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Impact of environmental enrichment on growth, behavior, and welfare of weanling piglets from pre-weaning to 6 weeks of age

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Abstract

The experiment was carried out to study the effect of environmental enrichment before and after weaning on the growth, behaviours, and welfare of weaning pigs. A total of 360 weaning pigs (average initial body weight 6.32 ± 0.10 kg) were randomly allotted to one of the three treatments on the basis of initial body weight. A completely randomized design was used to conduct this study. There were ten pigs per pen, with 6 replicates for each treatment. The experimental treatments were control; WBW-1, play object included one week before weaning/not included; and WBW-2, play object included two weeks before weaning/not included. Weaning pigs raised under environmental enrichment treatments had greater average daily gain and average daily feed intake in phase 1 and greater average daily gain and average daily feed intake in phase 2 and overall than pigs reared in the control group. However, treatment and interaction between treatment and play object installation did not exhibit significant differences. The WBW-1 exhibited a lower body weight coefficient of variation of weaning pigs in phase 1 and phase 2 than weaning pigs that were raised in the control group, however, the interaction between treatment and enriched environment did not show significant differences in phase 1 and 2. The incidence of diarrhea was numerically reduced by enriched environment effect in early phase 1 (d 7) and there were no significant differences in d 14 and d 28. Behaviour traits results showed lower agonistic behaviour, including tail and ear biting by enriched environment effect in phase 1. The enriched environment reduced the skin lesion score in phase 1, however, there were no significant differences in skin lesion score in phase 2. The concentration of hair cortisol was reduced by enriched environment effect at the end of phase 2. These findings suggest that environmental enrichment prior to the weaning process increased growth, group uniformity, and reduced incidence of diarrhea, agonistic behaviour, skin lesions, and concentration of hair cortisol during the post-weaning period. Impact of environmental enrichment on growth, behavior, and welfare of weanling piglets from pre-weaning to 6 weeks of age.

Keywords: Weaning, Suckling, Performance, Uniformity, Cortisol, Stress

Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Kim M.
Data curation: Lee J.
Formal analysis: Lee J.
Methodology: Oh S.
Software: Oh S.
Validation: Kim M.
Investigation: Lee J.
Writing - original draft: Lee J, Oh S.
Writing - review & editing: Lee J, Oh S, Kim M.

Ethics approval and consent to participate
The Institutional Animal Care and Use Committee of Kangwon National University approved the animal care and experimental techniques utilized in this study (Ethical code: KW-220413-1).

INTRODUCTION

Once piglets are born, they are typically housed with sows during a farrowing period until they are 3–4 weeks of age (WOA). Subsequently, the weaning process occurs around the age of weanling piglets in a commercial swine production cycle [1,2]. Although this conventional production system has been used in the swine industry, alternative production systems such as enriched environments or applications for animal welfare have received considerable attention from consumers for favorable outcomes. Therefore, the provision of an enriched environment for raising weanling piglets in commercial housing is being evaluated in several ways regarding optimal pig growth. Pigs raised in an enriched environment exhibited innate behavior, that is, more exploration and foraging, instead of expressing agonistic behavior. They are used to achieve a proper growth rate compared to pigs raised under conventional housing conditions [3,4]. As a common routine practice in commercial production conditions, weanling piglets undergo the weaning process when they reach approximately 4 WOA and regroup with other piglets. This process is considered a critical point for piglet growth and behavior through a number of stressors, such as separation from the sow and sudden changes in their environment (e.g., changes in diet type, regrouping with other piglets, and housing space) [5,6]. Consequently, an abrupt weaning process is linked to increased reciprocal fighting in other piglets, elevated stress levels, and retarded growth in weanling piglets [2,7,8]. Therefore, rearing of weanling piglets has received increasing attention in the context of animal welfare. Environmental enrichment is believed to be a pivotal element in reducing stress levels and promoting robust growth in piglets. Studies have shown that enriched environmental housing conditions lead to lower levels of agonistic behavior and improved growth [3,4]. Furthermore, well-known environmental enrichment practices involve the provision of extra space or the installation of objects in piglet pens to reduce aggressive behavior and alleviate stress levels in weaned piglets. Playing with objects may encourage the play behavior of piglets instead of fighting other piglets and is recognized as a welfare indicator [7,9]. A previous study showed that rearing piglets in an enriched environment resulted in better-socialized behavior than that in a conventional environment [4]. Furthermore, play effects such as increased locomotor activity by objects may be related to improved social play, and this novel environment may also result in a better response to confrontation phenomena in the post-weaning period [10,11,12]. Moreover, exposure to an enriched environment and objects early in life substantially decreased the agonistic behavior of weaning piglets [13].

Little attention has been paid to how the application of a novel environment in the pre-weaning period affects the post-weaning period. It is plausible to follow these two phases to elucidate the effects of object installation as a novel environment for rearing piglets before the start of the weaning process. Therefore, this study aimed to investigate the growth, behavior, and stress response of piglets from pre-weaning to 6 weeks after weaning.

MATERIALS AND METHODS

Test animals and experimental design

A total of 360 weaning pigs (LYD [Landrace × Yorkshire × Duroc]: average initial body weight [BW] 6.32 ± 0.10 kg) were randomly allotted to one of the three treatments on the basis of initial BW. This study used a completely randomized design (CRD). Each pen contained 10 pigs, with 6 replicates per treatment. The experimental treatments were the control (play object included/not included), play object included one week before weaning/not included (WBW-1) , and play object included two weeks before weaning/not included (WBW-2). Experimental diets were provided using commercial feed products. The experimental phases were phase 1 (0–14 days post-weaning) and phase 2 (15–28 days post-weaning). All pens contained a self-feeder and nipple drinker to allow ad libitum food and water. Two experimental treatments, WBW-1 and WBW-2, were provided with play objects (spring play objects, Taewoo Livestock, Seongju, Korea) fixed on the floor near the self-feeder.

Growth performance

The BW of all the pigs were measured at the end of each phase. The amount of feed supplemented was measured throughout the experimental period to calculate average daily feed intake (ADFI). The average daily gain (ADG), ADFI, and gain-to-feed ratio (G/F) were calculated at the end of each phase (phase 1: day 14, phase 2: day 28, and overall: 0–28 days after weaning).

Body weight uniformity

The BW uniformity was calculated at the end of each phase (phase 1: day 14, phase 2: day 28) as the coefficient of variation (CV, %) by dividing individual BW standard deviation by the mean BW.

Diarrhea incidence

The incidence of diarrhea was measured three times (days 7, 14, and 28). The criteria for collecting data on the incidence of diarrhea were as follows: 1 = hard, dry pellets in a small, hard mass; 2 = hard, formed stool that remained firm and soft; 3 = soft, formed, and moist stool that retained its shape; 4 = soft, unformed stool that assumed the shape of the container; and 5 = watery, liquid stool that could be poured [14].

Behavior observations

Piglet behavior was recorded twice at the end of each phase (days 14 and 28) by installing cameras (FIX extreme action camera, China) above each pen. The cameras were arranged through a cable duct located at the top of the middle of each pen to record behavior over the entire area. The video was recorded for 8 h, and the recorded video files were extracted and saved on a high-capacity USB flash drive for analysis. The observation days were at the end of each phase (phase 1: day 14, phase 2: day 28) after weaning and included an 8-h observation period (10:00 to 18:00). Each behavior was evaluated for 8 h from the video, and the number of behavior observations was shown as the number in an hour [15]. The criteria for analyzing the behavioral traits are presented in Table 1.

Skin lesion scoring

Evaluation of lesions on the body (ear, front, middle, hindquarter, and legs) or tail was conducted by inspecting the two sides of experimental weaning pigs twice at the end of each phase (days 14 and

Table 1. Ethogram used for the behavioral observations

Behavior	Definition
Nosing	Nosing another part of the body of a penmate
Biting	Biting on substrates in pens
Mounting	Standing on hind legs while having front legs on another pig`s back (not the sows)
Tail biting	A pig chews, sucks or plays with another's ears.
Ear biting	A pig chews, sucks or plays with another's tails.
Aggresive	Horizontal or vertical knocking with the head or forward thrusting with the snout toward a penmate; intense mutual/individual ramming or pushing a penmate; biting a penmate, except ear or tail

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28) after weaning [16].

Salivary and hair cortisol concentrations

Saliva and hair samples were prepared and harvested at the end of phase 2 (day 28 after weaning). To collect saliva samples, medical cotton was tied with string and attached to the fence of each experimental pen. After weaning, the pigs chewed the medical cotton for 5 to 10 min under fully wet conditions, and the ear tag of the pig was recorded during the chewing process. A supernatant of the saliva sample (~7–8 mL) was prepared by centrifugation at 3,000×g at 4℃ for 10 min and stored at −20℃ until analysis. Salivary cortisol concentrations were measured using a commercial ELISA kit (ADI-90-071, Enzo Life Sciences, Farmingdale, NY, USA) [17]. Freshly grown hair from individual weaning pigs was collected and used to analyze hair cortisol concentrations. The collected hair samples were washed three times with isopropanol, followed by drying in a vacuum dryer at 35℃, and then placed in an expanded metal lath plastic tube containing steel pellets and a bead beater (tacoTMPrep, 50/60 Hz 2A, GeneReach Biotechnology, Taichung, Taiwan). Hair cortisol was extracted using methanol after crushing at bead beater (tacoTMPrep, 50/60 Hz 2A, GeneReach Biotechnology, Taichung, Taiwan). A cortisol ELISA kit (ADI-900-071, Enzo Life Sciences) was used to determine the cortisol concentrations in the extracted sample [18].

Statistical analyses

The data generated in this study were statistically analyzed using SAS (9.2, SAS Institue, Cary, NC, USA) using the Proc general linear model procedure in a CRD. When significant differences were identified among the treatment means, they were separated using Tukey's Honest Significant Difference test. Statistical significance was set at $p < 0.05$.

RESULTS

Growth performance and uniformity

The effects of environmental enrichment-based object installation on growth performance are shown in Table 2. Piglets raised with post-weaning object installation exhibited a greater ADG in phases 1 ($p = 0.003$), 2 ($p = 0.038$), and overall ($p < 0.001$) than piglets reared without object installation. However, there were no ADG difference between the treatment before weaning. The post-weaning object installation increased ADFI in phases 1 ($p = 0.004$), 2 ($p = 0.001$), and overall ($p < 0.001$), however, the pre-weaning object instaslation was ineffective in increasing ADFI. There were no significant differences and interactions in the G/F between treatment and object installation. The effect of environmental enrichment-based object installation on group uniformity is shown in Table 3. Piglets reared under WBW-1 and WBW-2 treatments showed a lower CV in phases 1 ($p = 0.033$) and 2 ($p = 0.001$). The post-weaning installation of the object reduced CV in phases 1 ($p = 0.006$) and 2 ($p = 0.009$). However, the interaction effect between the treatment and object did not show any significant difference.

Diarrhea incidence

The effects of environmental enrichment-based object installation on the incidence of diarrhea are shown in Table 4. Piglets reared under the object installation conditions did not exhibit any significant differences. The post-weaning object installation effect showed only a tendency ($p = 0.058$) on day 7. In addition, the treatment and interaction effects between treatment and object did not show any significant differences.

Table 2. The effects of pre-weaning environmental enrichment-based materials on growth performance in pigs

	Control[1)]		WBW-1		WBW-2		SEM	*p*-value		
	X[2)]	O	X	O	X	O		BWN	AWN	Interaction
Phase 1 (d 0–14)										
ADG (kg)	281.92	304.04	286.59	335.63	283.28	322.32	19.87	0.444	0.003	0.630
ADFI (kg)	401.85	436.22	413.09	484.37	410.77	465.58	29.39	0.363	0.004	0.677
G/F	0.70	0.69	0.69	0.69	0.68	0.69	0.01	0.653	0.934	0.909
Phase 2 (d 15–28)										
ADG (kg)	398.02	438.48	406.26	437.78	414.97	440.64	28.55	0.872	0.038	0.921
ADFI (kg)	620.85	643.42	622.37	648.45	633.47	637.46	38.31	0.812	0.001	0.148
G/F	0.64	0.68	0.65	0.67	0.65	0.69	0.04	0.903	0.155	0.948
Overall (d 0–28)										
ADG (kg)	339.97	368.88	346.42	386.70	349.13	381.48	12.21	0.304	< 0.001	0.791
ADFI (kg)	511.35	535.65	517.73	566.41	522.12	551.52	14.35	0.164	< 0.001	0.430
G/F	0.66	0.68	0.66	0.68	0.66	0.69	0.02	0.946	0.093	0.920

1)Control, no environmental enrichment installation during lactation; WBW-1, environmental enrichment installation 1 week before weaning; WBW-2, environmental enrichment installation 2 weeks before weaning.

2)X, without object installation as environmental enrichment after weaning; O, with object installation as environmental enrichment after weaning.

ADG, average daily gain; ADFI, average daily feed intake; G/F, feed efficiency.

Table 3. The effects of pre-weaning environmental enrichment-based materials on uniformity in pigs

	Control[1)]		WBW-1		WBW-2		SEM	*p*-value		
	X[2)]	O	X	O	X	O		BWN	AWN	Interaction
CV										
Phase 1 (d 14)	12.31	10.73	10.27	8.69	11.97	9.68	1.06	0.033	0.006	0.864
Phase 2 (d 28)	13.24	12.87	11.12	8.22	10.96	9.11	1.05	0.001	0.009	0.250

1)Control, no environmental enrichment installation during lactation; WBW-1, environmental enrichment installation 1 week before weaning; WBW-2, environmental enrichment installation 2 weeks before weaning.

2)X, without object installation as environmental enrichment after weaning; O, with object installation as environmental enrichment after weaning.

CV, coefficient of variation.

Table 4. The effects of pre-weaning environmental enrichment-based materials on diarrhea incidence in pigs

	Control[1)]		WBW-1		WBW-2		SEM	*p*-value		
	X[2)]	O	X	O	X	O		BWN	AWN	Interaction
Diarrhea incidence										
d 7	3.58	3.02	3.31	2.92	3.29	2.80	0.41	0.676	0.058	0.958
d 14	2.66	2.75	2.85	2.99	2.79	2.46	0.47	0.667	0.913	0.747
d 28	2.15	2.32	2.52	2.52	2.32	2.38	0.57	0.787	0.823	0.976

1)Control, no environmental enrichment installation during lactation; WBW-1, environmental enrichment installation 1 week before weaning; WBW-2, environmental enrichment installation 2 weeks before weaning.

2)X, without object installation as environmental enrichment after weaning; O, with object installation as environmental enrichment after weaning.

Behavioral traits

The effects of environmental enrichment-based object installation on behavioral characteristics are shown in Table 5. Pigs reared with post-weaning object installation exhibited less biting ($p < 0.001$), tail biting ($p = 0.002$), ear biting ($p < 0.001$), and aggressive behavior ($p = 0.001$) than pigs reared

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Table 5. The effects of pre-weaning environmental enrichment-based materials on bahaviour characteristics in pigs

	Control[1)]		WBW-1		WBW-2		SEM	p-value		
	X[2)]	O	X	O	X	O		BWN	AWN	Interaction
D 14 (number/hours)										
Nosing	10.43	9.93	10.41	10.16	9.79	9.93	0.49	0.454	0.486	0.652
Biting	6.68	5.56	6.81	5.45	6.93	5.29	0.54	0.967	< 0.001	0.885
Mounting	0.54	0.62	0.58	0.47	0.56	0.60	0.24	0.934	0.959	0.834
Tail biting	4.06	3.16	3.93	3.20	3.97	3.14	0.41	0.982	0.002	0.960
Ear biting	2.79	2.18	2.87	2.04	2.95	2.12	0.28	0.918	< 0.001	0.809
Aggressive	2.37	1.81	2.20	1.79	2.16	1.56	0.23	0.404	0.001	0.844
D 28 (number/hours)										
Nosing	5.18	5.52	5.68	5.27	4.70	5.39	0.46	0.428	0.463	0.253
Biting	1.39	1.29	1.29	1.27	1.31	1.04	0.55	0.647	0.374	0.778
Mounting	0.47	0.58	0.60	0.75	0.54	0.52	0.22	0.589	0.568	0.867
Tail biting	0.54	0.56	0.77	0.62	0.54	0.45	0.19	0.346	0.543	0.832
Ear biting	0.85	0.72	0.52	0.64	0.77	0.58	0.16	0.232	0.525	0.393
Aggressive	0.41	0.47	0.50	0.54	0.52	0.47	0.18	0.856	0.850	0.919

[1)]Control, no environmental enrichment installation during lactation; WBW-1, environmental enrichment installation 1 week before weaning; WBW-2, environmental enrichment installation 2 weeks before weaning.

[2)]X, without object installation as environmental enrichment after weaning; O, with object installation as environmental enrichment after weaning.

without object installation on day 14 after weaning. However, there was no effects of pre-weaning object installation on behavioral factors of pigs on day 14. The treatment effect and interaction effect between treatment and object installation did not result in significant differences in behavioral characteristics. On day 28 after weaning, there was no significant difference between treatment, object installation, or the interaction between treatment and object installation related to behavioral characteristics.

Skin lesion score

The effects of environmental enrichment-based object installation on skin lesion score are shown in Table 6. Post-weaning object installation showed lower (p = 0.023) skin lesion scores in pigs on 14 days after weaning, however, there was no effects of pre-weaning object instalation. The treatment and interaction effects was insignificant in changing skin lesion scores on day 28 after weaning.

Salivary and hair cortisol levels

The effects of environmental enrichment-based object installation on cortisol levels in hair and saliva are shown in Table 7. Post-weaning object installation showed lower (p = 0.010) hair

Table 6. The effects of pre-weaning environmental enrichment-based materials on skin lesion score in pigs

	Control[1)]		WBW-1		WBW-2		SEM	p-value		
	X[2)]	O	X	O	X	O		BWN	AWN	Interaction
Skin lesion score										
D 14	41.67	35.59	42.53	37.39	40.34	34.83	4.04	0.710	0.023	0.986
D 28	80.41	78.63	80.87	79.64	83.48	79.28	3.31	0.729	0.219	0.800

[1)]Control, no environmental enrichment installation during lactation; WBW-1, environmental enrichment installation 1 week before weaning; WBW-2, environmental enrichment installation 2 weeks before weaning.

[2)]X, without object installation as environmental enrichment after weaning; O, with object installation as environmental enrichment after weaning.

Table 7. The effects of pre-weaning environmental enrichment-based materials on cortisol in pigs

	Control[1)]		WBW-1		WBW-2		SEM	*p*-value		
	X[2)]	O	X	O	X	O		BWN	AWN	Interaction
Cortisol (pg/mg)										
Hair	78.56	73.12	76.83	71.16	78.48	70.58	3.98	0.799	0.010	0.891
Saliva	5.02	4.65	4.80	4.65	4.90	4.46	0.47	0.896	0.245	0.906

1)Control, no environmental enrichment installation during lactation; WBW-1, environmental enrichment installation 1 week before weaning; WBW-2, environmental enrichment installation 2 weeks before weaning.

2)X, without object installation as environmental enrichment after weaning; O, with object installation as environmental enrichment after weaning.

cortisol in pigs after weaning, however, there was no effects of pre-weaning object installation and interaction in hair cortisol concentration. The treatment and interaction effects was insignificant in changing saliva cortisol.

DISCUSSION

Commercial weaning conditions were used to raise the piglet until 3–5 WOA. During the farrowing period, piglets did not interact with any other group of piglets. Therefore, it is not possible to enhance their socialization skills, and they are susceptible to various stressors, such as different forms of diet, nutrition, and joining new groups. Pre-weaning practices that contact and play with an object may be an appropriate provision to reduce the stress or behavioral disorders of piglets during a critical period [13,19]. In this regard, play objects were installed for 1 or 2 weeks before the weaning process during the farrowing period to determine the impact of object installation on growth, behavior, and responses to stressors at 6 weeks after weaning.

WBW-1 and WBW-2 treatments and the interaction between treatments and objects resulted in better growth of piglets through ADG, ADFI, and G/F. Furthermore, piglets reared under the WBW-1 treatment had greater ADG and ADFI than other piglets, which is consistent with the results of previous studies. Newly introduced enrichment induces greater ADG in weanling piglets [20], and this phenomenon may be related to the adjustment of energy to growth instead of being disturbed by anxious behaviors (e.g., fighting and biting) [13]. In addition, a previous study reported that piglets raised in an enriched environment during the pre-weaning period exhibited a lower BW loss than those raised in the conventional environment, and that condition were connected to approximately 4 WOA after weaning [21]. Another study observed that piglets reared in an enriched environment during the pre-weaning period showed a more sustained increase in weight gain even after weaning [22]. However, environmental enrichment had no effect on the growth of piglets from farrowing to 20 WOA [23].

The CV of BW uniformity was used to measure the BW range in an identical group of piglets/pigs by calculating the ratio of the standard deviation to the mean. Previous studies have reported greater BW variation in groups connected to the higher disadvantage of lighter pigs in growth and increment of competition over milk of sows or feed intake from the pre-/post-weaning period [24,25]. The current study showed a lower CV of BW of piglets raised in WBW-1 than in pigs reared in the control or WBW-2 until the end of the post-weaning period. Moreover, object installation resulted in a much lower CV of BW compared to no object installation. Our results are consistent with those of a previous study showing that litter size is related to growth and CV of BW of piglets, similar to the WBW-1 treatment, which had numerically lower litter size (9.91 vs. 10.25, control vs. 10.50, WBW-2) than other treatments at weaning [26]. Early exposure to an enriched environment positively impacted and lowered CV of BW, which may be related to early

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experiences with unfamiliar objects or environments that promote socialization and help average distribution of diet, which is linked to an improved piglet growth rates [27]. The variation in BW is strongly related to the piglet growth rate between pre-weaning and post-weaning periods and can also be influenced by various stressors [24,28]. Therefore, the results of the present study imply that enriched environments before weaning can affect the maintenance of a lowered CV of BW.

The conspicuous effect of environmental enrichment could be linked to the acceleration of post-weaning growth performance, including a lower incidence of diarrhea. The weaning process causes numerous stressors owing to different forms of diet, environment, and separation issues. Therefore, piglets suffer from lower feed intake or intestinal abnormalities (e.g., intestinal digestion and permeability); therefore, these issues are strongly associated with a higher prevalence of diarrhea in pigs [429]. In the present study, the WBW-2 treatment showed the lowest incidence of diarrhea until 2 weeks post-weaning; however, the control treatment had a lower incidence of diarrhea than the other treatments at 4 weeks post-weaning. These results are consistent with those of a previous study showing that environmental enrichment reduces the occurrence of diarrhea and that enrichment may be connected to distraction against competition among weanling piglets [30]. Post-weaning diarrhea is linked to a number of stressors, such as different diet types (milk to solid feed) or inflammatory pathogens including *Escherichia coli*, *Clostridiums*, *campylobacter* spp.), lowering feed intake of piglets [31–33]. The present results correlate with the growth performance results of the present study; thus, we may conclude that enriched environments have a positive influence on reducing the incidence of diarrhea.

Differences in behavior (e.g., the degree of aggression and biting) can be utilized to infer animal welfare. A conventional barren environment induces more aggressive behaviors in piglets than enriched housing conditions when rearing piglets. Moreover, the commercial early post-weaning period has a higher probability of producing aggressive behavior by the weaning process. This study exhibited a significantly reduced frequency of biting (e.g., upper part of body and legs), including tail and ear biting, and aggressive behavior by weaned piglets in the enriched environment treatments (WBW-1 and WBW-2) compared to the control treatment during the early post-weaning period. Moreover, object installation as enriched housing in the present study had a greater impact on reducing aggressive behavior 2 weeks before the weaning process. Similar to the current results, a previous study reported that piglets raised in enriched housing showed more inquisitive behavior with object play (e.g., chewing and sniffing) than those raised in traditional commercial housing [4]. In terms of this behavior, exploring another environment may be related to the piglet's extrinsic (e.g., foraging) or intrinsic (e.g., accumulation of new information) instincts, which could reduce the time spent engaging in reciprocal agonistic interactions with other piglets [10]. Moreover, piglets spent more time on the object in the daytime [13], and pigs exposed to an object maintained their memory of that object [9]. Thus, the present results indicate that the installation of enriched housing was helpful in elucidating the relationship between exposure to enriched housing before weaning and lower levels of agnostic behavior during the post-weaning period.

Skin lesion scoring is an important tool for evaluating aggression levels in pigs. To collect lesion scores, the body regions of pigs were classified into three regions, including the front (i.e., head, neck, front legs, and shoulders), middle (flanks and back), and rear (rump, hind legs, and tail), to elucidate the levels of reciprocal aggressive behavior in pigs [34]. The accumulation of lesion scores in these regions could indicate the degree of aggressive behavior among piglets during the weaning period. In the present study, the number of lesions was reduced by object installation as an enriched condition, indicating that the proportion of direct relationships with play objects before the weaning process may reduce the reciprocal agonistic behavior of piglets. These results are consistent with a previous study in which the enrichment environment group exhibited significantly reduced agonistic behavior among piglets [4]. Moreover, aggressive behavior is strongly linked to social hierarchy, as an increase in the number of lesions was found during the first week of the post-weaning period [7,13]. However, in contrast to the present study, another study assumed that early exposure to play objects did not exhibit a connection to agonistic behavior among weanling piglets, which may be related to their inevitable instinct as a form of hierarchy against newly comingled piglets [35]. According to literature reviews (announcements are still controversial in decision-making), but play objects may have an impact on reducing the incidence of agonistic behaviors during the early post-weaning period.

Assessing cortisol concentrations in the saliva or hair is widely used to quantify chronic stress responses and subsequently determine animal welfare in livestock [23,36–38]. As one of the released glucocorticoids, cortisol induced by the adrenal glands circulates within the blood flow owing to the adrenocorticotropic hormone. When animals are confronted with stress, the hypothalamic-pituitary-adrenal axis is triggered to emit this hormone throughout the body. For instance, weanling piglets initiate the release of cortisol during the weaning process, such as relocation to other groups of piglets, as a chronic stress response [7,39]. In the current study, enriched housing reduced the cortisol concentration in hair, and early exposure to playing objects resulted in better responses to stressors. These results are similar to those of a previous study in which pigs displayed lower cortisol levels when they played with an object after weaning [13]. Reduced agonistic behavior is attributed to richer environment housing, which may indicate a correlation between environment enrichment and cortisol levels in response to stressors [19]. However, salivary cortisol levels in the present study did not exhibit significant differences in enriched housing, in contrast to previous studies [7]. It is plausible that enriched housing may contribute to reducing hair or salivary cortisol levels; however, further evaluation is required to refine a proper method to assess cortisol levels related to the enriched environment.

CONCLUSION

The present results show that the provision of an enriched environment had a positive impact on growth performance (e.g., ADG, ADFI, and G/F ratio), lower CV of BW, diarrhea incidence, agonistic behavior, skin lesion score, and hair cortisol level, suggesting that exposure to play objects before weaning as an enriched environment promotes the growth and welfare of piglets. Therefore, further research is required to determine the potential benefits of environmental enrichment in rearing piglets until market weight is reached.

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