INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
19F–157/2020/23–2–409–416
DOI: 10.17957/IJAB/15.1303
http://www.fspublishers.org

Full Length Article

Effects of Pregnancy and Lactation Environments on Maternal Performance of Primiparous Sows during Lactation

Guoan Yin*, Lei Wang, Xiaoyu Zhao, Langchao Yu and Baojun Chen
College of Animal Science & Veterinary Medicine, Heilongjiang Bayi Agricultural University 163319 Daqing, China
*For correspondence: guoanyin@foxmail.com
Received 11 September 2019; Accepted 20 September 2019; Published 16 January 2020

Abstract

Loose house systems are being positively promoted in modern swine industry. While gestation crates have gradually been replaced by gestation pens, most farrowing and lactation sows are still restricted in crates. This study aimed to investigate the effects of different pregnancy environments and the combined effect of pregnancy and lactation environments on maternal behaviours of sows by rearing 12 gilts in three types of housing systems during pregnancy and lactation. All sows were videotaped for 3 days pre- and 28 days post-parturition. Maternal behaviors of sows, including prepartum nest-building behavior, postural changes, and nursing behavior, were recorded continuously. Additionally, the responsiveness of sows to piglets' screams was scored. Overall, sows in the gestation pens and farrowing pens combined (PP) group reached the peak of nest-building behaviour first among all 3 groups and showed a longer duration of nest-building behaviour than did the gestation pens and farrowing crates combined (PC) group ($P < 0.01$). The gestation crates and farrowing crates combined (CC) group performed a significantly higher frequency of nursing behaviour, more piglet crushing postural changes and higher percentage of sow-terminated nursing, when compared with the PC group ($P < 0.05$). Gestational environment had no effect on sow response to piglet screams. In conclusion, farrowing pens increase the expression of prepartum nest-building behaviour, and sows in the CC housing system showed increased piglet crushing postural changes and reduced willingness to nurse while those in the PC housing system showed reduced frequency of successful nursing.

Keywords: Sow; Behaviour; Gestation environment; Lactation environment; Maternal responsiveness; Housing system

Introduction

The maternal performance of lactating sows such as nest-building behaviors, nursing, epimiletic behavior, and the responsiveness to piglet screams directly determines the survival rate and weaning weight of piglets (Damm *et al.* 2005). Although, the maternal instinct of sows relies mainly on heredity (Canario *et al.* 2014), the pregnancy and lactation environments also impact the maternal performance of breeding sows by acting on the sow's physiology and psychology (Merlot *et al.* 2013; Bolhuis *et al.* 2018).

Crates had been widely used to rear breeding sows over the last 50 years, contributing to improved space utilization, cutting the capital cost of feeding and management, and reducing piglet mortality due to crushing (Edwards 2002). However, long-term restrictive situations of crates increase the risk of lameness in sows (Alakurikka *et al.* 2017). Some natural behaviors like nest-building and social behavior of sows were restricted in barren environments, causing abnormal physiology and behavior, such as chronic stress and stereotypies, in sows (Merlot *et al.* 2013; Hemsworth 2018). The pain from lameness and prenatal stress often leads to lack of maternal instinct, reflected by less pre-lying behaviors ('sniffing', 'looking around', and 'nosing'), restlessness and frequent postural changes, indifferent response towards piglets' screams, and less willingness to nurse, all of which result in increased piglet mortality owing to eventual starvation or crushing (Wischner *et al.* 2009, 2010).

As the welfare of sows has received increasing attention, the use of the loose housing system has gradually been promoted. EU member states have banned the use of crate housing systems for pregnant sows by law (Chapinal *et al.* 2010). However, factors such as high piglet mortality and increased capital cost of labor and housing construction hinder the promotion of farrowing pens in commercial pig farms. As such, gestation pen and farrowing crate combined (PP) feeding pattern has been widely adopted in many countries. Loose housing systems still need refinement in design to improve the welfare and production level of sows, which is an urgent issue in the modern swine industry.

There has been considerable research on the effects of lactation environments on maternal performance of sows showing that farrowing pens provide more breathing spaces for sows than do farrowing crates, and that sows perform more nest-building behavior (Hemsworth 2018),

To cite this paper: Yin G, L Wang, X Zhao, L Yu, B Chen (2020). Effects of pregnancy and lactation environments on maternal performance of primiparous sows during lactation. *Intl J Agric Biol* 23:409–416

exploratory, and social behaviors in farrowing pens (Temple *et al.* 2011). Many effective attempts have been made to improve the farrowing system, such as installing circular and ellipsoid crates in farrowing systems (Lou and Hurnik 1998) or anti-crushing bars in farrowing pens (Gu *et al.* 2011), or adjusting commercial farrowing pen size (Pavičić *et al.* 2005). In addition to there being no significant improvement in maternal performance in sows in farrowing pens, sows showed more piglet crushing postural changes such as sitting to lying and rolling onto either side, which is positively correlated with the risk of piglet crushing (Moustsen *et al.* 2012; Hales *et al.* 2014).

While most studies focus solely on the effect of lactation environments on maternal performance of sows, the effects of pregnancy environments on maternal performance of sows after farrowing was not clear. A few studies have shown that gestation pens have relieved the prenatal stress of sows by lifting space restrictions and conforming to the habits of pigs as social animals (Oliviero *et al.* 2008; Chapinal *et al.* 2010; Merlot *et al.* 2019). Thus, the gestation environment has influence on maternal performance of sows cannot be neglected. Meanwhile it is not sufficient to improve the system based only on the maternal performance in different farrowing systems as Merlot at el found that the effects of environmental stress during pregnancy on physiology and behavior can be extended to lactation (Merlot *et al.* 2013), and the stress from different pregnancy and lactation environments combined (like gestation pens and farrowing crates, gestation crates and farrowing pens) should not be ignored. This study compared the maternal performance in three housing systems including gestation pens and farrowing crates combined (PC), and gestation crates and farrowing crates combined (CC), which are the main housing systems in use on commercial pig farms, and gestation pens and farrowing pens combined (PP), which is being promoted for use in the near future. This was carried out in order to inform the optimization and adjustment of the present housing system and improve the welfare of sows and piglets.

Materials and Methods

Animals, treatments, management and feeding

This experiment lasted four months and was carried out in a commercial herd located in northern of China between September and December 2018 with a total of 16 Yorkshire × Landrace gilts, which were selected post-insemination from the same batch. All gilts were healthy and without clinical lameness, weighing 135±5kg at insemination when they were 215 ± 5 days-old. Pregnancy was confirmed in 12 of the 16 gilts 21 days post-insemination before they were randomly assigned to one of three types of housing systems (4 sows each) during pregnancy and lactation. This included the control PC group, treatment PP group, and gestation treatment CC group. Gilts were housed in the same room containing gestation crates or gestation pens from 21 days post-insemination to 7 days before the expected delivery date. All gilts were then transferred from the pregnancy unit to the farrowing unit and were farrowed in either farrowing crates or farrowing pens. Gilts were fed the recommended amount (refer to NRC, 2012) of complete formula feed three times daily (06:00, 10:00, and 17:00) and allowed to drink freely. The housing system was cleaned and straw was changed after feeding each morning. Other management standards, immunization procedures, and disease treatment conformed to the uniform standard of this pig farm, and the housing systems were maintained at an appropriate temperature and humidity (19.5 ± 1.5°C, 60 ± 5% in gestation unit; 21 ± 1°C, 70 ± 5% in lactation unit).

Housing environment

The gestation pens measured 3.2 m x 3.2 m and had cement floors with a slope of 5° to allow for drainage. It was divided into three parts including a lying area, dunging area, and feeding area, with four gilts housed in each gestation pen. The walls were surrounded by concrete walls or metal bars about 1.2 m high and the ground of the lying area was covered with about 100 mm thickness straw. The feeding area was equipped with four individual open feeding stalls, and the dunging area had been installed with slatted floors. This is illustrated by the planar graph in Fig. 1.

Gestation crates measured 2.1 m x 0.6 m and the ground consisted of a concrete floor with a slatted dunging area in the rear beyond which the ground was not straw covered. The gestation crates and gestation pens were located in the same pregnancy house both are equipped with the same type of drinker.

Farrowing pens measured 3.5 m x 2.0 m, within which sows could move freely, and had walls surrounded by metal bar board about 1.2 m high. The ground was above a solid concrete floor with a slatted dunging area in the rear and covered with about 100 mm thickness straw. This is illustrated by the planar graph in the Fig. 2.

Farrowing crates measured 2.1 m x 1.8 m, in which ground was not straw covered and the walls were surrounded by PVC board about 0.5 m high. The stall of sows was located in the middle of farrowing crates 0.6 m in width.

Farrowing pens and farrowing crates were located in the same farrowing house. Both were equipped with a piglet creep (heated area for piglets), different nipple drinker system for piglets or sows, a piglet nursery box with a heat lamp, a creep feeder, and a sow feeder. All farrowing units were equipped with a heating device in winter.

Behavioral observation and categorization

The behavior of sows was monitored by video surveillance system (JVS-H411-H1, Cloudsee, China) and cameras fixed in the front of the pens or crates. All sows were videotaped for the 3 days before and the 28 days after parturition.

Prepartum nest-building behavior*:* All sows' prepartum nest-building behavior was recorded 12 h before farrowing to the first piglets' birth. The duration and frequency of nest-building behavior were recorded in each hour period during the 12 h before farrowing. The nest-building behavior are defined in Table 1 and the nest-building behavior were analyzed by the follow indicator system:

1) Duration of nest-building behavior: nest-building behavior duration longer than 5 s was considered valid;

2) Frequency of nest-building behavior: frequency of nest-building behavior every hour during the 12 h before farrowing;

3) The peak of nest-building behavior: the hour with the longest nest-building behavior duration before farrowing.

Nursing behavior*:* The Nursing behavior of all sows was recorded starting from the final piglets' birth. The 24-h, 48-h, and 72-h periods following the birth of the last piglet were designated as day 1, day 2, and day 3 postpartum and the nursing behavior was analyzed by the follow indicator system:

1) Duration of nursing behavior: duration of active manipulation of the udder by more than half of the litter and duration of more than half of the litter leaving the udder or remaining inactive by the udder (Valros *et al.* 2002);

2) Frequency of nursing behavior: frequency of nursing behavior in each day postpartum;

3) Percentage of sow-terminated nursing: percentage of sows terminating nursing by either rolling over on the belly or standing up.

Postpartum postural changes*:* The postpartum postural changes of all sows were recorded starting from the first piglet birth. The 24, 48 and 72 h periods following this were designated as day 1, day 2, and day 3 postpartum and the nursing behaviors are defined in Table 2.

Postpartum responsiveness to piglet screams: All sow's responsiveness to her piglets' screams was investigated on the 4th day of each week postpartum. All screams of trapped piglets were recorded for 30 s from the corresponding sows and were played back to sows when they were lying down. The responsiveness of sows was scored according to the follow indicator system: 0-no response; 1-turn head; 2-move body; 3-lying to sitting; 4-lying to standing; 5-attempting to find or contact the voice player.

Statistical analysis

Microsoft Excel 2017 was used to process data and make graphs; all behavioral data conformed to the normal distribution before being analyzed with One-Way ANOVA (IBM S.P.S.S. statistics 22.0). The LSD was used for multiple comparisons. The data are expressed by mean ± standard deviation in table.

Results

Nest in different farrowing environments

The nest-building behavior performance of sows is shown in Fig. 3. The nest-building behavior of three groups increased from 12 h before farrowing; all sows reached the peak in duration of nest-building behavior 6–8 h before farrowing. The nest-building behavior of sows in the PP group increased most rapidly and peaked first among 3 groups.

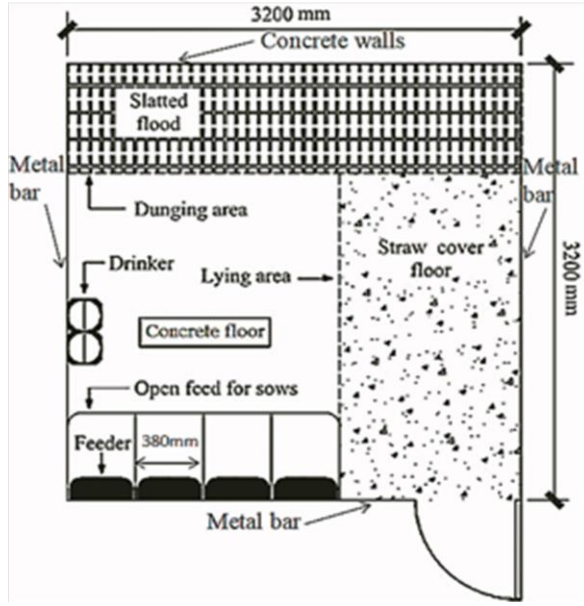

Fig. 1: The planar graph of gestation pens hosting the PP group and PC group during pregnancy (4 sows per pen)

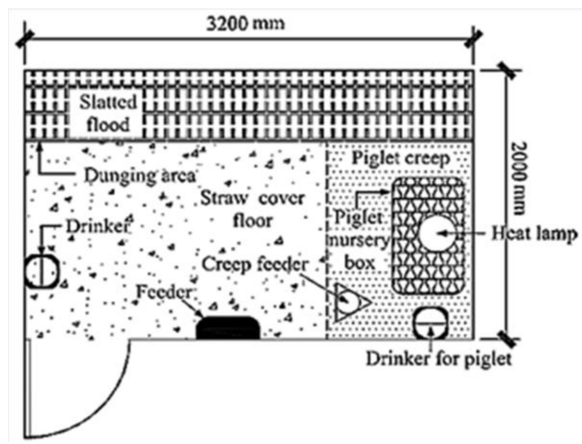

Fig. 2: The planar graph of farrowing pens hosting the PP group from 7 days before the expected date to after parturition (one sow per pen)

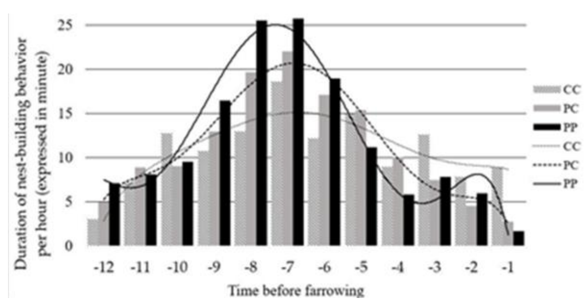

Fig. 3: The duration of nest-building behaviour in each hour before farrowing, the time of first piglets' birth as the starting time

Table 1: The categories and definitions of nest-building behaviour

Category	Definition
Pawing	Attempting to scrape the floor with front legs
Rooting	Pushing the floor or attempting to turn up the farrowing crate with the snout
Arranging	Manipulating or arranging nesting materials with the snout or mouth

The behavioral definitions of table reference from (Yun *et al*. 2014).

Table 2: The categories and definitions of postural changes

Category	Definition
Shifts from lateral recumbency	Shifting from a lateral to an alternative posture, including ventral recumbency, lateral recumbency, sitting, standing
Ventral to lateral recumbency	Ventral posture roll to one shoulder making contact with the floor
Sitting to lying	The posture of partly erected on stretched fore legs with hindquarters contacting the floor to the lying posture, including ventral recumbency and lateral recumbency*
Standing to lying	The upright body postures with hooves contacting the floor only to the lying posture, including ventral recumbency and lateral recumbency*

*Some behavioral parameters and their definitions are from (Yin *et al.* 2016).

Table 3: Nest-building behaviour before farrowing

Environment	PC	CC	PP
Total duration of nest-building behavior (min)	$82.92^{A} \pm 14.7$	$86.48^{A} \pm 6.23$	$143.99^{A} \pm 15.48$
Duration of peak nest-building behavior (min)	$58.78^{ab} \pm 20.14$	$31.47^{b} \pm 15.55$	$70.25^{a} \pm 19.15$
Duration of single-pass nest-building behavior (min)	$1.33^{A} \pm 0.24$	$1.44^{A} \pm 0.39$	$2.75^{B} \pm 0.81$
Frequency of nest-building behavior	60.75 ± 3.77	62.75 ± 14.45	54.33 ± 10.59

Note: Different superscript letters (a–b) indicate that variables within a row are significantly different ($P < 0.05$), (A–B) indicate that variables within a row are very significantly different ($P < 0.01$)

Table 4: Nest-building behaviour before farrowing

Environment	PC	CC	PP
Duration of nursing behavior (min)	12.85 ± 4.0	13.16 ± 5.31	16.31 ± 7.91
Frequency of nursing behavior	29.67 ± 4.23^{a}	34.75 ± 5.81^{b}	30.83 ± 6.60^{ab}
Percentage of sow-terminated nursing (%)	0.09 ± 0.09^{a}	0.34 ± 0.27^{b}	0.06 ± 0.06^{a}

Note: Different superscript letters (a–b) indicate that variables within a row are significantly different ($P < 0.05$).

Table 5: The sows' responsiveness to piglet screams

Time	PC	CC	PP
1st week	3.75 ± 1.89	3.75 ± 1.89	3.75 ± 2.50
2nd week	4.50 ± 1.00	3.00 ± 1.63	3.00 ± 2.30
3rd week	4.00 ± 2.00	2.75 ± 1.70	3.50 ± 1.91
4th week	4.00 ± 2.00	2.50 ± 2.30	3.25 ± 1.70

Note: Different superscript letters (a–b) indicate that variables within a row are significantly different ($P < 0.05$); the data of table were the scores of sows' responsiveness to piglet screams, The responsiveness of sows was scored according to the follow indicator system: 0-no response; 1-turn head; 2-move body; 3-lying to sitting; 4-lying to standing; 5-attempting to find or contact the voice player

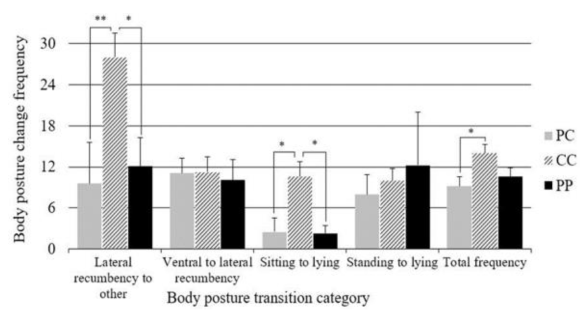

Fig. 4: Frequency of postural change across groups with $P < 0.05$

As shown in Table 3, the frequency and peak duration of NB showed no significant difference between the PC and PP groups ($P > 0.05$), and neither between the PC and CC groups. The total duration of nest-building behavior and the duration of single-pass nest-building behavior in the PP group were longer than that in the PC group ($P < 0.01$). However, the PC and CC sows showed no significant difference in this regard.

Nursing behavior in different pregnancy and lactation environments in combined housing systems

As shown in Table 4, the duration of nursing behavior was not significantly different ($P > 0.05$) among the three groups. Sows reared in gestation crates (CC group) showed a higher frequency of nursing behavior and a higher percentage of sow-terminated nursing than did sows reared in gestation pens during pregnancy (PC group) ($P < 0.05$). However, the lactation environments had no effect on nursing behavior ($P > 0.05$).

Postural changes in different pregnancy and lactation environments in combined housing systems

As shown in Fig. 4, the frequency of postural change from lateral recumbency to other postures was vastly higher in the

CC group than in the PC group ($P < 0.01$). In addition, the frequency of postural change from sitting to lying and total posture changes were significantly higher in the CC group than in the PC group ($P < 0.05$). In contrast, no significant differences ($P > 0.05$) were observed in various postural changes between the PC group and the PP group ($P > 0.05$); the frequency of postural changes from ventral to lateral recumbency and from standing to lying did not differ between treatments ($P > 0.05$).

Responsiveness of sows to piglet screams in different pregnancy environments

As shown in Table 5, the score of sows' responsiveness to piglet screams in gestation pens (PC group) was higher than in gestation crates during 1–4 week after farrowing, but there were no significant differences ($P > 0.05$) in different pregnancy environments.

Discussion

Modern sows still have a strong motivation to perform nest-building behaviors before farrowing, driven by the variation of endogenous hormones such as progestin (Castren *et al.* 1993), prostaglandin (PG) (Gilbert *et al.* 2001), and oxytocin (Gilbert *et al.* 2002). The performance of antepartum nest-building behaviors is also initiated on the basis on exogenous conditions including the abundance of nesting materials (Yin *et al.* 2016) and free space (Yun and Valros 2015). Therefore, the farrowing environment seems to positively affect the normal expression of postpartum nest-building behaviors in sows. The barren farrowing crates always lack favorable exogenous NB conditions (Yun *et al.* 2014; Yun and Valros 2015) such as abundant nesting materials and free space. The barren farrowing environment conflicts with sows' strong nest-building behavior motivated by endogenous hormone (Bolhuis *et al.* 2018). In the present study, farrowing pens promoted nest-building behavior in sows, evidenced by an increased frequency and earlier peak in nest-building behavior. The difference may be partly because farrowing pens provide adequate space for movement and nesting materials, satisfying the sows' exogenous requirements and promoting the release of endogenous hormones before farrowing. In contrast, nest-building behavior might be restricted in the barren environment of farrowing crates. The prepartum nest-building behavior of sows was initiated by prostaglandin F2α (PGF2α) and was affected by environmental feedback (Yun and Valros 2015). The spacious farrowing environment and appropriate nesting materials reduced prenatal stress in sows and promote the PGF2α-induced nest-building behavior. This may explain why the total duration of nest-building behavior and the duration of single-pass nest-building behavior of sows in farrowing pens was longer than that in farrowing crates. Several studies have suggested prolactin (PRL) can also initiate the nest-building behavior (Yun and Valros 2015). However, it is still unclear whether PRL-induced nest-building behavior is affected by environmental feedback. Yet, a few studies have suggested that the performance of nest-building behavior in prepartum sows might positively correlate with PRL and oxytocin, consequently effecting the maternal performance and nursing performance (Yun and Valros 2015). The release of PRL and oxytocin improve maternal performance during farrowing and as a result, sows change their posture carefully (Merlot *et al.* 2013), which would reduce the risk of piglets' mortality due to crushing. That might be due to the ameliorating effects of oxytocin on anxiety in sows (Yun *et al.* 2013). By regulating the release of oxytocin and prolactin, nest-building behavior affect sow's milk yield and nursing performance in early lactation (Yun and Valros 2015).

The first three days postpartum is a particularly critical period for piglet survival due to the key role of nursing performance of sows in early growth and development of piglets (Illmann *et al.* 2016). Sow's colostrum contains high concentrations of immunoglobulin IgG (Yi *et al.* 2019) which can enter the blood system of piglets through the intestinal epithelium, providing the initial immunity (Danielsen *et al.* 2006). The immunity from colostrum provides protection for piglets against pathogenic microbes in the environment. Therefore, sows early nursing performance determines the mortality and weaning weight of piglets during lactation.

The duration and frequency of nursing behavior are two key factors that affect nursing performance, which directly relates to whether piglets can get adequate nutrition from milk (Auldist *et al.* 2000). In the present study, the duration of nursing behavior was not significantly different in different pregnancy and lactation environments in combined housing systems, which is in line with findings from a study by Singh *et al.* (2017). Therefore, we can conclude that there was no effect of housing environments on nursing duration. However, sows reared in gestation crates showed a higher frequency of nursing behavior than did sows reared in gestation pens during pregnancy. Perhaps this was caused by stress of moving from a spacious environment to a restrictive one. Sow's breasts cannot store milk due to the lack of a milk pool and maintaining high nursing behavior frequency help piglets acquire more nutrition, preventing illness and promoting growth (Valros *et al.* 2002). In contrast, we found that sows in CC tended to display a higher percentage of sow-terminated nursing than in PC during lactation. This shows that long-term restrictive housing systems reduce the willingness to nurse (Illmann *et al.* 1999). Further, it has been confirmed that lactating sows in farrowing crates terminated more nursing bouts than those in farrowing pens (Singh *et al.* 2017). However, Pedersen (2015) found that the percentage of sow-terminated nursing in temporary confinement housing systems was higher that in loose housing systems. The higher the willingness of sows to nurse, the higher the success rate of piglet's lactation, which contributes to increased piglet production performance.

Starvation and crushing is the main reason driving neonatal piglet mortality (Westin *et al.* 2015). The mortality of piglets even as much as 10%–30% both in some commercial pig farm (Illmann *et al.* 2016), the 72 h postpartum period is the peak of piglet mortality (Tummaruk *et al.* 2017). The posture patterns of sows during lactation directly affects whether piglets will get enough milk. For example, the posture of lateral recumbency in sows provide a warm micro-environment and more opportunity to for piglets to nurse during lactation (Pedersen *et al.* 2003), which can also contribute to decrease piglet's mortality due to starvation or crushing by sow. however, the postural change of lateral recumbency to other postures might be associated with sow-terminated nursing (Liu *et al.* 2013). Sows performed postural changes of lateral recumbency to other postures frequently, indicating a decreasing willingness to nurse. In this study, the frequency of postural change from lateral recumbency to other postures and percentage of sow-terminated nursing was higher in CC than PC during the first 3 days postpartum. This is a reflection of sows reduced willingness to nurse because of restrictive pregnancy environments. Piglets need adequate colostrum within 3 days after the birth, to gain immunity and resistant outside pathogenic microorganisms (Devillers *et al.* 2011). As such, restrictive pregnancy environments might accelerate piglet mortality duo to starvation and disease.

Postural changes of sitting to lying, ventral to lateral recumbency and from standing to lying, all involve the process of lying down, which might increase piglet mortality due to crushing (Valros *et al.* 2003). In the present study, the frequency of postural changes from sitting to lying down was significantly higher in CC than in PC, which could indicate that the barren and restrictive environment in CC causes anxiety in sows, displayed through restlessness and pacing. Moreover, neonatal piglets are very vulnerable and frequent postural changes by sows might increase the risk of piglet mortality due to crushing during the interaction between piglets and sows to stimulate milk. Sows improve their level of comfort by constantly adjusting their posture when they are restricted in narrow space in order to relieve stress and adapt to adverse conditions. Some authors have reported that improved environmental enrichment, such as deep straw bedding and enlarged space per sow, satisfies the requirements of nest-building behavior of sows before farrowing. This enriched housing system could also reduce prenatal stress and anxiety in gestating sows (Merlot *et al.* 2017), which would in turn decrease postural changes and lower piglet mortality during farrowing and lactation (Bolhuis *et al.* 2018; Yi *et al.* 2019). In contrast, Valros *et al.* (2003) suggested that the postural change from sitting to lying down and rolling onto either side is associate with good maternal instincts as both behaviors are positively associated with sow's initiative to nurse piglets.

Neonatal piglets often lie near the sow's udder due to their weak constitutions and need for warmth. Moreover, neonatal piglets have an underdeveloped nerve centre in cerebra making it impossible to escape from under the sow during postural changes. There was a positive correlation between the responsiveness of sows to piglet screams and piglet's mortality due to crushing. Illmann *et al.* (2016) suggested that sows are highly responsive to piglet screams and change their posture in time, to prevent crushing piglets within 24 h postpartum. Several studies have demonstrated that the higher the responsiveness of sows to piglet screams, the lower the piglet mortality due to crushing (Andersen *et al.* 2005). High responsiveness of sows to piglet screams and immediate postural changes when piglets are crushed are criteria for good maternal performance.

In the present study, there was no significant difference in the scores of sows' responsiveness to piglet screams between different pregnancy environments. Several studies found that there is no significant difference in sows' responsiveness to piglet screams in loose housing environments or restrictive housing environment (Pedersen and Jensen 2008; Nowicki and Schwarz 2010). In contrast, a few studies revealed that the sows reared in farrowing pens perform better interactions with piglets when changing their body postures (Chidgey *et al.* 2016), and higher responsiveness to piglet screams than those in farrowing crates (Nowicki and Schwarz 2010). In addition, sows must stop their current behavior for a short time and raise their body when they hear piglets screams (Melisova *et al.* 2014). There was a possible correlation with increased oxytocin and prolactin secretion in sows. However, it is still controversial to evaluate the maternal performance of sows based on sows' responsiveness to piglet screams as suggested by Melisova *et al.* (2014) that sows might be able to distinguish between real screams and recordings. In this study, sows' responsiveness to piglet screams varies greatly among each group with the prolonging of time, which could be due to sows adapting to the recordings. At the same time, this adaptability varies greatly between individuals.

Conclusion

Providing abundant nesting materials and space to sows could increase prepartum nest-building behavior as sows in the PP housing system reached the peak of nest-building behavior faster and showed a longer duration of nest-building behavior than those in the PC housing system. Sows in PC housing system showed less crush related behavior including lateral recumbency to other postures and sitting to lying, as well as a lower percentage of sow-terminated nursing than those in CC housing system.

However, PC housing system lowered the frequency of nursing behavior. This suggests that, from different perspectives, the use of either gestation pens or farrowing pens can promote sows' maternal performance.

Acknowledgements

This project was supported by University Nursing program for Young Scholars with Creative Talents in Heilongjiang (No. UNPYSCT-2017107).

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