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Effect of crate opening from day 3 *postpartum* to weaning on nursing and suckling behaviour in domestic pigs

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Temporary crating may be a more acceptable housing system for lactating sows than permanent crating and loose-housing because it combines benefits of both systems while reducing some of their limitations. It remains unclear whether nursing and sucking behaviour is influenced after crate opening. The aim of this study was to assess the short- (24 h post-crate opening) and long-term (day 25 postpartum *(pp.)) effects of opening the farrowing crate from day 3 pp. to weaning on nursing and suckling behaviour. Sows were crated from 5 days* prepartum *either to weaning (permanently crated group;* n = *14) or 3 days pp. (temporarily crated group;* n = *13). Sows and their litters were observed on days 4 and 25. Duration of pre- and post-massages, nursing termination, number of piglets missing milk ejection and number of piglets fighting during pre- and post-massages were scored at 15-s intervals. Nursing success (i.e. with or without milk ejection) was also recorded. Data were analysed using PROC GLM and PROC GENMOD of SAS including housing, litter size and parity as fixed effects. Nursing behaviour did not differ between sows housed in temporary crates and those housed in permanent crates on days 4 and 25 pp., that is, same number of nutritive nursings (NNs), same proportion of non-NNs, same duration of post-massages and same proportion of termination of post-massages. There was only a housing effect on day 25; with sows having longer pre-massages in permanent crates (*$P < 0.05$*). Suckling behaviour was overall similar between treatments. There were no differences in the number of piglets attending pre- and post-massages, proportion of piglets fighting during pre-and post-massages and the proportion of piglets missing milk ejection on both days. The only housing effect was found on day 25 during which fewer piglets attended post-massages (*$P < 0.05$*) in permanent crates. Sows with larger litters terminated post-massages more often (*$P < 0.05$*), allowed shorter post-massages (*$P < 0.05$*) on day 4, and had more piglets miss milk ejection on days 4 and 25 (*$P < 0.05$*). In conclusion, the results of this study showed that housing had a very limited effect on nursing and suckling behaviour. Sow and piglet behaviours were not altered after crate opening (short-term effect) and nursing was to some extent calmer (shorter pre-massages and more piglets attended post-massages) in temporary crates on day 25. Increased litter size impaired nursing and suckling behaviour of sows and piglets independently of the housing system.*

Keywords: animal welfare, housing, lactation, sow behaviour, nursing

Implications

The present study shows that crate opening from day 3 *postpartum* (pp.) to weaning did not alter suckling and nursing behaviour 24 h after opening the crate compared to permanent crating (e.g. same number of nutritive nursings (NNs), same proportion of piglets missing milk ejection). Nursing behaviour was to some extent calmer (shorter pre-massages and more piglets attended post-massages) in temporary crates on day 25. Increased litter size had a negative effect on nursing and suckling behaviour. Short temporary confinement may thus be a safe alternative to permanent crating in regards to nursing and suckling behaviour.

Introduction

Farrowing crates seriously impair sow welfare, but they are still widely used on commercial pig farms (Wechsler and Weber, 2007; Kilbride *et al.*, 2012). Farrowing pens with temporary confinement during the first days of lactation have been developed as a compromise between conventional farrowing crates and pens to control piglet mortality due to crushing during this time period. The few available papers on temporary crating have mostly focussed on the opening time

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after parturition and the effect on piglet mortality and weight gain (e.g. Mousten *et al*., 2013) or the interaction between piglets and the sow (Chidgey *et al*., 2017; Singh *et al*., 2017).

Not much is known about the consequences of temporary crating on sow and piglets behaviour during nursing shortly after opening the crate (i.e. within 24 h, short-term effect) and before weaning (long-term effect). For the introduction of temporary crating to be successful under commercial conditions, it is important to know whether nursing behaviour is affected as it influences piglet weight gain and survival (Špinka *et al*., 1997; Andersen *et al*., 2011; Ocepek *et al*., 2017). Shortly after opening the crate, the increase of the available space might trigger higher activity (Heidinger *et al*., 2017; Goumon *et al*., 2018) and might lower the sow motivation to nurse and/or increase litter competition. So far, only Singh *et al*., (2017) compared nursing and suckling behaviour in temporary crating pens and farrowing crates on days 4, 11 and 18 pp. The authors found no effect of housing on nursing frequency and duration but without differentiating whether the nursing was with or without milk ejection and without assessing the duration of pre- and post-massages. Both are important parameters to assess milk transfer and calmness of a nursing (Špinka *et al*., 1997; Pedersen *et al*., 2011). Unexpectedly, in the same study (Singh *et al*., 2017), piglets of sows housed in temporary crates missed more nursing events on days 11 and 18 pp. and were more displaced from other piglets on day 11 compared to those of sow housed in permanent crates. Sows might then respond by not releasing milk (Appleby *et al*., 1999) or by terminating a nursing soon after milk ejection (Bozděchová *et al*., 2014; Illmann *et al*., 2018). It is therefore important to know whether litter competition indeed increases in temporary crates and whether nursing behaviour is affected after opening the farrowing crate.

The removal of confinement in temporary crates might have a long lasting positive effect on the course of nursings before weaning compared to permanent crates. It has been shown that nursing and suckling behaviour was calmer in farrowing pens compared to permanent crates at weeks 2 and 4 pp. (Pedersen *et al*., 2011). In that study, there were fewer teat fights, a lower number of piglets missing milk letdown, sows terminated fewer nursing bouts and allowed the piglets to perform longer post-massages in farrowing pens. Consequently, we would expect more fights and more piglets missing milk ejection in permanent crates before weaning than in temporary crates.

Thus, the aim of the study was to assess whether crate opening from the 3rd day pp. to weaning had short- (24 h post-crate opening) and/or long-term (day 25 pp.) effects on suckling and nursing behaviour compared to permanent crating.

Material and methods

This study was carried out from July 2015 to July 2016 at the research farm of the institute of animal science in Prague, Czech Republic. This work was part of a larger experiment investigating the effects of temporary crating on sows and piglets behaviour and physiology (Goumon *et al*., 2018). Thus, same animals, housing conditions and management were used in both studies.

Animals

A total of 27 Large White × Landrace sows (parity: 2.5 ± 0.5, range: 1 to 12) inseminated with Large White × Pietrain boar semen were used. Sows were moved from a group-housing gestation unit to a farrowing unit at approximately day 110 post-insemination and were farrowed in a room containing two farrowing pens with temporary crating and two farrowing pens with permanent crating. After balancing for parity, sows were randomly allocated to one of the following two treatments previously described by Goumon *et al*. (2018): sows permanently crated ($n = 14$ sows and 192 piglets born; litter size: 13.7 ± 0.7 piglets) were confined in a crate from 5 days pre-farrowing until weaning (approximately 28 days post-farrowing), while sows temporarily crated ($n = 13$ sows and 172 piglets born, litter size: 13.5 ± 0.7 piglets) were confined in crates from 5 days pre-farrowing until 3 days post-farrowing, and were let loose (opening of the crate) on day 4 (83.0 ± 1.3 h; day 0 being the day of farrowing) until weaning. A batch consisted of two sows, one for each treatment, housed in adjacent pens of the same type of farrowing system (Figure 1), with one treatment let loose from day 4 and the other one remained confined. One sow in the temporary crating treatment was removed due to illness. The crate was opened at around 10 h, after completion of a nursing. There was neither equalization nor cross fostering of the litters. All sows were familiar with permanent farrowing crating only. Farrowing was supervised through 24 h video recordings.

Housing

As described in Goumon *et al*. (2018), farrowing pens measured 5.88 m^2 and were equipped with movable bars, which enabled them to be modified into crates and vice versa (Figure 1). The sow area (the part of the pen accessible to the sow) for crated sows measured 1.63 m^2. When the sows were let loose, the sides of the crate were opened and placed along the sidewalls. In this configuration, the sow area measured 4.63 m^2. There were protection rails along the sidewalls for the prevention of piglet crushing when the sow was lying down. Solid concrete flooring was present in the whole pen. The creep area (the part of the pen accessible only to the piglets) measured 1.25 m^2 and was not covered, bedded with straw and had two hanging heat lamps during the whole lactation.

Management

As described in Goumon *et al*. (2018), sows were fed a standard lactation diet (17% CP, 13.75 MJ digestible energy/kg) twice a day, and water was available *ad libitum* from one nipple for the sow and another one for the piglets. The sows received one bag of chopped straw each morning

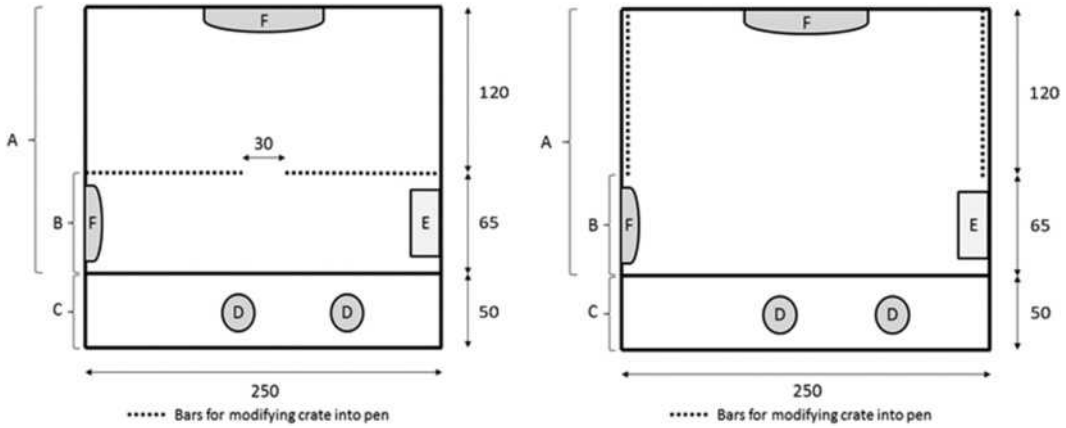

Figure 1 Farrowing pen equipped with movable bars, which allowed the modification from farrowing crate (left) to farrowing pen (right). A = sow area when farrowing crate is open; B = sow area when sow is crated; C = creep area for piglets; D = heating lamp; E = feed trough; F = piglet anti-crushing bars. All measurements are in centimetres.

Table 1 *Behaviours of sows and piglets*

	Definitions
Sow behaviour	
Beginning of a nursing	When more than 50% of the piglets performed pre-massage
End of a nursing	When either fewer than three piglets performed post-massage or when the sow exhibited postural changes (rolling, sitting or standing). Nursing can be terminated by either the sow or the piglets
Duration of pre-massage	Time from the beginning of nursing to milk ejection
Duration of post-massage	Time from the end of milk ejection to termination of nursing
Nutritive nursings	Nursing with milk ejection judged by rapid mouth suckling movements and the increase in the grunting rate exhibited by the sow (Illmann *et al.*, 1999)
Non-nutritive nursings	Nursing without milk ejection
Piglet behaviour	
Number of piglets missing milk ejection	Number of piglets which had no teat access during milk ejection
Number of piglets fighting during a nursing	Number of piglets biting and pushing its head or shoulders against another piglet during every 15-s interval after the beginning up to the termination of a nursing
Number of piglets attendance during a nursing	Number of piglets present at the udder during every 15-s interval after the beginning up to the termination of a nursing

and evening until they had farrowed, and once a day during the whole lactation. Pens were cleaned once a day. Piglets were ear tagged on day 3 pp.. All piglets received an iron injection and males were surgically castrated during the 1st week of life in accordance with normal farm practices. Piglets were neither tail docked nor teeth clipped. They were provided with creep food from day 7 pp.

Data collection

Piglet BW gain. As described in Goumon *et al.* (2018), piglets were individually marked using an animal marking crayon (Raidex, Germany) and weighed at the same time (around 09;30 h) on day 3 (30 min before opening), day 4 (24 h after opening of the crate) and day 25. This variable was analysed by using, for each litter, the difference in individual piglet weight, respectively, from days 3 to 4 (short-term effect) and days 4 to 25 (long-term effect).

Behavioural observations. In this study, sows and piglets were observed for 4 h on day 4 (i.e. after 24 h after opening the farrowing crate) and on day 25. All nursing episodes during these 4 h were observed directly, and accompanied by continuous video recordings using handheld cameras (Panasonic H280 and H50, Osaka, Japan). The following data were recorded: beginning of nursing, end of a nursing, duration of pre-massage, duration of post-massage, terminator of a nursing and occurrence of nutritive and non-NNs (Table 1).

The number of piglets performing each of the following behaviours was scored every 15 s during the entire nursing episode: the number of piglets present at the udder, the number of fights at the udder (de Passillé and Rushen, 1989) and the number of piglets missing milk ejection (definitions in Table 1). In order to compare the duration of pre-massages for NNs in individual sows, five 15-s intervals before milk ejection were used in the statistical analysis, based on the median length of pre-massages in all NNs observed during the study. In order to compare the length of post-massages in NNs, nine 15-s intervals after milk ejection were used, based on the median length of post-massages in all NNs terminated by the sow.

Statistical procedures

An individual sow was considered as an independent subject, and therefore included as a random effect in all models. The fixed effects included in all models were housing (temporary *v.* permanent crating) and two continuous variables: parity and litter size. Our main focus was to assess whether there were differences between treatments on days 4 and 25, therefore we analysed these 2 days separately.

A linear mixed model (PROC MIXED) was applied to detect the effect of housing on the duration of pre- and post-massages. A Poisson or binomial model with mixed effects (PROC GENMOD) was applied to test effects on termination of post-massages, number of NNs, the proportion of non-NNs and piglet behaviour (proportion of piglets missing milk ejection, number of piglets attending in 15-s intervals during pre-massages, number of piglets fighting in 15-s intervals during pre-massages, number of piglets attending in 15-s intervals during post-massages and number of piglets fighting in 15-s intervals during post-massages).

All data were analysed in SAS (SAS Institute Inc., Cary, NC, USA; version 9.4). Results were considered statistically significant at $P \leqslant 0.05$. Only significant results were shown, unless otherwise stated.

Results

Sow behaviour

Short-term effects of opening the crate. No housing effect was detected on the duration of the pre-massages, the number of NNs, the proportion of non-NNs and the proportion of nursings terminated by the sows (Table 2).

There was an effect of litter size; increasing litter size was associated with longer pre-massages ($F_{1,21} = 7.15$; $P < 0.05$), shorter post-massages ($F_{1,21} = 11.25$; $P < 0.01$; Figure 2a) and sows terminated more post-massages ($\chi^2 = 9.30$; $P < 0.01$; Figure 2b). Duration of pre-massages increased with higher sow parity number ($F_{1,21} = 7.15$; $P < 0.05$).

Long-term effects of opening the crate. Housing had an effect on pre-massages with longer pre-massages for sows housed in permanent crates ($F_{1,21} = 5.48$; $P < 0.05$, Table 2). Other nursing behaviour did not differ between housing conditions (Table 2).

Piglet behaviour

Short-term effects of opening the crate. No housing effect was detected on the proportion of piglets attending and fighting during pre- and post-massages, and the proportion of piglets missing milk ejection (Table 2).

Table 2. *Short-term (day 4, 24-h period after opening of the crate) and long-term effects (day 25) of temporary crating on nursing and suckling behaviour of sows and piglets*

	Permanent crating	Temporary crating	*P*-value
Short-term effect			
Sow behaviour			
Number of nutritive nursings	4.4	4.5	0.87
Proportion of non-nutritive nursings (%)	15.6	15.5	0.98
Duration of pre-massages (min)	1.6	1.7	0.11
Duration of post-massages (min)	2.2	3.0	0.06
Nursings terminated by the sow (%)	63.2	66.4	0.79
Piglets behaviour			
Proportion of piglets missing milk ejection (%)	3.5	3.1	0.73
Piglets fighting during pre-massages/15 s (%)	3.3	1.9	0.25
Piglet attendance during pre-massages (%)	95.8	95.1	0.53
Piglets fighting during post-massages/15 s (%)	6.9	6.5	0.93
Piglet attendance during post-massages (%)	93.4	93.4	0.99
Long-term effect			
Sow behaviour			
Number of nutritive nursings	4.4	4.4	0.98
Proportion of non-nutritive nursings (%)	11.0	13.5	0.72
Duration of pre-massages (min)	1.4	1.2	**0.03**
Duration of post-massages (min)	2.3	1.7	0.13
Nursings terminated by the sow (%)	59.1	72.4	0.22
Piglets behaviour			
Proportion of piglets missing milk ejection (%)	4.7	3.3	0.23
Piglets fighting during pre-massages/15 s (%)	2.4	1.6	0.28
Piglet attendance during pre-massages (%)	95.8	95.1	0.13
Piglets fighting during post-massages/15 s (%)	0.7	0.3	0.25
Piglet attendance during post-massages (%)	86.0	91.0	**0.03**

Least squares means are presented.
Bold values indicate a statistically significant difference ($P < 0.05$).

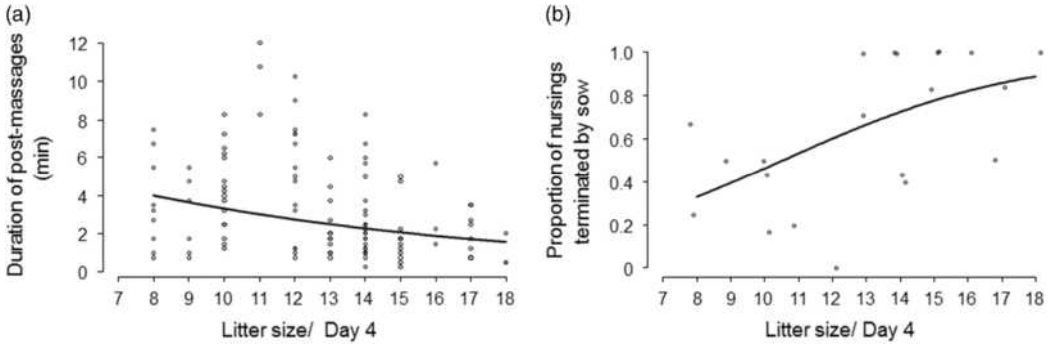

Figure 2 (a) Relationship between litter size and duration of post-massages (observed and fitted* values) on day 4. (b) Relationship between litter size and probability of a sow to terminate a nursing (observed and fitted* values) on day 4: *The curve is estimated based on the statistical model.

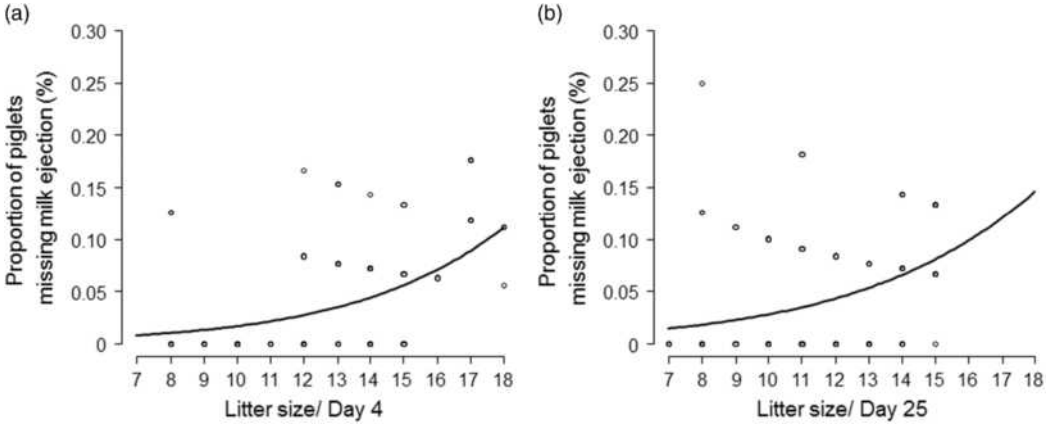

Figure 3 Relationship between litter size and proportion of piglets missing milk ejection (observed and fitted* values) on day 4 (a) and day 25 (b). *The curve is estimated based on the statistical model. The litter size differed between days 4 and 25 due to piglet mortality in some litters after day 4.

There was a litter size effect detected. More piglets missed milk ejection in larger litters ($\chi^2 = 5.02$, $P < 0.05$; Figure 3a).

Long-term effects of opening the crate. There was a housing effect on post-massage piglet attendance, with fewer piglets attending post-massages in permanent crates ($\chi^2 = 4.76$, $P < 0.05$, Table 2). Other observed suckling behaviour did not differ between treatments (Table 2).

There was an effect of litter size. The proportion of piglets fighting during pre-massages ($\chi^2 = 5.01$, $P < 0.05$; Figure 4) and the proportion of piglets missing milk ejection increased in bigger litters ($\chi^2 = 5.05$, $P < 0.05$; Figure 3b).

Piglet weight gain

Piglet weight gain did not differ in the 24-h period after opening the crate and from days 4 to 25 between permanent and temporary crating housing systems (167.9 *v.* 178.7 g ; SEM: 9.0; and 4091.1 *v.* 4359.0 g; SEM: 166.8, respectively). Litter size influenced BW ($P < 0.001$) with piglets in bigger litters having lower weights at both ages.

Discussion

Short-term effects of opening the crate

To our knowledge, this is the second study assessing the effect of removal of confinement from day 3 pp. to weaning on nursing and suckling behaviour of lactating sows and piglets, compared to permanent crating. The behavioural analysis in the present study was more detailed than the only available study of Singh *et al.* (2017). Specifically, more reliable indicators of litter competition, that is the differentiation between nutritive and non-NNs, the duration of pre- and post-massages and the number of piglets fighting at the udder were used (Špinka *et al.*, 1997; Pedersen *et al.*, 2011; Bozděchová *et al.*, 2014).

In the present study, the number of NNs and the proportion of non-NNs were similar in both treatments. These result indicates that nursing behaviour (e.g. the motivation to nurse and to release milk) was not impaired even when loose sows had increased activity levels, including more rolling within the 24-h period post-opening of the crate (Goumon *et al.*, 2018). The number of NNs is an important indicator of milk transfer as it is positively correlated with milk intake and piglets weight gain (Špinka *et al.*, 1997; Auldist *et al.*, 2000; Tanaka and Koketsu, 2007). Furthermore, the duration of pre-massages and of post-massages did not differ between treatments. Longer post-massage duration could support the release of prolactin and can increase the milk production (Špinka *et al.*, 1999). Thus, the present study clarifies the results of Singh *et al.* (2017) who showed that sows had the same number of nursings in both treatments, but without differentiating whether a nursing was nutritive or non-nutritive and considering only the whole duration of a nursing.

The results of the present study indicate that udder access was not altered after opening the crate as the same

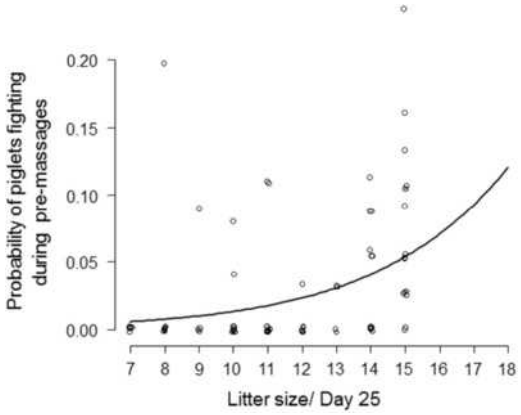

Figure 4 Relationship between litter size and the number of piglets fighting per 15-s interval in the last five intervals before milk ejection (observed and fitted* values) on day 25. *The curve is estimated based on the statistical model.

proportion of piglets attended nursings during pre- and post-massages in both treatments. This is supported by the fact that the number of piglets fighting, the proportion of piglets missing milk ejection and BW gains were similar in both temporarily and permanently crated sows. It has been shown that a high number of piglets fighting is a clear indicator of impaired teat access and of more piglets missing milk ejection during the neonatal period (days 1 and 2 pp., Bozděchová *et al*., 2014; Illmann *et al*., 2018) and in established lactation (days 15 and 28 pp., Pedersen *et al*., 2011). These results are in line with those of Singh *et al*. (2017) who found that the same proportion of piglets missing milk ejection in both temporarily and permanently crated sows on day 4 pp. but without assessing piglets fight at the udder.

Long-term effects of opening the crate

The prediction that opening the crate in temporary crating might have a long-lasting positive effect on the calmness of nursings before weaning compared to permanent crating was only partly confirmed. In the present study, piglets of temporarily crated sows showed shorter pre-massages and more piglets attended post-massages on day 25 compared to those of permanently crated sows. This indicates that piglets in permanent crates had to massage the teats longer in order to stimulate milk ejection. Some piglets may have had an impaired teat access caused by the protective bars of the farrowing crates and thus they had no possibility to efficiently massage their teats, which could have prolonged the release oxytocin and consequently milk ejection (Fraser, 1973). On the other hand, the present study did not find any difference in other indicators of greater calmness of nursing and suckling behaviour (e.g. proportion of piglets fighting or missing milk ejection or nursing termination by the sow) in temporary crates as suggested by Pedersen *et al*. (2011). It might be that even reduced crating duration of the sow, that is before parturition and during the 1st day pp. still has a long-lasting negative effect influencing calmness during nursing.

As expected, we did not find any evidence that litter competition increased in temporary crates as found by Singh *et al*. (2017). That study found a higher litter competition at the udder in temporary crates compared to permanent crates on days 11 and 18 pp., as indicated by a higher proportion of piglets missing nursing bouts and piglets displaced at the udder. These results are surprising because these differences become evident 1 week after opening the farrowing crates. The litter size was rather small (only 10 to 11 piglets) and the teat order should have been stable at this age (Puppe and Tuchscherer, 1999). The higher litter competition might be explained by management factors or the pen design where piglets did not get full access to the teats.

Litter size effect

In our study, litter size had a negative effect on nursing and suckling behaviour in both housing systems. With increasing litter size a higher proportion of piglets missed milk ejection on days 4 and 25. Furthermore, sows terminated more post-massages and allowed only shorter post-massages on day 4. It is crucial for each piglet not to miss the brief milk ejection period (typically 20 s each hour) which is the only period of the nursing bouts during which they can actually ingest milk (Illmann *et al*., 1999). Missing milk ejection prolongs the inter-nursing interval and lowers the milk intake for each piglet per time unit (Špinka *et al*., 1997; Jensen *et al*., 1998). In our study, the average litter size was almost 14 piglets (permanent crates: 13.7 ± 0.7 piglets *v.* temporary crates: 13.5 ± 0.7 piglets). It has been shown that at an average litter size of 12 piglets, one piglet per missed the milk ejection on day 1 pp. (Andersen *et al*., 2011) but also in later lactation (days 15 and 28 pp., Pedersen *et al*., 2011). Even though it was not the primary aim of the study, this finding underlines that increasing litter size may be a welfare problem and highlights the importance of addressing it in further studies (Rutherford *et al*., 2013; Ocepek *et al*., 2017).

With increasing litter size, more piglets were fighting during pre-massages on day 25. This supports the results of other studies reporting that litter competition continues in on-going lactation (Milligan *et al*., 2001; Pedersen *et al*., 2011). Some piglets in larger litters may not be physically able to reach their teats because the surface per piglet at the udder decreases more significantly than for piglets in smaller litters.

Conclusion

Our results show that opening the crate from day 3 pp. to weaning did not impair suckling and nursing behaviour shortly after removal of confinement. Nursings were to some extent calmer (shorter pre-massages and more piglets attended post massages) in temporary crates on day 25. Increased litter size was found to impair nursing and suckling behaviour of the sow and piglets independently of the housing system. To conclude, our study shows that temporary crating is a safe alternative to permanent crating in regards to nursing and suckling behaviour.

Acknowledgements

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Declaration of interest

The authors have declared that no competing interests exist.

Ethics statement

This study received approval for animal use and care from the Institutional Animal Care and Use Committee of the Institute of Animal Science and was conducted in accordance with Czech Central Committee for Protection of Animals number *60444/2011-17214*.

Software and data repository resources

Data and models are not deposited in an official repository.

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