Preweaning housing effects on behavior and physiological measures in pigs during the suckling and fattening periods

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ABSTRACT: The effect of the preweaning housing system on the stress response of pigs before weaning and during fattening was studied in 33 litters of domestic pigs. Three preweaning housing systems were compared: barren crate (standard farrowing crate without straw), enriched crate (20% larger crate, with straw), and as a control, a farrowing pen (pen, 60% larger than the barren crate, with straw). At 25 d of age, pigs were tested with an isolation test and 1 d later with a human approach test (HumanT). Pigs were weaned at 28 d of age. At 3 and 6 mo of age, pigs were tested with an isolation-human approach test. The latency and frequency of squeal calls and locomotor activity were analyzed for all 3 tests, whereas physical contact with the human was also analyzed for the HumanT and isolation-human approach test. At 6 mo of age, the pigs were transported to a slaughterhouse. One day before transport, immediately after transport, and 1 h after transport, saliva samples were taken for cortisol analysis. The pH of the LM was also measured 45 min after slaughter. The pH of the LM was also measured 45 min after slaughter. Preweaning housing system affected \((P < 0.05)\) the probability of squeal vocalizations, the latency of locomotion, and the duration of locomotion during the HumanT. Pigs from the enriched pens vocalized less, had a longer latency to move, and performed less overall locomotion than pigs from the barren crates. Preweaning housing system did not affect behavior of fattening pigs. Cortisol concentrations before and after transport were not affected by preweaning housing system. An interaction of cortisol concentrations and housing systems was observed between the control sample and the sample taken immediately after transport in pigs from the barren crates \((P < 0.05)\) compared with pigs from the enriched housing systems. Meat from pigs reared in the barren crate tended to have lower pH \((P < 0.10)\) and that of pigs reared in enriched crates had lower pH \((P < 0.05)\) than meat of pigs reared in enriched pens. No differences were observed between pigs from barren or enriched crates. Our results suggest that enrichment of the preweaning environment through enlarged space, provision of straw, and free movement for the sow had a positive effect on the coping behavior of pigs before weaning and prevented an increase in salivary cortisol concentration immediately after transport and a decrease in meat pH 45 min postmortem at the age of 6 mo. Minimal enrichment of the commercial farrowing crate did not affect behavior and physiological measures in pigs before and after weaning.

Key words: pig, preweaning housing, stress, welfare

INTRODUCTION

In intensive husbandry, pigs are often exposed to stressors such as mixing with unfamiliar animals (Jen-

1This study was financed through a grant from the Ministry of Agriculture in Czech Republic MZE 00027014 02 and Grant No. 523/ 04/2007 from the Czech Science Foundation. The authors thank T. de Vries for his kind help with preparing the English manuscript, M. Šimečková for statistical advice, and M. Špinka for his useful comments.

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Published December 8, 2014
challenges compared with pigs raised in an enriched environment (Beattie et al., 2000b; De Jong et al., 2000a; O’Connell et al., 2004). Subordinate pigs reared in a barren environment have increased fearfulness compared with dominant pigs (De Jonge et al., 1996). Housing pigs in an enriched environment throughout the preweaning period can have a positive effect on their coping ability as adult pigs (De Jonge et al., 1996; Olsson et al., 1999). Pigs reared in a barren environment showed more distress during fattening (Beattie et al., 2000a; O’Connell et al., 2004), had a greater cortisol response during transport (De Jong et al., 2000b), and had poorer meat quality compared with pigs reared in an enriched environment (Beattie et al., 2000b). In those studies, straw was provided and pen size during suckling was at least 2 times greater in the enriched environment than in the barren environment.

It is not known whether small differences between commercial housing systems during the preweaning period lead to changes in the coping ability of pigs. This study assessed whether an enriched preweaning housing system influences the coping ability of pigs before weaning and during fattening, the cortisol response of pigs after transport, and the meat quality of pigs.

### MATERIALS AND METHODS

#### Animals and Housing

All procedures involving animals were approved by the Institutional Animal Care and Use Committee. The experiment was conducted between 2001 and 2003 at the experimental unit of the Research Institute of Animal Production in Prague, Czech Republic. Thirty-three litters, born to 14 crossbred sows (Large White × Landrace sows, inseminated by Hampshire or Pietrain × Hampshire boars) ranging between 2 and 11 lactations (5 ± 2; mean ± SD), were observed. Litter size at weaning was 10.8 ± 1.6 (mean ± SD). We attempted to observe 3 litters from each sow in 3 different environments (see below); however, this was not fully possible because of some sows were culled from the herd. Therefore, 4 sows contributed to the data set with litters in 3 environments, 7 sows in 2 environments, and 3 sows in 1 environment. Technical problems during the recordings of the litters resulted in some litters being excluded from the analyses. Therefore, the number of subjects differed among the tests (see Table 1). We chose 2 commercial and 1 control housing system for the lactating sows and their litters.

**Preweaning Housing Systems.** The standard farrowing crate (barren crate) was positioned in a pen with a slatted metal floor. A nesting area was created for the pigs using a solid partition with an entrance for the piglets. This area was equipped with a heat lamp and a solid floor for the piglets. No straw was provided. The enriched farrowing crate with straw (enriched crate) was an ellipsoid-shaped farrowing crate divided by bars in the middle, which allowed the sow to walk around. The crate was positioned in a concrete-floored, straw-bedded pen, which included the heated nesting area for the piglets. The enriched farrowing pen with straw (enriched pen) was a straw-bedded, concrete-floored pen, which allowed free movement for the sow. The nesting area with a heat lamp for the piglets was also provided. The main differences among the 3 housing systems were the provision of straw in the enriched pen and enriched crate, free sow movement in the enriched pen, the possibility for the sow to walk around in the enriched crate, and a larger total area for the piglets in the enriched pen compared with the enriched crate compared with the barren crate (6.4 m² vs. 4.9 m² vs. 4.0 m²; Figure 1).

**Postweaning Housing.** This was the same for all pigs and was situated in the same building as the preweaning housing systems. At 27 ± 5 d (mean ± SD) of age, 2 litters from the same preweaning housing system were mixed in a new straw-bedded pen (3.0 × 2.8 m). There was an average of 20 ± 2 (mean ± SD) pigs in the new pen. At 12 wk of age, the same groups of pigs were moved to larger pens (4.2 × 4.2 m) with slatted floors and no straw. The tests were carried out no sooner than 1 wk after moving the pigs to the new pen. All groups of pigs in these pens had visual, olfactory, and audio contact with pigs in the other pens through a slatted wall.

Pigs were ear-notched at d 1 to 2 of age and were marked with numbers on their backs for individual identification before each observation. All of the males were castrated without anesthesia between 14 and 18 d of age in accordance with production practices in the Czech Republic. Sows were fed a complete feed for lactation sows twice daily (Sano, Czech Republic; 12.99 MJ per 1 kg of feed), and a complete feed for early weaning piglets (Sano; 13.34 MJ per 1 kg of feed) was available to piglets from 5 d of age. During the postweaning period, the pigs were fed ad libitum. From the age of 12 wk feed was delivered 3 times per day (0600, 1200, and 1700). Natural light entered all rooms through windows.

#### Behavioral Measures

Four focal pigs (the heaviest and the lightest female and male from each litter) were selected at 24 d of age. Those litters with only 2 males or 2 females were excluded from the tests. The range in BW between the lightest and the heaviest piglet was 2.0 to 11.5 kg.

In the same building, the experimental room (2.4 × 2.13 m) had a solid floor and no straw. Video cameras (Panasonic) and microphones (Sennheiser evolution 825-S, Sennheiser electronic GmbH & Co., KG, Wedemark, Germany) were positioned 2 m above the floor and were connected via cables to the VCR (Panasonic) in an adjacent room. All pigs were tested in a random order both between and within tests. Behavior was recorded and analyzed using the Observer Video Pro 5.0 software (Noldus, Wageningen, the Netherlands).
Table 1. Number of subjects and litters included in the statistical analyses

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolation test</td>
<td>Barren crate</td>
</tr>
<tr>
<td></td>
<td>37 (9 litters)</td>
</tr>
<tr>
<td>Human approach test</td>
<td>37 (9 litters)</td>
</tr>
<tr>
<td>Isolation-human approach test</td>
<td>11 (6 litters)</td>
</tr>
<tr>
<td>Cortisol concentration</td>
<td>20 (7 litters)</td>
</tr>
<tr>
<td>pH at 45 min postmortem</td>
<td>43 (13 litters)</td>
</tr>
</tbody>
</table>

1Barren crate = a standard farrowing crate (4.0 m²) without straw; enriched crate = a farrowing crate (4.9 m²) with straw; and enriched pen = a farrowing pen (6.4 m²) with straw.

2Test (3 min) of individual piglets on d 25.

3Test (3 min) of individual piglets with an unfamiliar person on d 26.

4Isolation test (2 min) of individual pigs followed by a human test (3 min) at 3 and 6 mo of age.

Tests Before Weaning. Before weaning, the 4 experimental pigs of each litter were individually tested with an isolation test (IsolT) at 25 d of age and a human approach test (HumanT) at 26 d of age. Both tests were conducted immediately after a nursing bout to prevent the influence of hunger on pig behavior (Weary and Fraser, 1995). All tests were conducted in the same manner. One piglet was put in a transport box and moved to the separate experimental room for 3 min. For the IsolT, the isolated pig was observed without any disturbance. For the HumanT, an unfamiliar person was sitting without any movement in the opposite corner from where the door was situated and was dressed in a long blue coat.

Tests During the Fattening Period. During the fattening period, the same 4 pigs were tested in a randomized order at 3 mo (13 to 15 wk) and 6 mo (24 to 26 wk) of age with an isolation-human approach test (Isol-HumanT). For this test, 1 pig was moved into an empty experimental room for 2 min of isolation. After the first 2 min, an unfamiliar person entered the room and stood without movement for the next 3 min in the opposite corner from where the door was located. In the case where a pig bit the person during this test, the pig was calmly pushed away by the person. All tests were carried out between 0900 and 1100. The analyzed behavioral measures of the tests are given in Table 2.

Physiological Measures

Transport and Cortisol Response. At 26 wk of age, each pen group was loaded on a truck at 0700 and transported to a slaughterhouse. After arrival, the pigs were unloaded and kept in a lairage for 1 h. The duration of loading, transportation, and unloading was 90 min. All groups of pigs were subjected to the same manipulations during transport. Saliva samples of focal pigs were taken 3 times (1 d before transport at 1600 as a baseline measure, and immediately after unloading and 1 h later). Saliva was collected by allowing the pigs to chew on 2 large cotton swabs attached to a 0.5-m-long holder until they were thoroughly moistened (about 30 to 60 s per sample). Swabs were placed in plastic tubes and centrifuged for 10 min at 400 × g. Saliva samples were then stored at −20°C until they were analyzed.
The concentration of cortisol in saliva samples was determined using an RIA kit (cat. #1841, Immunotech, Marseille, France). According to the manufacturer, cross-reactivities of the cortisol antibody with several endogenous and pharmaceutically employed steroids were as follows: cortisol, 100%; 11-desoxycortisol, 18.0%; corticosterone, 8.4%; 21-desoxycortisol, 7.5%; desoxycorticosterone, 7.3%; prednisolone, 6.0%; 17α-hydroxyprogesterone, 3.5%; hydroxycorticosteroid, 2.4%; and 11β-hydroxytestosterone, 2%. The intraassay and interassay CV were 6.44 and 9.12%, respectively. Recovery of cortisol added to saliva was between 94 and 106% for doses of 2, 4, and 8 ng of cortisol/mL. The minimal detectable concentration of the assay was 0.1 ng/mL.

**Meat Quality after Slaughter.** Immediately after the last saliva sample was collected, pigs were electrically stunned and slaughtered according to normal commercial practice. Meat quality measurements were carried out on all focal pigs. The pH of the LM was measured 45 min postmortem using an electrode probe attached to a portable pH meter (pH-star, SFK Technology A/S, Herlev, Denmark).

**Statistical Analysis**

All data were analyzed using SAS (SAS Inst. Inc., Cary, NC). Based on the analysis of individual differences, individual focal pigs from each litter were considered as the experimental units. The identity of the litter and the dam’s identity entered the model as random effects. The identity of the group of mixed litters after weaning was excluded from the statistical model. The likelihood ratio test (Verbege and Molenberghs, 2000) did not detect significance of this random effect.

Behavioral data collected during the IsolT, HumanT, and Isol-HumanT were not normally distributed and, therefore, were transformed. The latencies of squeal vocalization and locomotion were logarithmically transformed, the frequencies of squeal vocalization were square-root transformed, and the duration of locomotion was arcsine square-root transformed. Effects of housing, sex, and BW of pigs on behavior, cortisol response, and meat pH were tested using a mixed linear model (PROC MIXED). In cases where it was not possible to transform the data, we used logistic regression (PROC GENMOD), and we tested the influence of the effects on the probability of squeal calls and physical contacts with the human in the HumanT and Isol-HumanT.

For analyses of behavior during the IsolT, HumanT, and Isol-HumanT, the fixed effects were housing system (barren crate, enriched crate, and enriched pen), sex (male and female), and as a continuous variable, BW of the pigs. The dependent variables and types of statistical analyses are given in Table 2.

A repeated measures analysis (PROC MIXED) was used in the analysis of the cortisol response before and after transport. The dependent variable was the cortisol value, and the effects were housing system, sampling order (before transport, and immediately and 1 h after transport), the interaction of housing system × sampling order, sex, and as a continuous variable, BW of the pigs. For the analysis of meat pH, a linear mixed model was used. The dependent variable was the pH value of the meat and the effects were housing system, sex, and as a continuous variable, BW of pigs. The sex × housing system interaction was nonsignificant, and therefore, this interaction was dropped from the statistical model.

In the linear, mixed model analyses, in cases where the treatment effect was significant, the significance of the pairwise differences of the housing system effect between levels was assessed using least squares means. The least squares means were computed for each level, and their difference was tested using a t-test adjusted through the Tukey-Kramer (Bonferroni) method for multiple comparisons. In the GENMOD procedure, tests for specified hypotheses concerning the model parameters and the odds ratio for explanatory variables were constructed via the ESTIMATE statement. The odds ratio is a way of comparing whether the probability of a certain event is the same for 2 groups. An odds ratio of 1 implies that the event is equally likely in both groups. An odds ratio greater than 1 implies that the event is more likely in the first group. An odds ratio less than 1 implies that the event is less likely in the first group (Stokes et al., 2000).

**RESULTS**

**Tests Before Weaning and During the Fattening Period**

Piglet behavior during IsolT on d 25 was similar among preweaning housing systems. During the Hu-
Preweaning housing effects on pig behavior

Figure 2. Predicted probability to vocalize during a 3-min human approach test before weaning in pigs kept in 3 different preweaning environments (\(**P < 0.01\)).

...manT on d 26, pigs reared in barren crates were more likely to vocalize (\(P < 0.01\)) than pigs reared in the enriched crates and enriched pens (Figure 2). They also had the shortest latency to move (Figure 3a; \(P < 0.01\)), the longest duration of locomotion (Figure 3b; \(P < 0.05\)), and tended to have a greater probability to contact humans than piglets from enriched pens (\(P < 0.10\)). No differences in locomotion and contact were found between both types of crates. During fattening, the preweaning housing system had no significant effect on any of the measured behavioral parameters.

Salivary Cortisol

Salivary cortisol concentrations were similar (\(P > 0.10\)) among preweaning housing systems before, immediately after, and 1 h after transport. Regardless of preweaning housing system, all pigs experienced elevated (\(P < 0.001\)) salivary cortisol concentrations immediately after transport and then lower 1 h later (Figure 4a).

There was a housing \(\times\) sampling order interaction which showed that pigs reared in barren crates had the greatest increase (\(P < 0.05\)) in salivary cortisol concentration immediately after transport compared with their control sample taken in the home pen (Figure 4b). This interaction was not significant for those pigs reared in the enriched housing systems.

The pH-Value of Meat

The preweaning housing system affected (\(P < 0.05\)) the pH value of meat 45 min postmortem (Figure 5). Meat from pigs reared in the enriched crates was lower in pH than meat from pigs reared in the enriched pens. Pigs from barren crates tended (\(P < 0.10\)) to have lower pH of meat than pigs from the enriched pens. No differ-

Figure 3. Panel a) latency to move during a 3-min human approach test on d 26 of age (before weaning) in pigs kept in 3 different preweaning environments (least squares means ± SE; **\(P < 0.01\), *\(P < 0.05\)). Panel b) proportion of time spent in locomotion during a 3-min human approach test before weaning in pigs kept in 3 different preweaning environments (least squares means ± SE; *\(P < 0.05\)).
Figure 4. Panel a) salivary cortisol concentrations 18 h before transport (−18 h), immediately after transport (0 h), and 1 h after transport (1 h) for all pigs regardless of preweaning environment (least squares means ± SE; **P < 0.01). Panel b) salivary cortisol concentrations 18 h before transport (−18 h), immediately after transport (0 h) and 1 h after transport (1 h) pigs kept in 3 different preweaning environments. A significant effect (P < 0.05) was found between (18 h and 0 h in the barren crate group (least squares means ± SE).

Sex and Weight Effects

Sex affected (P < 0.01) frequency of vocalizations during the IsolT and the probability to squeal during the Isol-HumanT (P < 0.05) at the age of 3 mo with males squealing 1.5 times more often than females. The BW of pigs before weaning affected (P < 0.05) frequency of squealing and the latency to move during the IsolT. Particularly, with increasing BW, the latency to move decreased and the frequency of squealing increased. During the HumanT, increased BW increased (P < 0.05) the probability to contact the human. During the fattening period, BW of pigs affected (P < 0.01) duration of locomotion at 3 and 6 mo of age. As BW increased, the duration of locomotion decreased.

DISCUSSION

In this study enrichment of the preweaning housing system affected behavior of pigs during preweaning challenging tests. We were not able to detect such an effect at the ages of 3 and 6 mo. However, salivary cortisol and meat quality were affected by preweaning environment. Pigs reared in barren crates experienced a greater cortisol increase immediately after transport compared with their home pen control sample than pigs reared in both of the enriched environments. Meat from pigs reared in enriched crates was lower in pH, and the meat from pigs reared in barren crates tended to be lower in pH compared with the meat from pigs reared in enriched pens.
Isolation Test and Human Approach Test before Weaning

Enrichment of the preweaning housing system had no influence on stress response during the IsolT on d 25. However on d 26 during the HumanT, latency to move was similar between pigs reared in the 2 crates, but pigs from enriched pens had longer latency to move periods than pigs from either of the 2 other systems (Figure 3a). The enriched pen was straw bedded, and the pen size was about 60% (6.4 m²) larger and allowed free movement of the sow than in the barren crate (4.0 m²). We did not detect differences in both commercial preweaning housing systems (enriched crate vs. barren crate). The enriched crate had straw, but only differed from the barren crate in terms of space by 20% and the movement of the sow was limited. Regardless, level of enrichment of the enriched crate was intermediate between the barren crate and the enriched pen.

Pigs reared in enriched pens showed less behavioral signs of distress than piglets reared in barren crates during the HumanT on d 26. These pigs vocalized less, and showed less locomotor activity than pigs reared in the barren crates. An increased locomotor and vocal activity during challenging tests indicates a greater level of distress (Fraser, 1975; Marchant et al., 2001; Hillmann et al., 2003). This is supported by physiological measures. Stress vocalization is correlated with level of stress hormones in domestic pigs (Schrader and Todt, 1998; Schrader and Ladewig, 1999). In contrast with our prediction, the probability to contact a person was lower for pigs reared in enriched pens than for pigs reared in barren crates. Marchant et al. (2001) described a similar phenomenon. In that study, when a person entered the pen, the gilts that squealed more spent more time in close proximity to the human. The authors suggested that those gilts felt isolation as more stressful and may have used a person as a familiar reference point.

However, we were not able to detect an influence of preweaning housing system on distress levels during the IsolT on d 25. It is possible that separation from the dam and exposure to a novel environment caused a high stress response in all of the pigs, which may have masked the effect of the preweaning housing system. There were 25% more vocalizations from all pigs during the IsolT than in the pigs during the HumanT. Pigs respond to separation from the dam and littermates by increasing high frequency calls (Fraser, 1975).

Isolation - Human Approach Test During Fattening

During the fattening period there was no influence of preweaning housing system on any behavior reaction. Contrary to this, De Jonge et al. (1996) found an effect over several months of an enriched preweaning housing on behavior of adults even when the housing system was identical for all pigs after weaning. However, in that study, a super enriched preweaning environment (farrowing pen with an outdoor enclosure) was compared with farrowing crates. It seems that the influence of housing system on the stress reaction of pigs is more detectable when pigs are housed their whole life in an enriched environment, which was confirmed by several studies (Beattie et al., 2000a; De Jong et al., 2000a). However, providing an enriched housing system exclusively before weaning may have long-lasting influence on other behaviors, such as agonistic interactions. Pigs reared in enriched pens before weaning had less agonistic interactions during the fattening period compared with pigs reared in crates (Chaloupková et al., 2007).

Salivary Cortisol and pH of Meat

Transportation resulted in elevated salivary cortisol concentrations immediately after unloading and a lower value 1 h after transport in all pigs regardless of their preweaning housing system. We found an increase in cortisol immediately after transport compared with the control sample only in pigs reared in barren crates, but not in pigs reared in both enriched housing systems. This result suggests that pigs reared in the barren crates experienced the strongest stress reaction to transport. This result corresponds with findings de Jong et al. (2000b), who reported that salivary cortisol increased after transport, compared with values in the home pen in the barren-reared pigs but did not differ in the enriched-reared pigs. In contrast, other studies (Geverink et al., 1999; Beattie et al., 2000b; De Jong et al., 2000b) found that the enriched-reared pigs had greater concentration of salivary cortisol in the home pen, after loading, transport, and at the beginning of the lairage period compared with pigs reared in barren housing. A possible explanation is that pigs reared in barren housing throughout life may have a suppressed cortisol response and their circadian rhythm is blunted (De Jong et al., 1998; Beattie et al., 2000b).

The pH-value of the meat 45 min after slaughter was influenced by preweaning housing system. Meat from pigs reared in the enriched crates had a lower pH than meat from pigs reared in the enriched pens. Stress before slaughter can negatively affect meat quality (Van der Wal et al., 1999). The pH of meat decreases (less than 5.70), and then meat becomes undesirable PSE. Results of the current study suggest that pigs reared in preweaning crates may be more responsive to pre-slaughter manipulation. Beattie et al. (2000b) found decreased meat quality in barren-reared pigs compared with pigs that were reared in enriched conditions. Specifically, pork from barren-reared pigs had greater cooking losses and lower levels of intramuscular fat than pork from enriched-housed pigs. Greater amounts of intramuscular fat in enriched-reared pigs have previously been associated with improved tenderness and water holding capacity in pork (Candek-Potokar et al., 1998).
Sex and Weight Effect

Surprisingly, sex of the piglets had an effect on frequency of vocalizations. Males squealed more often than females before weaning and at 3 mo of age. These results are in contrast with findings of other researchers who reported no sex effect on coping behavior of fattening pigs (De Jong et al., 1998, 2000a,b) and piglets at the age of 2.5 wk (Erhard and Mendl, 1999). In our study, the greater frequency of vocalizations by males could be related to their castration that was performed 1 wk before the first test. Hay et al. (2003) demonstrated that the behavioral response caused by pain after castration in 1-wk-old boars persisted for over 4 d. Ruis et al. (1997) found greater basal salivary cortisol concentrations after isolation in boars at wk 12 and 20, which might have resulted from castration performed 2 to 4 d after birth.

In our study, BW of pigs also affected their behavior during the tests. Before weaning, pigs with greater BW showed a stronger stress response, manifested in more squealing, shorter latency of locomotion, and increased probability to contact a human during the HumanT. Conversely, during the fattening period, the proportion of locomotion decreased with increased BW. The effect of BW on coping behavior during a stress situation has not often been tested because most researchers have used focal pigs with similar BW (De Jong et al., 2000a,b; O'Connell et al., 2004). A BW effect was also confirmed during the mixing of unacquainted pigs; heavier piglets had more bites and spent more time fighting than the smallest piglets (Andersen et al., 2000a).

Enrichment of the preweaning environment through enlarged space, provision of straw, and free movement for the sow had a positive effect on coping behavior of pigs before weaning and prevented an increase in salivary cortisol concentration immediately after transport and a decrease in meat pH 45 min postmortem at the age of 6 mo. No long-term effects on behavior of the fattening pigs at the age of 3 and 6 mo were detected. Enrichment of commercial farrowing crates by providing 20% more space with straw in comparison with the standard farrowing crates did not affect the behavior and physiological measures of the pigs before and after weaning.

LITERATURE CITED