RESEARCH ARTICLE

J Anim Sci Technol 2022;64(3):574-587
https://doi.org/10.5187/jast.2022.e36

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

Effect of alternative farrowing pens with temporary crating on the performance of lactating sows and their litters

Si Nae Cheon[1,2], So Hee Jeong[1], Guem Zoo Yoo[1,3], Se Jin Lim[1], Chan Ho Kim[1], Gul Won Jang[1] and Jung Hwan Jeon[1]*

[1]*Animal Welfare Research Team, National Institute of Animal Science, Rural Development Agriculture, Wanju 55365, Korea*
[2]*Department of Animal Science, Gyeongsang National University, Jinju 52828, Korea*
[3]*Department of Animal Science, Jeonbuk National University, Jeonju 54896, Korea*

Check for updates

Received: Mar 23, 2022
Revised: Apr 29, 2022
Accepted: May 9, 2022

***Corresponding author**
Jung Hwan Jeon
Animal Welfare Research Team, National Institute of Animal Science, Rural Development Agriculture, Wanju 55365, Korea.
Tel: +82-63-238-7051
E-mail: jeon75@korea.kr

ORCID
Si Nae Cheon
https://orcid.org/0000-0003-1865-8970
So Hee Jeong
https://orcid.org/0000-0001-8325-162X
Guem Zoo Yoo
https://orcid.org/0000-0003-0997-4621
Se Jin Lim
https://orcid.org/0000-0002-0465-1666
Chan Ho Kim
https://orcid.org/0000-0003-2121-5249
Gul Won Jang
https://orcid.org/0000-0003-4258-6022
Jung Hwan Jeon
https://orcid.org/0000-0001-9725-547X

Abstract

This study was performed to development the alternative farrowing pen (AFP) and to investigate performance and behavior of lactating sows and their litter. A total of 64 multiparous sows were randomly divided into two groups and were allocated to farrowing crates (FCs) and AFPs. The AFPs contained a crate and support bars that could be folded to provide the sows with extra space on day 5 postpartum. Behavior was recorded by charge-coupled device cameras and digital video recorders, and the data were scanned every 2 min to obtain an instantaneous behavioral sample. Farrowing systems did not affect feed intake, back-fat thickness, litter size and piglet weight at birth and weaning ($p > 0.05$). In addition, there were no differences in the number of crushed piglets between the two farrowing systems ($p > 0.05$). However, the weaning-to-estrus interval was shorter in the sows of the AFPs than in thous of the FCs ($p < 0.05$). The sows spent most of their time lying down during the lactating period, at about 80% lateral recumbency and 10%–15% ventral recumbency. The only significant differences were in the feeding and drinking behavior between sows in the two farrowing systems ($p < 0.05$). The FC sows displayed more feeding and drinking behavior than the AFP sows, especially in the late lactating period ($p < 0.05$). Piglets in the FCs tended to spend more time walking than piglets in the AFPs ($p < 0.05$), whereas there were no differences in suckling and lying behavior between piglets in the two farrowing systems ($p > 0.05$). It is concluded that the AFPs with temporary crating until day 4 postpartum did not negatively affect performance and crushed piglet compared with the FCs. It also may improve animal welfare by allowing sows to move and turn around during the lactating period. Further research is needed to find suitable housing designs to enhance productivity and animal welfare.

Keywords: Alternative farrowing pen, Animal welfare, Lactating sows, Piglets, Temporary crating

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

Funding sources
This work was carried out with the support of "Cooperative Research Program for Agriculture Science and Technology Development (Project No.PJ01623002)," Rural Development Administration, Korea.

Acknowledgements
This study was supported by 2022 collaborative research program between university and Rural Development Administration, Korea.

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

Authors' contributions
Conceptualization: Jeon JH.
Data curation: Cheon SN, Jeon JH.
Formal analysis: Cheon SN, Jeon JH.
Methodology: Cheon SN, Jeon JH.
Software: Cheon SN, Jeon JH.
Validation: Cheon SN, Jeon JH.
Investigation: Cheon SN, Jeong SH, Yoo GZ, Lim SJ, Kim CH, Jang GW, Jeon JH.
Writing - original draft: Cheon SN.
Writing - review & editing: Cheon SN, Jeong SH, Yoo GZ, Lim SJ, Kim CH, Jang GW , Jeon JH.

Ethics approval and consent to participate
All experimental procedures were reviewed and approved by the Institutional Animal Care and Use Committee of the National Institute of Animal Science, Korea (NIAS-2021-527).

INTRODUCTION

Farrowing crates (FCs) are widely used in the swine industry to reduce the number of crushed piglets during the lactation period. However, FCs raises serious welfare concerns that they restrict the sow's physical movement and normal behavior, resulting in frustration and stress [1–4]. Recently, due to increasing public pressure to abolish FCs, loose farrowing systems (LFSs) have been introduced to improve sow and piglet welfare via different design features [5–7], compared to FCs such as reduced confinement and a greater amount of space. Sows in LFSs allow sows to turn around and interact more with their litters through providing more space. However, the important economic and welfare problem of pre-weaning piglet mortality in LFSs remains. Crushing is one of the major causes of pre-weaning piglet mortality, alongside starvation [8–12]. Piglets are most vulnerable until the first 4 days after birth, with more than 50%–80% of deaths occurring during this period [12–15]. Over the years, many researchers have endeavored to reduce the number of crushed piglets by sows by installing support devices, such as anti-crushing bars in LFSs [16,17]. Several studies have found no significant impact on piglet crushing mortality in LFSs because the sows lie down and roll over in the open area [18,19]. Attempts have been made to improve animal welfare for lactating sows and their litters, including circular, ellipsoid, rectangular, hinged crates and temporary crating systems. Nevertheless, these facilities are hard to install and manage in industrial swine farms.

Therefore, this study was performed to development the alternative farrowing pen (AFP) and to investigate the performance and behavior of lactating sows and their litter.

MATERIALS AND METHODS

Animals and management

The experiment was conducted on a commercial farm in Korea under mild weather (from October to November). A total of 64 multiparous sows (Yorkshire × Landrace) were randomly divided into two groups and were allocated to FCs and AFPs on day 7 prepartum from the expected farrowing day. All sows were familiar with FCs. On day 5 postpartum, the crates were opened to provide the sows with extra space in AFPs. All sows were fed a standard ration of commercial concentrate twice a day at 0700 and 1600 h (Table 1) and had *ad libitum* access to water. The management routine and handling of sows and piglets were performed based on the normal practices of the farm. The air temperature varied from 7.4 ± 3.4℃ to 23.0 ± 3.9℃, and the relative humidity was 66.7 ± 10.1%. An infrared lamp (250 W) was installed above the creep area, and it was turned on when the farrowing room temperature was below about 29°C during the 5 days postpartum. Ventilation was automatically controlled by fans. Some piglets were cross-fostered immediately after parturition so pens or crates would contain no fewer than nine and no more than twelve piglets.

Housing design

Figs. 1 and 2 show photographs and schematics of the farrowing pens with the crate closed (A) and opened (B). AFPs (210 × 180 cm) contained a crate (210 × 65 cm) and support bars to prevent the piglets from being crushed by the sows. These bars were flexible and could be easily folded to open the crates and provide the sows with more space (210 × 165 cm) than in the previous systems equipped with the swing-side crates. Thus, the sows could not only turn around but also move freely. Drinkers were located inside the feed trough at the front of the crates. All floors were slatted with triangular steel bars, and no nesting materials were supplied.

Table 1. Composition of diets fed to lactating sows (%)

Ingredient	Lactation
Corn	52.39
Soybean meal	29.00
Wheat	7.83
Wheat barn	2.00
Tallow	5.00
Lysine (95%)	0.20
Methionine (50%)	0.05
Limestone	0.83
Tricalcium phosphate	1.90
Salt	0.30
Vitamin-mineral mix[1)]	0.40
Antibiotics	0.10
Total	100.00
Chemical composition	
ME (kcal/kg)	3,386.00
Protein	18.60
Lysine	1.19
Methionine	0.31
Calcium	0.90
Phosphorus	0.73

[1)]Composition per kg of mix: 2,750,000 IU vitamin A, 220,000 IU vitamin D_3, 1,450 mg riboflavin, 11,000 mg d-pantothenic acid, 11,000 mg niacin, 110,000 mg choline, 11 mg vitamin B_{12}, 1,100 mg menadione, 2.2 g ethoxyquin, 11,000 IU vitamin E; Contained 20% Zn, 10% Fe, 5.5% Mn, 1.1% Cu, 0.15% I.

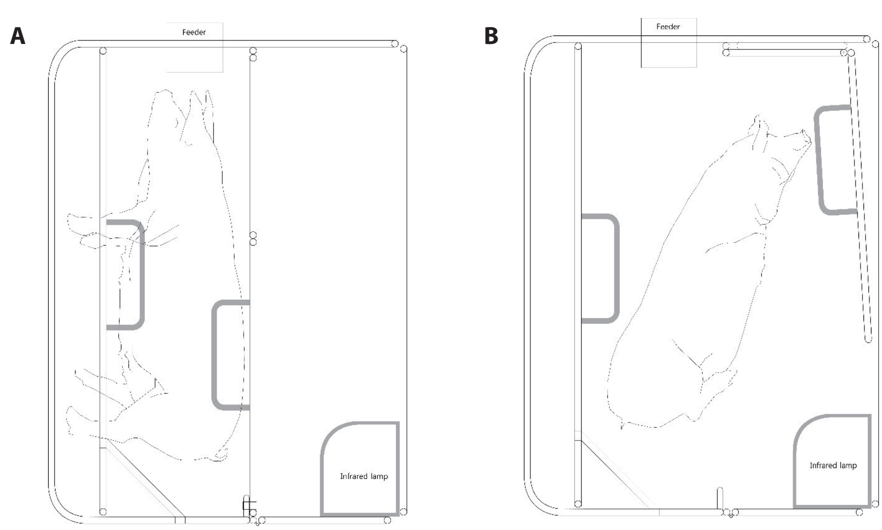

Fig. 1. Schematics of the alternative farrowing pen. (A) closed the crate (installed support bar), (B) opened the crate (removed support bar).

 https://doi.org/10.5187/jast.2022.e36

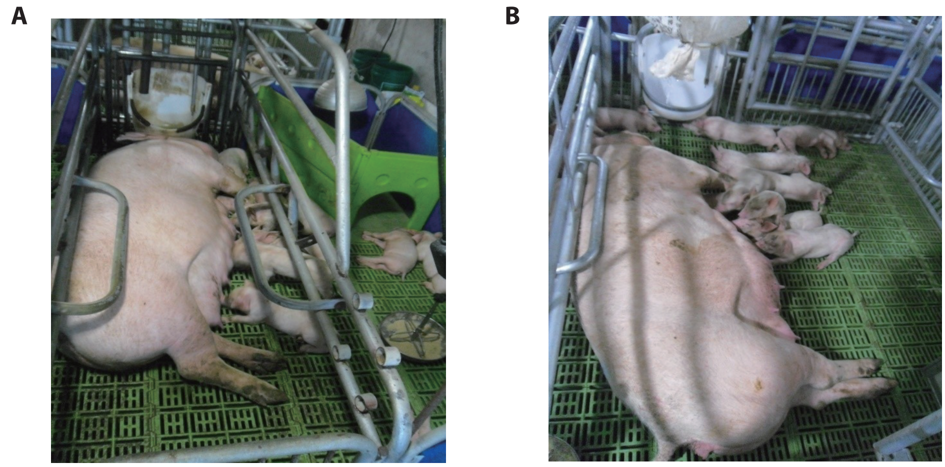

Fig. 2. Photographs of the alternative farrowing pen. (A) closed the crate (installed support bar), (B) opened the crate (removed support bar).

Performance

Leftover feed was removed every morning before new feed was offered. Feed intake was determined as the difference between the allowance and leftover feed collected the next morning. The back-fat thickness was measured ultrasonically (SSD-500V, Aloka, Wallingford, CT, USA) on each sow before farrowing and at weaning at the last rib and 65 mm from the dorsal midline [20,21]. The weights of suckling piglets were measured on day 1 and 21. A veterinarian monitored the deaths of piglets by crushing and disease through daily inspections, and the number of crushed piglets was recorded every day. Estrus checks for all sows were conducted twice daily using intact boars from 3 days after weaning until the end of estrus. The occurrence of estrus was defined by the standing reflex in front of a boar and the reddening and swelling of the vulva. Litter weight and litter size were recorded on the day of birth after cross-fostering and on the day of weaning.

Behavioral observations

Six multiparous sows (FCs: 3, AFPs: 3) and their litters were recorded during a 24-h period until 21 days postpartum using invisible LED lamps (950-nm wavelength), charge-coupled device cameras, and digital video recorders. The data were scanned every 2 min to obtain an instantaneous behavioral sample. The mutually exclusive behavioral categories that were recorded are shown in Table 2. One observer recorded all of the behavioral observations. Sows and piglets were not observed while staff performed husbandry tasks (vaccinations, fostering, etc.) throughout the study.

Statistical analysis

Parity, feed intake, back-fat thickness, weaning-to-estrus interval, litter size, birth weight, and weaning weight were statistically analyzed using the SAS GLM procedure (SAS Inst., Cary, NC, USA). These data were approximately normal and were thus analyzed without transformation. Chi-squared analysis [22] was used to determine significant differences in the crushing of suckling piglets by sows.

The number of times the animals engaged in each designated behavioral category each observation day was counted. These numbers were then converted into percentages. The data were approximately normal and were thus analyzed without transformation. The paired Student's *t*-test was used to compare the behaviors of sows and piglets reared in FCs and AFPs.

Table 2. The mutually exclusive behavioral categories used for behavioral observation

Behavior	Definition
Sow	
Lateral recumbency	Lying on side with one shoulder completely touching the ground, which included nursing
Ventral recumbency	Lying on udder with neither shoulder touching the ground
Sitting	Partly erect on extended front legs with the caudal end of body contacting the floor
Standing	Upright with all four feet on the ground
Feeding and drinking	Lowering head into the feeder and Touching the nipple water drinker with snout
Piglet	
Lying	Combined category of lying laterally and lying ventrally
Walking	Relatively low speed locomotion on the ground in which propulsive force derives from the action of legs, which included standing and sitting
Suckling	Successfully switching from teat massage and slow suckling movements to the rapid, regular suckling movements indicative of milk ingestion

RESULTS AND DISCUSSION

Performance

There were no differences in feed intake, back-fat thickness, weaning-to-estrus interval, piglet birth weight, or piglet weaning weight between the FC and AFP systems ($p > 0.05$, Table 3). Feed intake affects loss in back-fat thickness [23], so the back-fat thickness is used as an objective indicator of the body condition of sows and may compromise reproductive function post weaning [24–26]. A back-fat thickness that is too low or too high has adverse effects on the reproductive efficiencies of sows [27,28]. It is also important for maintaining sow health and welfare and will impact piglets health and growth also (during gestation and lactation).

Table 3. Effects of the AFP on the performance (mean ± SD) of sows and litters

Variables	Type of farrowing system		*p*-value
	FC	AFP	
Sow			
No. of sows	32	32	
Parity	4.5 ± 2.53	4.4 ± 2.5	ns
Feed intake (kg/d)	6.39 ± 0.47	6.39 ± 0.86	ns
Backfat thickness (mm)			
Before farrowing	15.7 ± 4.5	16.5 ± 4.7	ns
At weaning	14.2 ± 3.9	14.1 ± 4.3	ns
Backfat thickness loss	−2.1 ± 3.1	−2.5 ± 3.8	ns
Weaning to estrus interval	5.1 ± 1.0[a]	4.3 ± 0.5[b]	< 0.001
Piglet			
Litter size (piglets/litter)			
At d 1 postpartum[1)]	10.1 ± 1.2	9.8 ± 0.9	ns
At weaning	9.0 ± 1.2	8.8 ± 1.5	ns
Average birth weight (kg)	1.5 ± 0.3	1.6 ± 0.3	ns
Average weaning weight (kg)	7.6 ± 1.2	8.1 ± 1.3	ns

[1)]After cross-fostering.

[a,b]Values within treatment (rows) with different superscripts differ significantly ($p < 0.05$).

AFP, alternative farrowing pen; FC, farrowing crate; ns, not significant ($p > 0.05$).

https://doi.org/10.5187/jast.2022.e36

In this study, the weaning-to-estrus interval was shorter in AFP sows (4.3 ± 0.5 days) than in FC sows (5.1 ± 1.0 days) ($p < 0.05$). The weaning-to-estrus interval is affected by a variety of factors, such as lactation length, parity, and litter size [29–33]. Stevenson et al. [34] and McGlone et al. [35] reported that a supplemental photoperiod during the lactating period reduced the weaning-to-estrus interval. According to Prunier et al. [36], a high ambient temperature delays the weaning-to-estrus interval due to nutritional deficiency. These factors were controlled for all groups in this experiment, so it can be suggested that AFPs did not affect the weaning-to-estrus interval. AFPs may affect sows' stress reduction because they allow sows to move more freely.

Sow milk yield is affected by the piglet body weight, litter size, and dietary intake [37,38]. According to Noblet and Etienne [39], milk nutrient production during lactation is closely related to piglet weight gain and body weight. In particular, sow milk production affects suckling piglet growth [40], and there is a strong positive relationship between weaning weight and growth post-weaning [41]. Sow milk yield was not measured in this study, but we assumed that sows did not differ in milk yield because there was no difference in average birth weight or weaning weight between FC and AFP piglets.

The total number of crushed piglets did not differ between FC and AFP piglets (Fig. 3, $p > 0.05$), showing similar results to Condous et al. [42]. Sows normally spent most of their time lying on their sides in the first 24 h postpartum, after which they made more posture changes, which can lead to a greater risk of crushing [43–45]. Most crushing deaths occur when sows lie down from standing or roll over [46]. The effect of temporary crating in LFSs on piglet mortality has been investigated in several studies. Moustsen et al. [12] demonstrated that crating sows for 4 days postpartum was sufficient to reduce piglet mortality, whereas Goumon et al. [47] suggested that sows that were temporarily crated until day 3 or 7 postpartum had similar piglet mortality to those in FCs. Other studies have reported lower mortality in LFSs or no significant differences compared with FCs [48–50]. FCs result in high piglet mortality for other reasons, although there were fewer crushed piglets in FCs than in LFSs [48]. In this study, we found that FCs prevented crushing death and also restricted sows' movement after 4 days postpartum.

Sow behavior

Sow behavior was compared between the two farrowing systems on day 1, 2, 3, 4, 5, 6, 7, 14, and 20

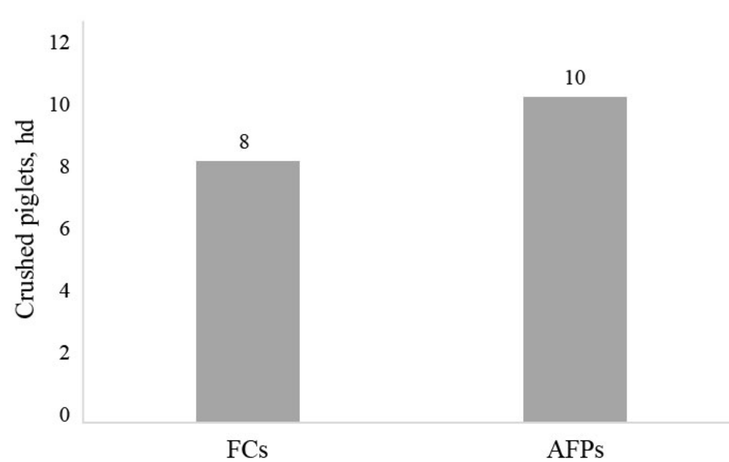

Fig. 3. The number of crushed piglets in the different farrowing systems. FC, farrowing crate; AFP, alternative farrowing pen.

Table 4. Spending time (± SD) of the sows' behaviors during the lactating period

Behavior	Housing system	Day									%	p-value
		1	2	3	4	5	6	7	14	20		
Feeding and drinking	FC	33 ± 25.3	21 ± 19.2	20 ± 13.9	61 ± 33.2	61 ± 26.6	55 ± 17.9	49 ± 13.3	85 ± 19.7[a]	95 ± 40.4	3.7	< 0.05
	AFP	30 ± 14.0	28 ± 24.2	27 ± 24.7	25 ± 11.0	36 ± 33.3	55 ± 17.9	40 ± 31.7	40 ± 5.3[b]	64 ± 2.0	2.4	
Lateral recumbency	FC	807 ± 358.1	1,305 ± 18.5	1,107 ± 136.0	1,233 ± 71.5	1,261 ± 46.6	1,302 ± 29.5	1,290 ± 69.5	1,179 ± 72.2	1,091 ± 27.3	82.1	ns
	AFP	1,108 ± 122.0	932 ± 234.2	1,092 ± 153.9	1,139 ± 247.2	1,183 ± 141.1	1,158 ± 29.5	1,213 ± 87.8	1,215 ± 90.4	1,145 ± 28.7	79.1	
Ventral recumbency	FC	361 ± 214.1	81 ± 12.1	205 ± 147.3	128 ± 74.1	97 ± 74.1	57 ± 52.7	81 ± 61.2	149 ± 104.9	209 ± 22.7	10.6	ns
	AFP	265 ± 122.3	419 ± 222.9	251 ± 63.8	226 ± 179.2	180 ± 91.8	57 ± 35.2	143 ± 37.2	163 ± 73.9	179 ± 43.9	15.3	
Sitting	FC	111 ± 105.8	8 ± 8.7	7 ± 6.4	14 ± 2.0	7 ± 3.1	15 ± 2.3	11 ± 4.6	14 ± 14.0	36 ± 16.4	1.7	ns
	AFP	23 ± 26.6	33 ± 31.9	55 ± 78.7	37 ± 59.5	18 ± 14.4	15 ± 2.3	24 ± 14.0	8 ± 10.4	28 ± 36.4	1.9	
Standing	FC	129 ± 88.5	25 ± 9.0	23 ± 15.3	5 ± 2.3	13 ± 5.0	11 ± 7.6	9 ± 12.9	13 ± 12.1	10 ± 9.2	1.9	ns
	AFP	15 ± 8.1	27 ± 30.3	15 ± 14.2	13 ± 12.2	23 ± 12.2	11 ± 18.0	20 ± 13.1	14 ± 12.0	24 ± 7.2	1.4	

[a,b]Values within treatment (columns) with different superscripts differ significantly ($p < 0.05$).

FC, farrowing crate; AFP, alternative farrowing pen; ns, not significant ($p > 0.05$).

postpartum (Table 4). There were no differences in lateral recumbency, ventral recumbency, sitting, or standing ($p > 0.05$). The farrowing system only had a significant effect on feeding ($p < 0.05$).

Although there was no significant difference in feed intake, sows housed in FCs displayed more frequent feeding behavior than those in AFPs. It may be correlated with stereotyped behavior, which is repetitive actions with no obvious purpose, such as bar biting, chewing, and excessive drinking or drinker-pressing without ingesting water [51]. Stereotyped behaviors typically occur in a barren environment as a means of coping with conflict and frustration [52–54]. In particular, drinker-pressing is seen in sows kept in stalls provided with a nipple drinker, which is one of the most interesting objects in the sows' surroundings [51]. According to Johnson et al. [55], indoor-housed sows spend more time drinking than sows housed outdoors because outdoor sows perform foraging and exploratory behavior more than indoor-housed sows. In a study by Lou and Hurnik [7], sows in rectangular crates engaged in more rooting but less drinking than sows in circular and ellipsoid crates. These results indicate that the housing environment influences stereotyped behavior, which is in agreement with the findings of Arellano et al. [56].

The sows spent most of their time lying down; almost 80% was spent in lateral recumbency and 10%–15% in ventral recumbency, corresponding to the results of other studies [55,57]. Contrary to our expectations, there was no difference in lying behavior between sows in the two farrowing systems, despite crating systems being opened on day 5 postpartum in AFPs. In addition, we did not find any differences in sitting and standing between sows in the two farrowing systems, which agreed with the results of a previous study [8]. While the duration in lateral recumbency tended to decrease from day 7 postpartum, the frequency was higher in the sows housed in AFPs than those housed in FCs. Additionally, ventral recumbency was seen more frequently in AFPs alongside an increase in standing behavior. Standing is generally associated with activity behavior, and previous studies have confirmed that sows in LFSs are more active than those in FCs [8,58]. AFP sows interact more with their environment, including their litters [59]. This is important for enhancing mother-young interactions and is thus beneficial for animals. Previous research has demonstrated that sows in LFSs vocalize to their piglets and perform piglet-directed behavior with physical contact more than sows housed in FCs [60–62]. In particular, there is evidence that early experience in an enriched environment may positively affect social skills or health later in life [63–65].

Piglet behavior

Piglet behavior was also compared between FC and AFP piglets, as with sow behavior (Table 5). Farrowing systems did not affect suckling and lying behavior ($p > 0.05$), but walking behavior was

 https://doi.org/10.5187/jast.2022.e36

Table 5. Spending time (± SD) of the piglets' behaviors during the lactating period

Behavior	Housing system	Day									%	p-value
		1	2	3	4	5	6	7	14	20		
Suckling	FC	330.6 ± 28.9	331.3 ± 18.9	287.3 ± 24.7	356 ± 30.1	326.6 ± 48.4	330.7 ± 57.1	274.7 ± 48.4	340.0 ± 28.0	304 ± 25.1	22.2	ns
	AFP	382.7 ± 130.5	340.2 ± 42.4	292.7 ± 64.6	318.8 ± 25.4	302.7 ± 46.7	298.2 ± 43.4	331.3 ± 18.9	287.3 ± 61.7	307.0 ± 80.9	22.1	
Lying	FC	1,072.3 ± 31.2	1,039.3 ± 22.3	1,069.3 ± 86.5	1,005.3 ± 46.9	1,061.3 ± 40.6	1,044.7 ± 37.5	1,083.3 ± 32.0	992.0 ± 26.5	1,020.0 ± 55.2	72.4	ns
	AFP	993.3 ± 139.2	1,060.2 ± 49.6	1,112.0 ± 62.6	1,070.8 ± 33.1	1,070.0 ± 37.5	1,088.5 ± 59.2	1,039.3 ± 22.3	1,069.3 ± 86.5	1,065.6 ± 100.1	73.8	
Walking	FC	37.1 ± 10.2	67.3 ± 11.5[a]	83.3 ± 38.3	78.0 ± 18.0	52.0 ± 9.2	64.7 ± 22.0	82.0 ± 19.7	108.0 ± 19.1	116.0 ± 53.3	5.3	< 0.05
	AFP	64.0 ± 23.1	39.5 ± 7.3[b]	35.3 ± 11.0	50.4 ± 9.5	67.3 ± 10.3	53.3 ± 17.0	67.3 ± 11.5	83.3 ± 38.3	67.4 ± 24.8	4.1	

[a,b]Values within treatment (columns) with different superscripts differ significantly ($p < 0.05$).

FC, farrowing crate; AFP, alternative farrowing pen; ns, not significant ($p > 0.05$).

higher in FCs than AFPs ($p < 0.05$).

Piglets will start to seek udders and teats immediately after birth, relying on a combination of visual, olfactory, tactile, and vocalization cues, and they have access to colostrum during the first 8 h postpartum [66]. Suckling behavior gradually develops a cyclical pattern, occurring every 30–70 min when induced by a nursing–suckling sound stimulus [67–69]. The sow gives a characteristic grunting call, so it is very important to synchronize the grunt rhythm [51]. In particular, rapid grunting is a signal of suckling that is strongly correlated with the time of milk let-down and successful suckling [70,71] because milk is only available for 15–20 s for every bout of suckling [72,73]. Suckling behavior gradually decreases throughout lactation. In a study by Bøe [74], there was a considerable reduction in the number of suckling bouts between week 1 and 3 in LFSs, with decreases in the time the sows spent with their litters. Jensen [75] also reported that sows kept in a semi-natural environment showed a significant reduction in nursing and contact with piglets during the first 4 weeks but increased foraging and locomotion. However, in this study, no differences were found in the duration and intervals of suckling bouts by day during the experiment period, even between two farrowing systems (Table 6, $p > 0.05$). The average duration and intervals of a suckling bout were 8.2 ± 1.6 and 37.1 ± 3.3 min for the FC piglets and 8.1 ± 1.6 and 37.4 ± 4.1 min for the AFP piglets, respectively. The average duration of a suckling bout was longer compared with the results of previous studies that reported it as being 6.3 [76] or 6.4 min [77]. These differences may be explained by the pre- or post-ejection udder massage duration. In particular, post-ejection udder massage occurred for up to 15 min compared to 1–2 min for pre-ejection udder massage [78]. The function of udder massages is still unclear, although it may help stimulate future milk production [79]. Another reason for the differences might be the sampling method used to observe suckling behavior. Previous research demonstrated that piglets in larger pens spent more time at the udder of sows and performed longer suckling behavior [80,81].

Piglet behavior is greatly influenced by the farrowing system and environment enrichment [65,82]. A larger space and the addition of materials (e.g., straw, wood-shavings, and peat) may lead to a decrease in aggressive behavior and an increase in exploratory or play behavior [83,84]. In

Table 6. The duration and interval of a suckling bout (min ± SD) during the lactating period

Variables	Housing system	Day									Mean	p-value
		1	2	3	4	5	6	7	14	20		
Duration	FC	7.9 ± 0.9	7.8 ± 1.5	8.4 ± 0.9	8.6 ± 0.7	7.5 ± 1.2	7.5 ± 0.3	6.9 ± 0.9	9.3 ± 1.3	10.0 ± 1.3	8.2 ± 1.6	ns
	AFP	8.9 ± 1.1	7.9 ± 0.8	7.5 ± 0.8	8.2 ± 0.4	7.9 ± 1.0	7.8 ± 1.2	7.3 ± 0.0	8.6 ± 1.6	8.8 ± 1.8	8.1 ± 1.6	
Interval	FC	33.0 ± 2.0	37.7 ± 0.6	39.3 ± 0.6	40.7 ± 1.5	41.7 ± 3.1	36.3 ± 2.1	36.3 ± 3.1	35.7 ± 0.6	33.0 ± 0.0	37.1 ± 3.3	ns
	AFP	37.7 ± 2.5	37.0 ± 2.6	38.3 ± 1.2	40.7 ± 4.7	37.7 ± 2.5	40.3 ± 3.2	38.7 ± 2.5	34.7 ± 7.4	31.7 ± 3.1	37.4 ± 4.1	

FC, farrowing crate; AFP, alternative farrowing pen; ns, not significant ($p > 0.05$).

particular, play behavior is considered a suitable indicator of piglet welfare. Some previous studies reported that piglets in LFSs spent more time engaging in play behavior than those in the FCs [61,85]. Others have found that piglet behavior is linked with sow behavior [86,87]. Piglets tend to be inactive when the sow is resting and more active when the sow is standing up. In this study, we observed only general behavior, and walking behavior involved a wide variety of behavior, such as stereotyped, aggressive, exploratory, and play behavior. Further study of more detailed behavior observation is needed to better understand suitable AFPs for sows and piglets to promote animal welfare.

CONCLUSION

It is concluded that the AFPs with temporary crating until day 4 postpartum does not impact performance and crushed piglet, compared with the FCs. It also may improve animal welfare by allowing sows to move and turn around during lactating period. The AFPs are not only meet the animal welfare standards in Korea but also more efficient at providing sows with additional space in the same area than previous swing-side type. In addition, the support bar is very easy to deal with when the crates are opened. We therefore suggested that it seems feasible to utilize alternative farrowing systems on commercial farms. Moreover, further research is needed to find suitable housing designs to enhance productivity and animal welfare.

REFERENCES

1. Cronin GM, van Amerongen G. The effects of modifying the farrowing environment on sow behaviour and survival and growth of piglets. Appl Anim Behav Sci. 1991;30:287-98. https://doi.org/10.1016/0168-1591(91)90133-i
2. Damm BI, Lisborg L, Vestergaard KS, Vanicek J. Nest-building, behavioural disturbances and heart rate in farrowing sows kept in crates and Schmid pens. Livest Prod Sci. 2003;80:175-87. https://doi.org/10.1016/s0301-6226(02)00186-0
3. Jarvis S, D'Eath RB, Robson SK, Lawrence AB. The effect of confinement during lactation on the hypothalamic–pituitary–adrenal axis and behaviour of primiparous sows. Physiol Behav. 2006;87:345-52. https://doi.org/10.1016/j.physbeh.2005.10.004
4. Baxter EM, Lawrence AB, Edwards SA. Alternative farrowing accommodation: welfare and economic aspects of existing farrowing and lactation systems for pigs. Animal. 2012;6:96-117. https://doi.org/10.1017/s1751731111001224
5. Johnson AK, Marchant-Forde JN. Welfare of pigs in the farrowing environment. In: Marchant-Forde JN, editor. The welfare of pigs. Dordrecht: Springer; 2009. p. 141-88.
6. Hansen LU. Test of 10 different farrowing pens for loose-housed sows. Copenhagen: Seges Danish Pig Research Center; 2018. Report No.: 1803.
7. Lou Z, Hurnik JF. Peripartum sows in three farrowing crates: posture patterns and behavioural activities. Appl Anim Behav Sci. 1998;58:77-86. https://doi.org/10.1016/S0168-1591(96)01144-6
8. Blackshaw JK, Blackshaw AW, Thomas FJ, Newman FW. Comparison of behaviour patterns of sows and litters in a farrowing crate and a farrowing pen. Appl Anim Behav Sci. 1994;39:281-95. https://doi.org/10.1016/0168-1591(94)90163-5
9. Edwards SA, Malkin SJ, Spechter HH. An analysis of piglet mortality with behavioural observations. Proc Br Soc Anim Prod. 1972.1986;1986:126. https://doi.org/10.1017/s0308229600016329

 https://doi.org/10.5187/jast.2022.e36

10. Weary DM, Pajor EA, Fraser D, Honkanen AM. Sow body movements that crush piglets: a comparison between two types of farrowing accommodation. Appl Anim Behav Sci. 1996;49:149-58. https://doi.org/10.1016/0168-1591(96)01042-8
11. Cronin GM, Lefébure B, McClintock S. A comparison of piglet production and survival in the Werribee Farrowing Pen and conventional farrowing crates at a commercial farm. Aust J Exp Agric. 2000;40:17-23. https://doi.org/10.1071/ea99124
12. Moustsen VA, Hales J, Lahrmann HP, Weber PM, Hansen CF. Confinement of lactating sows in crates for 4 days after farrowing reduces piglet mortality. Animal. 2013;7:648-54. https://doi.org/10.1017/s1751731112002170
13. Svendsen J. Perinatal mortality in pigs. Anim Reprod Sci. 1992;28:59-67. https://doi.org/10.1016/0378-4320(92)90092-r
14. Damm BI, Forkman B, Pedersen LJ. Lying down and rolling behaviour in sows in relation to piglet crushing. Appl Anim Behav Sci. 2005;90:3-20. https://doi.org/10.1016/j.applanim.2004.08.008
15. Glencorse D, Plush K, Hazel S, D'Souza D, Hebart M. Impact of non-confinement accommodation on farrowing performance: a systematic review and meta-analysis of farrowing crates versus pens. Animals. 2019;9:957. https://doi.org/10.3390/ani9110957
16. Marchant JN, Broom DM, Corning S. The influence of sow behaviour on piglet mortality due to crushing in an open farrowing system. Anim Sci. 2001;72:19-28. https://doi.org/10.1017/s135772980005551x
17. Gu Z, Gao Y, Lin B, Zhong Z, Liu Z, Wang C, et al. Impacts of a freedom farrowing pen design on sow behaviours and performance. Prev Vet Med. 2011;102:296-303. https://doi.org/10.1016/j.prevetmed.2011.08.001
18. Damm BI, Moustsen V, Jørgensen E, Pedersen LJ, Heiskanen T, Forkman B. Sow preferences for walls to lean against when lying down. Appl Anim Behav Sci. 2006;99:53-63. https://doi.org/10.1016/j.applanim.2005.09.014
19. Weber R, Keil NM, Fehr M, Horat R. Factors affecting piglet mortality in loose farrowing systems on commercial farms. Livest Sci. 2009;124:216-22. https://doi.org/10.1016/j.livsci.2009.02.002
20. Quiniou N, Noblet J. Influence of high ambient temperatures on performance of multiparous lactating sows. J Anim Sci. 1999;77:2124-34. https://doi.org/10.2527/1999.7782124x
21. Renaudeau D, Noblet J. Effects of exposure to high ambient temperature and dietary protein level on sow milk production and performance of piglets. J Anim Sci. 2001;79:1540-8. https://doi.org/10.2527/2001.7961540x
22. Runyon RP, Haber A. Fundamentals of behavioral statistics. Boston, MA: Addison-Wesley; 1971.
23. Pluske JR, Williams IH, Zak LJ, Clowes EJ, Cegielski AC, Aherne FX. Feeding lactating primiparous sows to establish three divergent metabolic states: Ⅲ. milk production and pig growth. J Anim Sci. 1998;76:1165-71. https://doi.org/10.2527/1998.7641165x
24. Charette R, Bigras-Poulin M, Martineau GP. Body condition evaluation in sows. Livest Prod Sci. 1996;46:107-15. https://doi.org/10.1016/0301-6226(96)00022-x
25. Maes DGD, Janssens GPJ, Delputte P, Lammertyn A, de Kruif A. Back fat measurements in sows from three commercial pig herds: relationship with reproductive efficiency and correlation with visual body condition scores. Livest Prod Sci. 2004;91:57-67. https://doi.org/10.1016/j.livprodsci.2004.06.015
26. Farmer C, Martineau JP, Méthot S, Bussières D. Comparative study on the relations between backfat thickness in late-pregnant gilts, mammary development and piglet growth. Transl

Anim Sci. 2017;1:154-9. https://doi.org/10.2527/tas2017.0018
27. Zaleski HM, Hacker RR. Variables related to the progress of parturition and probability of stillbirth in swine. Can Vet J. 1993;34:109-13.
28. Kim JS, Yang X, Pangeni D, Baidoo SK. Relationship between backfat thickness of sows during late gestation and reproductive efficiency at different parities. Acta Agric Scand A Anim Sci. 2015;65:1-8. https://doi.org/10.1080/09064702.2015.1045932
29. Xue JL, Dial GD, Marsh WE, Davies PR, Momont HW. Influence of lactation length on sow productivity. Livest Prod Sci. 1993;34:253-65. https://doi.org/10.1016/0301-6226(93)90111-T
30. Svajgr AJ, Hays VW, Cromwell GL, Dutt RH. Effect of lactation duration on reproductive performance of sows. J Anim Sci. 1974;38:100-5. https://doi.org/10.2527/jas1974.381100x
31. Hughes PE. Effects of parity, season and boar contact on the reproductive performance of weaned sows. Livest Prod Sci. 1998;54:151-7. https://doi.org/10.1016/s0301-6226(97)00175-9
32. Fahmy MH, Holtmann WB, Baker RD. Failure to recycle after weaning, and weaning to oestrus interval in crossbred sows. Anim Sci. 1979;29:193-202. https://doi.org/10.1017/s0003356100023412
33. Stevenson JS, Britt JH. Interval to estrus in sows and performance of pigs after alteration of litter size during late lactation. J Anim Sci. 1981;53:177-81. https://doi.org/10.2527/jas1981.531177x
34. Stevenson JS, Pollmann DS, Davis DL, Murphy JP. Influence of supplemental light on sow performance during and after lactation. J Anim Sci. 1983;56:1282-6. https://doi.org/10.2527/jas1983.5661282x
35. McGlone JJ, Stansbury WF, Tribble LF, Morrow JL. Photoperiod and heat stress influence on lactating sow performance and photoperiod effects on nursery pig performance. J Anim Sci. 1988;66:1915-9. https://doi.org/10.2527/jas1988.6681915x
36. Prunier A, de Bragança MM, Le Dividich J. Influence of high ambient temperature on performance of reproductive sows. Livest Prod Sci. 1997;52:123-33. https://doi.org/10.1016/s0301-6226(97)00137-1
37. King RH, Mullan BP, Dunshea FR, Dove H. The influence of piglet body weight on milk production of sows. Livest Prod Sci. 1997;47:169-74. https://doi.org/10.1016/s0301-6226(96)01404-2
38. Hurley WL. Mammary gland growth in the lactating sow. Livest Prod Sci. 2001;70:149-57. https://doi.org/10.1016/s0301-6226(01)00208-1
39. Noblet J, Etienne M. Estimation of sow milk nutrient output. J Anim Sci. 1989;67:3352-9. https://doi.org/10.2527/jas1989.67123352x
40. Hartmann PE, McCauley I, Gooneratne AD, Whitely JL. Inadequacies of sow lactation: survival of the fittest. In: Physiological strategies in lactation: the proceedings of a symposium held at the Zoological Society of London on 11 and 12 November 1982. London: Academic Press; 1984. p. 301-26.
41. Mahan DC, Lepine AJ. Effect of pig weaning weight and associated nursery feeding programs on subsequent performance to 105 kilograms body weight. J Anim Sci. 1991;69:1370-8. https://doi.org/10.2527/1991.6941370x
42. Condous PC, Plush KJ, Tilbrook AJ, van Wettere WHEJ. Reducing sow confinement during farrowing and in early lactation increases piglet mortality. J Anim Sci. 2016;94:3022-9. https://doi.org/10.2527/jas.2015-0145
43. Marchant JN, Rudd AR, Mendl MT, Broom DM, Meredith MJ, Corning S, et al. Timing and causes of piglet mortality in alternative and conventional farrowing systems. Vet Rec. 2000;147:209-14. https://doi.org/10.1136/vr.147.8.209

 https://doi.org/10.5187/jast.2022.e36

44. Melišová M, Illmann G, Chaloupková H, Bozděchová B. Sow postural changes, responsiveness to piglet screams, and their impact on piglet mortality in pens and crates. J Anim Sci. 2014;92:3064-72. https://doi.org/10.2527/jas.2013-7340
45. Hales J, Moustsen VA, Nielsen MBF, Hansen CF. The effect of temporary confinement of hyperprolific sows in sow welfare and piglet protection pens on sow behaviour and salivary cortisol concentrations. Appl Anim Behav Sci. 2016;183:19-27. https://doi.org/10.1016/j.applanim.2016.07.008
46. Weary DM, Phillips PA, Pajor EA, Fraser D, Thompson BK. Crushing of piglets by sows: effects of litter features, pen features and sow behaviour. Appl Anim Behav Sci. 1998;61:103-11. https://doi.org/10.1016/s0168-1591(98)00187-7
47. Goumon S, Leszkowová I, Šimecková M, Illmann G. Sow stress levels and behavior and piglet performances in farrowing crates and farrowing pens with temporary crating. J Anim Sci. 2018;96:4571-8. https://doi.org/10.1093/jas/sky324
48. KilBride AL, Mendl M, Statham P, Held S, Harris M, Cooper S, et al. A cohort study of preweaning piglet mortality and farrowing accommodation on 112 commercial pig farms in England. Prev Vet Med. 2012;104:281-91. https://doi.org/10.1016/j.prevetmed.2011.11.011
49. Pedersen LJ, Berg P, Jørgensen G, Andersen IL. Neonatal piglet traits of importance for survival in crates and indoor pens. J Anim Sci. 2011;89:1207-18. https://doi.org/10.2527/jas.2010-3248
50. Weber R, Keil NM, Fehr M, Horat R. Piglet mortality on farms using farrowing systems with or without crates. Anim Welf. 2007;16:277-9.
51. Fraser AF, Broom DM. Farm animal behaviour and welfare. 3rd ed. Wallingford: CAB International; 1997.
52. Fraser D. The effect of straw on the behaviour of sows in tether stalls. Anim Sci. 1975;21:59-68. https://doi.org/10.1017/s0003356100030415
53. Dantzer R. Behavioral, physiological and functional aspects of stereotyped behavior: a review and a re-interpretation. J Anim Sci. 1986;62:1776-86. https://doi.org/10.2527/jas1986.6261776x
54. Appleby MC, Lawrence AB. Food restriction as a cause of stereotypic behaviour in tethered gilts. Anim Sci. 1987;45:103-10. https://doi.org/10.1017/s0003356100036680
55. Johnson AK, Morrow-Tesch JL, McGlone JJ. Behavior and performance of lactating sows and piglets reared indoors or outdoors. J Anim Sci. 2001;79:2571-9. https://doi.org/10.2527/2001.79102571x
56. Arellano PE, Pijoan C, Jacobson LD, Algers B. Stereotyped behaviour, social interactions and suckling pattern of pigs housed in groups or in single crates. Appl Anim Behav Sci. 1992;35:157-66. https://doi.org/10.1016/0168-1591(92)90006-W
57. Lambertz C, Petig M, Elkmann A, Gauly M. Confinement of sows for different periods during lactation: effects on behaviour and lesions of sows and performance of piglets. Animal. 2015;9:1373-8. https://doi.org/10.1017/s1751731115000889
58. Zhang X, Li C, Hao Y, Gu X. Effects of different farrowing environments on the behavior of sows and piglets. Animals. 2020;10:320. https://doi.org/10.3390/ani10020320
59. Thodberg K, Jensen KH, Herskin MS. Nest building and farrowing in sows: relation to the reaction pattern during stress, farrowing environment and experience. Appl Anim Behav Sci. 2002;77:21-42. https://doi.org/10.1016/s0168-1591(02)00026-6
60. Chidgey KL, Morel PCH, Stafford KJ, Barugh IW. Sow and piglet behavioral associations in farrowing pens with temporary crating and in farrowing crates. J Vet Behav. 2017;20:91-101. https://doi.org/10.1016/j.jveb.2017.01.003

61. Singh C, Verdon M, Cronin GM, Hemsworth PH. The behaviour and welfare of sows and piglets in farrowing crates or lactation pens. Animal. 2017;11:1210-21. https://doi.org/10.1017/s1751731116002573
62. Bolhuis JE, Raats-van den Boogaard AME, Hoofs AIJ, Soede NM. Effects of loose housing and the provision of alternative nesting material on peri-partum sow behaviour and piglet survival. Appl Anim Behav Sci. 2018;202:28-33. https://doi.org/10.1016/j.applanim.2018.01.004
63. Baxter EM, Lawrence AB, Edwards SA. Alternative farrowing systems: design criteria for farrowing systems based on the biological needs of sows and piglets. Animal. 2011;5:580-600. https://doi.org/10.1017/s1751731110002272
64. Verdon M, Hansen CF, Rault JL, Jongman E, Hansen LU, Plush K et al. Effects of group housing on sow welfare: a review. J Anim Sci. 2015;93:1999-2017. https://doi.org/10.2527/jas.2014-8742
65. 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
66. De Passille AMB, Rushen J. Suckling and teat disputes by neonatal piglets. Appl Anim Behav Sci. 1989;22:23-38. https://doi.org/10.1016/0168-1591(89)90077-4
67. Lewis NJ, Hurnik JF. The development of nursing behaviour in swine. Appl Anim Behav Sci. 1985;14:225-32. https://doi.org/10.1016/0168-1591(85)90003-6
68. Quesnel H, Farmer C, Devillers N. Colostrum intake: influence on piglet performance and factors of variation. Livest Sci. 2012;146:105-14.
69. Widowski TM, Torrey S, Bench CJ, Gonyou HW. Development of ingestive behaviour and the relationship to belly nosing in early-weaned piglets. Appl Anim Behav Sci. 2008;110:109-27. https://doi.org/10.1016/j.applanim.2007.04.010
70. Whittemore CT, Fraser D. The nursing and suckling behaviour of pigs. II. Vocalization of the sow in relation to suckling behaviour and milk ejection. Br Vet J. 1974;130:346-56. https://doi.org/10.1016/S0007-1935(17)35837-2
71. Castren H, Algers B, Jensen P, Saloniemi H. Suckling behaviour and milk consumption in newborn piglets as a response to sow grunting. Appl Anim Behav Sci. 1989;24:227-38. https://doi.org/10.1016/0168-1591(89)90069-5
72. Fraser D. A review of the behavioural mechanism of milk ejection of the domestic pig. Appl Anim Ethol. 1980;6:247-55. https://doi.org/10.1016/0304-3762(80)90026-7
73. Algers B, Jensen P. Communication during suckling in the domestic pig. Effects of continuous noise. Appl Anim Behav Sci. 1985;14:49-61. https://doi.org/10.1016/0168-1591(85)90037-1
74. Bøe K. Maternal behaviour of lactating sows in a loosehousing system. Appl Anim Behav Sci. 1993;35:327-38. https://doi.org/10.1016/0168-1591(93)90084-3
75. Jensen P. Maternal behaviour and mother—young interactions during lactation in free-ranging domestic pigs. Appl Anim Behav Sci. 1988;20:297-308. https://doi.org/10.1016/0168-1591(88)90054-8
76. Ellendorff F, Forsling ML, Poulain DA. The milk ejection reflex in the pig. J Physiol. 1982;333:577-94. https://doi.org/10.1113/jphysiol.1982.sp014470
77. Lohmeier RY, Gimberg-Henrici CGE, Burfeind O, Krieter J. Suckling behaviour and health parameters of sows and piglets in free-farrowing pens. Appl Anim Behav Sci. 2019;211:25-32. https://doi.org/10.1016/j.applanim.2018.12.006
78. Jensen P, Gustafsson M, Augustsson H. Teat massage after milk ingestion in domestic piglets: an example of honest begging? Anim Behav. 1998;55:779-86. https://doi.org/10.1006/

anbe.1997.0651

79. Algers B. Nursing in pigs: communicating needs and distributing resources. J Anim Sci. 1993;71:2826-31. https://doi.org/10.2527/1993.71102826x
80. Cronin GM, Smith JA. Suckling behaviour of sows in farrowing crates and straw-bedded pens. Appl Anim Behav Sci. 1992;33:175-89. https://doi.org/10.1016/s0168-1591(05)80006-1
81. Cronin GM, Dunsmore B, Leeson E. The effects of farrowing nest size and width on sow and piglet behaviour and piglet survival. Appl Anim Behav Sci. 1998;60:331-45. https://doi.org/10.1016/s0168-1591(98)00159-2
82. Hötzel MJ. Improving farm animal welfare: is evolution or revolution needed in production systems? In: Appleby MC, Weary DM, Sandøe P, editors. Dilemmas in animal welfare. Wallingford, Oxfordshire: CABI; 2014. p. 67-84.
83. Petersen V, Simonsen HB, Lawson LG. The effect of environmental stimulation on the development of behaviour in pigs. Appl Anim Behav Sci. 1995;45:215-24. https://doi.org/10.1016/0168-1591(95)00631-2
84. Oostindjer M, van den Brand H, Kemp B, Bolhuis JE. Effects of environmental enrichment and loose housing of lactating sows on piglet behaviour before and after weaning. Appl Anim Behav Sci. 2011;134:31-41. https://doi.org/10.1016/j.applanim.2011.06.011
85. Arey DS, Sancha ES. Behaviour and productivity of sows and piglets in a family system and in farrowing crates. Appl Anim Behav Sci. 1996;50:135-45. https://doi.org/10.1016/0168-1591(96)01075-1
86. Chidgey KL, Morel PCH, Stafford KJ, Barugh IW. Observations of sows and piglets housed in farrowing pens with temporary crating or farrowing crates on a commercial farm. Appl Anim Behav Sci. 2016;176:12-8. https://doi.org/10.1016/j.applanim.2016.01.004
87. Van Beirendonck S, Van Thielen J, Verbeke G, Driessen B. The association between sow and piglet behavior. J Vet Behav. 2014;9:107-13. https://doi.org/10.1016/j.jveb.2014.01.005