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Can body nosing in artificially reared piglets be reduced by sucking and massaging dummies?

Daniela Frei[a,b], Hanno Würbel[b], Beat Wechsler[a], Lorenz Gygax[a,d], Joan-Bryce Burla[a], Roland Weber[c,*]

[a] Federal Food Safety and Veterinary Office, Centre for Proper Housing of Ruminants and Pigs, 8356 Ettenhausen, Switzerland
[b] University of Bern, Division of Animal Welfare, Länggassstrasse 120, 3012 Bern, Switzerland
[c] Agroscope, Centre for Proper Housing of Ruminants and Pigs, 8356 Ettenhausen, Switzerland
[d] Humboldt-Universität zu Berlin, Faculty of Life Sciences Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Animal Husbandry, Germany

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ABSTRACT

Selection for hyper-prolific sows has substantially increased litter size. Consequently, the number of piglets in a litter may exceed the number of functional teats. To solve this problem, surplus piglets may be removed from the sow 2 days after birth and raised artificially. However, these piglets show increased levels of oral behaviours, such as belly nosing, directed at other piglets. This behaviour resembles massaging and sucking at the sow's udder and thus is considered to be redirected suckling behaviour. The present study investigated whether oral behaviour directed at piglets can be reduced in artificially reared piglets by providing them with sucking and massaging dummies. In a two-by-two between-group factorial design, the artificial rearing pens were equipped with one of four treatments: a sucking dummy, a massaging dummy, a combined sucking–massaging dummy, or no dummy. The behaviour of 126 piglets (in 21 groups of 6 piglets) was scored from video by continuous focal observation lasting 90 min per piglet each on days 4 and 18 after introduction to the artificial rearing system. Data were analysed using linear mixed-effects models. Body nosing (composed of belly nosing and nosing on any other body part) increased from day 4 to 18 in all treatments, but piglets provided with a combined sucking–massaging dummy showed the smallest increase. Piglets spent more time nosing the combined dummy than the sucking or the massaging dummy. However, there was no causal inverse relationship between the duration of body nosing and dummy nosing. All but one piglet showed body nosing at least once. Resting, play-fighting, or oral manipulation of piglets (other than body nosing), dummies, and pen equipment were hardly affected by the treatments. Piglets with a combined dummy tended to have a longer average resting bout duration compared with piglets in other treatments. In conclusion, only the combined sucking–massaging dummy was effective in reducing the increase in body nosing over time. However, this reduction was rather small in absolute terms and the combined dummy did not prevent body nosing. The tested dummies were thus not successful in eliminating the redirected oral behaviour in artificially reared piglets.

1. Introduction

In recent years, the number of live born piglets increased steadily (SUISAG, 2006–2015; Tomiyama et al., 2011; Vidović et al., 2012) by selection for hyper-prolific sows. Consequently, the number of piglets in a litter may exceed that of functional teats. As sows lactate only for a short period of 10–20 s about once every hour (Fraser, 1980; Le Dividich et al., 2005), piglets without access to a teat will suffer from low energy supply (Le Dividich et al., 2005), be more susceptible to diseases (Varley et al., 1985) and face a higher mortality risk than piglets with access (Dyck and Swierstra, 1987; Andersen et al., 2011; Devillers et al., 2011). Therefore, management intervention is needed to raise surplus piglets.

A common way to raise surplus piglets is cross-fostering. With this method, piglets are relocated from a prolific sow to another lactating sow with fewer piglets or to a nurse sow rearing a second litter after her own litter has been weaned (Baxter et al., 2013). Another approach is split-suckling. Large litters are split into subgroups of weak and strong piglets, and the stronger ones are removed for a short time to promote weaker piglets' access to the udder (Baxter et al., 2013). On small farms with few potential foster sows or to avoid the work effort needed for split-suckling, surplus piglets may be taken away from the mother sow

* Corresponding author at: Agroscope, Tänikon 1, Ettenhausen, 8356, Switzerland.
E-mail address: roland.weber@agroscope.admin.ch (R. Weber).

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as early as 2 days after birth (to ensure minimally required colostrum supply) and introduced to an artificial rearing system where they are fed artificial milk (Baxter et al., 2013).

When piglets are raised by the sow, a nursing bout consists of several phases (Fraser, 1980): After the piglets assemble at the udder, a first massaging phase lasting about 1 min induces milk let-down; it is followed by a sucking phase and terminated by a second massaging phase lasting several minutes. In piglets reared without the sow in an artificial rearing system, milk intake is changed markedly because the milk cups used for drinking lack the opportunity to massage an udder and suck on teats. Several studies have reported that piglets reared without a sow develop abnormal oral behaviour termed belly nosing (Weary et al., 1999; Rzezniczek et al., 2015) consisting of rhythmic up and down movements with the snout on the belly of other piglets (Fraser, 1978). Results from experimental studies suggested that belly nosing is not an indicator of stress (Gardner et al., 2001a), is not influenced by diet quality or the presence of milk in the diet (Gardner et al., 2001b), is more closely associated with social interaction than with eating or drinking (Li and Gonyou, 2002) and has a number of aspects similar to honest begging in birds (Jensen et al., 1998). As belly nosing is similar to the massaging and sucking movements of piglets at the sow's udder during nursing, it has been interpreted as redirected suckling behaviour (Fraser, 1978). The behaviour typically starts a few days after weaning (Fraser, 1978), increases in duration and frequency over 2–4 weeks and then declines (Gonyou et al., 1998; Worobec et al., 1999; Bench and Gonyou, 2009). In addition, the prevalence of belly nosing increases with decreasing weaning age (Metz and Gonyou, 1990; Worobec et al., 1999). About 80% of piglets weaned at the age of 2 weeks show belly nosing (Li and Gonyou, 2002). Artificially reared piglets furthermore show increased levels of other oral behaviours such as sucking and nibbling directed at other piglets, and durations of resting and play-fighting behaviour decrease over time (Rzezniczek et al., 2015).

Piglets do not show belly nosing when being reared by the sow (Rzezniczek et al., 2015). The development of this abnormal behaviour, therefore, indicates that the behavioural needs of the piglets are not met in artificial rearing systems. It is therefore of interest whether housing conditions in these systems could be improved to reduce the prevalence of belly nosing. To this end, Widowski et al. (2005) provided piglets removed from the sow at 3 days of age with various feeding devices such as a nipple mounted on a Plexiglas wall or a nipple mounted on a bag of water. They found that piglets fed with milk from these devices spent less time belly nosing and more time resting than piglets fed milk at a trough. Similarly, Bench and Gonyou (2007) enriched the pen environment for piglets weaned at 7 days of age with baby nipples in the milk feed through and reported that belly nosing and other oral behaviours were reduced in comparison with piglets reared without such enrichment. The aim of this study was to examine systematically whether providing either sucking, massaging, or combined sucking and massaging dummies to piglets reared without the sow reduces oral behaviour directed at other piglets. In contrast to previous studies, we focussed on a simple applicable solution to improve the housing conditions of surplus piglets in practice.

For this purpose, we separated piglets from the sow at the age of 3–5 days and raised them in artificial rearing systems equipped with a sucking dummy, a massaging dummy, a combined sucking–massaging dummy, or no dummy. We hypothesised that the occurrence of belly nosing and body nosing (composed of belly nosing and nosing on any other body part), would be less in piglets provided with dummies than in piglets without dummies and that the duration of body nosing would be inversely related to the duration of dummy nosing.

2. Materials and methods

Ethical approval for the implementation of the study, including housing, all treatments, and animal handling procedures, was given by the Thurgau Cantonal Veterinary Office, Switzerland (TG01/15, Approval No. 26247).

2.1. Experimental design

The experiment was conducted between November 2015 and October 2016 at the Agroscope Research Station in Tänikon (Switzerland). In total, 126 Swiss Large White piglets were separated from 21 sows between 3 and 5 days after parturition to be raised in an experimental artificial rearing system. The short period of time the piglets stayed with the mother sow enabled them to ingest sufficient amounts of colostrum.

Data collection was carried out in seven batches. In each batch, 18 piglets were taken from three sows with farrowing dates no more than 4 days apart. Each sow contributed five to seven piglets from her litter. If possible, three male and three female healthy piglets with a weight close to the average litter weight were chosen from a given sow. If a sow did not have enough piglets matching these requirements (7 of 21 sows), additional piglets from the litters of the other sows of the same batch were selected. Piglets were marked individually with numbered and coloured ear tags.

The 18 piglets were allocated to three identical pens of the artificial rearing system. The six piglets in a given pen always consisted of three males and three females. Whenever possible, one male and one female piglet from each of the three sows were used (14 of 21 groups). Otherwise, at least two piglets came from the same sow (20 of 21 groups) or, in a single case, one sow contributed only one and another sow three piglets.

2.2. Artificial rearing system and management

The three pens of the artificial rearing system were lined up next to each other. Each pen measured 0.93×1.0 m and was limited by wooden walls of 0.5 m height. In line with the Swiss legal prescriptions, the space allowance per piglet was 0.15 m^2. The pens were divided into a resting and a feeding-dunging area of equal size, separated by a polyvinylchloride strip curtain (Fig. 1). The floor of the resting area was covered with a rubber mat and wood shavings as bedding material which was provided once daily. Further, the resting area was covered by a lid with an integrated heating plate. The feeding-dunging area had a slatted floor (slot width of 9 mm) and was equipped with two milk cups with an inside diameter of 10 cm (Neopigg™ Rescue Care, Provimi B.V., Rotterdam, Netherlands) which were placed at a distance of about 15 cm from the sidewalls (Fig. 1). Piglets were provided with artificial milk (Rescue Milk 2.0, Provimi B.V., Rotterdam, Netherlands) *ad libitum*. The milk was prepared freshly twice a day in a mixing tank and both the tank and the supply tubes to the milk cups were heated to ensure a milk temperature of about 25 °C. Further, water was provided *ad libitum* in a water bowl placed in the corner of the feeding-dunging area.

As the early weaned piglets were not familiar with the milk cups when being separated from the sow, they were trained to drink from the milk cups on the first day after relocation to the artificial rearing system. Therefore, each piglet was placed in front of a milk cup and its snout was moistened with milk. After that, their drinking ability was checked every 2–3 h. If a piglet was not drinking on its own, additional guidance was provided by repeatedly dipping the snout into the milk cup. All piglets drank independently after 24 h at the latest.

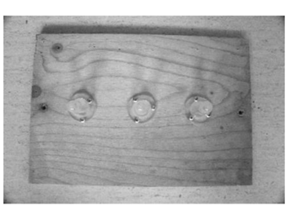
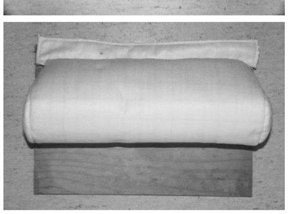
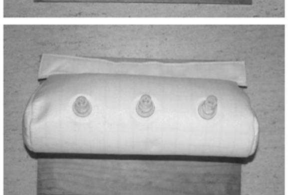
Male piglets were castrated under analgesia and isoflurane anaesthesia within the first 10 days of age (between days of behavioural observations). Canine teeth were neither clipped nor grinded and tails were not docked. When a piglet showed signs of diarrhoea, all piglets were treated with a herbal product (Stullmisan® S ad us. vet., Pharma Stulln GmbH, Stulln, Germany) administered into the mixing tank. If the piglets continued to be sick, they were treated with antibiotics by standard veterinary practice.

Fig. 1. Overview of the artificial rearing system pen, showing the feeding-dunging area with two with milk cups (left) and the resting area with two massaging dummies on the longitudinal wall (right).

2.3. *Treatments*

A two-by-two between-group factorial design was applied in which a sucking and a massaging opportunity either were or were not provided to the piglets, resulting in four different treatments (Table 1). Accordingly, a given pen was either equipped with a sucking dummy, a massaging dummy, a combined sucking–massaging dummy, or no dummy as a control (Table 1). Because the artificial rearing system had three pens, only three of four treatments were carried out in each of the seven batches. The order of the treatments and their allocation to the three pens were systematically balanced and all four treatments were applied within two consecutive batches. Resulting in a total of 21

Table 1
Description of the four treatments applied in the artificial rearing system.

Treatment		Dummy type
Control		No dummy.
Sucking		Sucking dummy made of three nipples (Milette Baby Care, for five-month-old babies) mounted on a wooden board (31 × 21 cm).
Massaging		Massaging dummy made of a cushion (30 × 12.5 cm, depth: 8 cm) consisting of soft filter mats (Polyester-Filter T15/500S, thickness: 22 mm) covered by a polyester case (PES 37450-3/01 ASC K2 SG, thickness: 1.7 mm, oleophobic and hydrophobic impregnation) and mounted on a wooden board (31 × 21 cm).
Combination		Combined sucking and massaging dummy made of three nipples fixed to a massaging dummy and mounted on a wooden board (31 × 21 cm).

groups, the massaging dummy treatment was applied in six batches, whereas the other three treatments were applied in five batches.

In treatments with dummies, pens were equipped with two dummies of the same type to provide sufficient sucking devices (one per piglet) or massaging surface for six piglets. The dummies were evenly spaced on the longitudinal wall of the resting area, with the lower part of the massaging and sucking dummies situated about 6 cm and 11 cm, respectively, above the floor (Fig. 1). As being installed in the heated resting area, the dummies were always slightly warm. To ensure the acceptance of the dummies used in this experiment (Table 1), different massaging and sucking dummies had been presented to the piglets in a preliminary preference study (Keller, 2016).

2.4. Behavioural observations

The behaviour of the piglets was video recorded in two time blocks from 05:00 h to 09:30 h and from 13:00 h to 17:30 h on day 4 and 18 after introduction to the artificial rearing system. In every time block, each piglet was observed as a focal animal three times for 15 min with the software ETHO (version 8.1.0.0; non-commercial, R. Weber, Agroscope, Switzerland) using continuous sampling (Martin et al., 1993). In each time block, all six piglets of a given group were observed three times in a different randomized order and the sequence in which observations were made in the different pens was varied between days. Frequency and duration of behavioural elements were recorded using the ethogram presented in Table 2.

Two video cameras were used per pen to cover the whole pen area. A miniature dome camera with an angle of view of 180° (Eyseo Super-Mini-Dome-Camera, IP42, 1.6 mm Objective) was placed on the sidewall in the resting area. To record the behaviour in the feeding-dunging area, an additional camera (CCD Everfocus EBD430, IP-V2, 9–22 mm Varioobjectiv) was fixed to the ceiling of the barn. The resting area was illuminated by a light at all times. To facilitate video recordings in the feeding-dunging area, room lights were additionally switched on for observation days. On the day before video recordings, all piglets were marked with liquid colour (FASTmark blue, RAIDEX, Dettingen/Erms, Germany; visible for about 3 days) on their back for individual recognition on the videos. The standard daily care (e.g. feeding, cleaning) was the same on all days and provided at about 07:30 h and 16:00 h.

2.5. Analyses

All analyses were performed in R (version 3.3.2; R Core Team, 2016).

2.5.1. Intra-observer reliability

To control for consistency in video observations over time, intra-observer agreement was assessed using Cohen's kappa coefficient (kappa, package 'psych'; Revelle, 2017) and linear regression (gls, package 'nlme'; Pinheiro et al., 2016). Therefore, the first 90 min of a randomly chosen video from the first batch and the first 90 min of a randomly chosen video from the current batch were re-scored before the start of the next batch. Re-scoring a video sequence from the first batch and the current batch reflected long-term and short-term consistency, respectively. Given the seven batches, both long- and short-term consistency were tested 6 times. For every 90-min video sequence, the total durations of all behaviours were calculated for each individual piglet. For the assessment of the intra-observer reliability, the sample for each assessment of agreement comprised the six individuals multiplied by eleven behaviours (eight as listed in Table 1 plus three additional behaviours, which were not included further in this study due to rare occurrences). The occurrence of the behaviours in the original scoring and the re-scoring was compared using Cohen's kappa. The durations of behaviours that did occur were additionally submitted to a regression of the re-scored durations in dependence of the original durations. The intercept and slope were estimated in this regression.

With respect to short-term reliability, Cohen's kappa showed a median value of 0.95 (range across batches 0.89–1.00), the intercept of the regression was 0.01 (−0.01–0.04), and the slope was 1.00 (0.99–1.00). With respect to long-term reliability, Cohen's kappa was 0.94 (0.85–1.00), the intercept of the regression was 0.04 (−0.11–0.06), and the slope was 1.00 (0.99–1.06). Therefore, the intra-observer consistency was considered to be very high.

2.5.2. Data processing and statistical analysis

Durations of each behaviour were summed per piglet and day. Relative durations were then calculated by dividing the summed durations by the total observation time of 90 min per piglet and day. These relative durations served as outcome variables. Additionally, the proportion of belly nosing on body nosing and the average resting bout duration (total duration of lying divided by the number of lying bouts) were analysed.

Statistical analysis of these outcome variables was conducted by using linear mixed-effects models (lmer, package 'lme4'; Bates et al., 2015). P-values were calculated based on a parametric bootstrap (PBmodcomp, package 'pbkrtest'; Halekoh and Højsgaard, 2014). Model assumptions were checked by graphical analysis of residuals for normal distribution and homoscedasticity of errors. Relative durations and the proportion of belly nosing were logit transformed to fit statistical assumptions. A log transformation was used for average resting bout duration.

Fixed effects were the availability of a sucking opportunity (factor with two levels: no, yes), the availability of a massaging opportunity (factor with two levels: no, yes) and the observation day (factor with two levels: day 4, day 18). A full model was first set up including the main effects and all potential interactions. For behaviours directly performed on a dummy (i.e. dummy nosing and manipulation of the dummy), no data were available from the control treatment. The predictor treatment was then coded as a factor with three levels (sucking opportunity, massaging opportunity, combination). Additionally, the

Table 2
Definitions of observed behaviours.

Behaviour	Definition
Belly nosing	Repetitive and rhythmic up and down movement with the snout (including sucking) on another piglet's belly (Fraser, 1978). The belly was defined by two imaginary lines from the armpit vertically up to the top of the shoulder and from the rear flank vertically up to the top of the hip.
Body nosing	Repetitive and rhythmic up and down movement with the snout (including sucking) on any part of the piglet's body; including belly nosing.
Dummy nosing	Repetitive and rhythmic up and down movement with the snout (including sucking) directed at a dummy.
Manipulation of piglets	Manipulations other than nosing, e.g. nibbling, licking, scratching, chewing or biting, directed at another piglet's body.
Manipulation of the dummy	Manipulations other than nosing, e.g. nibbling, licking, scratching, chewing or biting, directed at the dummy.
Manipulation of pen equipment	Manipulations like nibbling, licking, scratching, chewing and biting of pen equipment (except for dummies).
Play-fighting	Playful fighting characterised by scampering, hopping, head tossing, pivoting, shaking objects (Newberry et al., 1988), and running around with rapid changes in direction (Camerlink and Turner, 2013).
Resting	Lying inactively in a lateral or sternal position. Changes in lying position of less than one second and without disturbance by another piglet were disregarded.

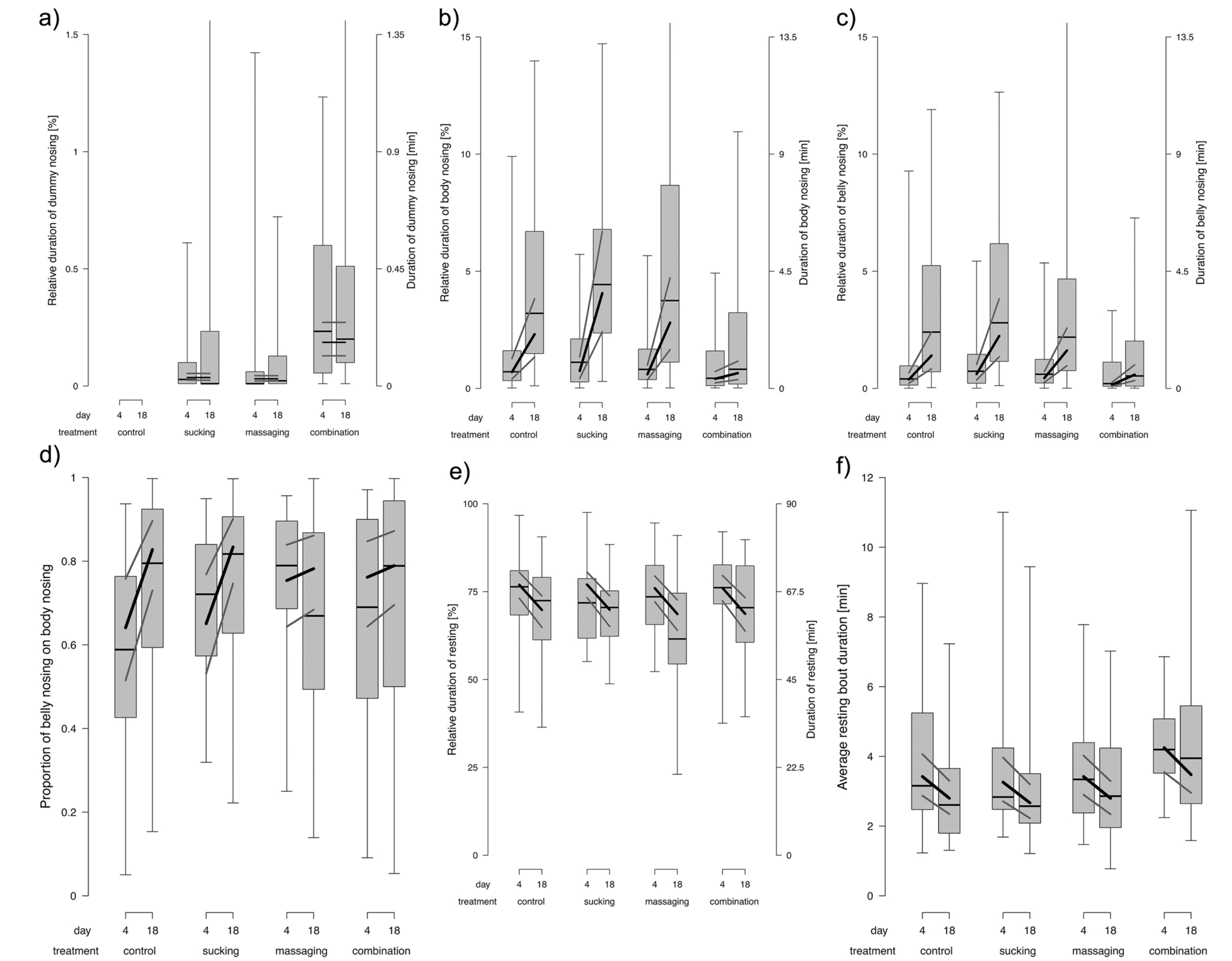


Fig. 2. Relative duration and absolute duration of dummy nosing (a), body nosing (b), belly nosing (c), and resting (e) as well as the proportion of belly nosing on body nosing (d) and the average resting bout duration (f) per piglet per 90 min on day 4 and 18 after introduction to the artificial rearing system for the treatments control, sucking, massaging, and combination. Boxplots show medians, interquartiles, and absolute ranges of data. In addition, model estimates (thick lines) and 95% confidence intervals (thin lines) are shown.

dependency between the duration of body nosing and the duration of dummy nosing on day 18 was analysed. This model included the additional fixed effect of treatment (three level factor) and the interaction of treatment and dummy nosing. For all models, the random effect, accounting for data dependency, included the piglet nested in pen nested in batch. Model selection was conducted as a stepwise backwards elimination, starting with the full model and using $p > 0.05$ as exclusion criterion. The minimal model considered was the main effects model.

3. Results

3.1. Dummy, body, and belly nosing

The relative duration of dummy nosing ranged from 0.0 to 3.0% and was higher in the combination treatment compared with the other treatments ($p < 0.001$), whereby no effect of the day was present ($p = 0.51$; Fig. 2a).

The relative duration of body nosing ranged from 0.01 to 28.8% and increased from day 4 to 18 in all treatments, but piglets in the combination treatment showed a much smaller increase compared with piglets in the other treatments (day × massaging opportunity × sucking opportunity: $p = 0.022$; Fig. 2b). Body nosing was not shown by seven piglets (control: 2, sucking: 2, massaging: 1, combination: 2) on day 4 and by one piglet (combination) on day 18. The piglet which did not show body nosing on day 18 also did not show body nosing on day 4.

On day 18, the relative duration of body nosing was not affected by the relative duration of dummy nosing ($p = 0.38$; Fig. 3) but was generally lower in the combination treatment compared with the other treatments ($p < 0.001$; Fig. 3). The relative duration of belly nosing ranged from 0.01 to 18.2% and increased from day 4 to 18 in all treatments ($p < 0.001$; Fig. 2c) but piglets in the combination treatment showed a lower relative duration of belly nosing compared with piglets in the other treatments (massaging opportunity × sucking opportunity: $p = 0.002$; Fig. 2c).

The proportion of belly nosing on body nosing increased from day 4 to 18 in all treatments, however, with a massaging opportunity present, the proportion of belly nosing was already on a higher level on day 4 in comparison with the treatments without a massaging opportunity (day × massaging opportunity: $p = 0.037$; Fig. 2d), whereas it was not affected by the opportunity for sucking ($p = 0.19$; Fig. 2d).

3.2. Manipulation of piglets, dummies, and pen equipment

The presence of a massaging dummy tended to reduce the relative duration of manipulation of piglets ($p = 0.088$) from 0.19%

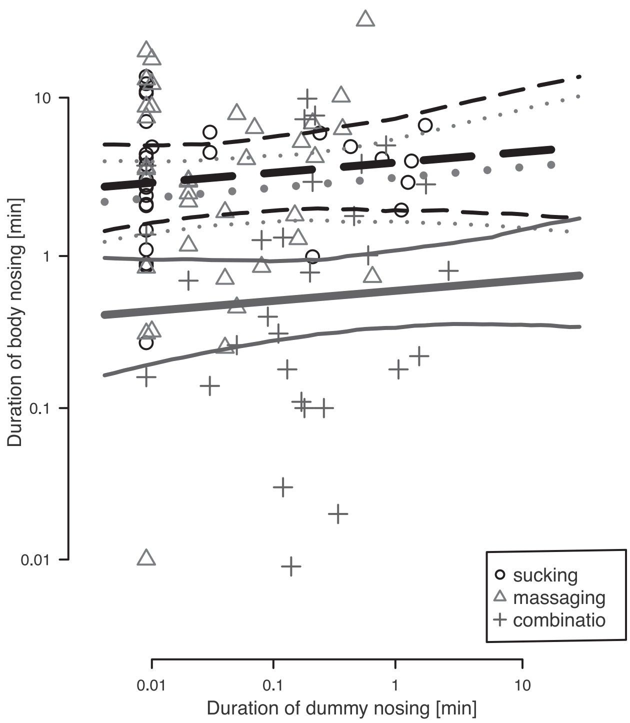


Fig. 3. Dependency between the duration of body nosing and the duration of dummy nosing per piglet per 90 min on day 18 after introduction to the artificial rearing system. In addition to the absolute durations, model estimates (thick lines) and 95% confidence intervals for the treatments sucking (dashed lines), massaging (dotted lines), and combination (solid lines) are shown.

[0.12–0.31] (model estimate [95% CI]) without massaging opportunity to 0.12% [0.08–0.20] with massaging opportunity. Neither the presence of a sucking dummy (p = 0.27) nor the day (p = 0.58) affected the relative duration of manipulation of piglets.

The relative duration of manipulation of the dummy was extremely low, nonetheless it was tendentially affected by the treatment (p = 0.086; sucking: 0.0001% [0.000007–0.0002], massaging: 0.0003% [0.00002–0.0004], combination: 0.0002% [0.00001–0.0003]) but not the day (p = 0.65).

The presence of a sucking dummy tended to reduce the relative duration of manipulation of pen equipment (p = 0.079) from 0.06% [0.03–0.09] without sucking opportunity to 0.04% [0.02–0.07] with sucking opportunity, but no difference was found dependent on the presence of a massaging dummy (p = 0.78). Further, the relative duration of manipulation of pen equipment increased from 0.03% [0.02–0.06] on day 4 to 0.07% [0.04–0.10] on day 18 (p = 0.009).

3.3. Resting behaviour and play-fighting

The relative duration of resting decreased from day 4 to 18 in all treatments ($p < 0.001$; Fig. 2e), but was not affected by a massaging (p = 0.55; Fig. 2e) or sucking opportunity (p = 0.97; Fig. 2e). The average resting bout duration of piglets in the combination treatment tended to be longer than of piglets in the other treatments (massaging opportunity × sucking opportunity: p = 0.066; Fig. 2f). Further, the average resting bout duration decreased from day 4 to 18 ($p < 0.001$; Fig. 2f). The relative duration of play-fighting ranged from 0.01 to 4.8% and was neither affected by the opportunity to massage (p = 0.77) or suck (p = 0.61), nor the day (p = 0.58).

4. Discussion

The current study examined whether nosing behaviour directed at other piglets (body nosing) by piglets separated from the sow three to five days after birth and reared in an artificial rearing system can be reduced by offering them sucking and massaging dummies simulating qualities of the sow's udder. The artificial rearing pens were equipped with one of four treatments: a sucking dummy, a massaging dummy, a combined sucking–massaging dummy or no dummy. In the analysis, we also tested whether these treatments had an effect on dummy nosing, the proportion of belly nosing on body nosing, the manipulation of dummies, other piglets, or pen equipment, as well as the resting behaviour and play-fighting.

In line with the results of Widowski et al. (2005) offering various types of milk feeders to artificially reared piglets, we observed that piglets provided with a combined sucking–massaging dummy spent more time nosing this device than piglets offered either a sucking or a massaging dummy. Similarly, Widowski et al. (2005) reported that artificially reared piglets spent more time sucking and massaging nipples mounted on a soft water bag than nipples fixed to a wall. In absolute terms, however, all three types of dummies used in the present study were little attractive to the piglets. On average, a given focal piglet showed dummy nosing for less than 10 s during the 90 min observation time. In a preference test, Welch and Baxter (1986) offered piglets artificial udders differing in softness and temperature and found that piglets spent 63.8% of the time in contact with a soft and warm (37 °C) udder, but only 17.6% with a hard and warm udder or 8.6% with a soft and cold (28 °C) udder, respectively. It is thus likely that the dummies used in the present study could be made more attractive by heating them to a higher temperature. Furthermore, the dummies would certainly be more attractive if they provided milk. However, we did not consider this option in our study because such artificial udders require labour-intensive cleaning (Jeppesen, 1981), which renders them impractical for commercial artificial piglet rearing systems. Instead, we focussed on a simple and practical solution to improve the housing conditions of surplus piglets.

Body nosing was not shown by seven piglets on day 4 and by one piglet on day 18. The relative durations of body nosing and belly nosing ranged from 0.01–28.8% and 0.01–18.2% of the observation time, respectively. Similarly, Li and Gonyou (2002) found large individual variation in the time piglets weaned at 12–14 days of age spent belly nosing, ranging from 0.1–8% of the observation time. The relative duration of body nosing and belly nosing increased from day 4 to 18 in all treatments in the present study. This is in line with previous studies reporting that belly nosing increases with age in early weaned piglets (Gonyou et al., 1998; Worobec et al., 1999; Bench, 2005).

The increase in body nosing and belly nosing was clearly the smallest in the treatment with the combined sucking–massaging dummy compared with the other treatments, suggesting that the combined treatment, providing the opportunity to express both sucking and massaging behaviour, was best suited to meet the piglets' behavioural needs. Surprisingly, the relative durations of body nosing and belly nosing on day 18 were higher in piglets with either a sucking or a massaging dummy (but not both) compared with piglets in the control treatment. In the treatments allowing either for sucking or for massaging on the dummy, the sucking or massaging of the dummy thus may have triggered the motivation to also perform the other behaviour of the two, which may then have been redirected to the body of another piglet. Moreover, body nosing and belly nosing were slightly more pronounced in the sucking treatment compared with the massaging treatment, suggesting that sucking on the dummy triggered massaging behaviour that could only be directed at other piglets (but not at the sucking dummy), whereas massaging behaviour triggered by the sucking dummy could be performed on both the dummy and the body of another piglet.

Interestingly, the duration of body nosing was not related to the time the piglets spent dummy nosing, meaning that there was no causal inverse relationship between the nosing behaviour directed at the dummies and at other piglets. This suggests that piglets have an individual level of motivation for nosing, which they distributed to both the dummies and other piglets, independent of the treatment.

The proportion of belly nosing on body nosing was generally rather high and increased from day 4 to 18 in all treatments. In line with this observation, Straw and Bartlett (2001) reported that, during days 1–3 after weaning, piglets weaned at 16–18 days of age directed nosing mostly towards body parts other than the belly, whereas belly nosing became more frequent with time. On days 13–16 after weaning, 67.9% of all nosing behaviour was directed at the belly, a level somewhat lower than that observed in the present study. Despite this trend, the proportion of belly nosing on body nosing was at a higher level on day 4 in treatments with a massaging opportunity present compared with treatments without. It is thus possible that the massaging dummy triggered the motivation to perform nosing behaviour more on the belly than on other parts of the body, such that early on the piglets determined the belly as a preferable location for nosing behaviour in the presence of a massaging dummy. A possible explanation may be that massaging directed at a massaging dummy, which shared some characteristics of a sow's udder (i.e. softness, size, and shape), provided tactile and visual stimuli similar to the belly.

Manipulations (other than nosing) of piglets, dummies, and pen equipment were consistently at low levels, showing no relevant relationship to the treatments. Likely, manipulation was not influenced by the presence of any dummy but rather by environmental enrichment and exploratory behaviour (Wood-Gush et al., 1990; Dybkjær, 1992). Dybkjær (1992) stated that piglets weaned at 4 weeks in barren housing conditions spent more time manipulating other piglets and the environment than piglets in enriched housing, and Beattie et al. (2000) stated that in pigs weaned at 21 weeks, environmental enrichment increased the time spent with exploratory behaviour.

The relative duration of resting decreased from day 4 to 18. This result is in line with the observations made by Rzezniczek et al. (2015) in a commercial artificial rearing system for surplus piglets and may indicate that resting behaviour of the growing pigs was increasingly affected by space allowance. Furthermore, the average resting bout duration decreased from day 4 to 18. This finding might be associated with the increase in body nosing observed over this period, as resting piglets are often disturbed when being body nosed (Gardner et al., 2001b). Accordingly, the average resting bout duration was longest in piglets in the combined dummy treatment characterised by the shortest relative duration of body nosing on day 18.

The time spent play-fighting was generally very short with on average 0.06 min during the 90 min of observation per piglet. Furthermore, this behaviour was not affected by observation day or the treatments used in the present study. Rzezniczek et al. (2015) reported similar durations of play-fighting in piglets kept in a commercial artificial rearing system and found that piglets reared by a sow showed more play-fighting. In contrast to our results, they observed a decrease in the duration of play-fighting in artificially raised piglets from day 4 to 18. This discrepancy is rather surprising because both studies were conducted similarly. The differences between the results of these two studies are difficult to explain.

Overall, the combination treatment, allowing for massaging and sucking behaviour, was most effective in reducing the increase in the relative duration of body nosing from day 4 to 18. At the same time, the combined sucking–massaging dummy was most attractive to the piglets and induced the most dummy nosing behaviour. Nevertheless, body nosing was still performed in the combination treatment, indicating that the behavioural need for massaging and sucking behaviour was not satisfied sufficiently. Further research is needed either on the design and effectiveness of more attractive but also practical dummies or – from the perspective of animal welfare probably more recommendable – on practical alternatives to artificial rearing systems. Possible strategies may include piglet fostering, nurse sow strategy, supplementation of artificial milk in the farrowing pen, or genetic selection for an adequate litter size.

5. Conclusion

Only the combined sucking–massaging dummy used in this experimental study was effective in keeping body nosing and belly nosing on an initial level in piglets reared in an artificial rearing system. However, also the combined dummy did not prevent body nosing and belly nosing. Piglets reared by the sow do not show belly nosing before weaning. Thus, the tested dummies were not successful in eliminating the redirected oral behaviour in artificially reared piglets and, hence, did not seem to satisfy the piglets' motivation for sucking and massaging behaviour.

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