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Improved udder access prolongs duration of milk letdown and increases piglet weight gain

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Abstract

Nursing-suckling behaviour and piglet weight gain were compared in traditional Danish farrowing crates and farrowing pens where sows were free to roam to determine if improved access to the udder could increase the milk intake of the piglets. The experiment was conducted in a Danish production herd, and behaviour and weight gain were registered on day 14, 15, 27 and 28 post-partum. The nursing-suckling behaviour was video recorded, and the duration of the milk letdown was used as an indicator of the milk intake of the piglets.

The milk letdown lasted 8.5 sec for the sows housed in crates and 10.3 sec for the sows housed in farrowing pens. The 1.8 sec longer duration (P<0.001) could be due to more peaceful piglets and calmer sows in the farrowing pens; the piglets had fewer teat fights (P=0.009) and less piglets missed the milk letdowns (P<0.001). The sows housed in farrowing pens ter-

minated fewer nursings (P<0.001), and thereby allowed the piglets to post-massage longer (P<0.001). Litter size did not influence the duration of milk letdown. The piglets housed in the farrowing pens had a higher weight at day 28 post-partum (P= 0.019) compared with the piglets housed in crates. The higher weight indicated that the piglets in the farrowing pens with easier access to the udder had a higher milk intake.

Keywords: Sow, Piglet, Nursing, Milk letdown, Crate, Farrowing pen

1. Introduction

The productivity of commercial piglet production largely depends on the number of weaned piglets per sow. However, producers also aim to produce large piglets at weaning with little variation in weight within litters. Weight at weaning is higher for piglets housed in farrowing pens than for piglets housed in crates (Biensen et al., 1996; Moustsen and Poulsen, 2004). This is most likely due to higher milk intake by the piglets in the farrowing pens. Milk is not present in the teats of the sow constantly, but only during milk letdown. The teats must be stimulated by the piglets before milk letdown can occur (Gill and Thompson, 1956; Ellendorff et al., 1982). Consequently, nursing in pigs follows a specific behavioural pattern that is normally divided into five phases (Whittemore and Fraser, 1974). In phase 1, the piglets gather by the udder to find their respective teat. The piglets massage the udder in phase 2, and in phase 3, they suckle with slow mouth movements. Milk letdown occurs in phase 4, lasting for 10-20 sec (Brooks and Burke, 1998). Finally, in phase 5, the piglets massage the udder again. Nursings happen every 40-60 minutes (Hartmann et al., 1997), and the piglets digest approximately 45-55 g milk per nursing (Theil et al., 2007). So, the duration of the milk letdown can be determined by observing the behaviour of the piglets as they suckle with rapid mouth movements during milk letdown (Hartmann et al., 1997; Brooks and Burke, 1998).

Arey and Sancha (1996) and Cronin and Smith (1992b) showed that nursing and milk letdown lasted longer for sows housed in the farrowing pens than sows housed in the crates. This sug-

gests that piglets housed in farrowing pens obtain more milk from their sows, resulting in a higher weight at weaning.

Stress has been linked with reduced milk production. Other species, such as sheep and cattle, have lower milk production and higher blood cortisol levels, when they were exposed to stress (Caroprese et al., 2010). Crates inhibit the sow's ability to move compared with a farrowing pen. Inhibition of the sow's to move may cause stress. However, changes in stress for sows housed in farrowing crates or pens could not be detected by blood cortisol levels (Jarvis et al. (2006). Cronin et al. (1991) only registered differences on day 28 post-partum. Sows housed in farrowing pens had a higher feed intake than sows housed in crates (Moustsen and Poulsen, 2004). However, Williams (1995) did not observe any correlation between feed intake of sows and milk production observed as weight gain by piglets. This was not surprising as sows mobilise body reserves for milk production when feed intake during lactation is low (Williams, 1995). Thus, it is highly unlikely that the sow or her capacity to produce milk is restricting weight gain in piglets when sows are housed in crates. It is more likely that the farrowing rails of crates take up too much space in the pens and restrict access of the piglets to the sow's udder. The restricted access increases competition for teats among the piglets, disturbing the sow and terminating more nursings before milk letdown.

This study tested the premise that increased access to the sow's udder increases milk intake by piglets. We tested this premise by assessing nursing-suckling behaviour and piglet weight gain in two types of farrowing pens: a traditional Danish crate and a pen where the sows were free to roam during lactation. As indicators of milk intake we measured duration of nursings including massage periods and extended milk letdown; piglets missing milk letdowns; teat fights; sows terminating nursings, and piglet weight gain.

2. Material and Methods

2.1. Experimental design

We measured the behaviour of sows and piglets during nursing and the weight gain in piglets when the piglets were farrowed in a traditional Danish crate and a pen where the sows were free to roam. These are referred to as ‘farrowing pens’ and ‘crates’. The experiment included two treatments, where the sows were housed in eight farrowing pens or in eight crates. The experiment was conducted between January 2009 and April 2009 and was repeated three times.

2.2. Housing

The experiment was conducted in a Danish production herd (Siljebjerggard, Horsens, Denmark) with 750 sows and on-farm production of crossbred gilts. The batch-operating system was run on a weekly basis with approximately 35 farrowings per week. The piglets were weaned after 25-28 days. There were two system for lactating sows in the herd: crates and pens for loose sows.

The experimental pens were located in two different farrowing units. The farrowing pens were located in a small farrowing unit containing 20 pens. Each measured 256 cm x 178 cm and were fitted with swing-side crates (Figure 1). When these crates were closed, they inhibited the movement of the sow. The crate was only closed during parturition. After parturition, the sides of the crate were opened and attached to the sides of the pen, and the sow was able to move around in the pen. The creep area was covered and fitted with a solid floor. The floor in the sow lying area was partly slatted (40 % opening) and partly drained (10 % opening). The pens with crates measured 263 cm x 185 cm (Figure 2) and were located in a farrowing unit containing 56 pens. The creep area was covered and with a solid floor. The floor in the sow lying area was fully slatted.

Both units had an equal pressure ventilation system and the same temperature strategy was used in both units.

[Figure 1] [Figure 2]

Sows from both units were automatically fed the same liquid diet three times a day. In the unit with farrowing pens, two sows shared one feed valve and in the unit with crates, four sows shared one feed valve. The sows were provided extra dry feed after requirement. Feed was not provided to the piglets. Both sows and piglets had free access to water.

The same management routines were used in both units. Nesting material was provided in the form of straw every day until farrowing. Work routines, such as castration, tail docking, straw assignment and daily supervision, were the same in the two units.

2.3. Animals

A total of 50 Danish crossbred (Landrace x Yorkshire) sows were selected for the experiment. The sows were randomly allocated to the groups by the herd management. No first-parity sows were included in the experiment because first parity sows are smaller and do not occupy enough space in the crate for space to become a limiting factor. The average parity number of the sows was four in the farrowing pen and three in the crates. Eight out of the 50 sows were excluded from the experiment leaving 42 sows with 516 piglets. Some were excluded because they were infected with disease. Others were excluded because they stood up during the nursing, and it was thereby impossible to observe their behaviour. The litters were equalised to approximately 14 piglets in each litter on day one post-partum. In some cases, a litter was equalised to 13 piglets if the sows in one batch did not give birth to enough piglets. Piglets weighing less than 700 g were excluded from the experiment so that each litter contained 13-

14 large “viable” piglets. After litter equalisation all piglets were ear tagged. Only one piglet was moved from one experimental pen to another, meaning that almost all the piglets were housed in the same pen from day one until day 14 post-partum. All dead and moved piglets were registered along with the weight and cause of the event. In total, 17 piglets were removed from the farrowing pens and three piglets were removed from the crates. Only eight of these piglets died, the other 12 were removed because they were too small or diseased.

No piglets were moved from one experimental pen to another from day 14 to day 28. This period was chosen because the piglets take up more space in the pen/crate in the last part of the four-week lactation period, and the space limitations should be largest at that time.

2.4. Daily gain recordings

Live-weight of all piglets was recorded on day 14 and 28 post-partum. In addition, a number was written on the back of the piglet with a broad marker on day 14 post-partum so that each piglet could be identified during video surveillance.

2.5. Observations of nursing behaviour on video

Each pen had a surveillance camera of the type MONACOR TVSSD-1400IR B/W CAMERA (Loligo Systems, Tjele, Denmark) placed above it, and the pigs were video recorded from day 14 until day 28 post-partum. During the period, the light in the farrowing unit remained on allowing piglets to be observed for 24 hours a day. The cameras were connected to four Dell stationary computers with PCI video capture cards (M. Shafro & Co., Riga, Latvia) and the program MSH-video server (M. Shafro & Co., Riga, Latvia) installed. The behaviour recordings were made on a computer with MSH-Video Client (M. Shafro & Co., Riga, Latvia) installed. An observer viewed the video recordings and registered the behaviour with codes in a LogViewer (M. Shafro & Co., Riga, Latvia) program, which registered the date and time of

155 the event. The LogViewer files were later analyzed in SAS (version 9.13; SAS Inst. Inc.,
156 Cary, NC, USA) for duration and frequency of each event.
157
158 Recordings of the behaviour were made on days 14, 15 and 27 post-partum. On day 14, the
159 piglets' teat order was recorded. The teat order was recorded during each milk letdown from
160 approximately noon until midnight. However, only piglets suckling the upper row of teats
161 could be identified on the video recordings. The teat order was not registered in LogViewer,
162 but noted and later compared with the piglets' weight gain. On days 15 and 27, the behaviour
163 of the piglets during nursing was registered. Duration of pre-massage, milk letdown, and post-
164 massage were registered on all nursings that commenced between 00:00 to 24:00. The number
165 of piglets missing milk letdown, the number of teat fights, and termination behaviour were
166 recorded.
167 The start of the nursing and pre-massage phases (phase 1 and 2) (Whittemore and Fraser,
168 1974; Ellendorff et al., 1982) was recorded when 75 % of the piglets had gathered around the
169 udder, found their teats and begun massaging the udder. The pre-massage period would trans-
170 form into phase 3 (Whittemore and Fraser, 1974; Ellendorff et al., 1982) when all the piglets
171 lay still and suckled with slow mouth movements, but the transition from massage to slow
172 suckling did not take place at the same time for all the piglets in a litter in this experiment. It
173 was, therefore, difficult to distinguish between phases 2 and 3, and in this experiment phase 1,
174 2 and 3 were referred to as one phase called pre-massage.
175 The start of the milk letdown (phase 4) (Whittemore and Fraser, 1974; Ellendorff et al.,
176 1982) was recorded when all the piglets suddenly pulled the teats back and raised their bodies
177 and stood/layed completely still. It was not possible to observe the mouth movements of the
178 piglets, but on some sows it was possible to observe the grunts by observing stomach move-
179 ments. Just before the milk letdown, the sow would grunt with very small intervals (Whitte-

more and Fraser, 1974), and it was possible to observe two or three grunts just before the milk letdown.

The start of the post-massage phase (phase 5) (Whittemore and Fraser, 1974; Ellendorff et al., 1982) was recorded when the first piglet let go of its teat and began massaging. Afterwards, all the other piglets followed.

The nursing was terminated by either sow or piglets. Either the sow rolled over or stood up and cut off access to the udder. The sow could also roll over or stand up before milk let down occurred. The piglets could terminate a nursing by leaving the udder or by falling asleep by it. The end of the nursing was recorded when 75 % of the piglets fell asleep or left the udder.

Nursings, where the sow rolled over or stood up before the milk letdown, or where the piglets massaged the udder without reaching the milk-letdown period, were analysed as incomplete nursings.

At the end of every nursing, the number of piglets that missed the milk letdown was recorded. Only piglets attending the udder during a nursing were recorded. Piglets that did not leave the creep area during a nursing and missed the milk letdown were not recorded.

Each time a teat fight occurred it was recorded. A teat fight was defined as two piglets raising their heads from the udder and biting at each other.

2.6. Statistical analyses

The statistical analyses were carried out using the MIXED, FREQ, GENMOD, NPAR1WAY and REG procedures in SAS (version 9.13; SAS Inst. Inc., Cary, NC, USA).

A general mixed-linear model was fitted to the durations of nursings, pre-massages, milk letdowns, and post-massages:

$$Y_{ijklmno} = \mu + t_i + d_j + a_k + b_l + f_m + (tb)_{ij} + S_{njk} + e_{ijklmno}\,; \qquad (1)$$

where $Y_{ijklmno}$ was one of the duration responses. The systematic effects were: t_i: treatment (i = 1, 2 for farrowing pen or crate), d_j: time of day (j = 1, 2 for day (05:00 am – 05:00 pm) or night (05:00 pm - 05:00 am)), a_k: day in lactation (k = 1, 2 for day 15 or 27 post-partum), b_l: termination behaviour (l = 1, 2 for sow or piglets terminate nursing) and f_m: teat fights (m = 1, 2 for yes or no). In order to account for repeated measurements, a random effect S_{njk}~N(0,σ^2s) of sow (n = 1,…, 42), time of day (j = 1,2) and day in lactation (k = 1,2) was included. An interaction term (treatment x termination behaviour) was included when the durations of nursing and post-massage were modelled (no other interactions were significant). The errors $e_{ijklmno}$ were assumed independent and normally distributed.

The duration of the nursings and post-massages were square-root transformed to fulfil the assumptions of normality.

The duration of milk letdown was modelled with day as the observational unit to find correlations with the duration of the post-massage by the following general mixed linear model:

$$Y_{ijk} = \mu + t_i + a_j + \beta x_{ijk} + S_k + e_{ijk} \; ; \qquad (2)$$

where Y_{ijk} was the duration of the milk letdown given as median per day, and the systematic effects were: t_i: treatment (i = 1, 2 for farrowing pen or crate), a_j: day in lactation (j = 1, 2 for day 15 or 27 post-partum), β was a regression coefficient, and x_{ijk} was the duration of previous post-massage. In order to account for repeated measurements, a random effect S_k~N(0,σ^2s) of sow (k= 1,…, 42) was included. The errors e_{ijk} were assumed independent and normally distributed.

The weight gain of the piglets was modelled with the individual sow as the observational unit by a general linear model:

$$Y_{ijkl} = \mu + t_i + f_j + p_k + e_{ijkl}\,; \tag{3}$$

where Y_{ijkl} was the average weight gain of the piglets between day 14 and day 28 post-partum, and the systematic effects were: t_i: treatment (i = 1, 2 for farrowing pen or crate), f_j: number of teat fights on day 14 (j = 0, 1 or >1) and p_k: piglets missing milk letdowns on day 14 post-partum (k = 0; where at the most 10 % of the nursings had piglets missing milk letdowns or 1; where at least 10 % of the nursings had piglets missing milk letdowns).

The data set of complete nursings and incomplete nursings was modelled by a general mixed linear model with the "sow day" as the observational unit:

$$Y_{ijkl} = \mu + t_i + a_j + f_k + S_l + e_{ijkl}\,; \tag{4}$$

where Y_{ijk} was number of either complete or incomplete nursings per day, and the systematic effects were: t_i: treatment (i = 1, 2 for farrowing pen or crate), a_j: day in lactation (j = 1, 2 for day 15 or 27 post-partum) and f_k: number of teat fights on day 14 post-partum (k = 0, 1 or >1). In order to account for repeated measurements, a random effect $S_l \sim N(0,\sigma^2_S)$ of sow (l = 1,…, 42) was included. The errors e_{ijkl} were assumed independent and normally distributed.

The piglets missing milk letdowns (percent of nursings per sow with or without piglets missing milk letdowns), piglets having teat fights (percent of nursings per sow with or without teat fights) and the termination behaviour (percent of nursings per sow teminated by sow or terminated by piglets) were processed as ordinal scale dataset as frequencies. The frequencies of each treatment were compared with a χ^2-test.

The data of piglets missing milk letdowns were analysed by a generalized linear model with "sow day" as the observational unit. A binary variable Y_{ijkl} was formed taking the value 0 if at least 10 % of the sows' nursings on a given day had at least one piglet missing milk letdown and $Y_{ijkl} = 1$ otherwise. The probability p_{ijkl}, that the binary variable equals zero, was analysed according to the following model:

$$\log\left(\frac{p_{ijkl}}{1-p_{ijkl}}\right) = \mu + t_i + a_j + f_k + S_l\,; \tag{5}$$

where the systematic effects were: t_i: treatment (i = 1, 2 for farrowing pen or crate), a_j: day in lactation (j = 1, 2 for day 15 or 27 post-partum) and f_k: number of teat fights on day 14 post-partum (k = 0, 1 or >1). The variable $S_l \sim N(0,\sigma^2_S)$ was the random effects of sows (l=1,…, 42).

The daily weight gain was analysed with a mixed model with the individual piglet as the observational unit:

$$Y_{ijklm} = \mu + t_i + o_j + q_k + S_l + e_{ijklm}\,; \tag{6}$$

where Y_{ijklm} was the daily weight gain of the piglet from day 14 until day 28, and the systematic effects were: t_i: treatment (i = 1, 2 for farrowing pen or crate), o_j: teat pair number (j = 1, 2, 3, 4, 5, 6 or 7; according to the number of teat pairs) and q_k: litter size day 14 (k = 9, 10, 11, 12, 13 or 14; according to the number of piglets in the litter). In order to account for repeated measurements, a random effect $S_l \sim N(0,\sigma^2_S)$ of sow (l = 1,…, 42) was included. The errors e_{ijklm} were assumed independent and normally distributed.

A t-test (The TTEST Procedure) was used to analyse the effect of treatment on the weight of the piglets (piglet weight, litter weight, daily weight gain per piglet). Nonparametric tests (NPAR1WAY procedure) were used to analyse the effect of treatment on litter size (days 1, 14 and 28 post-partum), parity number of sow, piglets removed from the experiment, the intervals between the individual nursings per day and the teat fidelity of the piglets (whether the piglets suckled on one specific teat or one specific teat pair). The effect of litter size on day 14 and 28 post-partum on the frequency of teat fights was also analysed by a nonparametric test. Nonparametric tests were used to analyse the effect of litter size on day 28 on piglets missing milk letdowns, summed duration of milk letdown per day and the median of the duration of the post-massage.

Regression analyses (REG procedure) were employed to detect correlation between the duration of milk letdown and piglet weight gain and litter weight, correlation between litter size and milk letdown and litter size and post-massage, correlation between duration of post-massage and piglet weight gain, and correlation between the duration of milk letdown on day 15 post-partum and the duration of milk letdown on day 27 post-partum.

3. Results

3.1. Pre-massage, milk letdown and post-massage

Data describing durations of pre-massage, milk letdown, post-massage and nursing are presented in Table 1.

[Table 1]

In total, 1134 nursings were analysed for sows and piglets housed in farrowing pens, and 1137 nursings were analysed for sows and piglets housed in crates.

The duration of the pre-massage did not differ between the two treatments. The sows housed in the farrowing pens had longer milk letdowns ($P<0.001$) than the sows housed in the crates.

The durations of the post-massage and the nursing lasted longer for the sows housed in crates if the piglets terminated the nursing, but the termination behaviour differed between animals in the crates and the farrowing pens ($P<0.001$). In the crates, 57 % of the nursings were terminated by the sows compared with 46 % in the farrowing pens. If the sow terminated the nursing, the duration of the post-massage was shorter ($P<0.001$).

The duration of the nursing ($P<0.001$) and pre-massaging ($P<0.001$) was longer at night than during the day. The post-massage period was longer during the night when the sow terminated the nursing. It was shorter when the piglets terminated the nursing at night ($P<0.001$). The time of day did not influence the duration of milk letdown. However, total milk letdown was longer during day 15 post-partum than day 27 (9.7 *v* 9.2 sec, $P<0.001$). In addition, there was a weak positive correlation between the durations of milk letdown on days 15 and 27 post-partum ($P<0.001$) (Model (2)). The duration of post-massage did not affect the duration of milk letdown in the following nursing (Model (2)).

3.2. Litter size and weight gain

The number of piglets in the litter tended ($P=0.083$) to be higher in the farrowing pens on day one post-partum (Table 2). On day 14 post-partum, the litter size was equal in the two groups. However, on day 28 post-partum the litter size was larger in the crates ($P=0.012$).

[Table 2]

The number of piglets removed from the experiment because of disease or death was lower for the piglets housed in crates compared with piglets housed in the farrowing pens between days 1 and 14 post-partum (P=0.003). Fewer piglets (P=0.007) were removed from the crates between days 14 and 28 post-partum.

Piglet weight on day 14 post-partum did not differ between the farrowing pens and the crates, but the piglets in the farrowing pens weighed more on day 28 post-partum (P=0.019) (Table 3). The average piglet weight was 7.1 kg in the farrowing pens and 6.3 kg in the crates on day 28 post-partum (the weights in Table 3 are presented as medians). Litter weight did not differ between the two groups. The litter weight on day 14 post-partum was 46.5 kg; 28.9-61.3 kg (median; min-max) in the pens versus 46.7 kg; 30.1-63.8 kg (median; min-max) in the crates. The litter weight (median; min-max) on day 28 post-partum was (79.8 kg; 47.3-116.7 kg) in the pens versus (78.1 kg; 46.4-114.2 kg) in the crates. The piglets' daily weight gain tended (P=0.066) to be higher in the farrowing pens (Table 3), but the litter daily weight gain was not significant different between the two groups (pen: 2.8 kg; 1.0-4.4 kg versus crate: 2.5 kg; 0.6-3.8 kg) (median; min-max).

[Table 3]

The litter size on day 28 post-partum was larger in the crates, but there was no correlation between litter size and duration of milk letdown or post-massage. On the other hand, the duration of milk letdown was positively correlated with the weight gain of the piglets (P<0.001) (Figure 3) and the litter weight gain (P<0.001). The duration of post-massage on day 27 post-partum was not correlated with litter weight gain.

[Figure 3]

3.3. Teat fights

The piglets housed in the crates had a higher percentage of nursings with more than one fight than the piglets housed in farrowing pens (71 % versus 29 %, P=0.008).

The number of fights did not differ on days 15 and 27 post-partum.

Teat fights during nursings did not affect the duration of milk letdown. However, the termination behaviour was influenced (Model (1)). When no teat fights occurred during the nursing, 50 % of the nursings were terminated by the sow whereas 72 % of the nursings were terminated by the sow if teat fights occurred during the nursing (P<0.001).

Teat fights did not affect litter weight gain between days 14 and 28 post-partum. Litter size did not affect the number of teat fights.

3.4. Piglets that missed milk letdowns

In the crates, 62 % of the nursings had a piglet missing a milk letdown compared with 38 % in the farrowing pens (P<0.001). When teat fights occurred, more piglets missed a milk letdown (P<0.001). The number of piglets missing milk letdown did not differ between days 15 and 27 post-partum (Model (5)).

Litter size affected the number of piglets missing the milk letdowns (P=0.007). The larger the litter size on day 28 post-partum, the more piglets that were missing. However, when there was the same number of piglets in the litter in both the groups, a larger number of piglets missed milk letdowns in the crates. Even with a litter size as low as 11 piglets, more piglets missed milk letdowns in the crates.

3.5. Complete and incomplete nursings

A complete (productive) nursing is a nursing containing milk letdown, whereas an incomplete (non-productive) nursing does not contain milk letdown.

The number of complete nursings per sow per day did not differ between the two pen types (Table 2). The number of teat fights influenced the number of complete nursings via an interaction with the day in lactation (P=0.031). On day 27 post-partum, the number of complete nursings decreased when the number of teat fights increased (Model (4)).

The number of incomplete nursings per sow per day did not differ between the two types of pens and corresponded to 22-26 % of the nursings (Table 2). The teat fights and the day in lactation did not influence the number of incomplete nursings (Model (4)).

The interval between a complete nursing and the following incomplete nursing did not differ between the two pen types. Neither did the interval between a complete nursing and the following complete nursing (Table 2).

3.6. Teat order

It was possible to observe 374 out of 516 piglets during nursing on day 14 post-partum. Piglets suckled on a specific teat or a specific teat pair. Some piglets always laid on top and suckled on a specific teat pair, whereas the piglets that suckled on a specific teat were only visible on the video recordings when the sow lay on a specific side. In the crates, more piglets suckled on a specific teat (P=0.047).

The daily weight gain of the piglets was under influence of which teat pair number the piglets suckled on (P<0.001) (Model (6)). Figure 4 shows how the piglets suckling on the anterior teats had a higher weight gain. The litter size had an affect on the daily weight gain of the piglets (P=0.0431), but did not interact with the teat pair number.

[Figure 4]

4. Discussion

A general observation in the current experiment was that nursings in the farrowing pens were observed as calmer events, with the only activity being pre-massage, milk letdown, and post-massage. The piglets laid still in a fan-like arrangement (illustrated in Figure 1). In the crates, nursings were often more frantic events, with piglets fighting for position, climbing on top of one another and the farrowing crate bars to suckle (illustrated in Figure 2). The frantic nursings in the crates presumably explain the increased number of teat fights that led to more piglets missing milk letdown. However, the teat fights did not affect the duration of milk letdown or the weight gain of the piglets.

More piglets were removed from the farrowing pens between days 14 and 28 post-partum because of disease or death. Consequently, there was on average one more piglet in the crates on day 28. In the literature, it is unclear whether litter size affects teat fights. Some studies have demonstrated that it does (Fraser, 1975; Milligan et al., 2001), while others have not (Scheel et al., 1977; Depassillé and Rushen, 1989). However, the first two studies only included 14 (Scheel et al., 1977) and seven (Depassillé and Rushen, 1989) litters compared to 92 (Fraser, 1975) and 51 (Milligan et al., 2001) litters, and teat fights were only recorded on the day of parturition. Litter size did not have an effect on the number of teat fights during nursing in this experiment. It was likely caused by the low variation in litter size. The experiment was not designed to test the litter size, but litter size did affect the number of piglets missing milk letdowns. The number of piglets missing milk letdowns increased with the number of piglets in the litter.

This experiment established that when fights occurred during the nursing it was the sows that terminated the nursings (71 % of all the nursings). Newberry and Woodgush (1985) and Cas-

trén et al. (1989) also observed that fights and screams caused the sow to terminate the nursing before milk letdown occurred in semi-natural environments.

Less fighting occurred mainly in the farrowing pens and the sows were calmer. Only 46 % of the nursings were terminated by the sows. Thodberg et al. (2002) also observed fewer sow terminated nursings in the farrowing pens compared with the crates, but this was only observed among first parity sows. Second parity sows terminated the same proportion of nursings in the farrowing pens as in the crates. Valros et al. (2002) observed the opposite where slightly more sows terminated nursings in the farrowing pens compared with the crates.

The more fidgety piglets in the crates did not result in a larger number of incomplete nursings. The number of incomplete nursings was the same between the two groups. Six to seven nursings out of 27 (22-26 %) were incomplete, which is in agreement with other studies (Fraser, 1977; Castrén et al., 1989; Illmann et al., 1999; Valros et al., 2002). The time interval between a complete nursing and an incomplete nursing was shorter compared with the time interval between two complete nursings which is in concurrence with observations by Whatson and Bertram (1980).

Milk production is triggered by the hormone prolactin (Stabenfeldt and Davidson, 2002) which is only synthesised when tactile stimulations of the teats occur like pre and post-massage (Stabenfeldt and Davidson, 2002). Longer duration of post-massage increases the concentration of prolactin in the blood (Algers et al., 1991) and could thereby increase the milk production. The sows in this experiment that allowed longer post-massage could have a higher prolactin concentration in the blood and perhaps a higher milk production.

Milk letdowns lasted 1.8 sec longer in the farrowing pens in this experiment. Cronin and Smith (1992b) also observed significantly longer durations of the milk letdowns on day 1-3 post-partum in farrowing pens (23 sec) compared with crates (18 sec). Blackshaw et al. (1994) observed significantly longer durations of phase 3 (slow sucking) and phase 4 (rapid

sucking/milk letdown) in farrowing pens (3.1 min) compared with crates (2.3 min), although the time periods of Blackshaw et al. (1994) seem long compared with the results in this experiment. Both experiments indicate that the piglets had a higher milk intake in the farrowing pens. The longer durations of the milk letdowns in the farrowing pens could be caused by the longer post-massage, due to the calmer sows and nursings. However, the duration of milk letdown was not affected by the duration of the previous post-massage. These results do not support the hypothesis proposed by Algers and Jensen (1985) in which the piglets order the amount of milk by the duration of the previous post-massage.

In the present study, a nursing bout was initiated when 75 % of the piglets were active by the udder and a nursing bout ended, when 75 % of the piglets no longer were active at the udder. This definition of a nursing bout differs from other studies, where the limits of nursings were 50 % of piglets present by the udder (Blackshaw et al., 1994; Valros et al., 2002; Wallenbeck et al., 2008). This means that a nursing will begin sooner and last longer, leading to longer nursings and longer post-massages compared to the other studies (Blackshaw et al., 1994; Valros et al., 2002; Wallenbeck et al., 2008). However, the primary parameter of the present study was the milk letdown period, which was comparable between studies whereas the nursing period was secondary.

Access to the udder was not the only difference between the two groups. There was one more piglet in the crates on day 28 post-partum. In the experimental period, the herd had problems with diarrhoea among the suckling piglets. Both piglets housed in farrowing pens and in crates suffered from diarrhoea, but possibly the piglets housed in farrowing pens suffered more. A contributing factor is likely the difference in floor design; the floor in the farrowing pen was partly drained, partly slatted, whereas the floor in the crates was fully slatted. Slatted floors are expected to keep a better hygiene in the crates making the piglets less prone to infection with disease agents causing diarrhoea.

The fact that the milk letdowns had longer duration in the farrowing pens and that the number of complete nursings was the same between the two pens indicated that the piglets housed in the farrowing pens had higher milk intake than piglets housed in the crates. The piglets housed in the farrowing pens weighed significantly more (on average 737 g/piglet) on day 28 post-partum, and the daily weight gain had a tendency to be higher. This is twice as high as was reported by Biensen et al. (1996) (370 g/piglet) and Moustsen & Poulsen (2004) (300 g/piglet). The higher weight gain indicates that the milk intake was elevated in the farrowing pens, which is further substantiated by the fact that the duration of milk letdown was positively correlated with piglet and litter weight gain.

The duration of the previous post-massage did not affect the duration of the milk letdown. It was difficult to link the post-massage to the milk intake and weight gain, because the post-massage was measured at litter level and not piglet level. The piglets massaged the udder with different durations, and the possible effect on the individual teat is still rather unclear. However, Thodberg and Sorensen (2006) established that the weight of the mammary glands, which were on top because the sow lay more on one side during the nursing, weighed more than the other mammary glands. This could be caused by the piglets performing post-massage for longer on the teats on top, because it is easier for the piglet to massage if it is lying on top. The weight of mammary glands was positively correlated with the piglets' weight gain in another experiment (Nielsen et al., 2001).

There is reason to believe that the higher weight gain in the farrowing pens was caused by the longer duration of milk letdowns, which was probably due to improved access to the udder during nursing in the farrowing pen. Other experiments have also documented that improved access to the udder have a positive effect on the weight of the piglets (Lou and Hurnik, 1994;

Moustsen and Duus, 2006) and higher weight at weaning (Curtis et al., 1989) (Biensen et al., 1996; Moustsen and Poulsen, 2004). Identical observations were made by Cronin and Smith, (1992a) in straw-added pens compared with crates.

While observing the nursing behaviour a stable teat order was observed among the suckling piglets in this experiment. Piglets suckled either on one specific teat or on a specific teat pair, meaning that some piglets always lie on top or on the bottom. The piglets suckling at the anterior teats had a higher weight gain confirming observations by Fraser and Jones (1975), Algers et al. (1990) and Bøe and Jensen (1995).

5. Conclusion

The duration of the milk letdown was 1.8 sec longer in the farrowing pens compared with the crates and litter size did not influence the duration of milk letdown. The piglets housed in the farrowing pens weighed more on day 28 post-partum indicating that the piglets in the farrowing pen had a higher milk intake. This higher milk intake was most likely caused by improved access to the udder in the farrowing pens. The piglets were calmer during nursings in the farrowing pens, which led to a reduction in teat fights, and a decreased number of piglets missing milk letdowns. The sows also terminated less nursing in the farrowing pens and allowed the piglets to perform post-massage for longer. This could explain the expected higher milk intake.

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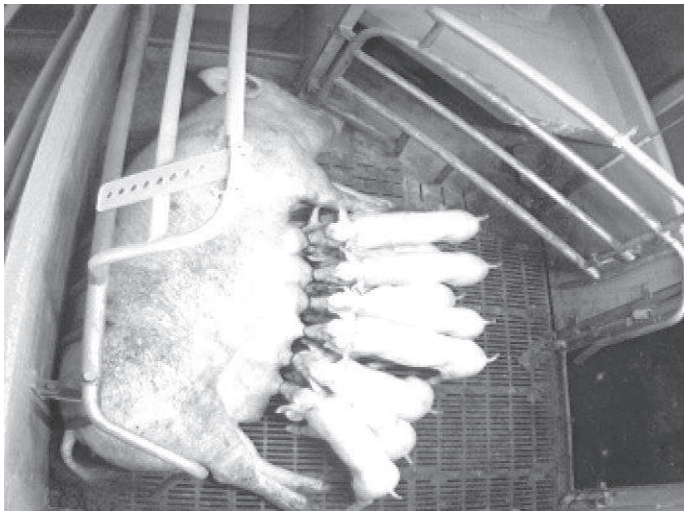


Figure 1: Photo of the farrowing pen with swing-side crate.

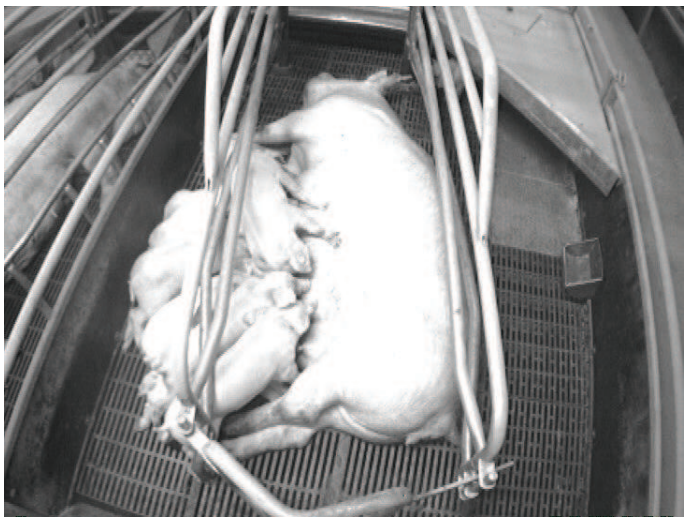


Figure 2: Photo of the crate.

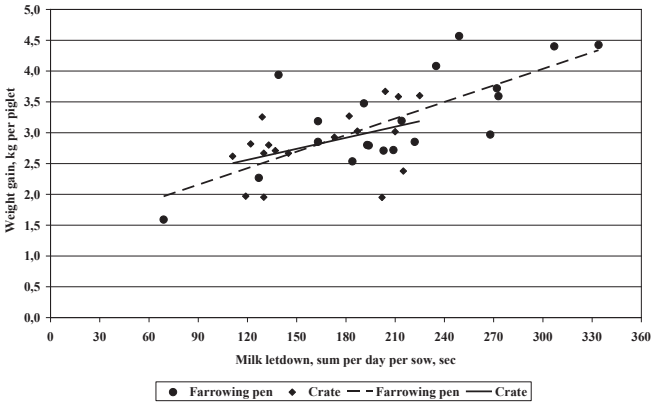
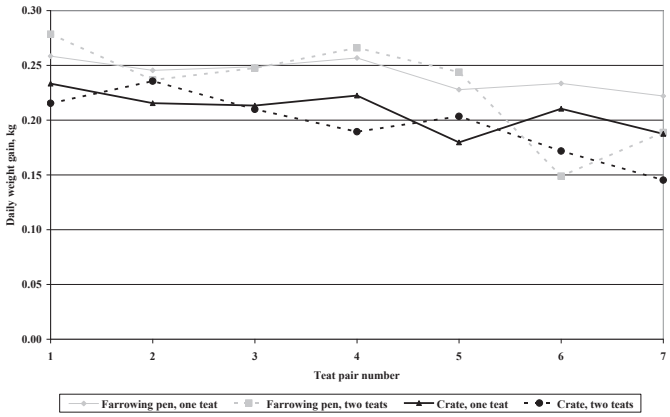


Figure 3: Average piglet weight gain per litter (in kg) between 14 and 28 days post-partum as a function of the sum of the duration of milk letdown on day 28.



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671 **Table 1: Duration (in seconds) of pre-massage, milk letdown, post-massage and nursing: number of ob-**
672 **servations, minimum and maximum. Estimates and *P*-values according to data analysis in Model (1). The**
673 **data of the duration of the nursings and the post-massages were square root transformed in order to fulfil**
674 **the normality assumptions. In the table the durations presented are transformed back.**

	Farrowing pen			Crate			P value
	n	min-max	estimate	n	min-max	estimate	
Pre-massage, sec	1134	3-1309	162	1137	9-1639	162	NS
- complete nursing, sec	873	29-532	100	863	11-434	105	NS
Milk letdown, sec	873	3-20	10.3	863	2-20	8.5	<0.001
Post-massage, sec	873	3-1214		863	5-1537		
- piglets terminate, sec	465	59-1214	504	371	110-1537	549	0.005
- sow terminate, sec	408	3-718	77	492	5-828	71	NS
Nursing, sec	1134	3-1371		1137	9-1763		
- piglets terminate, sec	616	104-1371	597	486	159-1763	644	0.008
- sow terminate, sec	518	3-804	178	651	9-1283	180	NS

675

676 **Table 2: Litter size, nursings and intervals between nursings, median (min-max).**

	Farrowing pen		Crate		*P*-value
	n	median	n	median	
Litter size day 1 post-partum, piglets	21	14 (12-15)	21	13 (12-14)	0.083
Litter size day 14 post-partum, piglets	21	13 (9-13)	21	13 (11-14)	NS
Litter size day 28 post-partum, piglets	21	12 (8-13)	21	13 (11-14)	0.012
Total nursings per 24 hours	42	27 (16-35)	42	27 (20-36)	NS
- complete	42	21 (10-26)	42	22 (12-26)	NS
- incomplete	42	6 (1-13)	42	7 (1-14)	NS
Interval between complete and incomplete[a], min	42	45.6 (33.7-244.8)	41	43.3 (22.2-112.0)	NS
Interval between complete and complete[b], min	42	50.9 (41.0-70.3)	42	50.1 (37.9-62.6)	NS

677 [a] Interval between the start of a complete nursing and the start of the following incomplete nursing.

678 [b] Interval between the start of a complete nursing and the start of the following complete nursing.

679

680 **Table 3: Average piglet weight (in kg/d) per litter, mean ± SE.**

	Farrowing pen		Crate		*P*-value
	n	Mean ± SE	n	Mean ± SE	
Piglet weight day 14, kg	21	3.7 ± 0.1	21	3.6 ± 0.1	NS
Piglet weight day 28, kg	21	7.1 ± 0.2	21	6.3 ± 0.2	0.016
Piglet daily weight gain, kg/d	21	0.237 ± 0.01	21	0.202 ± 0.01	0.038

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