglets' activities were divided into lying, sitting, standing/walking, suckling playing and playing with objects. Lying occurred when the whole length of the body came in contact with the floor (lateral and sternal lying). Sitting was documented when the hindquarters came into contact with the floor and the body was supported by

the front legs. Standing/walking was defined as an upright position, all four legs being extended or moving with contact on the floor. Suckling was described if at least 50% of the litter was at the udder and udder massage (before and after milk flow) occurred. Playing was defined as individual playing (running, jumping, pivoting, flopping down from a standing to a lying position and head shaking) and as social playing (two or more piglets; collectively running and jumping, nudging, i.e., slightly pushing and mounting). Playing with objects involved interacting (biting, pushing and sniffing with the snout) with inanimate objects of the housing environment, such as rubber bollards, rubber steps and straw. If the activity could not be classified at the moment of time sampling, the video was analysed five seconds before and after this point, to ascertain the accurate behaviour.

Furthermore, the piglets' location was analysed, either with regard to the proximity to the mother sow or with regard to the pen where the piglets were born. For this purpose, direct observation was performed in three batches, starting when the piglets had left the pens (second week post-partum). These observations were carried out once a week by one trained person, during a period of three hours a day, using time sampling. Every 30 min, the number of piglets at the same location (same pen or common area) as the mother sow was counted, as well as the number of piglets in the pen where they were born. The location during suckling was not considered for this analysis. Each piglet originating from the same litter was marked with the same colour, using livestock marking spray. Individual identification of each piglet was enabled by ear tags, each piglet being marked before the piglets could leave the pens.

2.3. Experiment after Weaning

At weaning, some piglets were selected for a further experiment and moved from the farrowing accommodation to two identical nursery pens (0.35 m^2 per animal, fully slatted plastic floor). These piglets were mixed into groups of ten, equally distributed according to weight and sex, with five piglets from two different origin litters, each. Piglets within a group originated from the same farrowing system. Water and solid food were available ad libitum. Skin lesions were determined before weaning and four days after weaning, by the same method as applied during the suckling period (same observer and scoring system). Piglets were weighed at weaning, four days after weaning and at the end of the nursery period (28 days after weaning). The daily weight gain of the piglets during the nursery period was calculated.

2.4. Statistics

The statistical analysis was conducted using the software package IBM SPSS Statistics, Version 23. The data, as well as the residuals, were tested for normal distribution, using frequency distribution vertical bar graphs and the Shapiro–Wilk test.

For statistical analysis of body weight gain and cumulative lesion score before weaning, univariate analysis of variance (SPSS General Linear Model, Proc. univariate), followed by Bonferroni-adjusted post-hoc analysis was performed, according to the following model:

$$Y = \mu + \text{scoring i} + \text{batch j} + \text{treatment k} + \text{sex l} + \text{scoring} \times \text{treatment} + \text{e ij}$$

where y = body weight/cumulative lesion score, μ = overall mean, scoring i = effect of time of scoring (i = 1–3), batch j = effect of batch of experiment (j = 1–5 for GH and j = 1–3 for IH), treatment k = effect of group composition (k = GH or IH), sex l = effect of piglets' sex (l = castrated male or female), scoring $\times$ treatment= effect of interaction of scoring and treatment and ijkl = random residual error.

For behavioural data, pairwise comparisons using Wilcoxon-tests were applied to detect significant differences between the percentages of piglets being at different locations and showing different behaviours in GH, since the data were not normally distributed.

For analysis of the cumulative lesion score and daily weight gain after weaning, univariate analysis of variance (SPSS General Linear Model, Proc. univariate), followed by Bonferroni-adjusted post-hoc analysis was performed, according to the following model:

$$Y = \mu + \text{batch i} + \text{treatment j} + b\ (\text{body weight k} - \text{body weight}) + e\ ijk$$

where y = daily weight gain/cumulative lesion score, μ = overall mean, batch i = effect of batch of experiment (i = 1–5), treatment j = effect of group composition (j = GH or IH), (body weight k − body weight) = individual body weight at weaning as co-variable and e ijk = random residual error.

3. Results

3.1. Skin Lesions and Body Weights of the Piglets before Weaning

In both housing systems, the cumulative lesion score increased with the age of the piglets (Figure 3). Four days after the piglets had left the pens and started co-mingling with the piglets from foreign litters, the cumulative lesion score of piglets in the GH was higher, compared to the piglets in IH, even if the occurrence of injuries was low in both systems (7.8 ± 0.2 vs. 5.4 ± 0.3; $p < 0.001$, F = 23.732, df = 1). At weaning, the highest lesion scores were detected (8.3 ± 0.2 in GH vs. 7.0 ± 0.3 in IH; $p = 0.005$, F = 7.987, df = 1), while the increase in the cumulative lesion score, from four days after leaving the pens to weaning, was not statistically significant in GH ($p = 0.645$, F = 151.412, df = 2), in contrast to IH ($p < 0.001$, F = 52.481, df = 2).

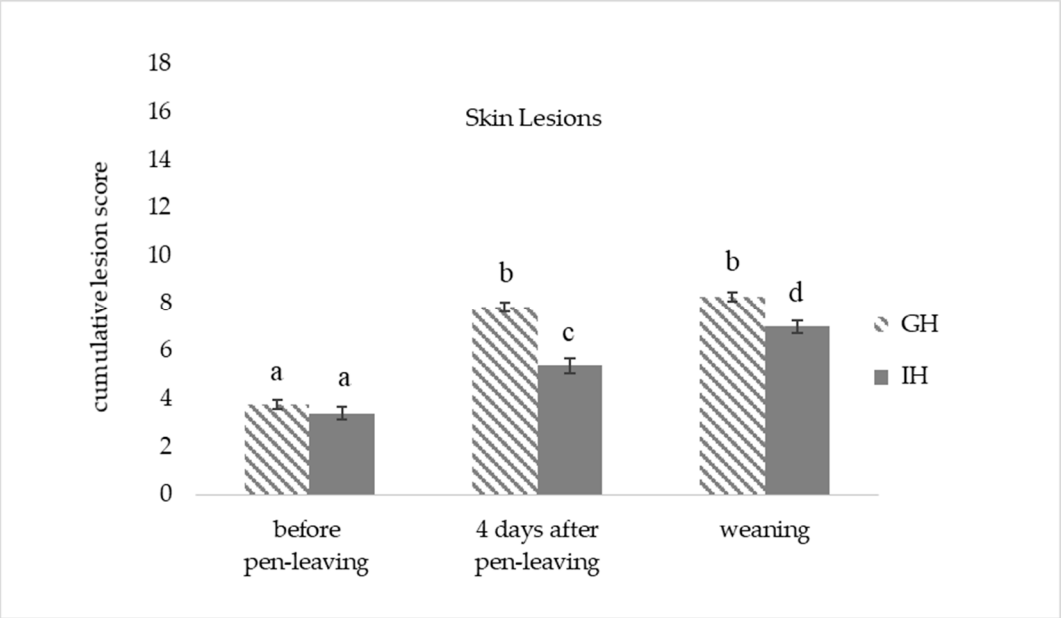

Figure 3. Least-Square-Means and standard errors (±SE) of the cumulative lesion score for the piglets during the suckling period (before pen-leaving = 1st week; 4 days after pen leaving = 2nd/3rd week; weaning = 5th week of life) for GH (group housing n = 274 piglets) and IH (individual housing n = 126 piglets). Significant differences are indicated by different letters ($p < 0.05$).

The body weights did not differ significantly between both housing systems before and four days after the piglets had left the pens ($p > 0.05$, Figure 4). However, a significant increase in body weights during the different suckling weeks could be found in both housing systems ($p < 0.001$). At weaning, piglets from IH weighed more than piglets from GH (9.9 ± 0.2 kg vs. 9.2 ± 0.2 kg; $p = 0.014$, F = 6.099, df = 1).

Figure 4. Least-Square-Means and standard errors (±SE) of the body weights (kg) during the suckling period (before pen-leaving = 1st week; 4 days after pen-leaving = 2nd/3rd week; weaning = 5th week of life) for GH (group housing n = 274 piglets) and IH (individual housing n = 126 piglets).

3.2. Behavioural Observations in Pre-Weaning Group Housing

During the entire observation period, the piglets were most frequently observed inside the pens. The lowest percentage of piglets was found in the piglet area (Table 2). In the 5th week, more piglets were observed in the common and the piglet area, compared to the 3rd week ($p < 0.001$). Accordingly, the percentage of piglets inside the pens decreased from the 3rd to the 5th week ($p < 0.001$). In the afternoon, from 13:00 h–17:00 h, more piglets were observed in the common area, compared to morning, from 06:00 h–10:00 h, and at night, from 00:00 h–04:00 h (40.1 ± 1.2% vs. 26.4 ± 1.2% and 34 ± 1.3% $p < 0.001$ and $p = 0.002$). Correspondingly, a lower percentage of piglets was found in the pens in the afternoon compared to the morning and night (50.9 ± 1.1% vs. 59.6 ± 1.0% and 59.9 ± 1.2% $p < 0.001$). In contrast, more piglets were observed in the piglet area in the morning compared to other times of the day (morning: 14.0 ± 0.5% vs. afternoon: 9.0 ± 0.6% and night: 6.1 ± 0.6%, $p < 0.001$).

Table 2. Mean percentage and standard errors (±SE) of piglets at different locations within the group housing system in the 3rd and 5th week post-partum. Significant differences are indicated by different letters ($p < 0.05$).

	Pens (%)	Common Area (%)	Piglet Area (%)
Week 3	66.6 ^{a} (±1.4)	26.8 ^{c} (±1.3)	6.5 ^{e} (±0.5)
Week 5	48.4 ^{b} (±1.1)	38.4 ^{d} (±1.4)	13.1 ^{f} (±0.6)
Average	57.1 ^{a} (±1.0)	32.9 ^{b} (±1.0)	10.0 ^{c} (±0.4)

In the 2nd week, post-partum, immediately after the piglets had left the pens, more piglets were observed close to the mother sow, in comparison to the following weeks (2nd week: 50%, 3rd week: 26.1%, 4th week: 36.4%; 5th week: 36.4% of the total litter was located close to the mother sow, Figure 5). In contrast, only low percentages of piglets were found in their original pens, where they were born, during the entire suckling period (2nd week: 8.3%, 3rd week: 9.1%, 4th week: 8.3%, 5th week: 0% of the total litter born in the pen).

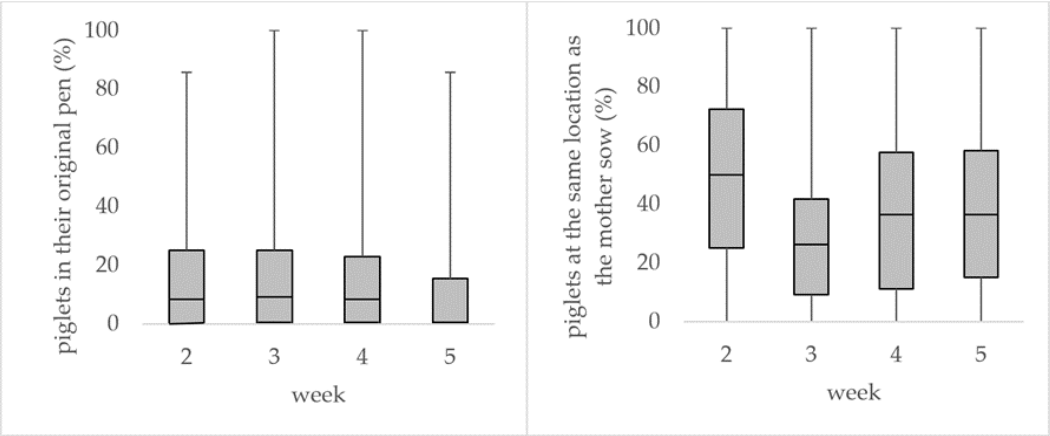

Figure 5. Percentage of piglets that were in the same pen as they were born (original pen) and that were at the same location as the mother sow, during direct observation from the 2nd to the 5th week post-partum.

The most frequent activity of the piglets was lying ($p < 0.001$, Table 3). The highest percentage of lying piglets was observed inside the pens (44.5%). In contrast, the percentage of standing/walking piglets was highest in the common area (10.0%). Similarly, playing piglets were observed more often in the common area compared to the pens. For the piglet area, the same tendency as in the pens was found; hence, lying could be found obviously more often compared to standing/walking, although the values of the different activities were lower.

Table 3. Mean percentage and standard errors (±SE) of piglets showing various activities in the different locations. Significant differences are indicated by different letters ($p < 0.05$).

	Lying	Standing/Walking	Sitting	Suckling	Playing	Object Playing
Pens	44.5 (±1.2)	6.1 (±0.3)	0.3 (±0.0)	4.3 (±0.5)	0.3 (±0.1)	1.6 (±0.1)
Common area	13.7 (±0.9)	10.0 (±0.5)	0.5 (±0.1)	5.9 (±0.6)	2.2 (±0.2)	0.7 (±0.1)
Piglet area	7.2 (±0.4)	2.4 (±0.2)	0.1 (±0.0)	0.0 (±0.0)	0.1 (±0.0)	0.2 (±0.0)
Total	65.4 ^{a} (±1.5)	18.4 ^{b} (±0.8)	1.0 ^{c} (±0.1)	10.2 ^{d} (±1.0)	2.6 ^{e} (±0.3)	2.5 ^{e} (±0.2)

With increasing age, the percentage of lying piglets significantly increased in the common area (3rd week 6.5% vs. 5th week 20.3%, $p < 0.001$) as well as in the piglet area (3rd week 4.2% vs. 5th week 9.8%, $p = 0.001$). In contrast, the percentage of piglets lying inside the pens decreased from the 3rd to the 5th week (53.4% vs. 36.4%; $p < 0.001$). The percentage of piglets which were standing/walking did not change with the increasing age of the piglets ($p = 0.873$). Similarly, the percentage of suckling piglets remained nearly constant with increasing time ($p = 0.203$). Piglets sitting inside the pens were found less often in the 5th week, compared to the 3rd week (0.5% vs. 0.2%, $p = 0.019$); in contrast, the percentage of sitting piglets did not change in the common area and in the piglet area ($p = 0.333$ and 0.328). More playing piglets were found in the common area in the 3rd week, compared to the 5th week (2.8% vs. 1.6%; $p = 0.010$). Inside the pens, as well as in the piglet area, the percentage of piglets which were playing, remained nearly constant with increasing time ($p = 0.429$ and 0.122). The number of piglets seen playing with objects slightly increased in all locations from the 3rd to the 5th week (pens: 1.3% vs. 1.8% $p = 0.128$; common area: 0.5% vs. 0.8% $p = 0.059$; piglet area: 0.1% vs. 0.3% $p = 0.022$).

3.3. Skin Lesions and Weight Gain of Piglets after Weaning

For the piglets originating from IH, the cumulative lesion score increased significantly during the first four days after weaning and mixing (7.1 ± 0.6 before weaning vs. 14.9 ± 0.7 four days after weaning; $p = 0.014$, F = 67.872, df = 1, Figure 6). In contrast, for the piglets originating from GH, the

lesion scores were in a similar range during these four days (9.4 ± 0.6 before weaning vs. 8.3 ± 0.6 four days after weaning; $p = 0.208$, F = 3.355, df = 1).

When piglets were mixed at weaning, piglets within groups were equally distributed regarding weight and sex. Piglets in groups originating from the pre-weaning group housing had a mean initial body weight of 11.3 kg ± 1.1 kg (SD). Piglets in groups originating from the pre-weaning individual housing weighed 10.7 kg ± 1.3 kg (SD) on average. During the first four days after weaning, daily weight gain was significantly higher for the piglets originating from the pre-weaning group housing, compared to the individual housing (317.6 ± 17.7 g/day vs. 222.2 ± 21.8 g/day; $p = 0.003$, F = 5.863, df = 2). Piglets originating from the pre-weaning group housing also tended to show a higher daily weight gain for the total nursery period, compared to the piglets originating from the individual farrowing system (545.4 ± 14.0 g/day vs. 496.0 ± 17.2 g/day; $p = 0.085$, F = 2.834, df = 2).

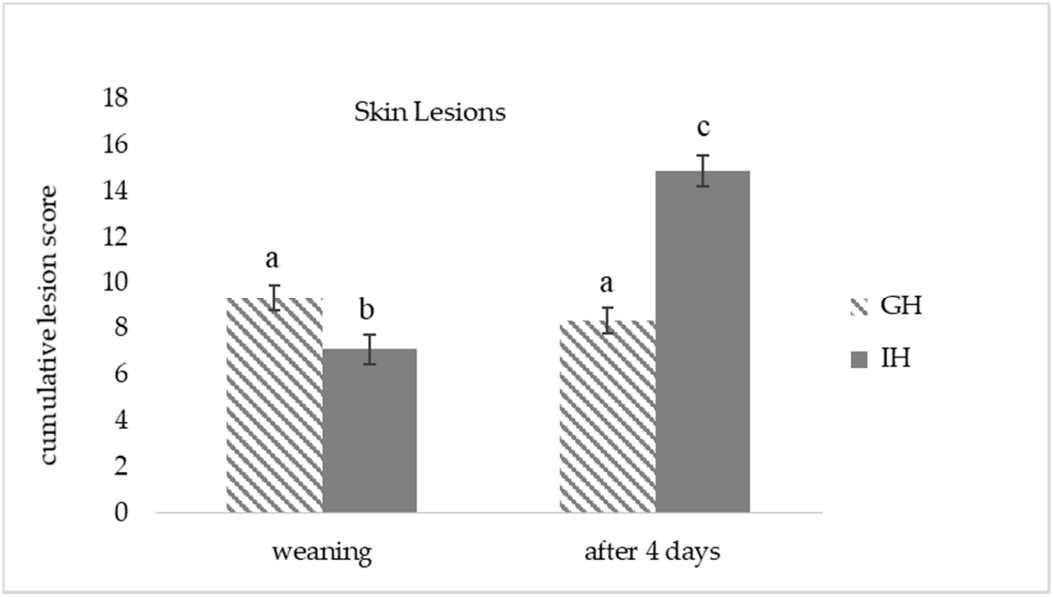

Figure 6. Least-Square-Means and standard errors (±SE) of the cumulative lesion score of the weaned piglets previously housed in pre-weaning GH (group housing n = 40) or in IH (individual housing n = 30). Significant differences are indicated by different letters ($p < 0.05$).

4. Discussion

The aim of this study was to obtain data from a novel group housing system for five lactating sows and their litters, with regard to its animal-friendly piglet rearing. Therefore, behavioural analyses during lactation concerning activity and location of the piglets were conducted to ascertain whether the piglets utilised the additional space offered in GH or continued spending time in the pens where they were born. Furthermore, weight gain and skin injuries of the piglets from GH were analysed before and after weaning, and were compared to the piglets originating from conventional individual housing. In contrast to previous studies, piglets in GH were given the opportunity to decide freely the moment of nest-leaving and co-mingling with non-littermates and foreign sows. Furthermore, a housing system was investigated, which was designed for practical use on commercial farms. Even if the sample size was low, especially for the study after weaning, meaningful results could be obtained from the present study concerning the effects of pre-weaning group housing on the piglets' behaviour and health, before and after weaning.

4.1. Skin Lesions and Daily Weight Gain before and after Weaning

During the suckling period, the cumulative lesion score was higher in the GH, compared to IH, after the GH-piglets had left the pens where they were born. In GH, a significant increase was found only

from the 1st (before pen-leaving) to the 2nd/3rd week of life (four days after pen-leaving). According to the literature, fighting to establish a social hierarchy occurred during the first two [32]–three [33] days after mixing unfamiliar piglets at weaning. This indicated that the increase in the number of skin lesions was related to the rank-order fighting between piglets, after they had left the pens and co-mingled with their non-littermates. This corresponded to the results of other studies which found more skin lesions after enabling contact between the non-littermates [17,22,25]. In contrast, Kutzer et al. [15] observed only very few skin lesions with no difference between the different housing systems, four days after mixing (group housing with contact with non-littermates, loose single housing and conventional single housing with and without contact with non-littermates). However, in the present study, the piglets in single housing without any contact with non-littermates also showed a significant increase in the scoring index during the suckling period, which might have been due to the aggressive interactions when littermates were growing up with restricted space allowance in the farrowing pen.

After weaning, the cumulative lesion score doubled in the first four days, after mixing the piglets originating from IH, compared to the pre-weaning lesion score. In contrast, in the groups of piglets originating from GH, the cumulative lesion score was in a similar range, presumably, since the pre-weaning housing system enabled the piglets to co-mingle and a social hierarchy was already established during the suckling period. This effect was also obvious when the pre-weaning social structure was disrupted and the piglets were moved to an unknown environment. Previous studies investigating early contact between non-littermates during the suckling period in the pre-weaning group housing systems [15,25] or in single housing systems with crates [17,19,22,23], also revealed that the piglets with early contact, sustained fewer injuries or showed a reduced fighting in the post-weaning period. This effect could be found even if the piglets that socialised with non-littermates, pre-weaning, were mixed with further unfamiliar piglets which they did not meet during the suckling period [26,27,34], and when mixing did not occur at weaning, but later on in the 8th week of life [26,34]. In the present study, even if only few piglets were selected from the pre-weaning group housing system and regrouped after weaning—piglets within groups being balanced by weight and sex—they obviously fought less and sustained fewer injuries than the unacquainted piglets that were mixed at weaning.

When comparing the occurrence of skin lesions during lactation (after enabling the first contact with non-littermates in GH) and after weaning, it was found that the weaned pigs originating from IH sustained more injuries four days after weaning, than the suckling piglets in GH four days after leaving the pens. This corresponded to the results of Pitts et al. [14] who investigated the incidence of fighting among unweaned piglets, between five and twenty-six days of age. The authors observed that younger piglets experienced fewer injuries and had shorter fights, after mixing, compared to older piglets.

Individual body weights differed between the housing systems at weaning, since the piglets from GH weighed less than the piglets from IH. Likewise, Bohnenkamp et al. [35] and Bates et al. [36] observed lower weaning weights of the piglets in group housing, compared to single housing. Bohnenkamp et al. [35] mixed piglets five days post-partum by removing the flexible steps; they assumed that the lower weaning weights were caused by the early mixing of the piglets, causing disturbances during suckling, and by the enhanced play behaviour. In a study by Bates et al. [36], where piglets were co-mingled seven days post-partum, in a group housing system, the lower weaning weights of the piglets were explained by a decreased milk consumption. In contrast, other authors who mixed piglets, 11 days, 12 days and 13 days after farrowing, respectively, detected no differences in body weight gain between the co-mingled piglets and a control group, before weaning [19,20,23]. These authors investigated single housing systems, where the sows remained confined to the farrowing crates while the piglets could co-mingle with foreign litters. Additionally, Kutzer et al. [15], investigated a group housing system (contact between foreign litters 10 days post-partum), a single housing system with farrowing crates, and a loose housing system, with and without contact between litters 10 days after farrowing, and found no differences in body weight gain before weaning. However, in the study of Salazar et al. [37] the piglets weighed less during lactation although they had been socialised under

commercial conditions where only the barriers between the two pens had been removed on day 14, after farrowing. It could be assumed that the lower weaning weights of the piglets in GH found in the present study were related to the higher space allowance, enabling an enhanced active behaviour (playing, standing/walking) compared to IH.

During the first four days after weaning and the total nursery period, daily weight gain was higher for the piglets originating from GH, compared to IH. However, a significant difference was only found for the first four days. This corresponded to the results of Kutzer et al. [15], who also observed that piglets previously housed in pre-weaning group housing had significantly higher body weight gain after weaning. Similarly, Hessel et al. [19] found significantly higher body weight gains after weaning for the piglets that had been socialised with other piglets, during the suckling period, in particular, during the first week after weaning. The authors explained that co-mingling litters before weaning reduced the weaning stress, by decreasing the agonistic interactions, thus, enhancing the piglets' performance. However, Bohnenkamp et al. [25] could not observe significant differences concerning body weights during the whole nursery period between the piglets previously housed in group housing (with contact with non-littermates during lactation) and in single housing (without contact with non-littermates during lactation), after mixing at weaning. However, the piglets from group housing did show less fighting behaviour. The authors saw the early time of mixing during lactation (five days post-partum) as being responsible for these results. Additionally, Parratt et al. [22], allowed piglets to co-mingle five days pre-weaning (i.e., 16 days post-partum) and could not observe any effect on the growth performance post-weaning, although the previously mixed group showed a reduced fighting behaviour, after weaning. Hence, allowing the piglets to determine the time of co-mingling as in the current study, might not have a negative influence on the occurrence of agonistic behaviour and weight gain after weaning. Nonetheless, it might have a positive influence, especially, during the first days after weaning, potentially indicating that the weaning stress is reduced.

4.2. Behavioural Observations in Group Housing

In total, the most observed behaviour of the piglets was lying, followed by standing/walking, suckling, playing and sitting. A similar distribution of behaviours was also found in other studies. Hessel et al. [19] observed that piglets in conventional farrowing pens with crates, spent 76.15% of their time lying, were active (defined as standing and moving in the pen) in 11.98% of their time and suckled in 11.87% of all observations. Arey and Sancha [38] compared conventional farrowing crates (FC) and a family system (FS), where sows and piglets were housed in groups with straw-bedded farrowing pens and an outer communal area. The authors found no significant difference in standing (FS: 39.5% vs. FC: 35.5% of all observations) and substrate-directed (i.e., straw/wood shavings) behaviour (FS 5.4% vs. FC 3.4%) between the systems. Lying in total (i.e., side and ventral) was found in 60.5% of all observations in the family system and in 64.5% of the time in the farrowing crate.

In the present study, standing and walking, as well as playing, were observed most frequently in the common area, indicating that the additional space of the common area was obviously used by the piglets, for active behaviour. Accordingly, more piglets were observed in the common area in the afternoon, which is considered as being the active period of the day [39]. In contrast, lying was found with the most frequency inside the pens, where the heated creep areas were placed. As lying was the preferred behaviour of the piglets, it was not surprising that on all days of observation, most piglets were found inside the pens. The percentages of piglets observed in the common area and in the piglet area, increased with the age of the piglets, while the values for the pens decreased ($p < 0.05$). Obviously, piglets when growing, slept less in the pens and used the additional space allowance outside the pens. The lowest percentage of piglets was found in the piglet area, which was most likely due to the small size and hence the little space in total available to the piglets in this area (1.75 m^2).

From the moment the piglets left the pens (with 10.6 days post-partum on average), only few piglets were seen in their original pen where they were born, also indicating that the offered additional space in the housing system was used frequently. Especially immediately after the piglets had left the

pens, a high percentage of piglets was observed close to the mother sow, independent of her location in the system. In an earlier study in the same group housing system, we observed that the sows abandoned their previous farrowing pens, spending time in different pens and in the common area from the moment the piglets had left the pens [31]. Hence, piglets seemed to prefer proximity to the sow in comparison to the pen where they were born. Similarly, piglets under semi-natural conditions followed the sow on foraging excursions from their second week of life [4,5]. About ten days after farrowing, sows and piglets abandoned the nest and returned to the flock [10,40], where the piglets gradually became integrated with the foreign litters [10]. A similar situation was observed with the pre-weaning group housing system investigated in the present study.

5. Conclusions

The pre-weaning group housing system investigated in the present study enabled social enrichment due to early contact with non-littermates and foreign sows and also offered an increased space allowance for active behaviour before weaning. It was shown that the different areas of this housing system were intensively used by the piglets and that the natural behaviours could be performed. Piglets originating from the pre-weaning group housing not only sustained fewer injuries but also showed a higher daily weight gain after weaning, compared to the piglets originating from the farrowing pens with crates. Thus, rearing piglets in pre-weaning group housing met the natural behavioural needs of the young suckling piglets and seemed to reduce social stress after weaning, thus, potentially increasing piglet welfare under practical farming conditions. However, due to the low sample size available in this study, in particular for the experiment after weaning, further research is needed to confirm our results. Besides the aspects analysed in the present study concerning piglets' behaviour and development, the system might have implications for increased workload by farmers, e.g., time taken to catch piglets for routine procedures. Further research is required to establish labour costs associated with GH.

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Data Availability: The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Statement: The authors declare that the experiment was in accordance with EU (European Directive 2008/120/EC) and German law. This study received approval from the Animal Welfare Officer of the University of Veterinary Medicine, Hannover, Foundation, Germany.

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