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Research article

Influence of deep bedding and fermented feed supplementation on the behavioral patterns, adult fly *(Musca domestica)* density and performance of crossbred pigs

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Abstract

This study determined the effects of deep bedding floor and fermented feed supplement on the behavioral pattern and adult fly *(Musca domestica)* density that would be affect to the performance of crossbred pigs. The performance data from 64 (Thai native x Meishan x Duroc) crossbreds were combined from two replicated studies. Pig behavior was continuously video recorded in a real-time mode on Day 1 (initial day), 2, 3, 7 and the end day of Month 1, 2, 3 and 4 for 32 pigs in one block. A 2 x 2 factorial arrangement in a completely randomized design was used with four replicates in one block. Factor A was a deep bedding floor (DB) or solid bedding of concrete floor (SB). Factor B was a feed type of concentrate feed supplemented with a fresh banana stem (BF+CON) or fermented banana stem (FF+CON). The results showed that effects of floor type and feed type on production performance were significant ($P<0.05$), with concrete floors showing better performance than deep bedding. The study found no significant impact of feed type on growth performance in pigs. Nevertheless, floor type and feed type interaction on production performance was significant for final weight, ADG, and FCR throughout the experiment (0–120 days). However, the behavior of pigs was influenced by floor type. DB pigs spent more time exploring the pen, but spent less time standing and walking than SB pigs. DB variations were found to be dispersed, with positive correlations between standing, nuzzling, walking, and feeding. Despite the possibility of flies being flown across the row, DB row pigs had significantly ($P<0.05$) fewer flies than SB row pigs. The heatmaps showed that the two groups have different behavioral dependency. The study concluded that the deep bedding floor type allowed for natural exploring behavior of the pigs and reduced the number of flies in the system. However, adverse effects were observed in performance, indicating the need for further study to improve the system.

Keywords: Adult Fly, Deep bedding, Fermented Feed, Growth performance, Pig Behavior

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INTRODUCTION

In northern Thailand's highlands, local small-scale farmers raise native pigs or native crossbred pigs using available resources like crop residues and diverse banana trees, crucial components of their diet (Sringarm et al. 2022). To establish an efficient and cost-effective approach, farmers adopt a deep bedding (DB) management practice in which a thick layer of bedding material, such as straw or sawdust, was provided in the pig housing area. The deep bedding served various purposes, including providing comfort to the pigs, regulating temperature, absorbing moisture, and composting pig manure to produce fertilizer. On average, about 1 to 1.5 tons of fertilizer were produced annually for every five DB pigs (Tubiello et al., 2013). Compared to traditional concrete floor systems, the DB method presented numerous benefits. It enhances animal welfare (Tuyttens, 2005; Zhou et al., 2015), fosters social interactions (Morrison et al., 2003), and minimizes odors (Kaufmann, 1997; Zhou et al., 2015). Research by Honeyman et al. (2001) indicated that DB could generate temperatures exceeding 40°C at depths of 15–30 cm, maintaining temperatures above 30°C across approximately half of the bedded area. Pigs could regulate their comfort by burrowing into the bedding, especially in colder periods in northern Thailand. Morrison et al. (2007) found that DB pigs exhibited heightened activity and exploration, potentially due to more significant temperature fluctuations. In addition, small-scale farmers seek to curtail feed expenses by employing fermented feed (FF). FF has garnered attention for its capacity to enhance nutrient absorption and growth (Xu et al., 2020), while also functioning as feed preservation during dry periods. It also contributed to maintaining gut health and a balanced gut microbial ecology (Cho et al., 2011). The appealing aroma of fermented feed further enhanced its palatability (Arjin et al., 2021). The DB and FF would encourage the pig to express more natural behaviors in which not only enhance animal welfare but also played a vital role in growth, impacting feed intake and stress levels. In the conventional open-house system, the emergence of flies within pig farms becomes an unavoidable occurrence. These flies can impose negative consequences on the well-being of the pigs, such as irritations and skin problems. Efforts should be made to minimize the presence of flies due to their potential for transmitting various pathogens, including *E. coli*, Salmonella, Brachyspira (swine dysentery), Lawsonia (ileitis), and Tuberculosis (Meerburg et al., 2007). In European pig farming, the utilization of straw bedding for pigs can lead to hygiene issues as it tends to attract flies. Strategies involving chemical and biological controls have been explored to manage its density. However, farmers implementing deep bedding in Asia have observed significantly lower fly densities within the system (personal communications). Therefore, this study was undertaken to assess the influence of BD and FF on behavioral pattern and adult fly *(Musca domestica)* density that would be affect to the performance of crossbred pigs.

MATERIALS AND METHODS

Animals

The protocol for this study was approved by the Animal Care and Use Committee of Chiang Mai University, Thailand (2561/AG-0004) before conducting the experiments. This study was conducted at the Faculty of Agricultural Technology, Chiang Mai Rajabhat University, Chiang Mai, Thailand. The study sample was analyzed at the Department of Animal and Aquatic Sciences, Faculty of Agriculture, Chiang Mai University, Thailand. A total of 64 barrow crossbred pigs (Thai native x Meishan x Duroc) crossbreds were combined from two repleted studies (block in time with 32 pigs for each study) with an average initial body weight of 13.71 ± 2.82 kg were grouped in a 2 × 2 factorial design with eight pigs per group to determine the effects of floor type and feed type on the behavioral responses, growth performance, and adult fly *(Musca domestica)* density. One pen of 4 square meters contained 2 pigs. Factor A was floor type: deep bedding (90 cm depth of rice husks to absorb pig manure (DB)) or solid bedding of concrete floor (SB). Factor B was feed type: concentrate feed supplemented with fresh banana stem (BF) or fermented banana stem (FF). Indigenous microorganisms (IMO) were cultured from the bamboo soil surface at the experimental site (Kumar and Gopal, 2015) and sprayed with IMO dilution (1:200 water v/v) on the DB floor every two weeks. In the SB pen, daily removal of feces and weekly water cleaning were conducted. The DB pen employed 3-5 cm of fresh bedding, treated biweekly with IMO spray.

Production performance evaluation

The weight of the experimental pigs and their feed intake were measured on days 1, 30, 60, 90, and 120, as well as weekly intervals in between. The pen was used as the unit of measurement to calculate parameters including Average Daily Gain (ADG), Average Daily Feed Intake (ADFI), and Feed Conversion Ratio (FCR). ADG was calculated by dividing the increase in live weight for each period by the number of days. FCR was calculated by dividing feed intake by live weight gain, while ADFI was determined by subtracting the refused feed left in the trough from the total feed offered daily.

Dietary treatments and preparation

The pigs were fed a commercial diet that contained 3905 Kcal/kg ME and 18% protein on a dry matter basis. The banana stem was chopped into 1–2-centimeter lengths. To prepare the fermented banana stem (FF), the chopped banana stems were placed in plastic tanks in layers of 10 kilograms each. After each layer was added, 100 grams of salt (NaCl) and 400 grams of sugar were added. The layer was then pressed and compacted to ensure anaerobic conditions before the next layer was added. This process was repeated five times, and the container was sealed. Each tank contained a total of 50 kilograms of banana stems, 500 grams of salt, and 2 kilograms of sugar. The tanks were sealed and fermented for 21 days before being used as pig feed (Arjin et al., 2021). To prepare the fresh banana stem feed, the banana stems were chopped to lengths of 1-2 centimeters in the morning each day. They were then mixed 1:1 with concentrate feed. The concentrate feed mix containing fresh banana stem (BF+CON) and fermented banana stem (FF+CON) was mixed in a 1:1 ratio (w/w). The animals were fed a diet that was 50% commercial feed and 50% banana stem (fresh and fermented). The diet was fed to the pigs on an as-fed basis, and each pen had two pigs. The pigs had ad libitum access to feed and water throughout the experimental period. The chemical analysis of nutrients in the diets is shown in Table 1.

Table 1 Nutrient chemical composition of experimental diet (%, dry matter basis).

Item	CON	BF + CON (1:1)	FF + CON (1:1)
Crude Protein, %	18.02	12.96	13.42
Ether Extract, %	4.76	4.59	4.15
Crude Fibre, %	4.77	9.27	8.52
Metabolisable Energy, Mcal/kg	3.91	3.98	4.15
Neutral Detergent Fibre, %	30.63	44.30	41.24
Acid Detergent Fibre, %	10.85	22.56	21.03
Acid Detergent Lignin, %.	3.25	4.13	3.54

CON = concentrate; BF + CON = concentrate mix with fresh banana stem; FF + CON = concentrate mix with fermented banana stem

Behavior observation

Pig behavior was continuously video recorded in a real-time mode using a digital video recorder with six cameras for one day for initials until the end of the production period (120 days; average temperature and humidity ranged 27.25–28.05 °C, 75.35–79.29 % RH.). The video recording by the camera was used to monitor the pen area to ensure that there was no visual blind spot. All cameras were positioned 3.0 m above the floor. Pigs' behaviors were continuously observed through the video by one experienced observer. Records were made on Day 1, 2, 3, 7 and the end day of Month 1, 2, 3 and 4. Every observation day was divided into two sessions; 12 hours in the daytime (from 06:00 to

17:55 h) and 12 hours in the nighttime (from 18:00 to 05:55 h) (Morrison et al., 2003). The scan sampling method at a 5-minute interval was used to collect individual behavioral data from the video (adapted from Wattanakul et al., 1998). Pigs were given identification markings on the back. Each pen was recorded in a total of 9 behaviors (sleeping, standing, walking, sitting, exploring pens, agonistic behavior, social activity, eating, and drinking). Pig which played agonistic behavior by fighting together were noted on every occasion (Wiegand et al., 1994). The definition of each behavior was described in Table 2. The behavioral time budget refers to the proportion of time engaged in each behavior, which was calculated by dividing the sum of the duration of each behavior by the total time of observation. (Wei et al., 2019)

Table 2 Description of behaviors recorded over the study period.

Behavior	Description
Sleeping	Body is attaching the ground position. No movement.
Standing	Weight is supported by four limps. No movement.
Walking	A slow four-beat gait with forward movement.
Siting	Body is in an upright position, with hindquarters and two forefeet contact with ground.
Digging	Use their snouts and legs to dig in the ground
Fighting	Pigs were in continuous contact with one another, pushing and circling. At intervals, bouts of vigorous biting and head-knocking occur. Engage with the other, each apparently trying to injure the other.
Nuzzling	Use their snout to rub against something or another pig
Exploring pens	Pig's snout approaches or digs any part of the pen.
Agonistic Behavior	A pig aggressively rams or thrusts other pigs with head or snout.
Social or playing activity	Rubbing or snout-touching another pig's body in the same pen.
Eating	Chewing the feed in its mouth.
Drinking	Pig manipulates the nipple drinker.

Adapts from Wei et al. (2019)

Adult fly density recorded

To investigate the welfare of the pigs, adult fly *(Musca domestica)* density was recorded using the spot card technique (Stafford, 1988). White file cards were placed at the height of 1.5 meters above the pig pens for a period of 3 consecutive days. A fly adhesive paper trap (18.5 x 25 cm) was placed between two adjacent pens with the same bedding treatment, covering an 8 square-meter area. After a period of 3 days, the number of trapped flies were count and divided by 8 to calculate the adult fly density per square meter. The records were made 5 times on the arrival day (Day1-3), Month 1, 2, 3 and 4. As the pigs were reared in the same opened building with two different row of bedding types so, the different of fly density was compared between the different of floor types.

Statistical Analysis

Data were analyzed as a 2x2 factorial in completely randomized design (CRD) using the ANOVA procedures of Statistical Analysis System, that included effects due to floor type and feed type along with interactions. The significance of the differences between the treatment group means for each parameter was evaluated using the Duncan's New Multiple Range Test (DMRT). Probabilities of <0.05 and <0.01 were taken to indicate significant differences. All statistical analyses were computed in accordance with the method of Steel and Torries (1980).

The two-tailed t-test was used to analyses the behavioral and the density of fly differences between the Deep bedding (DB) and the Solid bedding of concrete floor (SB). Pens were treated as independent units for the statistical analyses. P-value less than 0.05 and P-value less than 0.01 were considered statistically significant and very significant, respectively.

RESULTS

Growth performance

The effects of floor type and feed type on production performance of crossbred pig are shown in Table 3. During the whole experimental period (0–120 days), there were significant effects of floor type on the final weight, average daily gain (ADG), and feed conversion ratio (FCR). Concrete floors had better performance than deep bedding ($P < 0.05$). Additionally, there were significant effects of floor type on body weight at 60, 90, and 120 days. On the other hand, the effect of feed type on production performance was not significant in this experiment ($P > 0.05$). The interaction between the effects of floor type and feed type on production performance was found to be significant for the final weight, ADG, and FCR of the whole experimental period (0–120 days) found that interaction between floor type and feed type were significant ($P = 0.023$) when considering the final weight of the pigs. Pigs raised on concrete flooring and fed a specific type of feed (FF) had the highest final weight (78.32 kg), while pigs on deep bedding and fed the same feed had the lowest final weight (65.01 kg). This significant interaction suggests that the combination of specific feed types with different bedding materials can have a notable impact on the final weight of the pigs. The ADG interaction was also significant ($P = 0.020$) for the average daily gain of the pigs. Pigs raised on concrete flooring and fed a specific type of feed (FF) had the highest average daily gain (0.54 kg), while pigs on deep bedding and fed the same feed had the lowest average daily gain (0.43 kg). The FCR interaction floor type and feed type was significant ($P = 0.028$) for the feed conversion ratio. This interaction effect highlights how the combination of feed and bedding choices can affect the efficiency of feed conversion in pigs. This interaction effect indicates that the combination of feed composition and bedding type influences the daily growth rate of the pigs. However, the interaction of floor type and feed type for the body weight at 120 days was also found to be significant ($P < 0.05$).

Behavior

No significant impact of feed type on growth indicators ($P > 0.05$). Consequently, the analysis focused on behavior and fly density data in relation to different floor types. Figure 1- 8 shows the effects of floor type on the behavior of pigs. During the continuously video recorded observation period, the behavior of pigs at 1-3 days, week 1, and month 1 (Figures 1-5) showed that after releasing the pigs to the new pen, pigs reared in the DB spent more time exploring the pen by digging than pigs reared in the SB ($P < 0.05$). On the other hand, the behavior of pigs at 1-2 days and 1 week (Figures 1, 2, and 4) showed that the DB pigs spent less time standing and walking than SB pigs ($P < 0.05$). However, this study found that the eating behavior was significantly different at month 1, with the SB pigs spending more time eating or at the trough than DB pigs ($P < 0.05$). Meanwhile, there was no significant difference in the lying, standing, walking, sitting, digging, fighting, nuzzling, eating, and drinking activity between the treatments at 2, 3, and 4 months ($P > 0.05$). The principal component analysis (PCA) was utilized to illustrate the pig's behavior on a different floor (Figure 9).

Table 3 Effect of deep bedding floor and fermented feed supplement on growth performance of crossbred pigs.

	Deep bedding		Concrete		SEM	P-value		
	BF	FF	BF	FF		Feed	Bedding	F. x B.
Total period								
Initial weight (kg)	13.54	13.78	13.59	13.95	0.524	0.773	0.920	0.956
Final weight (kg)	68.62	65.01	74.06	78.32	0.817	0.843	0.000	0.023
ADFI (kg)	2.73	2.73	2.78	2.73	0.025	0.565	0.632	0.625
ADG (kg)	0.46	0.43	0.50	0.54	0.006	0.984	0.000	0.020
FCR	5.97	6.49	5.52	5.10	0.100	0.870	0.000	0.028
Day 30								

	Deep bedding		Concrete		SEM	P-value		
	BF	FF	BF	FF		Feed	Bedding	F. x B.
Body weight (kg)	23.04	22.47	22.85	24.47	0.667	0.769	0.568	0.478
ADFI (kg)	1.47	1.40	1.42	1.56	0.050	0.694	0.602	0.291
ADG (kg)	0.32	0.29	0.31	0.34	0.016	0.924	0.530	0.353
FCR	5.15	5.26	4.83	4.70	0.282	0.984	0.445	0.833
Day 60								
Body weight (kg)	34.73	33.17	35.34	38.52	0.671	0.548	0.035	0.088
ADFI (kg)	1.74	1.75	1.87	1.92	0.045	0.742	0.101	0.783
ADG (kg)	0.39	0.36	0.42	0.48	0.012	0.568	0.005	0.062
FCR	4.51	4.96	4.64	4.15	0.169	0.956	0.315	0.175
Day 90								
Body weight (kg)	50.32	47.77	55.02	58.60	0.789	0.751	0.000	0.063
ADFI (kg)	2.45	2.31	2.52	2.49	0.037	0.254	0.096	0.447
ADG (kg)	0.52	0.49	0.66	0.67	0.023	0.838	0.002	0.634
FCR	4.86	8.11	3.91	3.78	0.151	0.836	0.001	0.542
Day 120								
Body weight (kg)	68.62	65.01	74.06	78.32	0.817	0.843	0.000	0.023
ADFI (kg)	2.89	3.03	2.90	2.84	0.027	0.208	0.261	0.379
ADG (kg)	0.61	0.58	0.63	0.66	0.029	0.997	0.344	0.661
FCR	4.82	5.35	4.73	4.62	0.285	0.620	0.337	0.443

BF= fresh banana stem, FF = fermented banana stem

The variations in deep bedding were dispersed throughout the plot, comprising 33.26% in the first principal component (PC1) and 16.61% in second principal component (PC2). Pig behavior variables, including standing, nuzzling, walking, and feeding, exhibited a positive correlation in the same direction. However, the inverse relationship was observed between these behaviors and digging, sitting, fighting, and lying. Construct the floor variations that were distributed for 39.38% and 14.72% in PC1 and PC2, correspondingly. It is noteworthy that the correlation between lying behavior and reclining and digging in PC2 was the exact opposite. Furthermore, there was a negative correlation between lying on the concrete floor and the following PC1 behaviors: drinking, fighting, strolling, eating, standing, and nuzzling.

The heatmap depicting the Pearson correlation among pig behaviors reveals distinct patterns between two groups (Figure 10): those in deep bedding and those on concrete. In DB group, there is a strong correlation among most behaviors, with both positive and negative associations evident. However, fighting and drinking appear to be outliers, displaying a lack of correlation with other behaviors. This suggests that these activities occur independently and were neither a cause nor an effect of the other behaviors observed in the study. Conversely, the SB group showed a marked difference. Here, fighting and drinking were more closely correlated with other behaviors. For instance, the negative correlation between fighting and lying has intensified, dropping from -0.01 to -0.28. Similarly, the positive correlation between drinking and walking has increased from 0.14 to 0.44. These changes indicate that, for SB pigs, these behaviors might not be as autonomous as for those on DB; they could be influenced by or may influence other behaviors. The key insight from the heatmaps was the contrasting behavioral interdependence observed between the two groups. DB pigs tended to engage in fighting and drinking without these behaviors being influenced by, or influencing, other behaviors. In contrast, SB pigs exhibited a greater degree of behavioral interconnectivity, where fighting and drinking were more significantly correlated with other behaviors. This suggests an environmental influence on the expression of behaviors, with the type of bedding or flooring playing a pivotal role in the pigs' behavioral dynamics.

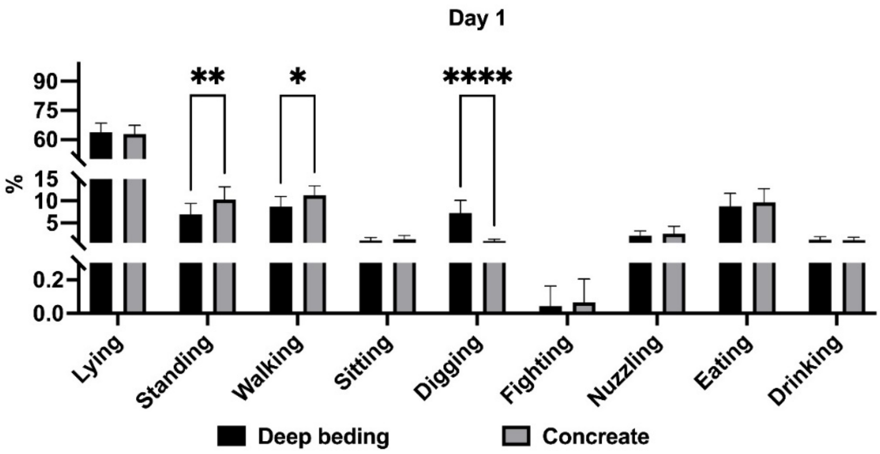

Figure 1 Effect of floor type on behavior of crossbred pigs at day 1

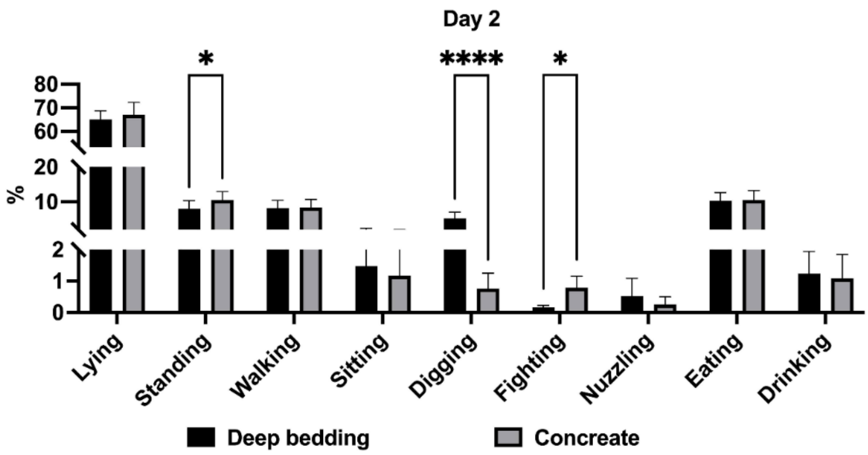

Figure 2 Effect of floor type on behavior of crossbred pigs at day 2

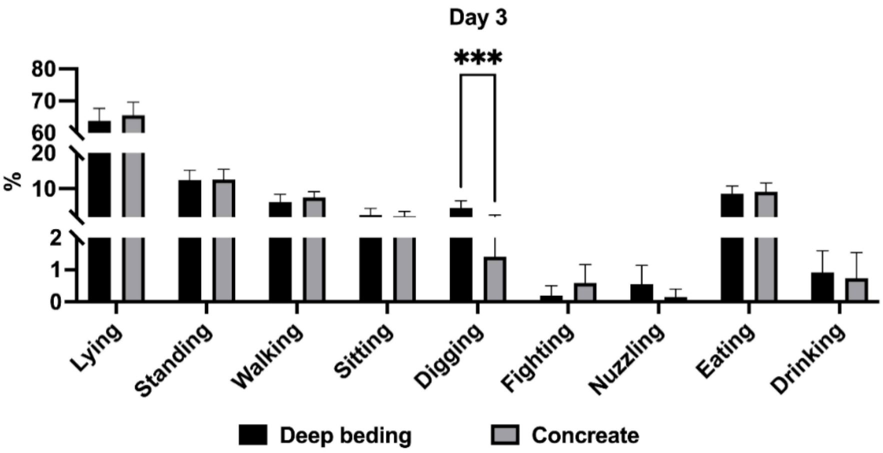

Figure 3 Effect of floor type on behavior of crossbred pigs at day 3

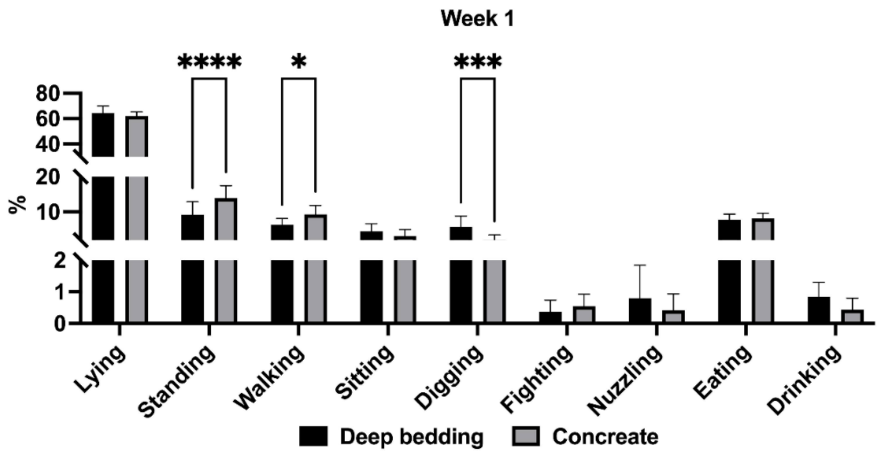

Figure 4 Effect of floor type on behavior of crossbred pigs at week 1

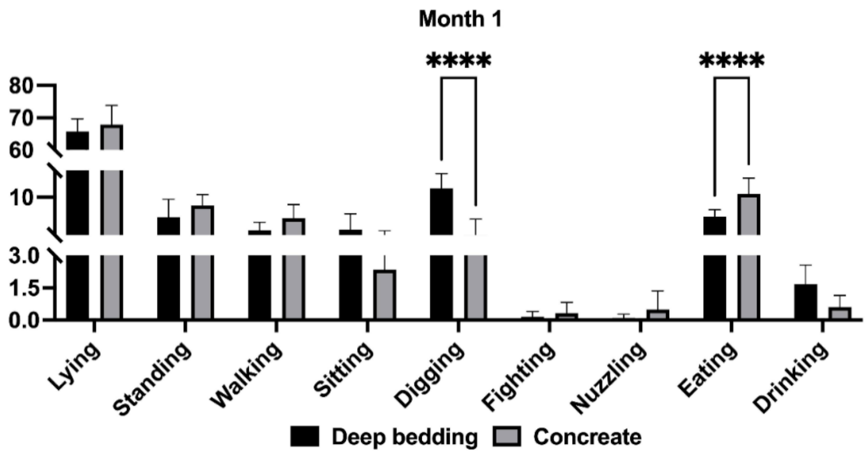

Figure 5 Effect of floor type on behavior of crossbred pigs at month 1

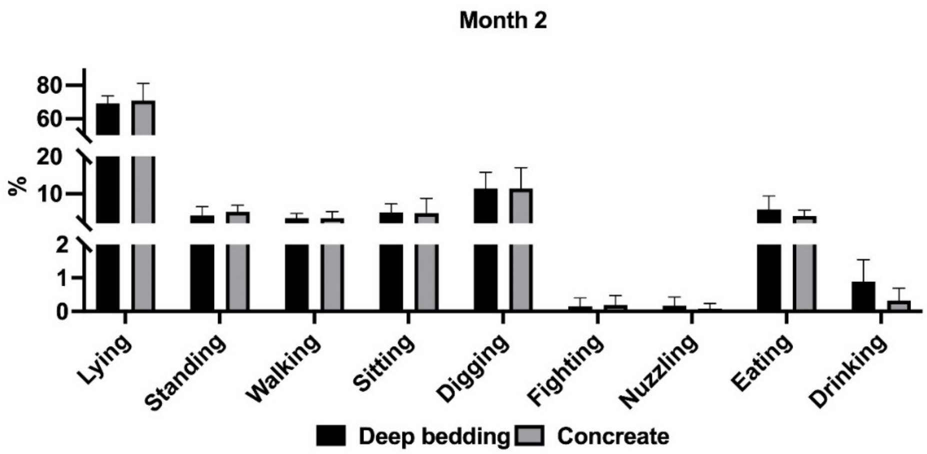

Figure 6 Effect of floor type on behavior of crossbred pigs at month 2

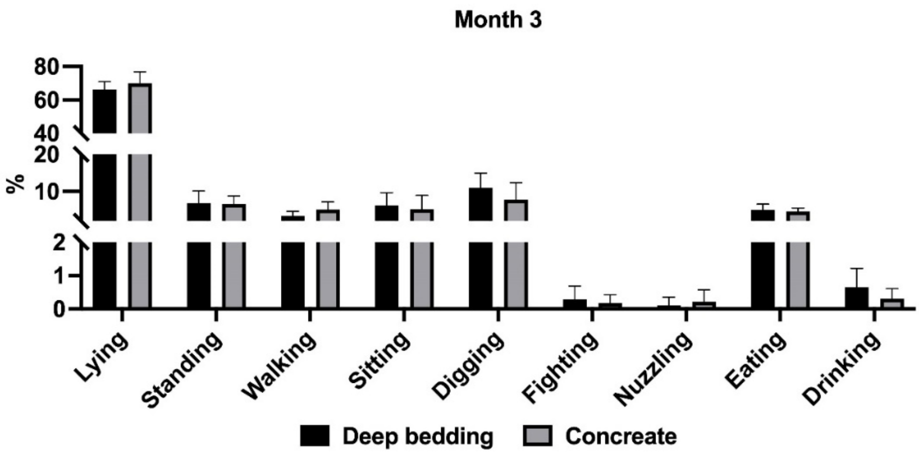

Figure 7 Effect of floor type on behavior of crossbred pigs at month 3

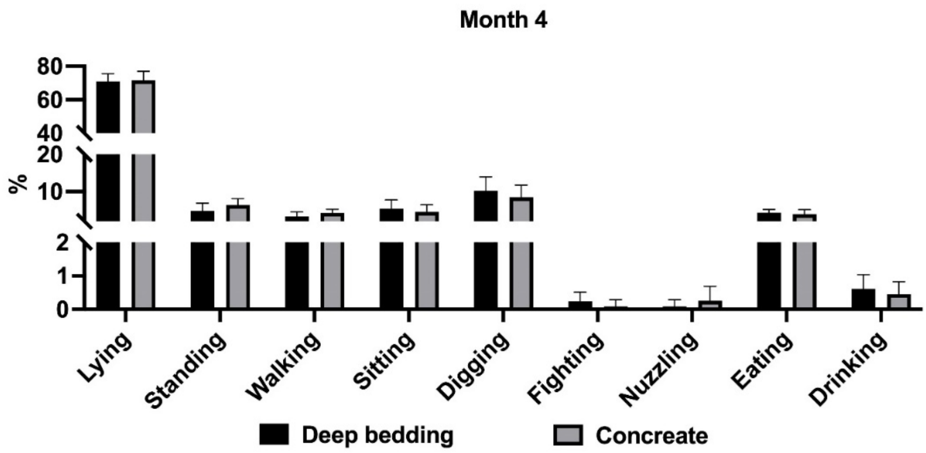

Figure 8 Effect of floor type on behavior of crossbred pigs at month 4

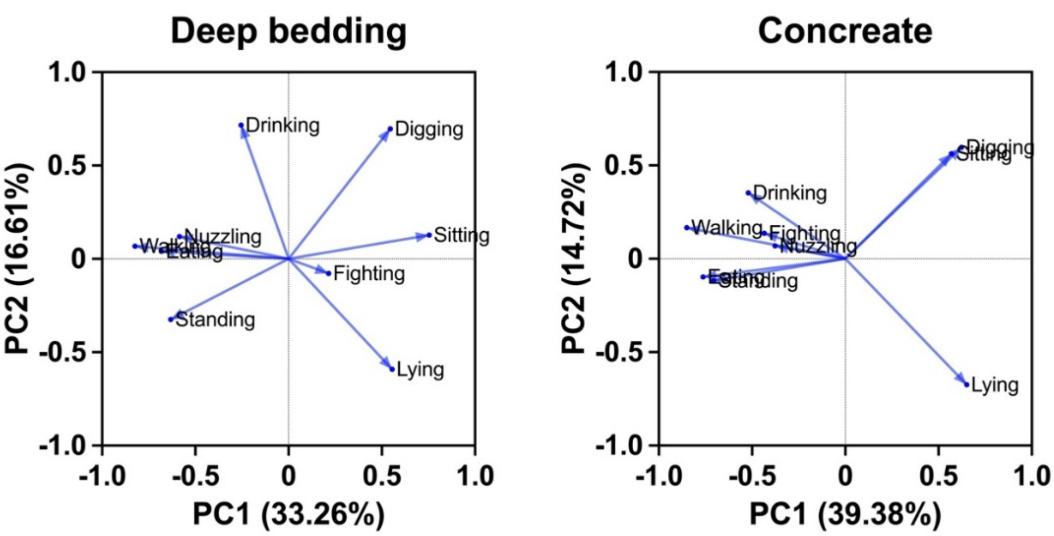

Figure 9 Principal component analysis (PCA) of pig behavior on difference floor.

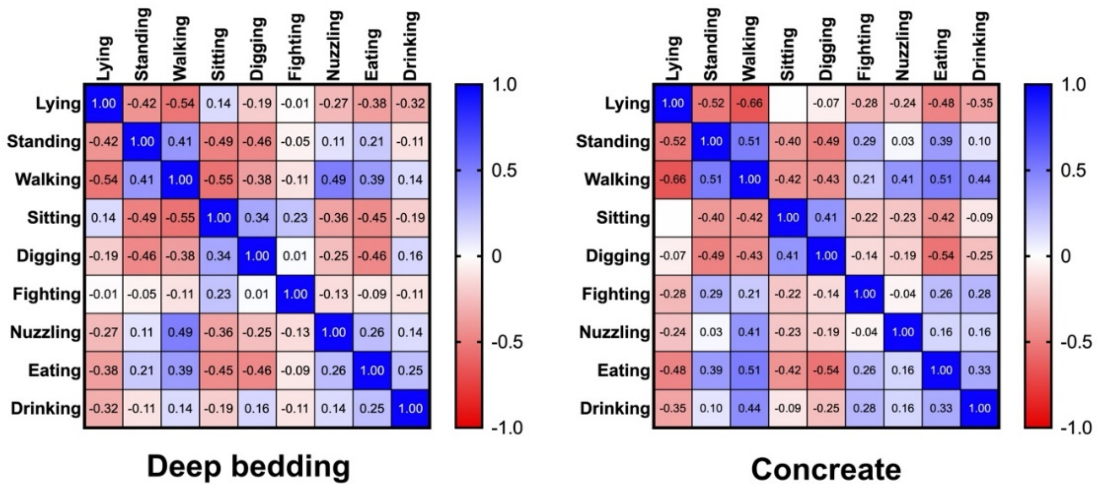

Figure 10 Heatmap of Pearson square correlation of pig behavior on difference floor.

Adult fly density

The fly density as the number of flies in Table 4. Even though, the pigs were reared in the same building and the row of DB and SB were separate by the 1.5 meters walking way, The flies might be flew across the row. The results of 5 period records from the arrival day to 4 months of rearing showed that the DB pigs had significantly fewer flies density than SB pigs in every recorded period (Average of 2.94 ± 3.40 vs. 9.51 ± 3.64 No./sq.m., P < 0.05).

Table 4 Effects of floor type on density of adult fly. (number/m²)

Period	Deep bedding (DB)	Concrete floor (CF)	P-value	% of Fly reduction DB compared to SB
Day 1	1.09^{a}	15.34^{b}	0.014	92.87
Month 1	8.91^{a}	10.72^{b}	0.046	16.90
Month 2	1.03^{a}	7.50^{b}	0.011	86.25
Month 3	1.09^{a}	7.56^{b}	0.004	85.54
Month 4	2.50^{a}	6.41^{b}	0.012	60.97
Average	2.94 ± 3.40 ^{a}	9.51 ± 3.64^{b}	0.020	69.23

*Values are means ± SD.
^{a} and ^{b} Treatment means with different superscripts in the same row are significantly different (P<0.05)

DISCUSSION

Growth performance

This study found that pigs raised on a solid concrete floor (SB) had better growth performance compared to those on deep bedding (DB). Pigs in SB systems were likely more efficient at gathering and consuming dropped feed. In DB systems, it was observed that very few fallen feeds got combined with the bedding material within the pen, potentially making it more challenging for pigs to retrieve and consume. This difference in feed accessibility between SB and DB systems could have contributed to the observed variations in growth performance. The behavior data also supported that the DB pigs spent more time than SB in exploring the floor by digging or rooting and nuzzling. Similarly, study Matte (1993) report the effect of deep litter housing on growth performance of pigs. The body weight was depressed on deep litter when compare partially slatted floors. According with Chaiwang et al. (2021) found that the final weight, average daily gain, and feed conversion ratio of pigs reared on SB were significantly higher than those of pigs raised on DB. Angulo-Arroyave et al. (2019) report study productive performance of growing piglets in deep bedding system. The animals showed performance in the plastic floor better than deep bed systems. Furthermore, Kidega et al. (2021) conducted a study that investigated the effects of different floor types on the growth performance and carcass back-fat thickness of pigs. The study compared pigs raised on IMO-treated deep litter floors, untreated deep litter floors, and concrete floors. The results revealed significant ($P \leq 0.05$) differences in feed intake (FI) and weight gain (WG) among the three floor types. Pigs raised on concrete floors exhibited a higher FI by 2.4 kg compared to those on IMO-treated deep litter floors, and a 3.4 kg increase compared to those on untreated deep litter floors. Furthermore, the WG of pigs on concrete floors was 2.4 kg greater than that of pigs on IMO-treated deep litter floors, and a substantial 9.4 kg higher than pigs raised on untreated deep litter floors. However, Correa et al. (2009) and Sheen et al. (2005) both reported that pigs reared in deep litter floor housing systems demonstrated weight gain and feed conversion ratio comparable to those witnessed in traditional pig houses with concrete flooring. While, Hötzel et al. (2009) found that non-significant effects on performance of pigs reared on deep bedding with two different substrates, wood shavings and rice husks, or in barren, part-slatted, concrete-floored pens during the summer months in Brazil.

There was no significant difference in ADFI between pigs fed the BF and FF group in this study. However, when calculate ADFI to CF intake, NDF intake and ADF intake, the pigs fed FF had more than CF intake, NDF intake, and ADF intake than pig fed BF group. Similarly, report Arjin et al. (2021) showed study efficiency of fresh and fermented banana stems on nutrient digestibility, the fresh and fermented banana stems no difference on in vitro digestibility crude fiber and apparent total tract digestibility (ATTD) crude fiber, effects on growth performance of crossbred pigs. Taksinanan et al. (2020) report study effects of dietary fiber level from grounded rice hull not affected on growth performance of weaning-pigs. When increasing total dietary fiber in diet from 130 to 150 g/kg diets the nutrient digestibility of energy and protein did not differ among treatments, whereas the digestibility of crude fat and fiber tended to increase. As same as this study show the result pigs fed FF group had high CF intake, NDF intake, ADF intake but not effect on growth performance. Berrocoso et al. (2015) study effects of inclusion of additional fiber (sugar beet pulp, straw, oat hulls and wheat middlings) contain 2.5 and 5.0% diet on growth performance of piglets. This study show piglet performance was not affected by source or level of dietary fiber, but apparent total tract digestibility (ATTD) of all nutrients decreased.

Behavior

In general, pigs raised in deep bedding floor (DB) had behavior activity better than solid bedding of concrete floor (SB). Similarly, study of Morrison et al. (2003) show pigs in the deep-litter system spent more time behavior activity compared to conventionally housed pigs. There was an increase in physical pen interactions and a higher incidence of social tactile interactions and agonistic and sexual behaviors in the deep-litter treatment.

Such differences in social behavior may be responsible for differences in growth performance commonly observed in deep-litter systems. In this study, pigs raised in DB system had behavior activity such as standing, walking, and eating lower than SB system, while pigs in DB system had exploring pens by digging activity more than SB system. According to Wei et al. (2019) showed that study comparison of two housing systems on behavior and performance of fattening pigs. The results showed that deep little (DL) pigs spent more time exploring, while outdoor playground (PG) pigs were more aggressive and engaged in higher levels of abnormal behavior, specifically stereotyped behavior and mouth-holding/biting tail. No difference was observed for the final body weight and feed conversion efficiency. Wei et al. (2019) suggested that the DL system improves pig welfare at aspects of exploratory behavior and abnormal behavior compared with the PG housing system under the conditions studied, providing a basis for the selection and design of optimum housing systems for pigs. Lahrmann et al. (2015) showed some reported the effect of long or chopped straw on pig behavior, the result showed pigs spent time to interacting behavior (such as rooting/investigatory behavior) with straw bedding/solid floor when long and chopped straw were provided. In this study, pigs reared in DB system was exploring pen activity more than SB system. Similarly, reported Hötzel et al. (2009) study on behavior and performance of pigs finished on deep bedding with wood shavings or rice husks in summer. The result that showed the behavior of pigs reared with bedding, such as increased play activity and substrate manipulation and less peer-directed behaviors, indicated improved welfare compared to pigs reared in concrete-floored pens. In both bedding substrates, pigs spent more time lying or standing on the beds than on the concrete floor. Amaral et al. (2021) study was to characterize the thermal environment and evaluate the behavior of finishing pigs housed in deep bedding and conventional systems. the pig in the deep bedding system were more active and visited the drinking fountains more frequently. Despite the higher level of activity of the animals in the deep bedding system. The pigs raised in solid bedding of concrete floor, more activity in walking, giving social activity and eating more than pigs raised in DB system. Some study showed, Amaral et al. (2021) found that the frequency of the behavioral pattern of "eating" was higher in the concrete floor pen, followed by the composite systems of deep bedding (wood shavings and rice husks). Similarly, Hötzel et al. (2009) found that pigs raised in solid bedding more behavior such as eating, manipulating object and oral-nasal contact (as well as giving social activity) in summer period due to the skin temperature was higher for pigs reared on bedding (wood shavings = 32.5 ± 0.45 °C, rice-husk bed = 32.2 ± 0.5 °C than on the concrete flooring (31.7 ± 0.3 °C). However, these results indicate that both substrates are suitable bedding materials and welfare for pigs.

Adult fly density

Fly populations in pig farming are not only a nuisance to pigs but also a significant welfare concern, often leading to complaints from neighboring communities (Caicedo et al., 2021). Flies can also serve as vectors of diseases, highlighting the importance of effective fly control strategies. In this study, the fly numbers in the deep bedding (DB) system were significantly lower compared to the standard recommendations for fly control. Stafford (1988) suggested that 100 or more spots per sticky card (3x5 inches) indicate the need for fly control measures, whereas Burgess (2023) considered five flies or fewer per square meter as normal. These findings underscore the effectiveness of the DB system in controlling fly populations. Deep-litter housing systems, while beneficial in many aspects, can also provide both biological matter and ammonia to the flies. However, Riedel et al. (2024) found that fly numbers varied based on the time of the bedding period and the materials used. The regular addition of fresh, dry rice husk bedding aids in moisture absorption, thereby reducing potential fly breeding sites. Additionally, Rondón et al. (2014) demonstrated that rice husk bedding is more effective in reducing parasites compared to other types of bedding such as grass hay. Moreover, spraying an Indigenous Microorganisms (IMO) dilution (1:200 water v/v) on the DB floor every two weeks might contribute to the reduction in fly populations. Decomposition during the composting process increases the temperature of the bedding material (Yadav et al., 2020), which could potentially disrupt the fly egg development process. Lagu et al. (2017) reported a reduction in the prevalence and intensity of internal parasites in pigs treated with IMO, highlighting the multifaceted benefits of the DB system. Additionally, benefits of the DB system extend beyond fly control. Zhou et al. (2015) reported significantly lower concentrations of NH_3 and CO_2 in deep-litter systems compared to concrete-floor systems. This suggests improved air quality and reduced ammonia emissions, which are beneficial for pig health and environmental sustainability.

CONCLUSIONS

Pigs raised on deep bedding had significantly lower final weight, ADG, and higher FCR than pigs raised on concrete flooring. They also spent more time exploring the pen by digging, less time standing and walking, and had fewer flies. Feeding types did not differ. However, deep bedding may be more natural better for pig behavior and welfare, as it provides a more comfortable and enhance welfare for sustainable pig production. The DB system also provide the benefit of lower adult fly density than in the open housing system.

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AUTHOR CONTRIBUTIONS

Nuttawut Krutthai: Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing.
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CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

REFERENCES

Amaral, A.G., Carvalho, L.H., Barbosa, E.C., Dantas, A.F.M., Silva, S.R., 2021. Characterization of the thermal environment and evaluation of the behavior of finishing pigs housed in deep bedding and conventional systems. Animals. 11(1), 16.

Angulo-Arroyave, J.J., Herrera, A., Osorio-Díaz, A., 2019. Productive performance of growing piglets in deep bedding system and plastic floor. Rev. Colomb. de Cienc. Pecu. 32(2), 259-268.

Arjin, C., Souphannavong, C., Sartsook, A., Seel-Audom, M., Mekchay, S., Sringarm, K., 2021. Efficiency of fresh and fermented banana stems in low protein diet on nutrient digestibility, productive performance and intestinal morphology of crossbred pig; (Thai native x Meishan) x Duroc. Vet. Integr. Sci. 19(1), 51-64.

Berrocoso, J., Martínez-Sánchez, J., García-Gallardo, J., Fereres, P., 2015. Effects of inclusion of additional fiber (sugar beet pulp, straw, oat hulls and wheat middlings) on growth performance, nutrient digestibility, and fecal microbiota of piglets. Anim. Feed. Sci. Technol. 208, 108-117.

Burgess, R., 2023. How to assess fly density on pig farms. Available online: https://www.daltonengineering.co.uk/blogs/news/assess-fly-density-on-pig-farms (Accessed on February, 2024)

Caicedo, C.A., Rodríguez, M.A., Ramírez, Y., Rojas, D.A., 2021. Fly control in pig farms: a review. Rev. MVZ Cordoba. 26(2), 9784-9795.

Chaiwang, N., Bunmee, T., Arjin, C., Wattanakul, W., Krutthai, N., Mekchay, S., Sringarm, K., 2021. Effect of deep bedding floor and fermented feed supplement on productive performance, carcase, meat quality and fatty acid profile of crossbred pigs. Ital. J. Anim. Sci. 20(1), 479–488.

Cho, J.H., Zhao, P.Y., Kim, I.H., 2011. Probiotics as a dietary additive for pigs: a review. J. Anim. Vet. Adv. 10(16), 2127–2134.

Correa, J.C., Pereira, L.F., Cunha, J.F., Souza, J.M., 2009. Performance of pigs reared in deep-litter and partially slatted floor systems during the summer. Livest. Sci. 121, 81-88.

Honeyman, M.S., Harmon, J.D., Kliebenstein, J.B., Richard, T.L., 2001. Feasibility of hoop structures for market swine in Iowa: pig performance, pig environment, and budget analysis. Appl. Eng. Agric. 17, 869–874.

Hötzel, M., Lopes, E., De Oliveira, P., Guidoni, A., 2009. Behaviour and performance of pigs finished on deep bedding with wood shavings or rice husks in summer. Anim. Welf. 18(1), 65-71.

Kaufmann, R., 1997. A deep litter fermentation system for fattening pigs-technical improvements and assessment of environmentally relevant data. J. Rech. Porc. Fr. 29, 311–318.

Kidega, K., Aliro, T., Mugonola, B., Ndyomugyenyi, E.K., Okello-Uma, I., 2021. Effects of different floor types on the growth performance and carcass back-fat thickness of pigs. Livest. Res. Rural. Dev. 21(2), 47-53.

Kumar, B.L., Gopal, D.V.R.S., 2015. Effective role of indigenous microorganisms for sustainable environment. 3 Biotech. 5(6), 867–876.

Lagu, C., Andama, M., Lee, S., Park, M., Ainomugisha, A., 2017. Prevalence and Intensity of Internal Parasites in Pigs under Indigenous Micro-Organism (IMO) and Conventional Piggery Farms, Greater Mbarara, Uganda. Livest. Res. Rural. Dev. 29, 1-11.

Lahrmann, H.P., Oxholm, L.C., Steinmetz, H., Nielsen, M.B.F., D'Eath, R.B., 2015. The effect of long or chopped straw on pig behaviour. Anim. 9(5), 862–870.

Matte, J.J., 1993. A note on the effect of deep-litter housing on growth performance of growing finishing pigs. Can. J. Anim. Sci. 73: 643-647

Meerburg, B.G., Vermeer, H.M., Kijlstra, A., 2007. Controlling risks of pathogen transmission by flies on organic pig farms, A review. Outlook. Agric., 36(3), 193–197.

Morrison, R.S., Hemsworth, P.H., Cronin, G.M., Campbell, R.G., 2003. The social and feeding behaviour of growing pigs in deep-litter, large group housing systems. Appl. Anim. Behav. Sci. 82, 173–188.

Morrison, R.S., Johnston, L.J., Hilbrands, A.M., 2007. The behaviour, welfare, growth performance and meat quality of pigs housed in a deep-litter, large group housing system compared to a conventional confinement system. Appl. Anim. Behav. Sci. 103, 12–24.

Riedel, A., Pieper, R., Lautner, M., Leiding, C., Jung, M. Schulze, M., 2024. Influence of deep-litter bedding materials on environmental and welfare-related factors in boar studs. Appl. Anim. Behav. Sci. 273(2024), 10621.

Rondón, R.A., Herrera-Ortiz, J.M., Mejía, J.J., 2014. Effect of rice husk bedding on parasite control in growing pigs. Rev. MVZ. Cordoba. 19(3), 4679-4687.

Sheen, S.Y., Su, C.C., Lee, M.S., Chang, H.L., Hong, C.M., 2005. Study on the management model of litter bedded pig houses. Livest. Res. 34(2), 69-78.

Sringarm, K., Chaiwang, N., Wattanakul, W., Mahinchai, P., Satsook, A., Norkeaw, R., Seel-audom, M., Moonmanee, T., Mekchay, S., Sommano, S.R., Ruksiriwanich, W., Rachtanapun, P., Jantanasakulwong, K., Arjin, C., 2022. Improvement of intramuscular fat in longissimus muscle of finishing Thai crossbred black pigs by perilla cake supplementation in a low-lysine diet. Foods. 11(7), 907.

Stafford, K.C., 1988. 'Housefly (Diptera: Muscidae) monitoring method comparisons and seasonal trends in environmentally controlled high-rise, caged-layer poultry houses', J. Econ. Entom. 81, 1426–1430.

Steel, R.G.D., Torrie, J.H., 1980. Principles and procedures of statistics. A biometrical approach, (2nd edition). McGraw-Hill Book, New York.

Taksinanan, N., Tartrakoon, W., Attamangkune, S., Incharoen, T., Charoensook, R., 2020. Effects of dietary fiber level in weaning pig diets on growth performance, nutrient digestibility and intestinal morphology. Am. J. Anim. Vet. Sci. 15(1), 81-88.

Tubiello, F.N., Salvatore, M., Rossi, S., Ferrara, A., Fitton, N., Smith, P., 2013. The FAOSTAT database of greenhouse gas emissions from agriculture. Environ. Res. Lett. 8(1), 015009.

Tuyttens, F., 2005. The importance of straw for pig and cattle welfare: a review. Appl. Anim. Behav. Sci. 92(3), 261-282.

Wattanakul, W., Stewart, A.H., Edwards, S.A., English, P.R., 1998. The effect of cross-suckling and presence of additional piglets on sucking behaviour and performance of individually housed litters. Anim. Sci. (Penicuik, Scotland). 66(2), 449-455.

Wei, S., Guo, Y., Yan, P., 2019. Comparison of two housing systems on behaviour and performance of fattening pigs. J. Appl. Anim. Res. 47(1), 41–45.

Wiegand, R.M., Gonyou, H.W., Curtis, S.E., 1994. Pen shape and size: effects on pig behavior and performance. Appl. Anim. Behav. Sci. 39(1), 49-6.

Xu, B., Li, Z., Wang, C., Fu, J., Zhang, Y., Wang, Y., Lu, Z., 2020. Effects of fermented feed supplementation on pig growth performance: a meta-analysis. Anim. Feed. Sci. Technol. 259, 114315.

Yadav, S., Bharti, P.K., Chandrahas, C., Gaur, G.K., Abhishek, A., Singh, M., Somagond, A., 2020. Aerobic composting of pig excreta as a model for inoculated deep litter system in sty using Indigenous Microorganisms (IMOs). Indian J. Anim. Sci. 90(12), 1649–1654.

Zhou, C., Hu, J., Zhang, B., Tan, Z., 2015. Gaseous emissions, growth performance and pork quality of pigs housed in deep-litter system compared to concrete-floor system. Anim. Sci. J. 86(4), 422–427.

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