agriculture

MDPI

Article

Effect of Stocking Density on Behavior and Pen Cleanliness of Grouped Growing Pigs

Yaqiong Zeng [1], Hao Wang [1,2,*], Rongdan Ruan [3], Yongzhen Li [2], Zuohua Liu [1], Chaoyuan Wang [2] and Anfang Liu [4]

1 Chongqing Academy of Animal Sciences, Chongqing 402460, China; zengyq@cqaa.cn (Y.Z.); liuzh@cqaa.cn (Z.L.)
2 Key Laboratory of Agricultural Engineering in Structure and Environment, Ministry of Agriculture and Rural Affairs, Beijing 100083, China; yongzhenli@cau.edu.cn (Y.L.); gotowchy@cau.edu.cn (C.W.)
3 Pu'er Municipal Bureau of Agriculture and Rural Affairs, Pu'er 665999, China; ruanrongdan@pesnyncj.wecom.work
4 College of Animal Science, Southwest University, Chongqing 402460, China; liulb515@swu.edu.cn
* Correspondence: wanghaocau@cau.edu.cn; Tel.: +86-023-46793979

Abstract: In recent years, animal cleanliness during production has gradually attracted increasing attention. Although pigs by nature tend to excrete in dark and humid corners, in the prevalent highly intensive pig production, excessive stocking density often restricts the ability of pigs to excrete at designated points, thereby leading to pollution of the pens. To study the effect of stocking density on pen cleanliness and the relevant pig behavior, a total of 216 Landrace × Yorkshire × Duroc hybrid pigs were randomly grouped at 0.5, 0.7, or 0.9 m^2 per pig at 59 ± 3 days of age. The temporal and spatial distributions of lying and excreting behavior of pigs were monitored on days 1, 7, and 35 after transfer, and the cleanliness of pig pens under three stocking densities was scored. The results showed that there were no significant differences in excreting or lying time rhythms among the three treatments. In the initial and stable periods of group transfer, the excretion rate of pigs on slatted floors was significantly higher than that on solid floors at 0.9 m^2/pig ($p < 0.01$). During the group stabilization stage and at the end of the experiment, the lying rate of pigs on solid floors under 0.9 m^2/pig was 10.81%, that is, 7.43% higher than that of 0.7 m^2/pig, and the differences were significant. Judging from the pollution score of the solid floors, the three stocking densities all showed more serious pollution at the corners, and the pollution score of the pens with a density of 0.9 m^2/pig was lower than that of the pens with a density of 0.5 and 0.7 m^2/pig. The analysis of whether pigs had corresponding behaviors in specific functional areas showed that pigs at a density of 0.9 m^2/pig had a 10.14% lower lying rate on slatted floors (the expected excretion area) than on solid floors, whereas the densities of 0.5 and 0.7 m^2/pig showed the opposite pattern. Pigs at a density of 0.9 m^2/pig had lower excretion rates in both corners of the solid floors (the desired lying area) than that of the 0.5 m^2/pig group ($p < 0.05$) and 0.7 m^2/pig group ($p > 0.05$). These results indicate that when the effective occupied space of pigs was larger, specific behaviors were more likely to occur in the set functional areas, and the cleanliness of the pen was higher. Under the conditions of this experiment, the recommended stocking density for growing pigs was 0.9 m^2/pig. Of course, a larger space may be more beneficial to animal health and welfare, but the economic costs must also be considered.

Keywords: stocking density; pen cleanliness; excretion behavior; lying behavior

check for updates

Citation: Zeng, Y.; Wang, H.; Ruan, R.; Li, Y.; Liu, Z.; Wang, C.; Liu, A. Effect of Stocking Density on Behavior and Pen Cleanliness of Grouped Growing Pigs. *Agriculture* **2022**, *12*, 418. https://doi.org/10.3390/agriculture12030418

Academic Editor: Javier Álvarez-Rodríguez

Received: 1 March 2022
Accepted: 14 March 2022
Published: 16 March 2022

1. Introduction

As a result of the large-scale and intensive development of China's pig breeding industry, the natural habits of pigs are inevitably limited under the goal of pursuing high production efficiency. For example, the nature of pigs' fixed-point excretion cannot be accommodated, resulting in pen pollution. Pen pollution can have diverse adverse effects. First, pen pollution is the main source of harmful gases in pig houses. Among these, ammonia emissions are particularly affected by floor areas contaminated by feces and urine [1], and NH_3 emissions are highly correlated with ground contamination from feces (r = 0.852) [2]. When the amount of manure accumulated on the floor is reduced, NH_3 emissions can be reduced by 40% to 60% [3–6]. Second, pen pollution is detrimental to the health and welfare of pigs. The floor in the pig house can become heavily contaminated, and the accumulation of feces can easily lead to slipping of pigs, which increases the risk of hoof damage and infection [7–10]. Pigs prefer to perform activities in clean and dry areas, and maintaining the cleanliness of the pen can promote their healthy development [11]. In addition, keeping the pens clean can minimize the cleaning intensity of the pens and reduce the labor cost [12].

There are many factors that affect the cleanliness of pig houses. For example, the contamination level of pens increases with the temperature in pig houses [13–15]. When the temperature increased by about 6 °C, the lying behavior on solid floors in the pig house decreased by 42.3%; the urination and defecation increased by 75.8% and 139.5%, respectively, and the pollution of the pen was more serious [16]. Pig excretion behavior changes when the rearing equipment is altered [17]; for example, adding an additional drinker to the slatted floor area outside the house when there was already a drinker in the slatted floor increased indoor pollution [18]. As an important environmental factor in pig production, stocking density has a direct impact on pen pollution. At higher stocking densities, it is relatively difficult for pigs to move between different areas [19] and thus the pigs are more likely to excrete in the lying area and to lie down in the excretion area. At lower stocking densities, more area is available for excretion, and pigs are less likely to develop group behavior, meaning that the pigs will tend to excrete in a space not used for other activities [20]. Too high or too low stocking density can easily cause pen pollution. Therefore, a proper stocking density is necessary to maintain the cleanliness of the pen.

In this study, the timing and areas for excretion and lying behavior of growing pigs under different stocking densities were analyzed, and the cleanliness of the pig house was scored. On this basis, the relationship between stocking density, pig herd behavior, and pen cleanliness was examined. The appropriate stocking density of growing pigs was determined in order to provide a reference for the welfare and clean breeding of live pigs.

2. Materials and Methods

2.1. Experimental Design and Feeding Management

The study was conducted from August 8 to September 18, 2018, in a growing-finishing pig house at the Chongqing Academy of Animal Sciences, Chongqing city, China (latitude: 29°15′–29°41′ N; longitude: 105°17′–105°44′ E). The outdoor ambient temperature and relative humidity (RH) were 25–35 °C and 60–95%, respectively, during the trial.

A total of 216 Landrace × Yorkshire × Duroc hybrid growing pigs (live weight 23.5 ± 3.7 kg, 59 ± 3 days of age) were randomly assigned to 12 pens. According to the current industry standards in China (NY/T1568–2007), the stocking densities of the trials were set at three levels of 0.5, 0.7, and 0.9 m^2/pig (four pens per treatment and 18 pigs per pen). The experiment was carried out for 35 days and the final body weights of the pigs were 50.5 ± 6.5 kg.

The experimental pig house was fully enclosed, and each pen was equipped with one plastic feeder and two bowl-shaped drinkers, so that the pigs were allowed free access to food and water. An evaporative cooling pad system was used to control the thermal environment in the house. Feeding was carried out at 8:00–9:00 and 16:00–17:00 every day. The solid floor was cleaned twice per day before feeding.

2.2. Pig Pen Area Division and Behavior Observation

A division diagram of the pen area is shown in Figure 1. The floor of the experimental pig house was partly slatted (1/2 slatted flooring and 1/2 solid concrete flooring). The expected lying area was the solid concrete floor (area II: II_1, II_2, and II_3), while the slatted area (area I: I_1, I_2, and I_3) was designated for excreting. A camera was installed above each pig pen, and a digital video system with a resolution of 1280×960 (Dahua Technology, Zhejiang Province, China) was used for automatically recording the behavior of the pigs. The video recordings from the 1st, 7th, and 35th days of the experiment were selected for manual observation.

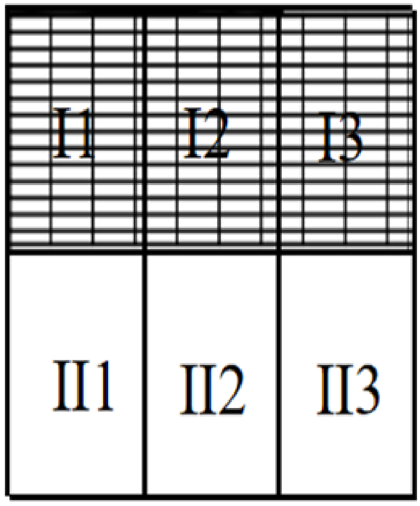

Figure 1. Division diagram of pen area for behavior observation.

2.2.1. Excreting Behavior

Days with complete video recordings after the grouping stabilized were selected to analyze the daily excretion patterns of growing pigs. Based on the number of excretions that occurred in a certain area per hour, the excretion behavior in each area on days 1, 7, and 35 was analyzed, and the excretion rate of each area was calculated. The distinguishing principle of excretion behavior was that the pigs would stand still to defecate or urinate, and that the duration of this behavior was more than three seconds.

The excretion rate of a certain area = the number of excretion behaviors in this area/the total number of excretion behaviors in all areas × 100.

2.2.2. Lying Behavior

Days with complete video recordings after the grouping stabilized were selected to analyze the daily variation in the lying behavior of the finishing pigs. The purpose of observing the lying behavior in this experiment was to explore its relationship with the cleanliness of the pen. Pigs were basically lying down at night, and thus it was more convenient and representative to observe the frequency of lying behavior of pigs during the day. Based on the number of pigs lying in a given area per hour, the lying behavior of pigs in each area from 8:10 to 18:10 on the 1st, 7th, and 35th days was analyzed, and the lying rate of each area was calculated. Pigs lie down at the junctions of multiple areas to distribute themselves in the areas where most of the body is located. The criteria for lying behavior were that the pigs were observed to lie on their side or lie prone on the solid or slatted floor for more than three seconds.

Lying rate in a certain area = number of lying pigs in this area/total number of lying pigs in all areas × 100.

2.3. Floor Cleanliness Score for Pig Pens

The videos recorded on days 7 and 35 were manually observed at 7:00–8:00 (before manure removal in the morning), 10:00–11:00 (after the pigs were fed), and 15:00–16:00: (before feces removal in the afternoon). The pen was divided into 20 small areas on average, and then the feces status and the area covered by manure were scored in each area. The scoring standards are shown in Table 1. This work was performed by a trained professional.

Table 1. Scoring standards for cleanliness of each area.

Score	0	1	2	3
Feces or not	None	Yes	/	/
Fecal state	/	Dry manure	Patches of moist feces	Large tracts of moist feces
Area covered by feces	/	<1/3	1/3–2/3	>2/3

The actual photos corresponding to the cleanliness scoring standard are shown in Table 2.

Table 2. Live pictures corresponding to the scoring standards.

Scoring Standard	Sample Image	Covered Area	Sample Image
Dry manure		<1/3	
Patches of moist feces		1/3–2/3	
Large tracts of moist feces		>2/3	

2.4. Statistical Analyses

The experimental data were statistically analyzed using Excel 2010. The effects of stocking density on pig excretion, lying behavior, and pen cleanliness were analyzed by one-way ANOVA, and the correlation between the two behaviors and pen cleanliness was analyzed. The test results were expressed as the mean ± SE. $p > 0.05$ was considered as indicating no significant difference between treatments; $p < 0.05$ indicated a significant difference, and $p < 0.01$ indicated an extremely significant difference.

3. Results

3.1. Excreting Behavior

3.1.1. Circadian Rhythm of Excreting Behavior

As shown in Figure 2, the excretion time rules of pigs with different treatments were basically the same. The peak excretion occurred around 7:00 am. Relative to the rest of the daily cycle, 14:00–17:00 was also a peak excretion period. The least number of excreting behaviors occurred between 4:00 and 5:00 at night. According to the observations, there was also a small peak of excretion around 11:00 after feeding.

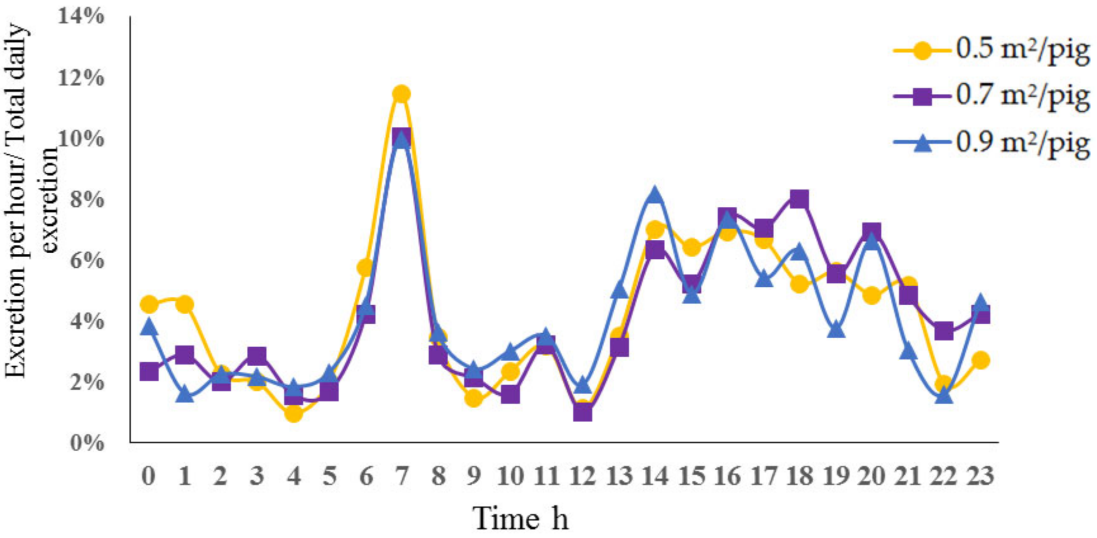

Figure 2. Daily variation in pigs' excretion.

3.1.2. Excretion Location and Pen Area Distribution

Figure 3 shows the spatial distribution of pigs' excretion rate. In the excretion area (zone I), the excretion rate of each treatment in area I was higher than that in area II at the initial stage of transfer (1 d). The excretion rates of the three treatments in area I were 2.52 times ($p > 0.05$), 1.75 times ($p > 0.05$), and 3.51 times ($p < 0.01$) those of area II. During the population stabilization stage, the excretion rate of 0.9 m^2/pig group in zone I was higher than that in zone II (67.75% vs. 32.09%, $p < 0.01$), and the excretion rates of 0.5 and 0.7 m^2/pig groups in zone I were lower than those in zone II. Most of the excretion behavior occurred in zone II in the later stages of the experiment. Regarding excretion occurring in the set excretion area, the excretion rate of 0.9 m^2/pig group in zone I was higher than those of 0.5 and 0.7 m^2/pig groups throughout the experimental period. The excretion rate of the 0.9 m^2/pig group was 10.96% higher than that of 0.5 m^2/pig group ($p > 0.05$) and 32.79% higher than that of 0.7 m^2/pig group ($p < 0.05$) during the population stabilization stage. In addition, in the excretion area, pigs had more excretion behaviors in zones I_1 and I_3. Taking the population stabilization stage as an example, the excretion rates of zone I_1 in 0.5, 0.7, and 0.9 m^2/pig groups were 16.84 times ($p < 0.05$), 13.23 times ($p < 0.01$), and 9.54 times ($p > 0.05$), respectively, those in zone I_2. The excretion rate of area I_3 was 6.85 times ($p > 0.05$), 11.68 times ($p < 0.05$), and 5.81 times ($p > 0.05$) that of area I_2.

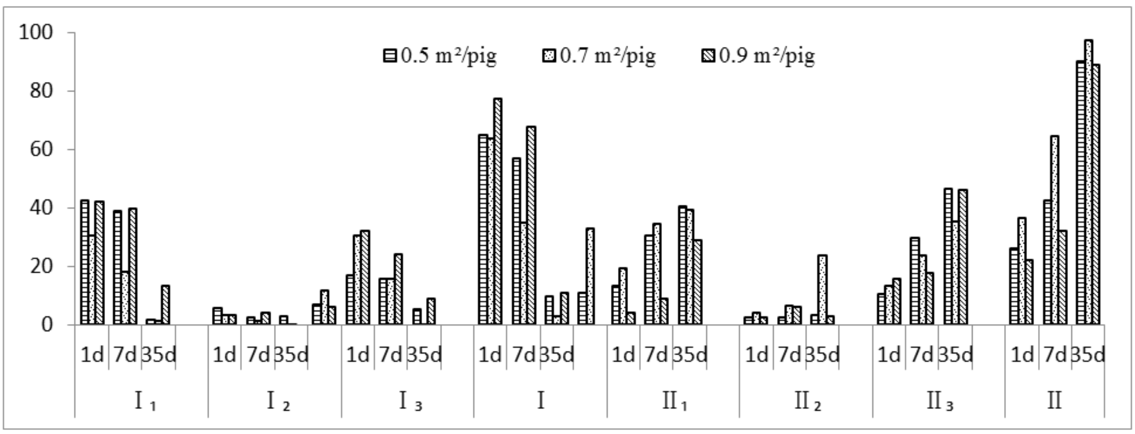

Figure 3. Spatial distribution of excretion rate of pigs with different stocking densities.

3.2. Lying Behavior

3.2.1. Circadian Rhythm of the Lying Behavior

The lying behavior of pigs mainly occurred at night and after feeding (Figure 4). Pigs were basically in a lying state during the two periods of nighttime: 0:00–5:00 and 20:00–23:59. More than 80% of the pigs were lying down between 11:00 and 12:00 after feeding. Due to the interference of pen cleaning and pig feeding, the two time periods of 7:00–8:00 and 14:00–18:00 showed the least number of pigs lying down. However, there were still more than half of the pigs in each pen lying down. There was no significant difference in the number of pigs lying down under different treatments ($p > 0.05$). The average lying rate was in the range of 78–80%.

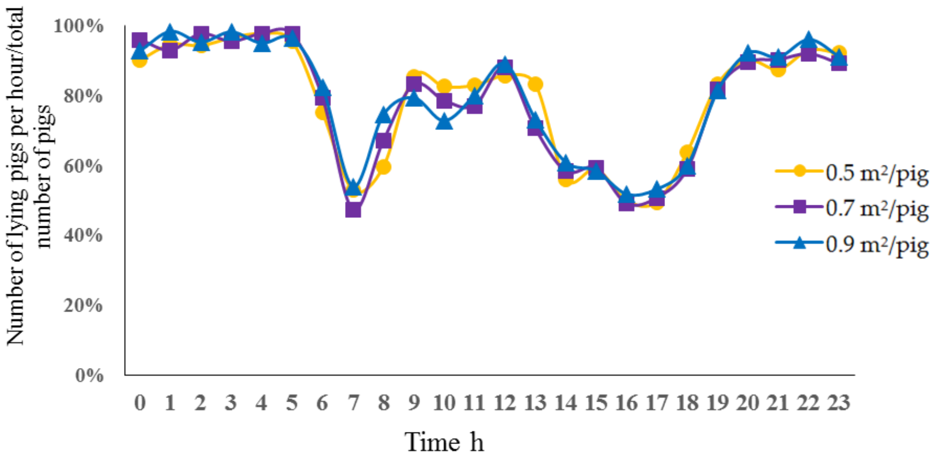

Figure 4. Daily variation in pigs' lying.

3.2.2. Lying Position and Its Distribution in the Pens

The lying rates of pigs in each area are presented in Table 3. At the initial stage of transfer (d1), the lying rate of pigs in zone II was higher than that in zone I under the three stocking densities. In the stable stage of the population (d7) and at the end of the experiment (d35), the lying rate of pigs in the 0.9 m^2/pig group was 10.81% and 7.43% higher than that in the 0.7 m^2/pig group ($p > 0.05$). In the set lying area (II), the lying rate of pigs in the 0.9 m^2/pig group in areas II_1 and II_2 was higher than that in the 0.5 and 0.7 m^2/pig groups during the test period, and the opposite pattern was observed in the II_3 area. When the population was stable, the lying rates of pigs in areas II_1 and II_3 of each treatment were higher than those in area II_2, and the lying rate of pigs in area II_1 in the 0.9 m^2/pig group was 4.41% and 5.31% higher than that in 0.5 and 0.7 m^2/pig groups, respectively ($p < 0.05$).

Table 3. The lying rate of pigs at different stocking densities in each area.

Feeding Age	Stocking Densities	I_1	I_2	I_3	I	II_1	II_2	II_3	II
d1	0.5 m^2/pig	16.55 ± 2.32	15.33 ± 1.61	15.1 ± 4.62	46.98 ± 5.37	18.01 ± 2.02	13.17 ± 4.04	21.84 ± 2.86	53.02 ± 5.37
	0.7 m^2/pig	15.47 ± 3.22	15.44 ± 1.24	18.1 ± 5.28	49.01 ± 4.99	18.39 ± 2.55	14.26 ± 4.74	18.34 ± 4.11	50.99 ± 4.99
	0.9 m^2/pig	15.98 ± 5.51	10.24 ± 3.27	13.92 ± 5.17	40.15 ± 5.92	22.63 ± 3.18	17.66 ± 5.06	19.57 ± 2.2	59.85 ± 5.92
d7	0.5 m^2/pig	16.66 ± 3.5	17.12 ± 4.42	16.42 ± 1	50.2 ± 4.82	16.15 ± 2.11	15.41 ± 4.74	18.24 ± 0.87	49.8 ± 4.82
	0.7 m^2/pig	16.71 ± 1.15	19.88 ± 3.68	19.16 ± 3.36	55.74 ± 6.2	15.25 ± 3.03	13.93 ± 3.13	15.07 ± 0.83	44.26 ± 6.2
	0.9 m^2/pig	16.83 ± 7.47	9.95 ± 4.06	18.15 ± 4.27	44.93 ± 3.92	20.56 ± 1.88	17.18 ± 3.34	17.33 ± 2.02	55.07 ± 3.92
d35	0.5 m^2/pig	18.17 ± 8.29	8.4 ± 1.37	22.42 ± 7.69	48.99 ± 9.8	14.13 ± 7.71	15.74 ± 13.67	21.14 ± 7	51.01 ± 9.8
	0.7 m^2/pig	17.18 ± 4.22	12.82 ± 5.06	21.83 ± 4.54	51.83 ± 2.19	14.1 ± 5.22	20.15 ± 13.14	13.92 ± 11.71	48.17 ± 2.19
	0.9 m^2/pig	13.94 ± 9.87	11.63 ± 6.63	18.83 ± 8.38	44.4 ± 9.95	16.08 ± 10.89	22.74 ± 10.4	16.78 ± 6.25	55.6 ± 9.95

Note: Area I is the slatted floor, one end is the wall; I_1, I_3 are the corners of the slatted floor area, next to other pens, and I_2 is the middle area of the slatted floor. Area II is the solid floor, one end is the aisle; II_1, II_3 are the corners of the solid floor area, next to other pens, and II_2 is the middle area of the solid floor. This note applies to the entire article.

3.3. The Interactive Pattern of Excretion and Lying Behavior in Pigs

3.3.1. Pig Excretion in the Lying Area

As shown in Figure 3, in the designated lying area (II), with the increase in the number of feeding days, the excretion rate of pigs in the lying area also increased in the three treatments, and the increases in area II_1 and area II_3 were significant. The excretion rates of the three treatments in zone II_1 increased by 26.98%, 19.89%, and 24.54%, and in zone II_3 increased by 36.08%, 21.95% and 30.60% in the lying area, respectively. In terms of the stable stage, the excretion rates of pigs in the 0.9 m^2/pig group in area II_1 were 21.63% and 25.74% lower than those in 0.5 and 0.7 m^2/pig groups, respectively ($p < 0.05$), and the excretion rate in zone II_3 was 12.21% and 5.99% lower than those of 0.5 and 0.7 m^2/pig groups, respectively ($p > 0.05$).

3.3.2. Pig Lying in the Excretion Area

In the designed excretion area, although the lying rates of pigs in each treatment were lower than those in the lying area at the beginning of the group transfer, they were all higher than 40% (Table 2). The lying rates of 0.5 and 0.7 m^2/pig groups were 6.83% and 8.86% higher than that of the 0.9 m^2/pig group, and the lying rates of 0.5 and 0.7 m^2/pig groups in I_2 area were significantly higher than that of the 0.9 m^2/pig group ($p < 0.05$). On day 7, the lying rates of 0.5 and 0.7 m^2/pig groups in zone I were 0.4% and 11.48% higher than in zone II, respectively, and the rate of 0.9 m^2/pig group was 10.14% lower than that in zone II. The lying rate of the 0.7 m^2/pig group in the I_2 area was significantly higher than that of the 0.9 m^2/pig group ($p < 0.05$). In contrast, there was no significant difference in the lying rate between the lying area and the excretion area on day 35.

3.4. Floor Cleanliness of the Pig Pen

3.4.1. Stocking Density and Pen Floor Cleanliness

The manure coverage and cleanliness score of the pen solid floor are shown in Figure 5 and Table 4. In the process of scoring the cleanliness of the pen, we found that the fecal and urine contamination on the solid flooring was more representative of the state of the pen. Most of the manure on the slatted flooring became trampled by pigs and thus had little impact on the cleanliness of the pen. On the 7th day of the experiment, the excretion pattern of pigs after grouping had basically been formed. The scores of each treatment in areas II_1 and II_3 were higher than those in area II_2, and the area covered by feces also showed the same pattern. The area covered by feces in the 0.9 m^2/pig group in area II_1 was 7.92% and 11.67% lower than those of 0.5 and 0.7 m^2/pig groups, and the area in the 0.9 m^2/pig group in area II_2 was 3.75% and 9.58% lower than those of 0.5 and 0.7 m^2/pig groups, respectively. On the 35th day, the pen cleanliness of 0.5 and 0.7 m^2/pig groups had dropped sharply, and the scores of each small area on the solid flooring were higher than those in the 0.9 m^2/pig group. From day 7 to day 35, the area covered by feces increased by 33.33% and 20% in 0.5 and 0.7 m^2/pig groups, respectively, in area II_1. The 0.5, 0.7 and 0.9 m^2/pig groups in area II_2 increased by 25%, 11.25%, and 2.67%, respectively, whereas in area II_3 the three treatments increased by 30.42%, 6.67%, and 14.58%. The corner pollution was the most serious.

3.4.2. Pig Behavior and Floor Cleanliness

As the experiment progressed, the excretion rate of pigs in the lying area gradually increased in the three treatments, and the pollution of the pens increased simultaneously. In the 0.9 m^2/pig group, the excretion rates of pigs in areas II_1 and II_3 were lower than those in the 0.5 and 0.7 m^2/pig groups, and the fecal coverage area of the corresponding areas also showed the same regularity. In contrast, for the lying pattern of pigs in the excretion area, during the stabilization stage the lying rates in zone I of 0.5 and 0.7 m^2/pig groups were higher than those of the 0.9 m^2/pig group, and the pen pollution scores of the 0.5 and 0.7 m^2/pig groups were also higher than those of the 0.9 m^2/pig group.

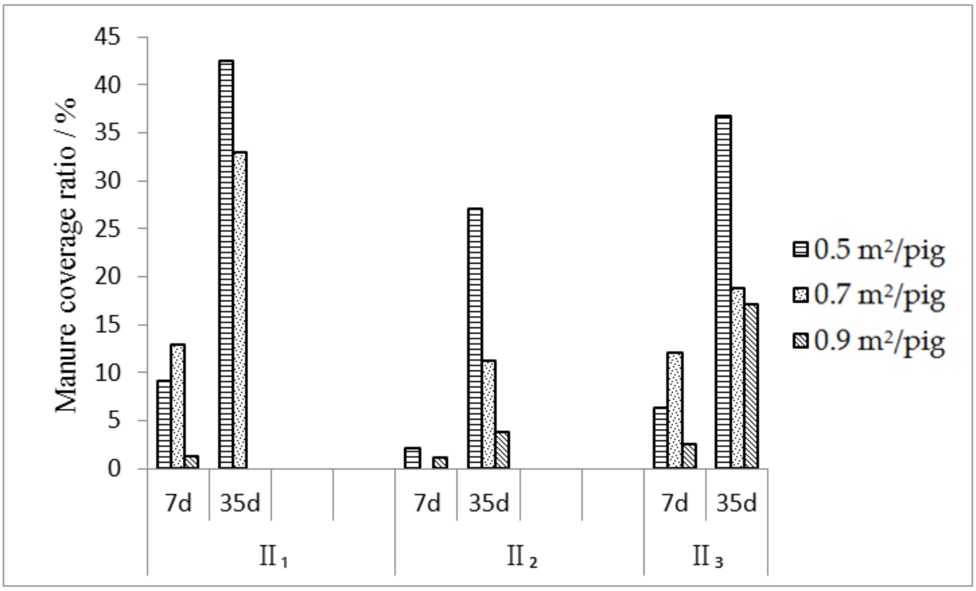

Figure 5. Manure coverage of the solid floor.

Table 4. Cleanliness score of the pig pen solid floor.

Feeding Age	Area	0.5 m^2/Pig	0.7 m^2/Pig	0.9 m^2/Pig
7 d	II$_1$	1.1	1.4	0.9
	II$_2$	0.9	0.8	0.5
	II$_3$	1.1	1.3	1.0
35 d	II$_1$	2.6	2.2	0.8
	II$_2$	1.9	1.3	1.0
	II$_3$	2.4	1.6	1.5

4. Discussion

Excretion behavior is the direct factor affecting the cleanliness of the pen. The excretion behavior of pigs is temporally organized, and the concentrated excretion time is basically after eating and drinking or when getting up and lying down. A previous study found that the excreting behavior followed a daily cyclical pattern, with the peak excretion between 13:00 and 14:00 and the least excretion between 04:00 and 05:00, and 67.3% of the excretion occurred during the day [21]. Another study found that the excretion behavior peaked at 14:00–15:00 in the afternoon, and the number of excretions was the least at 02:00–03:00 at night [16]. Most of the excreting behaviors of pigs in this study occurred in the daytime, and the lowest excretion frequency occurred between 03:00 and 05:00 at night. The time range of the peak excretion was basically the same, both at 07:00–08:00 and at 14:00–17:00. In actual production, the pen should be cleaned after the pigs have excreted intensively. According to the excretion time rule of growing pigs, the two time periods of 7:00–8:00 and 17:00–18:00 should be selected for centralized manure removal each day. Pigs have the habit of excreting in a fixed location, and they generally prefer to excrete in the corners of the stalls [22,23]. Guo et al. also found that the excretion rate of pigs increased significantly in the area closer to the corner, and 76.5% of the excretion behavior occurred near the corner [21]. In the present experiment, we observed that in order to avoid disturbance, the pigs preferred the corners as the excretion area, and the level of contamination in the corner of the pen was the most serious. In addition, related studies have shown that stocking density has no significant effect on the excretion frequency of pigs [24], but there are few reports on the effect of density on the area where excretion occurs. In this study, when the pigs effectively occupied a large space in the early stages of the experiment, most of the excretion behaviors could be carried out in the expected areas. However, with the growth of pigs, the effective occupied space of pigs was gradually reduced, and the excretion zone became blurred. With the lower stocking density of 0.9 m^2/pig group, the excretion behavior was more likely to occur in the expected area; although its frequency on the slatted flooring decreased near the end of the trial, the pattern was maintained.

Lying behavior directly reflects the resting state of pigs, and in addition reflects growth performance. Regarding the cleanliness of the pen, pigs lying in a specific area was conducive to keeping the pen clean, while chaotic functional partitioning of the pen led to pen pollution. For example, pigs intermittently alternated lying in the excretion area and excreting in the lying area, a pattern that can aggravate the pollution of the pen. Understanding the circadian rhythm of pigs' lying behavior can aid in pen cleaning management. Marko et al. found that pigs had the most lying behavior during 02:00–03:00 at night and the least lying between 14:00 and 15:00 pm [16]. Nasirahmadi et al. found that the pigs were almost all lying down at 0:00–6:00, and the least amount of lying occurred between 8:00 and 10:00 (putting the nest material in the test pen) and 15:00–18:00, when on average about 65% of the pigs were in a recumbent state [25]. The lying behavior of pigs in this study mainly occurred in the two time periods of 0:00–6:00 and 21:00–23:59 at night. During the day, the least amount of lying behavior occurred at 7:00–10:00 and 15:00–18:00, as these two periods were often disturbed by activities such as pen cleaning and pig feeding. The lying behavior of pigs is closely related to the growth stage and feeding conditions. For example, the lying time and frequency of pigs were relatively reduced in the early stages of group transfer, then gradually increased in the later periods with the stability of the group. This study found that, in the early stages of the transfer, under the conditions of high stocking density, the lying area on the solid flooring could no longer satisfy the pigs' requirement, and thus some pigs were lying on the slatted floor. In the stable stage, the lying behavior of pigs basically formed a habitual pattern. In the 0.9 m^2/pig group, the pigs occupied more space and were more prone to lying down in the set lying area. In the later stages of the experiment, the pig herd gradually increased the excretion behavior in the lying area, while a larger effective occupancy space could alleviate this unfavorable phenomenon. Our findings are similar to those of Hillmann et al. That study compared the changes in the lying area of pigs under the two stocking densities of 0.7 and 1.4 m^2/pig, and found that when the ambient temperature in the house was lower, the pigs in the high-density environment would lie more in the excretion area [26]. Spoolder et al. also found significant relationships between pigs' lying space requirements and body weight and house ambient temperature [27]. As body weight and temperature increased, so did the pigs' lying area. Fu et al. studied the effect of three stocking densities (0.8, 1.2, and 1.6 m^2/pig) on several physiological indicators of pigs. They found that the higher the stocking density, the higher the body surface temperature of pigs, especially in the middle and later stages of growing and fattening [28]. In the latter stage, excessive stocking density affected the body surface temperature of pigs, resulting in poor heat dissipation capacity. Some pigs were observed lying on the slatted flooring to maintain normal body temperature and meet basic body requirements [29]. In this study, with the stability of the group and the increase in the weight and size of the pigs, in the later stages of the experiment the pigs increased the production of body heat. In order to accelerate the heat dissipation, they would reduce contact with their peers, change their lying posture, and increase the lying area. The reason pigs' lying preference had shifted from solid flooring to slatted flooring was that the ventilation under the slatted flooring effectively dissipated heat. However, the functional zoning in the pig house was chaotic, leading to contamination of the pens. In the later stages of the experiment, the effective occupied space of pigs under the three stocking densities became limited. Therefore, in actual production the pigs should be transferred according to the overall growth status of the group. This would avoid the restriction of pig behavior and the decline in animal welfare caused by excessive stocking density.

Pig excretion and lying are the two main behaviors related to pen pollution, and the increase in stocking density is an important factor. When the stocking density is too high, the functional zoning of the pen becomes blurred, and the pigs cannot perform group behaviors. Excretion in the lying area and lying in the excretion area will aggravate the pollution of the pen. In this study, as the experiment progressed, the excretion rate of pigs in the lying area also increased in the three treatments, and the pollution of the pen increased simultaneously, indicating that the excretion behavior of pigs directly affected the cleanliness of the pen. During the later stages of the experiment, most of the pigs were lying on the slatted floor area, contrary to the functional partitioning that we had designed, and the solid flooring pollution was also more serious than in the early stages. Regardless of excretion or lying behavior, the area where they occurred was closely related to the stocking density. Our study found that the higher the stocking density, the higher the frequency of pigs excreting on the solid flooring, and the pollution level of the entire pen increased. This result was consistent with the study by Jensen et al., who found that group sizes of 33–42 pigs led to more unclean and wetter conditions compared to 17–21 pigs [29]. Many other studies have also found that, as pigs grow and increase in weight, the contamination of pig pens becomes more serious [30,31]. This shows that, with the growth in individual pigs, the effective occupied space of pigs becomes reduced, making it difficult for pigs to form fixed excretion points and thereby aggravating the pollution of the entire pen. In actual production, the growth of pigs should be dynamically monitored and grouped according to time. Reasonable stocking densities for pigs at different growth stages should be set. If possible, long and narrow pens should be designed to make it easier for pigs to distinguish functional areas and thereby fundamentally alleviate pen pollution.

5. Conclusions

In our study, the diurnal regularity of excretion and lying behavior, which is closely related to pen cleanliness, was not affected by stocking density. However, growing pigs (30–50 kg) with a stocking density of 0.9 m^2/pig were more likely to perform specific behaviors in the set functional areas; the functional partition of the pen was easier to implement, and the cleanliness of the pen was higher. At the same time, the stocking density also complied with the Chinese industry standard of 0.6–0.9 m^2/pig (NYT1568–2007). In actual production, the group should be transferred according to the overall growth status of the pig to effectively avoid the restriction of pig behavior and the decline in animal welfare caused by an excessive stocking density.

Author Contributions: Conceptualization, Y.Z., H.W. and R.R.; Formal analysis, H.W. and R.R.; Funding acquisition, Z.L.; Investigation, Y.Z.; Methodology, Y.Z. and Y.L.; Project administration, H.W.; Resources, Z.L.; Supervision, Y.Z.; Writing—original draft, Y.Z. and R.R.; Writing—review & editing, H.W., C.W. and A.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Chongqing Rongchang Agriculture and Animal Husbandry High-tech Industry Research and Development Project (cstc2019ngzx0018), Ministry of Finance and Ministry of Agriculture and Rural Affairs: National Modern Agricultural Industry Technology System (CARS-35).

Institutional Review Board Statement: The study was approved by the Ethics Committee of Chongqing Academy of Animal Sciences.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Aarnink, A.J.A.; Swierstra, D.; van den Berg, A.J.; Speelman, L. Effect of Type of Slatted Floor and Degree of Fouling of Solid Floor on Ammonia Emission Rates from Fattening Piggeries. *J. Agric. Eng. Res.* **1997**, *66*, 93–102. [CrossRef]
2. Ni, J.Q.; Vinckier, C.; Coenegrachts, J.; Hendriks, J. Effect of manure on ammonia emission from a fattening pig house with partly slatted floor. *Livest. Prod. Sci.* **1999**, *59*, 25–31. [CrossRef]
3. Næss, G.; Bøe, K.E.; Ruud, L.E. Floor cleanliness dairy freestall barns. In Proceedings of the 10th International Livestock Environment Symposium (ILES X), Omaha, NE, USA, 25–27 September 2018.

4. Cai, L.; Yu, J.; Zhang, J.; Qi, D. The effects of slatted floors and manure scraper systems on the concentrations and emission rates of ammonia, methane and carbon dioxide in goat buildings. *Small Rumin. Res.* **2015**, *132*, 103–110. [CrossRef]
5. Fraley, S.M.; Fraley, G.S.; Karcher, D.M.; Makagon, M.M.; Lilburn, M.S. Influence of plastic slatted floors compared with pine shaving litter on Pekin Duck condition during the summer months. *Poult. Sci.* **2013**, *92*, 1706–1711. [CrossRef]
6. Svennerstedt, B. Drainage Properties and Ammonia Emissions in Slatted Floor Systems for Animal Buildings. *J. Agric. Eng. Res.* **1999**, *72*, 19–25. [CrossRef]
7. Von Borell, E.; Hurnik, J.F. Stereotypic behavior, adrenocortical function, and open field behavior of individually confined gestating sows. *Physiol. Behav.* **1991**, *49*, 709–713. [CrossRef]
8. Wegner, K.; Lambertz, C.; Das, G.; Reiner, G.; Gauly, M. Effects of temperature and temperature-humidity index on the reproductive performance of sows during summer months under a temperate climate. *Anim. Sci. J.* **2016**, *87*, 1334–1339. [CrossRef]
9. Pertagnol, J. Untersuchung zu Verschiedenen Zuluftführungs-und Kühlungsmöglichkeiten in Mastschweineställen. Dissertation, Universität Hohenheim, Stuttgart, Germany, 2014.
10. Steffen, H. *Nutztierhaltung und—Hygiene*; Utb Gmbh: Willmering, Germany, 2006.
11. Peter, E.; Manuel, S.K.; Büscher, W. Feasibility Study: Improving Floor Cleanliness by Using a Robot Scraper in Group-Housed Pregnant Sows and Their Reactions on the New Device. *Animals* **2019**, *9*, 185.
12. Bøe, K.E.; Hall EJ, S.; Cronin, G.M. The effect of pen design on pen floor cleanliness in farrowing pens for loose housed lactating sows. *Livest. Sci.* **2019**, *229*, 37–42. [CrossRef]
13. Huynh, T.T.; Aarnink, A.J.; Gerrits, W.J.; Heetkamp, M.J.; Canh, T.T.; Spoolder, H.A.; Kemp, B.; Verstegen, M.W. Thermal behaviour of growing pigs in response to high temperature and humidity. *Appl. Anim. Behav. Sci.* **2005**, *91*, 1–16. [CrossRef]
14. Aarnink, A.J.; Schrama, J.W.; Heetkamp, M.J.; Stefanowska, J.; Huynh, T.T. Temperature and body weight affect fouling of pig pens. *J. Anim. Sci.* **2006**, *84*, 2224–2231. [CrossRef]
15. Savary, P.; Gygax, L.; Wechsler, B.; Hauser, R. Effect of a synthetic plate in the lying area on lying behaviour, degree of fouling and skin lesions at the leg joints of finishing pigs. *Appl. Anim. Behav. Sci.* **2009**, *118*, 20–27. [CrossRef]
16. Marko, O.; Conor, M.G.; Busančić, M.; Aarnink AJ, A. Drinker position influences the cleanness of the lying area of pigs in a welfare-friendly housing facility. *Appl. Anim. Behav. Sci.* **2018**, *198*, 44–51.
17. Andersen, M.L.; Pedersen, L.J. The effect of feed trough position on choice of defecation area in farrowing pens by loose sows. *Appl. Anim. Behav. Sci.* **2011**, *131*, 48–52. [CrossRef]
18. Vermeer, H.M.; Altena, H.; Vereijken, P.F.G.; Bracke, M.B.M. Rooting area and drinker affect dunging behaviour of organic pigs. *Appl. Anim. Behav. Sci.* **2015**, *165*, 66–71. [CrossRef]
19. Randall, J.M.; Armsby, A.W.; Sharp, J.R. Cooling gradients across pens in a finishing piggery: II. Effects on excretory behaviour. *J. Agric. Eng. Res.* **1983**, *28*, 247–259. [CrossRef]
20. Baxter, S. *Intensive Pig Production: Environmental Management and Design*; Great Britain: Granada, Spain, 1984; pp. 240–244.
21. Guo, Y.; Lian, X.P.Y. Diurnal rhythms, locations and behavioural sequences associated with eliminative behaviours in fattening pigs. *Appl. Anim. Behav. Sci.* **2015**, *168*, 18–23. [CrossRef]
22. Buchenauer, D.; Luft, C.; Grauvogl, A. Investigations on the eliminative behaviour of piglets. *Appl. Anim. Ethol.* **1982**, *9*, 153–164. [CrossRef]
23. Wechsler, B.; Bachmann, I. A sequential analysis of eliminative behaviour in domestic pigs. *Appl. Anim. Behav. Sci.* **1998**, *56*, 29–36. [CrossRef]
24. Cornale, P.; Macchi, E.; Miretti, S.; Renna, M.; Lussiana, C.; Perona, G.; Mimosi, A. Effects of stocking density and environmental enrichment on behavior and fecal corticosteroid levels of pigs under commercial farm conditions. *J. Vet. Behav.* **2015**, *10*, 569–576. [CrossRef]
25. Nasirahmadi, A.; Edwards, S.A.; Matheson, S.M. Using automated image analysis in pig behavioural research: Assessment of the influence of enrichment substrate provision on lying behaviour. *Appl. Anim. Behav. Sci.* **2017**, *196*, S1737238366. [CrossRef]
26. Hillmann, E.; Mayer, C.; Gygax, L. Effects of space allowance on behavioural and adrenocortical reactions to elevated temperatures in fattening pigs. *Landbauforsch. Völkenrode* **2005**, *55*, 255–260.
27. Spoolder, H.A.; Aarnink, A.A.; Vermeer, H.M.; van Riel, J.; Edwards, S.A. Effect of increasing temperature on space requirements of group housed finishing pigs. *Appl. Anim. Behav. Sci.* **2012**, *138*, 229–239. [CrossRef]
28. Fu, L.; Li, H.; Liang, T.; Zhou, B.; Chu, Q.; Schinckel, A.P.; Yang, X.; Zhao, R.; Li, P.; Huang, R. Stocking density affects welfare indicators of growing pigs of different group sizes after regrouping. *Appl. Anim. Behav. Sci.* **2016**, *174*, 42–50. [CrossRef]
29. Jensen, T.; Kold Nielsen, C.; Vinther, J.; D'Eath, R.B. The effect of space allowance for finishing pigs on productivity and pen hygiene. *Livest. Sci.* **2012**, *149*, 33–40. [CrossRef]
30. Bate, L.A.; Hacker, R.R.; Phillips, P.A. Effect of growth on porcine defecation patterns. *Can. Agric. Eng.* **1988**, *30*, 107.
31. Yan, X.; Zhang, Q.; Connor, L. Effect of slatted floor configuration on air quality and floor cleanliness in a sow barn. In Proceedings of the 10th International Livestock Environment Symposium (ILES X), Omaha, NE, USA, 25–27 September 2018.