RESEARCH ARTICLE

J Anim Sci Technol 2024;66(6):1246-1256
https://doi.org/10.5187/jast.2023.e128

JAST
Journal of Animal Science and Technology
pISSN 2672-0191 eISSN 2055-0391

Response to environmental enrichment of weanling pigs on growth, behaviour and welfare after weaning

Junhyung Lee[1], Seungmin Oh[2], Minju Kim[3,4]*

[1]*Department of Animal Biosciences, University of Guelph,Guelph, ON N1G 2W1, Canada*
[2]*Gyeongbuk Livestock Research Institute, Yeongju 63052, Korea*
[3]*School of Animal Life Convergence Science, Hankyong National University, Ansung 17579, Korea*
[4]*Institute of Applied Humanimal Science, Hankyong National University, Ansung 17579, Korea*

Abstract

The experiment was carried out to examine the growth, behaviour, and welfare response of weaning pigs to environmental enrichment from d 1 to d 28 after weaning. A total of 240 weaning pigs with average initial body weight (BW) 6.56 ± 0.17 kg were randomly allotted to one of the four treatments on the basis of initial BW. 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, EE-1 (inclusion of play object until one week after weaning), EE-2 (inclusion of play object until two weeks after weaning), and EE-4 (inclusion of play object until four weeks after weaning). The pigs raised the EE-2 and EE-4 treatments had greater average daily gain (p = 0.002). The average daily feed intake (p = 0.016) was increased in the EE-2 treatment in phase 1. The pigs in the EE-4 treatment had greater average daily gain (p = 0.039) and average daily feed intake (p = 0.030) in phase 2 than pigs raised in the control treatment, and overall (average daily gain: p = 0.006, average daily feed intake: p = 0.014). The pigs under enriched environment treatments (EE-2 and EE-4) decreased BW uniformity in phase 1 (p = 0.006) and phase 2 (p < 0.001) than pigs in the control treatment. The incidence of diarrhea was lowered (p < 0.001) in early phase 1 (d 7 after weaning) under environmental enrichment treatments (EE-2 and EE-4). Behaviour traits exhibited reduced agonistic behaviour, such as biting (p = 0.018), tail biting (p = 0.001), and ear biting (p = 0.016) under environmental enrichment treatments (EE-2 and EE-4) in phase 1. The skin lesion score was reduced (p = 0.015) in the EE-4 treatment in phase 1. Hair cortisol was reduced in the EE-4 treatment (p = 0.032) at the end of phase 2, however, there were no significant differences in salivary cortisol concentration. These findings demonstrated beneficial effects on growth, group uniformity, behaviour, incidence of diarrhea, skin lesions, and concentration of hair cortisol through exposure to environmental enrichment after weaning.

Keywords: Weanling pig, Body weight uniformity, Behaviour, Stress, Welfare

Check for updates

Received: Oct 4, 2023
Revised: Nov 2, 2023
Accepted: Nov 13, 2023

***Corresponding author**
Minju Kim
School of Animal Life Convergence Science, Hankyong National University, Ansung 17579, Korea.
Tel: +82-31-670-5124
E-mail: minjukim@hknu.ac.kr

ORCID
Junhyung Lee
https://orcid.org/0000-0002-7937-7817
Seungmin Oh
https://orcid.org/0000-0001-8848-8028
Minju Kim
https://orcid.org/0000-0001-6950-0458

Competing interests
No potential conflict of interest relevant to this article was reported.

Funding sources
Not applicable.

Acknowledgements
Not applicable.

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
This article does not require IRB/IACUC approval because there are no human and animal participants.

INTRODUCTION

The modern swine industry constantly addresses its interest in promoting optimal growth and increasing the market weight of pigs. In this context, it has been found that the ideal growth of weanling pigs during the weaning period is closely related to enhanced outcomes during the growth and finishing periods [1]. The weanling pigs are subjected to various stressors through environmental changes, such as separation from sows, different forms of diet, and mixing with other groups of weanling pigs [2]. In most cases, weaning stress is considered a prominent management concern related to achieving optimal growth and inducing desirable behaviors in weanling pigs. In this regard, the weaning period is a critical phase for weanling pigs, which can have a significant impact and is strongly associated with reduced feed intake, higher incidence of diarrhea, and greater agonistic behavior during the early weaning period [3].

An enriched environment was introduced as an alternative housing system to reduce stress levels in weanling pigs induced by the weaning process, replacing the traditional barren housing system. Enriched environments enhance the welfare of livestock, which induces more instinctive behavior through different forms of housing or play object installation to enhance their optimal growth [4,5]. One relevant welfare indicator is the level of play activity, which is the natural behavior of an animal that can be a source of play and a reduction in vigilance or aggression toward the external environment [6]. Thus, supporting the play activity levels of weanling piglets could be related to reducing depression or strong negative emotions in these piglets [7]. Despite this, observing exploration or foraging behavior in weanling piglets in a conventional environment is a significant challenge. They exhibit elevated concentrations of cortisol and more reciprocal agonistic behavior, such as fighting and ear-tail biting, as an aim of social dominance and the hierarchal order with another group of weanling piglets [8,9]. As a detrimental consequence of that competitive activity, weanling piglets may also show a greater body weight (BW) variation within a group, and previous studies demonstrated that BW variation is connected to the growth performance of weanling piglets after weaning under commercial environments. Furthermore, a nonuniform growth rate can reduce the efficiency of the production cycle because of higher BW variation in weanling piglets [10-11]. This study aimed to address the impact of environmental enrichment on growth, BW uniformity, incidence of diarrhea, behavior, skin lesions, and salivary and hair cortisol levels in piglets after weaning.

MATERIALS AND METHODS

Test animals and experimental design

A total of 360 weaning pigs (Landrace × Yorkshire × Duroc [LYD]: average initial BW 6.56 ± 0.17 kg) were randomly allotted to one of the three treatments based on initial BW. A completely randomized design was used in this study. There were ten pigs per pen, with six replicates per treatment. The experimental treatments were the control, EE-1 (inclusion of play object until one week after weaning), EE-2 (inclusion of play object until two weeks after weaning), and EE-4 (inclusion of play object until four weeks after weaning). For environmental enrichment, the play object was anchored to the floor near a self-feeder (spring play object; Taewoo Livestock, Seoungju, Korea). Experimental diets were provided using commercial feed products. The experimental phases were phase 1 (d 0–14 post weaning) and phase 2 (d 15–28 post weaning). All pens contained a self-feeder and nipple drinker to provide ad libitum to feed and water.

Growth performance

The amount of feed supplemented was measured throughout the experimental period to calculate the 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: d 14, phase 2: d 28, and overall: d 0–28 after weaning).

Body weight uniformity

Coefficient of variation (CV) of BW was calculated at the end of each phase (phase 1: d 14, phase 2: d 28) as the CV by dividing the individual BW standard deviation by the mean BW.

Incidence of diarrhea

The incidence of diarrhea was measured three times (on d 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 [12].

Behavior observations

Piglet behavior was recorded at the end of each phase (d 14 and 28) by installing cameras (FIX Extreme Action Camera, Wuhan Tao Cheng Network Technology, Hubei, 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: d 14, phase 2: d 28) after weaning and included an 8 h observation period (10:00–18:00). Each behavior was evaluated for 8 h using the video footage, and the number of behavioral observations was shown as the number per hour [13]. The criteria for analyzing the behavior traits are shown in Table 1.

Skin lesion scoring

Evaluation of lesions on the body (ear, front, middle, hindquarters, and legs) or tail was conducted by inspecting the two sides of experimental weaning pigs at the end of each phase (d 14 and 28) after weaning [14].

Salivary and hair cortisol concentrations

Saliva and hair samples were prepared and harvested at the end of phase 2 (d 28 after weaning). Medical cotton was attached to the fence of each experimental pen with string to collect saliva

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
Aggression	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

https://doi.org/10.5187/jast.2023.e128

samples. After weaning, the pigs chewed the medical cotton for 5 to 10 min until fully wet. The cotton was retrieved using the string, and the ear tag of the pig was recorded during the chewing process. Supernatant of the saliva sample (~7–8 mL) was prepared by centrifugation at 3,000×g at 4℃ for 10 min and was stored at −20℃ until analysis. Salivary cortisol concentration was measured using a commercial ELISA kit (ADI-90-071, Enzo Life Sciences, Farmingdale, NY, USA) [15]. Freshly grown hair from individual weaning pigs was collected and used for the analysis of 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 EML plastic tube containing steel pellets and a bead beater (tacoTMPrep, 50/60 Hz 2A, GeneReach Taichung, Taichung, Taiwan). Hair cortisol was extracted using methanol after crushing at Biotechnology Corp., Taiwan. A cortisol ELISA kit (ADI-900-071, Enzo Life Sciences) was used to determine the cortisol concentrations in the extracted sample [16].

Statistical Analyses

Data generated in the present study were subjected to a statistical analysis system (SAS Institute, Cary, NC, USA) using the general linear model procedure in a completely randomized design. 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 on growth performance are summarized in Table 2. In phase 1, pigs raised in EE-2 and EE-4 had greater ADG ($p = 0.002$) than those raised in the control. In phase 2, pigs raised in EE-4 had greater ADG ($p = 0.039$) than pigs raised in the control. Overall, pigs from EE-2 and EE-4 showed a greater ADG ($p = 0.006$) than the control. In phase 1, the ADFI of pigs in the EE-2 was higher ($p = 0.016$) than the control. In phase 2, pigs treated with EE-2 showed higher ADFI ($p = 0.030$) than pigs reared in the control. Overall, pigs raised in the EE-4 treatment had a greater ADFI ($p = 0.014$) than the control. However, G/

Table 2. Effects of environmental enrichment on growth performance in weanling pigs

Item	Control	EE-1	EE-2	EE-4	SEM	*p*-value
Phase 1 (d 0–14)						
ADG (kg)	288.10^{b}	302.02^{ab}	323.69^{a}	316.31^{a}	8.58	0.002
ADFI (kg)	417.13^{b}	429.92^{ab}	460.26^{a}	447.75^{ab}	12.84	0.016
G/F	0.69	0.70	0.70	0.71	0.01	0.168
Phase 2 (d 15–28)						
ADG (kg)	406.79^{b}	409.88^{ab}	414.40^{ab}	433.21^{a}	9.14	0.039
ADFI (kg)	617.08^{b}	620.33^{ab}	626.43^{ab}	654.04^{a}	12.43	0.030
G/F	0.66	0.66	0.66	0.66	0.01	0.892
Overall (d 0–28)						
ADG (kg)	347.44^{b}	355.95^{ab}	369.05^{a}	374.76^{a}	7.36	0.006
ADFI (kg)	517.10^{b}	525.13^{ab}	543.34^{ab}	550.89^{a}	10.36	0.014
G/F	0.67	0.68	0.68	0.68	0.01	0.212

^{a,b}Means with different superscripts in the same row differ significantly ($p < 0.05$).

EE-1, inclusion of play object until one week after weaning; EE-2, inclusion of play object until two weeks after weaning; EE-4, inclusion of play object until four weeks after weaning; ADG, average daily gain; ADFI, average daily feed intake; G/F, gain to feed ratio.

F did not exhibit any significant differences in phase 1, phase 2, or the overall period. The effects of environmental enrichment on group CV are presented in Table 3. Pigs raised in EE-2 and EE-4 had lower uniformity than the pigs raised in the control group in phases 1 (p = 0.006) and 2 (p < 0.001), and overall (p < 0.001).

Diarrhea incidence

The effects of environmental enrichment on the incidence of diarrhea are shown in Table 4. The incidence of diarrhea was lower (p < 0.001) in pigs raised in EE-2 and EE-4 than the control treatment in early phase 1 (the first week after weaning). However, environmental enrichment did not exhibit any significant differences among the treatments at the end of phase 1 and phase 2.

Behavior traits

The effects of environmental enrichment on behavioral traits are shown in Table 5. Pigs raised in EE-2 and EE-4 exhibited lower biting (p = 0.018), tail biting (p = 0.001), and ear biting (p = 0.016). However, there were no significant differences in behavioral traits in phase 2.

Skin lesion score

The effects of environmental enrichment on skin lesion scores are shown in Table 6. Pigs raised in EE-4 had lower skin lesion scores (p = 0.015) than those raised in the control. However, there was no significant difference between the treatments in phase 2.

Salivary and hair cortisol levels

The effects of environmental enrichment on salivary and hair cortisol concentrations are shown in

Table 3. Effects of environmental enrichment on uniformity in weanling pigs

Item	Control	EE-1	EE-2	EE-4	SEM	p-value
Phase 1 (d 14)						
CV	12.43[a]	11.77[ab]	10.86[b]	10.45[b]	0.53	0.006
Phase 2 (d 28)						
CV	13.49[a]	12.41[ab]	11.37[bc]	10.50[c]	0.58	< 0.001
Overall (d 28)						
CV	13.49[a]	12.41[ab]	11.37[bc]	10.50[c]	0.58	< 0.001

[a–c]Means with different superscripts in the same row differ significantly (p < 0.05).

EE-1, inclusion of play object until one week after weaning; EE-2, inclusion of play object until two weeks after weaning; EE-4, inclusion of play object until four weeks after weaning; CV, coefficient of variation.

Table 4. Effects of environmental enrichment on the incidence of diarrhea in weanling pigs

Item	Control	EE-1	EE-2	EE-4	SEM	p-value
Phase 1 (d 7)						
Diarrhea incidence	3.77[a]	3.28[ab]	2.83[b]	2.80[b]	0.21	< 0.001
Phase 1 (d 14)						
Diarrhea incidence	2.27	2.30	2.50	2.37	0.50	0.968
Phase 2 (d 28)						
Diarrhea incidence	1.70	1.67	1.82	1.80	0.44	0.981

[a,b]Means with different superscripts in the same row differ significantly (p < 0.05).

EE-1, inclusion of play object until one week after weaning; EE-2, inclusion of play object until two weeks after weaning; EE-4, inclusion of play object until four weeks after weaning.

 https://doi.org/10.5187/jast.2023.e128

Table 5. Effects of environmental enrichment on behaviour in weanling pigs

Item	Control	EE-1	EE-2	EE-4	SEM	*p*-value
Phase 1 (d 14)						
Nosing	9.56	10.19	10.00	9.27	0.46	0.221
Biting	6.48[a]	6.08[ab]	5.38[b]	5.31[b]	0.39	0.018
Mounting	0.63	0.56	0.58	0.54	0.22	0.984
Tail biting	4.17[a]	3.63[ab]	3.29[b]	3.02[b]	0.24	0.001
Ear biting	2.88[a]	2.54[ab]	2.02[b]	2.04[b]	0.28	0.016
Aggressive	2.52	2.23	1.77	1.83	0.29	0.056
Phase 2 (d 28)						
Nosing	5.04	4.96	5.23	5.27	0.45	0.880
Biting	1.31	1.10	1.17	1.25	0.33	0.924
Mounting	0.67	0.71	0.69	0.73	0.19	0.990
Tail biting	0.63	0.71	0.60	0.56	0.25	0.945
Ear biting	0.69	0.75	0.71	0.67	0.20	0.978
Aggressive	0.71	0.63	0.63	0.75	0.24	0.936

[a,b]Means with different superscripts in the same row differ significantly ($p < 0.05$).

EE-1, inclusion of play object until one week after weaning; EE-2, inclusion of play object until two weeks after weaning; EE-4, inclusion of play object until four weeks after weaning.

Table 6. Effects of environmental enrichment on skin lesion score in weanling pigs

Item	Control	EE-1	EE-2	EE-4	SEM	*p*-value
Phase 1 (d 14)						
Skin lesion score	45.40[a]	43.80[ab]	40.74[ab]	37.23[b]	2.41	0.015
Phase 2 (d 28)						
Skin lesion score	78.76	75.50	75.90	78.09	3.02	0.644

[a,b]Means with different superscripts in the same row differ significantly ($p < 0.05$).

EE-1, inclusion of play object until one week after weaning; EE-2, inclusion of play object until two weeks after weaning; EE-4, inclusion of play object until four weeks after weaning.

Table 7. Effects of enrichment on salivary and hair cortisol concentrations in weanling pigs

Item	Control	EE-1	EE-2	EE-4	SEM	p-value
Saliva						
Cortisol	4.79	4.45	4.30	4.07	0.51	0.564
Hair						
Cortisol	76.07[a]	75.10[ab]	72.05[ab]	68.97[b]	2.40	0.032

[a,b]Means with different superscripts in the same row differ significantly ($p < 0.05$).

EE-1, inclusion of play object until one week after weaning; EE-2, inclusion of play object until two weeks after weaning; EE-4, inclusion of play object until four weeks after weaning.

Table 7. Pigs reared in EE-4 had lower ($p = 0.032$) hair cortisol concentrations than pigs reared in the control. However, there was no significant difference in the cortisol levels of the saliva among the treatments.

DiSCUSSION

Growth performance and uniformity

Concerns regarding animals' welfare and growth have led to an increased focus on stress management. In particular, the agonistic behavior induced by the early weaning period is related to growth retardation during the growing and finishing phases of pigs [17]. Environmental enrichment as a play object installation resulted in an increase in growth performance, that is, ADG and ADFI, compared to the control group during the current study, although the enrichment effect on growth was the highest in the EE-2 group. This may result in different responses of the piglets to the object, and interest in the enriched environment appears to diminish with age during the weaning phase [18,19]. Similarly, the growth of weaning pigs raised in an enriched environment was higher than that of those raised in a commercial barren environment; however, the enriched environment did not affect growth performance until 20 weeks of age [20]. As a crucial period, the weaning process is strongly connected to the growth of weaning pigs, but it is also linked to the timing of the final market weight and profitability of the producer. Accordingly, the management CV of BW just before or immediately after weaning may be used as a critical indicator to predict the final outcome of weaning pigs [21]. The observed CV of BW in the present study was approximately 10%, and the EE-4 group had the lowest CV of BW compared to the other groups, including the control group. Furthermore, enriched groups had slightly better BW evenness within a group; however, various factors may contribute to this phenomenon. Therefore, further studies are warranted.

Incidence of diarrhea

As a common condition, post-weaning diarrhea is a well-known disease that is induced by weaning stress in weaned piglets worldwide. Since the start of the weaning process, weaned pigs quickly adapt to various environmental changes, such as different forms of diet and mixing with other pigs. Furthermore, as a result of these changes, weaned pigs exhibit abnormal symptoms, such as lower feed intake and a higher incidence of diarrhea, which are closely associated with the retarded growth of pigs [22–24]. In the present study, pigs raised in the EE-4 group showed the lowest incidence of diarrhea in the early post-weaning period (d 7 post-weaning), although they had a higher incidence of diarrhea than those in the rest of the weaning period. Few studies have examined the incidence of diarrhea in weaned pigs in environments enriched with play objects to demonstrate the precise relationship between environmental enrichment and the incidence of diarrhea. However, few studies have reported that feed intake and CV of BW can be used as indicators to measure the proper growth of weaned pigs [25]. Weaning stress, which is strongly associated with an increase in the inflammatory response in the gastrointestinal tract, is one of the various stressors contributing to the incidence of diarrhea in weaned pigs [26]. In this regard, the results of the present study, which are closely related to previous results showing improved ADG, ADFI, and CV of BW conditions in an enriched environment, may contribute to another positive effect of enriched environments in weaning pigs.

Behavioral traits

The behavior of animals is considered an essential factor in their growth and welfare, and animals must be exposed to objects that are sufficient to maintain their behavior [27]. It is well known that agonistic behavior during the early post-weaning period, which is common in commercial barren environments, is directly related to poor feed intake and growth in weaning pigs. In the present study, pigs exhibited reduced agonistic behavior, including torso, leg, ear, and tail biting, during the early post-weaning period (d 14). The results of the present study are consistent with previous studies showing that an enriched environment led to elevated play behaviors [28,29] or more proactive and explorative behavior in weaning pigs [28,30,31]. Enriched housed pigs have been shown to spend more time playing before weaning and up to 7 weeks after weaning, and these behaviors are strongly related to less agonistic behavior [28,29]. Moreover, these results were associated with increased weight gain and adaptability to the new environment of weaning pigs,

 https://doi.org/10.5187/jast.2023.e128

and exposure to enriched housing could impact later life behavior and welfare [32]. Therefore, it can be inferred from these results that positive behavioral changes in weaning pigs in an enriched environment are a better outcome in terms of the growth and welfare of weaning pigs.

Skin lesion score

The consequences of the weaning process, which is the phased formation of reciprocal dominance relationships through agonistic behavior, are well-known phenomena [33]. Most weaned pigs show this aggressive tendency by fighting or biting other pigs from different groups. This behavior manifests as an accumulation of skin lesions throughout the body, legs, ears, and tail [34,35]. The results of the present study showed that pigs raised under exposure to the enriched environment had reduced skin lesion scores compared to the control group, and there was a trend towards a decrease in the number of skin lesions as exposure time to the enriched environment increased. These results are linked to those of previous studies that observed that over 20% lowered oral activities related to skin lesions in pigs reared in enriched environments [36], and the response to enriched environments is correlated with the age of the pigs [37]. These facts led us to conclude that access to an enriched environment contributed to a reduced skin lesion score, which is consistent with the diminished reciprocal agonistic behavior observed in the present study.

Salivary and hair cortisol levels

When animals encounter stressful conditions, such as a shortage of environmental enrichment, they can activate the hypothalamic-pituitary-adrenal axis, which is associated with the secretion of glucocorticoid cortisol, an indicator of stress levels measured in blood, urine, saliva, and hair [38]. In the present study, the EE-4 group had lower hair cortisol concentrations during the weaning phase; however, the enriched environment did not affect salivary cortisol concentrations. These results are consistent with previous studies that have shown that barren environments adversely affect the welfare of weaned pigs and that it is connected to the increment of hair cortisol levels in pigs raised in a barren environment [20,39]. Cortisol concentration in hair is a response to chronic stress that is distinct from salivary cortisol levels, which are related to acute stress response in weaning pigs [40]. These responses indicate that they were subjected to sustained stress over weeks while growing in a non-enriched environment, similar to the present study. However, in contrast to the present study, previous studies have demonstrated increased salivary cortisol concentrations in pigs raised in barren environments [41,42]. In this context, the weaning process, including relocation or social mixing, is a stressor that can be characterized by elevated salivary cortisol levels. However, salivary cortisol levels recovered to normal ranges within 8 h, indicating that it is most likely an acute stress response [43,44]. There was a 1.47-fold increase in salivary cortisol concentration after weaning; however, this increase was reduced by 1.26-fold greater two days after weaning. This can be explained as a transient response that progressively decreases concentration [45]. Therefore, environmental enrichment conditions may be consistently more favorable for reducing stress on the growth and welfare of weaning pigs; however, further research is required to refine the appropriate assay that may influence the results.

CONCLUSION

The use of play objects for 2 or 4 weeks improved ADG and ADFI, lowered CV of BW, diarrhea incidence, agonistic behavior, skin lesion score, and hair cortisol concentration. The results showed that the use of play object for one week was not adequate. Further research is required to refine more specific periods related to providing enriched environments through additional parameters, such as the installation of different types of play objects and how this environment might also impact the growing and finishing phases.

REFERENCES

1. Hosseindoust AR, Lee SH, Kim JS, Choi YH, Kwon IK, Chae BJ. Productive performance of weanling piglets was improved by administration of a mixture of bacteriophages, targeted to control Coliforms and Clostridium spp. shedding in a challenging environment. J Anim Physiol Anim Nutr. 2017;101:e98-107. https://doi.org/10.1111/jpn.12567
2. Lee SH, Hosseindoust AR, Kim JS, Choi YH, Lee JH, Kwon IK, et al. Bacteriophages as a promising anti-pathogenic option in creep-feed for suckling piglets: targeted to control Clostridium spp. and coliforms faecal shedding. Livest Sci. 2016;191:161-4. https://doi.org/10.1016/j.livsci.2016.08.003
3. Hosseindoust AR, Lee SH, Kim JS, Choi YH, Noh HS, Lee JH, et al. Dietary bacteriophages as an alternative for zinc oxide or organic acids to control diarrhoea and improve the performance of weanling piglets. Vet Med. 2017;62:53-61. https://doi.org/10.17221/7/2016-VETMED
4. Poole TB. The nature and evolution of behavioural needs in mammals. Anim Welf. 1992;1:203-20. https://doi.org/10.1017/S0962728600015013
5. Kim KH, Hosseindoust A, Ingale SL, Lee SH, Noh HS, Choi YH, et al. Effects of gestational housing on reproductive performance and behavior of sows with different backfat thickness. Asian-Australas J Anim Sci. 2016;29:142-8. https://doi.org/10.5713/ajas.14.0973
6. Newberry RC, Wood-Gush DGM, Hall JW. Playful behaviour of piglets. Behav Processes. 1988;17:205-16. https://doi.org/10.1016/0376-6357(88)90004-6
7. Spinka M, Newberry RC, Bekoff M. Mammalian play: training for the unexpected. Q Rev Biol. 2001;76:141-68. https://doi.org/10.1086/393866
8. Fraser D, Phillips PA, Thompson BK, Tennessen T. Effect of straw on the behaviour of growing pigs. Appl Anim Behav Sci. 1991;30:307-18. https://doi.org/10.1016/0168-1591(91)90135-K
9. Stricklin WR, Mench JA. Social organization. Vet Clin North Am Food Anim Pract. 1987;3:307-22. https://doi.org/10.1016/s0749-0720(15)31154-3
10. Choi YH, Hosseindoust A, Kim MJ, Kim KY, Lee JH, Kim YH, et al. Additional feeding during late gestation improves initial litter weight of lactating sows exposed to high ambient temperature. Rev Bras Zootec. 2019;48:e20180028. https://doi.org/10.1590/rbz4820180028
11. López-Vergé S, Gasa J, Farré M, Coma J, Bonet J, Solà-Oriol D. Potential risk factors related to pig body weight variability from birth to slaughter in commercial conditions. Transl Anim Sci. 2018;2:383-95. https://doi.org/10.1093/tas/txy082
12. Kim TG, Kim MJ, Lee JH, Moturi J, Ha SH, Tajudeen H, et al. Supplementation of nano-zinc in lower doses as an alternative to pharmacological doses of ZnO in weanling pigs. J Anim Sci Technol. 2022;64:70-83. https://doi.org/10.5187/jast.2022.e2
13. Oh S, Hosseindoust A, Ha S, Moturi J, Mun JY, Tajudeen H, et al. Metabolic responses of dietary fiber during heat stress: effects on reproductive performance and stress level of gestating sows. Metabolites. 2022;12:280. https://doi.org/10.3390/metabo12040280
14. Fu L, Li H, Liang T, Zhou B, Chu Q, Schinckel AP, et al. Stocking density affects welfare indicators of growing pigs of different group sizes after regrouping. Appl Anim Behav Sci. 2016;174:42-50. https://doi.org/10.1016/j.applanim.2015.10.002
15. Nejad JG, Ataallahi M, Park KH. Methodological validation of measuring Hanwoo hair cortisol concentration using bead beater and surgical scissors. J Anim Sci Technol. 2019;61:41-

 https://doi.org/10.5187/jast.2023.e128

6. https://doi.org/10.5187/jast.2019.61.1.41
16. Moturi J, Hosseindoust A, Tajudeen H, Mun JY, Ha SH, Kim JS. Influence of dietary fiber intake and soluble to insoluble fiber ratio on reproductive performance of sows during late gestation under hot climatic conditions. Sci Rep. 2022;12:19749. https://doi.org/10.1038/s41598-022-23811-8
17. Campbell JM, Crenshaw JD, Polo J. The biological stress of early weaned piglets. J Anim Sci Biotechnol. 2013;4:19. https://doi.org/10.1186/2049-1891-4-19
18. van de Weerd HA, Day JEL. A review of environmental enrichment for pigs housed in intensive housing systems. Appl Anim Behav Sci. 2009;116:1-20. https://doi.org/10.1016/j.applanim.2008.08.001
19. Docking CM, Van de Weerd HA, Day JEL, Edwards SA. The influence of age on the use of potential enrichment objects and synchronisation of behaviour of pigs. Appl Anim Behav Sci. 2008;110:244-57. https://doi.org/10.1016/j.applanim.2007.05.004
20. Beattie VE, Walker N, Sneddon IA. Effects of environmental enrichment on behaviour and productivity of growing pigs. Anim Welf. 1995;4:207-20. https://doi.org/10.1017/S0962728600017802
21. Francis DA, Christison GI, Cymbaluk NF. Uniform or heterogeneous weight groups as factors in mixing weanling pigs. Can J Anim Sci. 1996;76:171-6. https://doi.org/10.4141/cjas96-026
22. Lee JJ, Kyoung H, Cho JH, Choe J, Kim Y, Liu Y, et al. Dietary yeast cell wall improves growth performance and prevents of diarrhea of weaned pigs by enhancing gut health and anti-inflammatory immune responses. Animals. 2021;11:2269. https://doi.org/10.3390/ani11082269
23. Choi Y, Hosseindoust A, Ha SH, Kim J, Min Y, Jeong Y, et al. Effects of dietary supplementation of bacteriophage cocktail on health status of weanling pigs in a non-sanitary environment. J Anim Sci Biotechnol. 2023;14:64. https://doi.org/10.1186/s40104-023-00869-6
24. Lee J, Hosseindoust A, Kim M, Kim K, Choi Y, Moturi J, et al. Effects of hot melt extrusion processed nano-iron on growth performance, blood composition, and iron bioavailability in weanling pigs. J Anim Sci Technol. 2019;61:216-24. https://doi.org/10.5187/jast.2019.61.4.216
25. Wensley MR, Tokach MD, Woodworth JC, Goodband RD, Gebhardt JT, DeRouchey JM, et al. Maintaining continuity of nutrient intake after weaning. II. Review of post-weaning strategies. Transl Anim Sci. 2021;5:txab022. https://doi.org/10.1093/tas/txab022
26. McCracken BA, Spurlock ME, Roos MA, Zuckermann FA, Gaskins HR. Weaning anorexia may contribute to local inflammation in the piglet small intestine. J Nutr. 1999;129:613-9. https://doi.org/10.1093/jn/129.3.613
27. Tajudeen H, Moturi J, Hosseindoust A, Ha S, Mun J, Choi Y, et al. Effects of various cooling methods and drinking water temperatures on reproductive performance and behavior in heat stressed sows. J Anim Sci Technol. 2022;64:782-91. https://doi.org/10.5187/jast.2022.e33
28. Bolhuis JE, Schouten WGP, Schrama JW, Wiegant VM. Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl Anim Behav Sci. 2005;93:213-28. https://doi.org/10.1016/j.applanim.2005.01.006
29. Bolhuis JE, Schouten WGP, Schrama JW, Wiegant VM. Effects of rearing and housing environment on behaviour and performance of pigs with different coping characteristics. Appl Anim Behav Sci. 2006;101:68-85. https://doi.org/10.1016/j.applanim.2006.01.001
30. Beattie VE, O'Connell NE, Moss BW. Influence of environmental enrichment on the behaviour, performance and meat quality of domestic pigs. Livest Prod Sci. 2000;65:71-9. https://doi.org/10.1016/S0301-6226(99)00179-7
31. Averós X, Brossard L, Dourmad JY, de Greef KH, Edge HL, Edwards SA, et al. A meta-

analysis of the combined effect of housing and environmental enrichment characteristics on the behaviour and performance of pigs. Appl Anim Behav Sci. 2010;127:73-85. https://doi.org/10.1016/j.applanim.2010.09.010

32. Luo L, Reimert I, Middelkoop A, Kemp B, Bolhuis JE. Effects of early and current environmental enrichment on behavior and growth in pigs. Front Vet Sci. 2020;7:268. https://doi.org/10.3389/fvets.2020.00268
33. Mendl M. The social behaviour of non-lactating cows and its implications for managing sow aggression. Pig Vet J. 1994;34:9-20.
34. McGlone JJ. A quantitative ethogram of aggressive and submissive behaviors in recently regrouped pigs. J Anim Sci. 1985;61:556-66. https://doi.org/10.2527/jas1985.613556x
35. O'Connell NE, Beattie VE. Influence of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. Anim Welf. 1999;8:269-79. https://doi.org/10.1017/S0962728600021758
36. Manciocco A, Sensi M, Moscati L, Battistacci L, Laviola G, Brambilla G, et al. Longitudinal effects of environmental enrichment on behaviour and physiology of pigs reared on an intensive-stock farm. Ital J Anim Sci. 2011;10:e52. https://doi.org/10.4081/ijas.2011.e52
37. Hill JD, McGlone JJ, Fullwood SD, Miller MF. Environmental enrichment influences on pig behavior, performance and meat quality. Appl Anim Behav Sci. 1998;57:51-68. https://doi.org/10.1016/S0168-1591(97)00116-0
38. Ghassemi Nejad J, Ghaffari MH, Ataallahi M, Jo JH, Lee HG. Stress concepts and applications in various matrices with a focus on hair cortisol and analytical methods. Animals. 2022;12:3096. https://doi.org/10.3390/ani12223096
39. van der Staay FJ, van Zutphen JA, de Ridder MM, Nordquist RE. Effects of environmental enrichment on decision-making behavior in pigs. Appl Anim Behav Sci. 2017;194:14-23. https://doi.org/10.1016/j.applanim.2017.05.006
40. Short SJ, Stalder T, Marceau K, Entringer S, Moog NK, Shirtcliff EA, et al. Correspondence between hair cortisol concentrations and 30-day integrated daily salivary and weekly urinary cortisol measures. Psychoneuroendocrinology. 2016;71:12-8. https://doi.org/10.1016/j.psyneuen.2016.05.007
41. Grimberg-Henrici CGE, Vermaak P, Elizabeth Bolhuis J, Nordquist RE, van der Staay FJ. Effects of environmental enrichment on cognitive performance of pigs in a spatial holeboard discrimination task. Anim Cogn. 2016;19:271-83. https://doi.org/10.1007/s10071-015-0932-7
42. de Jong IC, Prelle IT, van de Burgwal JA, Lambooij E, Korte SM, Blokhuis HJ, et al. Effects of environmental enrichment on behavioral responses to novelty, learning, and memory, and the circadian rhythm in cortisol in growing pigs. Physiol Behav. 2000;68:571-8. https://doi.org/10.1016/S0031-9384(99)00212-7
43. Blecha F, Pollmann DS, Nichols DA. Immunologic reactions of pigs regrouped at or near weaning. Am J Vet Res. 1985;46:1934-7.
44. Nejad JG, Ghaseminezhad M, Sung KI, Hoseinzadeh F, Cabibi JBA, Lee J. A cortisol study; facial hair and nails. J Steroids Horm Sci. 2016;7:177. https://doi.org/10.4172/2157-7536.1000177
45. Escribano D, Ko HL, Chong Q, Llonch L, Manteca X, Llonch P. Salivary biomarkers to monitor stress due to aggression after weaning in piglets. Res Vet Sci. 2019;123:178-83. https://doi.org/10.1016/j.rvsc.2019.01.014

 https://doi.org/10.5187/jast.2023.e128