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Access to chewable materials during lactation affects sow behaviour and interaction with piglets

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ABSTRACT

We investigated how providing chewable materials to piglets during the early weeks of life affect sow behaviour, sow and piglet interaction and sow health in pens with farrowing crates.

We divided 59 pregnant sows into two treatment groups: the Control group (C, n = 29) and the Rope-Paper group (RP, n = 30). Piglets in the C group had the minimum enrichment required by Finnish legislation. For the RP group, we added sisal ropes and non-glossy newsprint paper. We recorded the behaviour of sows and their litters for a four-hour period during the first 7–18 days of life of the piglets. Skin and udder damage of the sow was recorded once a week five times. Behavioural data was divided into two categories according to the age of the litters. The first group contained litters aged from 7 to 13 days (n(RP) = 22 n(C) = 22) and the second group litters aged 14 days or older (n(RP) = 24 n(C) = 24).

Younger piglets (age 7–13 days) in the RP group manipulated the udder more frequently ($p < 0.01$) and the duration of udder manipulation was longer than in the C group ($p = 0.02$). Further, the RP group had more udder contact events in which 20 % or less of the piglets took part and in which less than 50 % took part ($p < 0.01$ for both).

Older piglets (age ≥ 14 days) in the RP group touched the sows' body more frequently ($p < 0.05$).

Sows in the C group were standing ($p = 0.01$), eating ($p = 0.04$) and performing oral-nasal manipulation ($p < 0.01$) more often.

In the C group, repeated measures of skin lesions differed significantly between observation days ($p = 0.00$), sows tending to have a higher skin lesion score in observation week 5, with a median score of 1.5 (1–3), than in observation week 4, with a median score of 1 (1–2) ($p = 0.06$).

In conclusion, piglets that had access to chewable materials after birth made more contact with the sow during lactation. However, sows in the C groupperformed more active behaviour. The behavioural mechanisms underlying these changes are not yet clear. Further investigations of the usage of chewable materials in farrowing units equipped with crates and their effects on the behaviour of sows and piglets are therefore warranted.

1. Introduction

Approximately 95 % of sows in Europe spend 3–4 weeks in crates during farrowing and lactation (Barnett et al., 2001; Baxter et al., 2010). In crates, the sow has a restricted possibility to control nursing frequency, which is considered to be stressful (Hötzel et al., 2004; Pajor et al., 2000). Generally, the nursing frequency decreases over time if the sow has the possibility to control it (Cox and Cooper, 2001). For example, in the study from Arey and Sancha (1996) sows in crates nursed 1.56 times per hour, while sows in family systems nursed only 1.35 times per hour, during the first two weeks of lactation (Arey and Sancha, 1996). Udder massage before and after nursing is related to piglets attempting to stimulate milk production to ensure sufficient milk production in the future (Algers and Jensen, 1985; Gill and Thomson, 1956). However, teat contacts that do not lead to nursing can be unpleasant and painful (Vieuille et al., 2003).

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Already during the early weeks of their lives the piglets express exploratory behaviour such as rooting, chewing and sniffing (Stolba and Wood-Gush, 1989). During the lactation period in a poor and restricted environment piglets might use the udder of a crated sow as a manipulating and foraging object (Jensen and Recén, 1989; Petersen et al., 1995) and direct rooting and chewing behaviour towards the sow (Arey and Sancha, 1996). This alters the behavioural patterns of the sow, which may be interpreted as an attempt to move away from the piglets (Vieuille et al., 2003). If the sow cannot avoid the piglets, she may experience stress in late lactation, as indicated by increased cortisol levels (Cronin et al., 1991; Jarvis et al., 2006). Redirected behavioural patterns of the sow, such as bar biting, during lactation are considered to be a sign of discomfort (Thodberg et al., 2002), probably reflecting frustration at being unable to avoid the piglets (Hötzel et al., 2004; Jensen, 1988) or being unable to give them maternal attention (Lammers and De Lange, 1986).

Early experience of enrichment may affect the physiological signs of stress in piglets over time (De Jonge et al., 1996), resulting in reduced damaging behaviour such as tail biting (Munsterhjelm et al., 2009; van Nieuwamerongen et al., 2015; Telkänranta et al., 2014), reduced aggression (De Jonge et al., 1996; van Nieuwamerongen et al., 2015), increased weight gain (De Jonge et al., 1996), earlier onset of puberty (De Jonge et al., 1996) and increased amount of feed eaten after weaning (van Nieuwamerongen et al., 2015). Moreover, early contact with enrichment may act as a stimulus for the immune system and enhancing immune development (Luo et al., 2020; van Nieuwameronge et al., 2015). According to van de Weerd et al. (2003) the pigs are attracted to objects which are deformable, ingestible and chewable.

Most of the research on environmental enrichment in pigs is done later in life, focusing on weaner, grower and finisher pigs. Investigations of the effects of the environment during the early weeks of life are mainly directed to free -farrowing systems. Pigs reared by crated sows exhibit additional stress compared with piglets nursed by free farrowing sows (De Jonge et al., 1996). The significance of enrichment provided in the farrowing unit with pens equipped with farrowing crates remains unclear.

The aim of this study was to determine how providing chewable materials to piglets during early weeks of life affect sow behaviour, sow and piglet interaction and sow health in pens with farrowing crates. Regarding the sow- piglet interactions the focus was on whether (i) nursing behaviour and (ii) manipulative behaviour of piglets were directed towards the sow. Regarding the sow, the focus was on (iii) the effect of these behavioural patterns of piglets on the behaviour, skin lesions and udder health of the sow. We hypothesized that access to enrichment would diminish manipulative behaviour of piglets towards the sow, increase successful nursing and therefore improve the welfare and health of the sow.

2. Materials and methods

2.1. Approval of the study

The study protocol was approved by the Viikki Campus Research Ethics Committee of the University of Helsinki, Finland (Record 3C/2010).

2.2. Housing and management

Housing and management are described here briefly. The details have been presented elsewhere (Telkänranta et al., 2014).

The study was carried out on a commercial piglet-producing farm in western Finland. The farm was health-certified by SIKAVA, the health classification register for pig farms in Finland. The herd had about 300 sows farrowed in batches of 20; all of them were inseminated with a commercial mixture of semen (2.5. $\times$ 10^9 spermatozoa per dose) from several boars. All sows and gilts farrowing during the time that the experiment was carried out were eligible for the study. They were included if no signs of illness were detected on veterinary clinical examination. Gilts were included as a key age group to provide continuation of renewal of sows and their behaviour and performance is therefore of great interest. Parity in the treatment groups was balanced. We selected 64 cross-bred sows for the experiment, 2–6 days before the expected farrowing. In the farrowing unit, sows and their litters were housed in pens of 2 m x 2.4–2.6 m with a farrowing crate and slatted floor, excluding the solid creep area and the solid area on the front half of the crate. Sows were crated during the entire lactation period and piglets were weaned at the age of 21–25 days. Four of the selected sows with their litters had to be excluded from the study during lactation because of illness and one additional sow because of continuous attempts to escape from the crate, resulting in 50 sows and nine gilts in the experiment. Seven sows were Norwegian-Landrace and 52 Yorkshire-Landrace crosses. Cross-fostering was done inside the treatment groups during the first 24 h from birth. The mean litter size was 11 (range 7–13). Teeth of the piglets were not clipped and the tails were undocked.

2.3. Treatments

Sows were divided into two treatment groups: the Control group (C, n = 29) and the Rope-Paper group (RP, n = 30) and the parity was balanced. Enrichment materials were put into the pens before farrowing and fresh material was given twice daily at approximately 8:30 and 15.30.

All of the pigs, including the sows, had the minimum enrichment required by Finnish legislation (Ministry of Agriculture and Forestry in Finland, 2002). The legislation states that all pigs, including sows and piglets, must have access to material with which the animals can express their natural behavioural needs such as exploring and rooting at all times. The requirement was fulfilled with a plastic ball of 5.5 cm in diameter (Anti-Bite polyurethane ball, Albert Kerbl GmbH, Germany) attached with a 20 cm metal chain on the side of the pen and two handfuls of wood shavings given on the concrete part of the pen twice daily. Additionally, the RP group piglets (n = 30) had ten approximately 1.3 m long sisal ropes of 1 cm in diameter (Piippo Oy, Finland). The ropes were attached on the side of the pen by tying the rope from the middle. Sows did not have access to the ropes. Furthermore, RP piglets and the sow were given non-glossy newsprint paper: one double page for sow and piglets under two weeks of age and two double pages for piglets two weeks of age or older. Newspaper and wood shaving were given at different times of the day and dirty material was disposed of when necessary. The newspaper was stored for at least two months before use. This was to ensure that the solvent ingredients from the ink (Eurostar Black LF, product code DE109KLS03, Flint Group Finland Oy, Finland) had evaporated.

2.4. Data collection

2.4.1. Piglet growth

Piglets were weighted within the first 24 h after birth and at weaning.

2.4.2. Video recordings for behavioural analysis

Behaviour of the sows and their litters was recorded with wireless Intellicam IPC04 video cameras run on Blue IrisTM software (Perceptive Software, Lenexa, KS, USA). The cameras were installed in front of every pen, attached to the feeding pipe, so that the view covered the whole pen. The cameras stayed in their position throughout the whole experiment and were cleaned and redirected if needed in the morning of the recording day to ensure good quality. Once the cameras had been set up and focused, the starting and stopping of video recordings were carried out via remote control from a separate room. For technical reasons, piglets under four days of age were not recorded. To respect farm

routines, all sows and litters were recorded on Monday or Tuesday, independent of the age of the piglets. Therefore, each litter and the sow were recorded for four hours once (n = 4) or twice (n = 52) at one-week intervals during the three-week lactation period, resulting in 108 videos (54 for each treatment group).

2.4.3. Behavioural observations

The observation took place between 10:00 and 14:00 h once or twice ending up to a total of 240 min of video analysis per sow per observation period. The behaviour of the sows and the litters was recorded continuously for a four-hour period with the Observer XT 10® (©Noldus Information Technology, Wageningen, the Netherlands) based on the ethogram presented in Table 1. If several behaviours were detected at the same time, all of them were included as independent events. The behaviour of the piglets was observed by one observer and the behaviour of the sow by another to ensure reliability. Homogeneity of the video observations was ensured by comparing the results of one video in the beginning, in the middle and at the end of the observations.

2.4.4. Skin lesion scores

The evaluation of skin lesions was done once before farrowing, right after transportation of sows to the farrowing unit to establish the baseline (Week 1). After this, an evaluation was done once a week four times during lactation, ending up with five evaluations (Week 2–5). The timing of the procedure was independent from the timing of the video recordings and was carried out by one of four trained observers. Training was given by a veterinarian and the procedure was practiced before the experiment at the farrowing unit of the farm with sows not participating in the experiment. Inter-observer reliability was ensured by comparing the collected data in the beginning and at the end of the experiment.

The sow's body was examined in five separate regions (Fig. 1). Skin lesions of the sow were scored as described in the Welfare Quality® protocol (Welfare Quality®, 2009): The severity of the lesions is considered to correspond to the number of lesions and registered and summed as described in Table 2. After registering and summing the lesions the examined regions (Fig. 1) were scored on a scale of a– c as follows: a, up to four lesions visible; b, 5–10 lesions visible; c, 11–15 lesions visible. Based on the scoring of regions each sow was given an individual score on the scale of 0–2 as follows: 0, all regions with score a; 1, any region with score b and/or one region with score c; 2, two or more regions with score c or more than 15 lesions in one or more regions.

2.4.5. Udder health and filling stage

The evaluation of udder health was done once before farrowing in the farrowing unit to establish the baseline (Week 1). After this, an evaluation was done once a week four times during lactation ending up 5 evaluations (Week 2–5). The procedure was carried out by one of four trained observers and the evaluation was the same as for the evaluation of skin lesions. Training was given by a veterinarian and the procedure was practiced at the farrowing unit of the farm with sows not participating the experiment. Inter-observer reliability was ensured by comparing the collected data in the beginning and at the end of the experiment.

Mastitis was scored as described in the Welfare Quality protocol® for pigs (Welfare Quality®, 2009) and teat lesions according to Persson, 1997. Each udder lobe was inspected for mastitis and teat lesions visually and by palpation and scored for lesions from 0 to 3 and for mastitis 0 or 1, 0 showing no symptoms of mastitis. Teat with no visible injuries was given score 0, with small superficial abrasion, score 1, a teat with wound penetrating more deeply and extending from the apex was given score 2 and severe wound with tissue lost was given score 3. Four assessors were trained by a veterinarian in the same piggery with sows not included in the experiment. The number of all lesions was summed.

Since milk production in lacteal glands of one sow may differ considerably (Gill and Thomson, 1956), filling stage of each lacteal gland was scored on the scale of 1–3, 1 being an empty, small udder with no signs of milk production; 2 being slightly filled, but not fully filled; and 3 being fully filled, but not hard.

2.5. Data handling and statistical analysis

All videos were analysed continuously for frequency and duration of piglet and sow behaviour (Table 1).

In 11 of the 108 video recordings, piglet contacts with the sow were not possible to observe reliably because of the placement of the camera, lighting or other technical reasons. These videos were excluded from the

Table 1
Ethogram of the behavioural analyses of the litters and the sow. Videos were analysed continuously for 240 min per observation day. If several behaviours were detected at the same time, all of them were included as independent events.

Behaviour	Unit	Definition
Piglet		
Nasal contacts with the sow	Frequency	Any part of the piglets' and sows' snout touch each other
Successful nursing	Frequency	Fast-suckling phase, in which the piglets suck synchronized, showing 4–5 mouth movements per second for 10–30 s, can be observed
Udder massage	Frequency, duration	One or more piglets rub the udder for more than 10 s, the number of piglets massaging is recorded. This parameter includes nursing-related rubbing.
Body contacts with the sow	Frequency, duration	One or more piglets touch the sow's body, excluding the head or udder. If the contact continues for more than 10 s the event is considered a manipulation and the duration is recorded. The number of piglets touching / manipulating is recorded.
Sow		
Eats or drinks	Frequency, duration	Sow puts her head in to the trough or touches the water nipple for more than 5s
Object or structure manipulation	Frequency, duration	Sow paws with front foot, bites or roots the floor, pen structures or objects for more than 5 s.
Sits	Frequency, duration	Both front legs are straight, posterior and hind legs touch the ground
Sternal	Frequency, duration	Sow lies on her sternum
Lateral	Frequency, duration	Sow lies with udder exposed; head, hip bone and shoulder are in contact with the ground
Stands	Frequency, duration	Sow stands on all four feet
Bottom-up	Frequency, duration	Sow's hind legs are extended, both front knees touch the ground

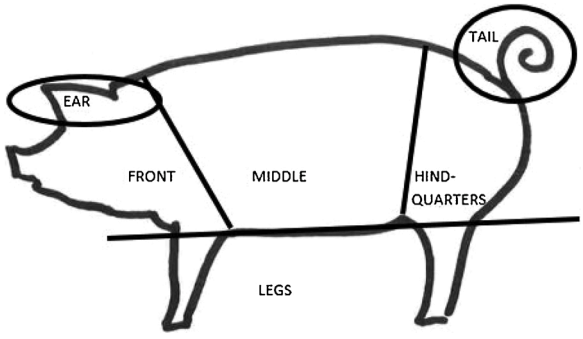

Fig. 1. In the Welfare Quality® protocol (Welfare Quality®, 2009), the sow's body is evaluated in five separate regions: ears, front (head to back of shoulder), middle (back of shoulder to hind-quarters), hind-quarters, legs (from the accessory digit upwards).

Table 2
Description of the scoring of wounds on the sows body after Welfare Quality® protocol Welfare Quality® (2009). In Welfare Quality® protocol the amount of the lesions is considered to correspond with the severity of a wound: According to lesions severity, one lesion registered as 1, 5 or 16 lesions as presented in the table.

Description of lesion	Number of lesions registered, based on Welfare Quality®, 2009
A scratch longer than 2 cm Two parallel scratches with a space between them of up to 0.5 cm A lesion of less than 2 cm	1 lesion
Bleeding lesion of 2– 5cm Healed lesion of over 5 cm	5 lesions
Deep and open lesion of over 5 cm	16 lesions

analysis of piglet behaviour, however sow behaviour was observed as described earlier, thus resulting in 108 pieces of 240 min recordings for analysis of sow behaviour (RP n = 54; C n = 54) and 97 for their litters (RP, n = 48; C, n = 49). Based on the finding that piglet activity changes as the piglets grow (Cox and Cooper, 2001) behavioural data was divided into three categories according to the age of the piglets as follows: week 1: piglet aged under 7 days, week 2: piglet aged 7–13 days, week 3: piglet aged 14 days or older.

Because the observation was done once weekly, regardless of the age of the piglets, three of the sows had two videos in the same age category. The video recorded later was excluded to avoid pseudoreplication. Further, the video recordings on week 1 (n (RP) = 2, n(C) = 3), was omitted from the statistical analysis because of the small sample size.

In the end 48 videos of the sow behaviours were analysed in both age categories, ending up to 52 analysed videos from week 2 (n(RP) = 26, n (C) = 26) and 48 analysed videos from week 3 (n(RP) = 24, n(C) = 24). For the piglet behaviour 44 videos were analysed from week 2 (n(RP) = 22; n(C) = 22) and 48 from week 3 (n(RP) = 24; n(C) = 24).

Based on the finding that synchronization is required for successful nursing to occur (Valros et al., 2002) we divided the manipulation of the udder into two groups: synchronized manipulation in which 50 or 80 % of the piglets participated and in non-synchronized manipulation in which 20 % of the piglets participated.

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 24.0 (IBM Corporation, released 2015, Armonk, NY, USA). The variables were tested for normality using the Kolmogorov-Smirnov test. Most variables were not normally distributed, even after logistic transformation. Therefore, non-parametric tests were used.

Differences in parity, pen length and litter size between the treatments, as well as behavioural parameters, were analysed by applying Mann-Whitney *U* test

The development over time according to piglet age of the different behaviours, described in Table 1, was analysed with related-samples Friedman's two-Way analysis of variance. The individual level of skin lesions was calculated for each observation day, and the effect of the treatment on the progression of the lesions was subjected to Friedman's two-way analysis of variance with repeated measures, with observation day being the repeated factor. The difference in skin lesions between the treatments was analysed with Mann-Whitney *U* test for each observation day separately.

The number of each grade of udder lesions was summed for each evaluation and subjected to Friedman's two-way analysis of variance with repeated measures to assess development over time. The number of all teat lesions for each observation was summed, regardless of the severity. The sum of the lesions was compared between the treatments with Mann-Whitney *U* test for evaluations from 1 to 5 separately.

3. Results

3.1. Characteristics of animals

Median parity of the sows was 3 (min 1, max 11, n = 53). Parity did not differ between treatment groups, nor did total median number of piglets born (Median 11, range 4–18). No differences were found in total median number of piglets born alive (11, 7–13) or in the piglet average weight at birth (1.5 kg, 1.1–2.1) and weaning (7.9 kg, 6.9–9.5) ($p < 0.1$ for all).

3.2. Time effect on behaviour of sows and piglets

Overall descriptive statistical parameters of the behaviours are given in Table 3.

No differences in medians of the behaviours emerged in the repeated measurements of the behaviour of the sows nor the piglets overall ($p < 0.1$ for all).

3.3. Treatment effects on piglet behaviour and nursing

There were no differences in successful nursing frequency between the treatment groups ($p < 0.1$ for all) at any age (see Table 3 for descriptive statistical parameters).

On week 2 piglets in the RP group manipulated the udder more frequently (Med 91, 39–145, n = 22) (Mann-Whitney U = 365.5, $p < 0.01$) and duration of udder manipulation was longer (83, 30–119) (U = 339, p = 0.023) than in the C group (62(34–154) / 49 (20–109, n = 22)) (Fig. 2).

On week 2, the RP group had more udder contact events in which 20 % or fewer of the piglets participated with a median of 30 times (5–103), and in which less than 50 % participated with a median of 53 (12–132) compared with the C group with a median of 15 (4–38) for 20 % and a median of 29 (10–56) for 50 % ($p < 0.01$ for both, U = 375.5 / 358) (Fig. 3).

On week 3, there was a difference in frequency of body contacts (p = 0.047, U = 384.5). The RP group touched the sow's body more

Table 3
Overall descriptives for the behaviour of sows (n = 108) and their litters (n = 97) for a total of 8 h observation. Observation included two 4 -h periods, one period during the piglets 7- 13 days age and one during 14 days or older. The videos were analysed continuously for frequency and duration.

Behavioural parameters, sows	Median (Min– Max)
Bottom up frequency / duration (min)	2 (0–11) / 0 (0–3)
Sit frequency / duration (min)	8 (0–25) / 5 (0–41)
Stand up frequency / duration (min)	4 (0–14) / 13 (0–84)
Sternal frequency / duration (min)	10 (2–32) / 117 (24–222)
Lateral frequency / duration (min)	5 (3–5) / 100 (0–203)
Body position change frequency	17 (5–74)
Eat or drink frequency / duration (min)	5 (0–20) / 4 (0–88)
Object manipulation frequency / duration (min)	13 (0–31) / 8 (0–199)
Behavioural parameters, litters	
Udder manipulation frequency / duration (min)	65 (8–163) / 57 (5–161)
Body contacts with the sow frequency	80 (7–400)
Body manipulation directed by piglets towards the sow frequency / duration (min)	1 (0–76) / 1 (0–71)
Nasal contacts with sow, frequency	85.5 (26–260)
Udder manipulation events in which less than 20 % of piglets participated	18 (5–79)
Udder manipulation events in which more than 50 % of piglets participated	29 (0–95)
Udder manipulation events in which more than 80 % of piglets participated	22 (9–53)
Successful nursings, frequency	5 (0–8)

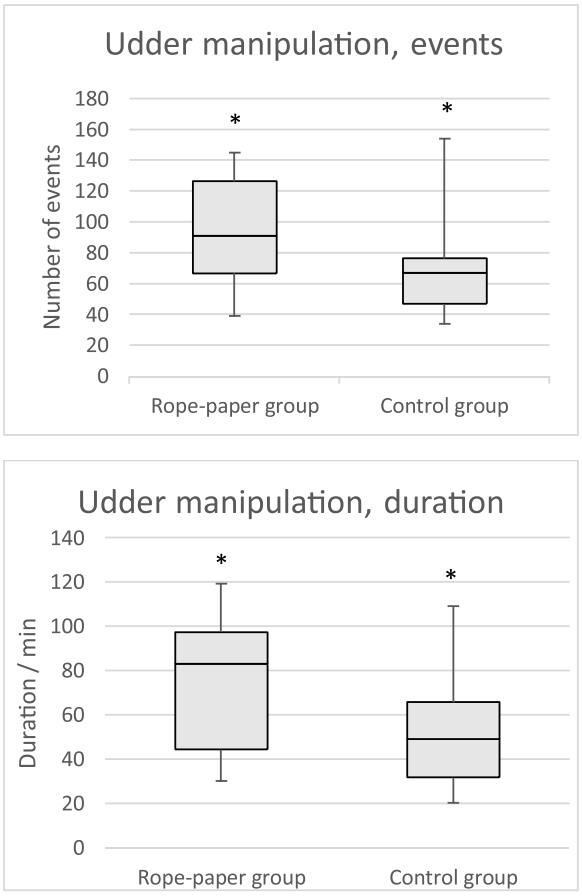

Fig. 2. Number of udder manipulation events and duration of all udder manipulation in minutes during a four-hour observation period for piglets aged 7– 13 days. The parameters were analysed by applying nonparametric Mann-Whitney *U-test.** indicates a difference of $p < 0.05$, median with interquartile range and 95 % CI.

frequently, with a median of 111 events (7–400) than the C group, with a median of 59 (12–264) (Fig. 4).

3.4. Treatment effects on sow behaviour

On week 3, the sows were standing ($p = 0.01$, $U = 186$), eating ($p = 0.04$, $U = 207.5$) and performing oral-nasal manipulation ($p < 0.01$, $U = 178.5$) more often in the C group than in the RP group. For the C group, the median for standing was 4 events over the four-hour observation period (0–11), for eating 6 events (0–17) and for oral-nasal manipulation 15 events (2–31). For the RP group, the median for standing was 2 events (0–9), for eating 2 events (0–16) and for oral-nasal manipulation 5 events (0–28). The duration of standing ($p = 0.02$, $U = 195.5$) and oral-nasal manipulation ($p = 0.02$, $U = 196$) was longer in the C group with a median of 17 min (0–68) for standing and 11 min (1–50) for oral-nasal manipulation. For the RP group, the median was 6 min (0–47) for standing and 3 min (0–33) for oral-nasal manipulation (Fig. 5 a– e).

3.5. Skin and vulva lesions

Individual score for skin lesions did not differ between the treatment groups on any of the observation days, with a median of 1 (1–3) ($p < 0.1$ for all).

In the C group, repeated measures of skin lesions differed significantly between the observation days ($\chi^2(4) = 18$, $p = 0.00$). There was a tendency of sows to have higher skin lesion score on observation week 5 (fifth evaluation), with a median of 1.5 (1–3), than observation week 4

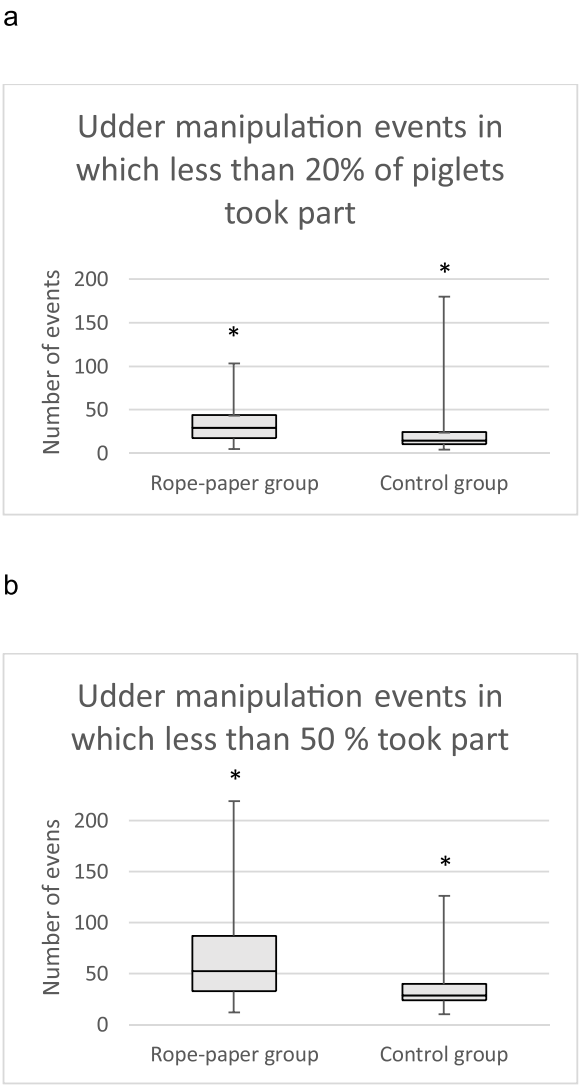

Fig. 3. Udder manipulation events in which less than 20 % (a) or less than 50 % (b) of the piglets aged 7- 13 days participated during 240 min observation. The parameters were analysed by applying nonparametric Mann-Whitney *U* test. The Rope-Paper group manipulated the udder more often in both categories. Differing parameters ($p < 0.05$) are indicated with *, median with interquartile range and 95 % CI.

(fourth evaluation), with median of 1 (1–2) ($p = 0.06$).

No differences emerged in the repeated measures of the skin lesions of the RP group ($p < 0.1$).

3.6. Udder health

No differences emerged between the treatment groups in the mastitis score, with a median of 0 (0–2), or in the filling stage of the udder, with a median of 2 (0–3). Further, no differences emerged in the development of these parameters over time ($p < 0.1$ for all).

No differences between the treatment groups in summed number or severity of teat lesions were found. Furthermore, no differences emerged in repeated measurements in number or severity of the teat lesions (statistical parameters are presented in Table 4).

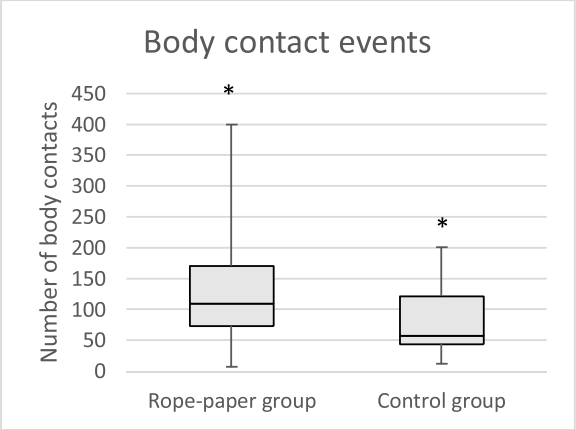

Fig. 4. Number of contacts made towards the sow by piglets aged 14– 25 days (treatment group n = 24, control group n = 24) during the four hour observation period. The parameters were analysed by applying nonparametric Mann-Whitney *U* test . Differing parameters ($p < 0.05$) are indicated with *, median with interquartile range and 95 % CI.

4. Discussion

4.1. Sow and piglet interaction

Contradictory to our hypothesis, piglets in the Rope-Paper group (RP) made more udder and body contacts with the sow than piglets in the Control group (C). The increase in contact was present for udder manipulation in piglets aged 7–13 days, and for body contacts in piglets from 14 days of age.

Teat contacts that do not lead to nursing are an important part of the nursing behaviour (Algers and Jensen, 1985; Gill and Thomson, 1956), but may be unpleasant and painful for the sow. Our finding diverges from the results of Petersen et al. (1995), who found that piglets in the enriched pens manipulated the udder less than piglets in the Control group. In their study, however, the litters and the sow were moved into pens without farrowing crates at two weeks of age, the Control group was not given any material or objects and the observation was done later, at four weeks of age.

Access to materials is known to enhance the exploratory behaviour (Yang et al., 2018) and barren environment leads the piglet to perform the behaviour towards other piglets (Beattie et al., 2000; Petersen et al., 1995). Webster (1998) and Docking et al. (2008) suggest in their studies that sucklers perform most of the exploratory behaviour at the udder and discuss that therefore provision of chewable materials may enhance the foraging and exploratory behaviour at the udder, which seems to be the case in our study as well.

In our study the videos were recorded after feeding during the morning, which is demonstrated to be the most active time for the exploratory behaviour of piglets (Webster, 1998). The materials used in our study were chewable, deformable, destructible and novelty was brought by giving new newspaper and wood shavings daily. According to van de Weerd et al. (2003); Docking et al. (2008) and Schmitt et al. (2020) these elements of the objects attract pigs. Therefore, we assume that chewable materials chosen enhanced the exploratory behaviour of the piglets in the Rope-Paper group but was directed not only towards the material but also towards the sow.

4.2. Sow behaviour

Intrerestingly, despite the difference in piglet behaviour, the sows seemed to behave more calmly in the Rope-Paper group; compared with the Control group, these sows did not manipulate the surroundings and interrupt eating as often and also stood up less and spent less time standing. These behaviours may be considered as signs of stress (Jarvis et al., 2006; Yun et al., 2015).

Another behaviour indicative of stress in sows is dog-sitting (Thodberg et al., 2002). The sows in question had a tendency to sit more during late lactation than at the beginning of lactation, probably because they were trying to avoid having the piglets massage the udder. In natural conditions, the pre-massage period stays constant, while the final massage of the udder after nursing decreases consistently staying low after ten weeks of lactation (Jensen and Recén, 1989). We did not distinguish between pre- and post-nursing udder manipulation and found no difference in udder massage behaviour regardless of the treatment in the two age groups over time, unlike Cox and Cooper (2001). Cox and Cooper (2001) showed that udder manipulation time increases in conventional systems, which is not the case in free farrowing environments in which the sow can avoid the piglets. Our finding is in line with other results regarding the stress experienced by the sow (Jarvis et al., 2006).

A calmer behaviour not only indicates less stress in the sow, but it also protects the piglets. Changes in position of the sow are the reason for most piglet deaths, by crushing (Vieuille et al., 2003). Therefore, calmness of the sow is favourable (Vieuille et al., 2003). According to our findings, chewable materials potentially support calmer behaviour, although the mechanism remains unclear.

The sows from the Rope-Paper group received a double page of newspaper to avoid frustration due to the sow not reaching the material given to the piglets. Although the sows did not have contact to ropes, it cannot be excluded that stress level may have been reduced also because of the availability of the newspaper for the sow herself, giving an opportunity to perform exploratory behaviour, not merely because of the effect of the material on piglet behaviour. Valros et al. (2017) suggested that the motivation to perform exploratory behaviour increases during the lactation period over time. This is in line with our study, since the differences in sow behaviour were detected after two weeks of lactation. It is also possible, that the sow performed manipulative behaviour instead of eating by putting her head in the trough or touching the water nipple, but appearance of these activities more frequently can be considered as a sign of frustration.

Limited resources lead to social competition between the piglets, which can be seen as aggression among the piglets (Docking et al., 2008). It is possible that in our study the presence of chewable materials, which all the piglets could use simultaneously, affected piglet behaviour by the udder by diminishing fights between piglets during nursing. Fighting is known to make the sow to terminate the suckling more often (Lohmeier et al., 2019). This might have also been the reason that the Control group sows stood up more frequently, as the sows in the Rope-Paper group allowed the piglets to manipulate the udder longer and more frequently. Observation of the fighting levels during nursing between the piglets was beyond the scope of this study, but would be a relevant topic for future studies.

A previous study of the same piglets (Telkänranta et al., 2014) shows that the piglets in the Rope-Paper group directed more oral-nasal manipulation towards these experimentally provided objects. Biting of the floor and wall is performed much more frequently in barren pens, as is nudging of littermates, compared with environments with chewable materials (Beattie et al., 2000; Petersen et al., 1995). Therefore, the higher intensity in udder manipulation and body contacts that piglets directed towards the sow in the Rope-Paper group may be a consequence of a rise in general gross-level activity of the piglets as also suggested by Cox and Cooper (2001) and Hötzel et al. (2004). In our study, we did not measure the overall activity of the piglets, but the behavioural analysis of the same piglets done by Wainio (2013) shows, that the Rope-Paper group was more active in both age groups. Still, the Rope-Paper group had fewer manipulative contacts with their littermates (Telkänranta et al., 2014). However, Wainio (2013) and Telkänranta (2014) did not make a difference between aggressive behaviour and manipulative behaviour, which may be a topic of future studies. Contradictory Lewis

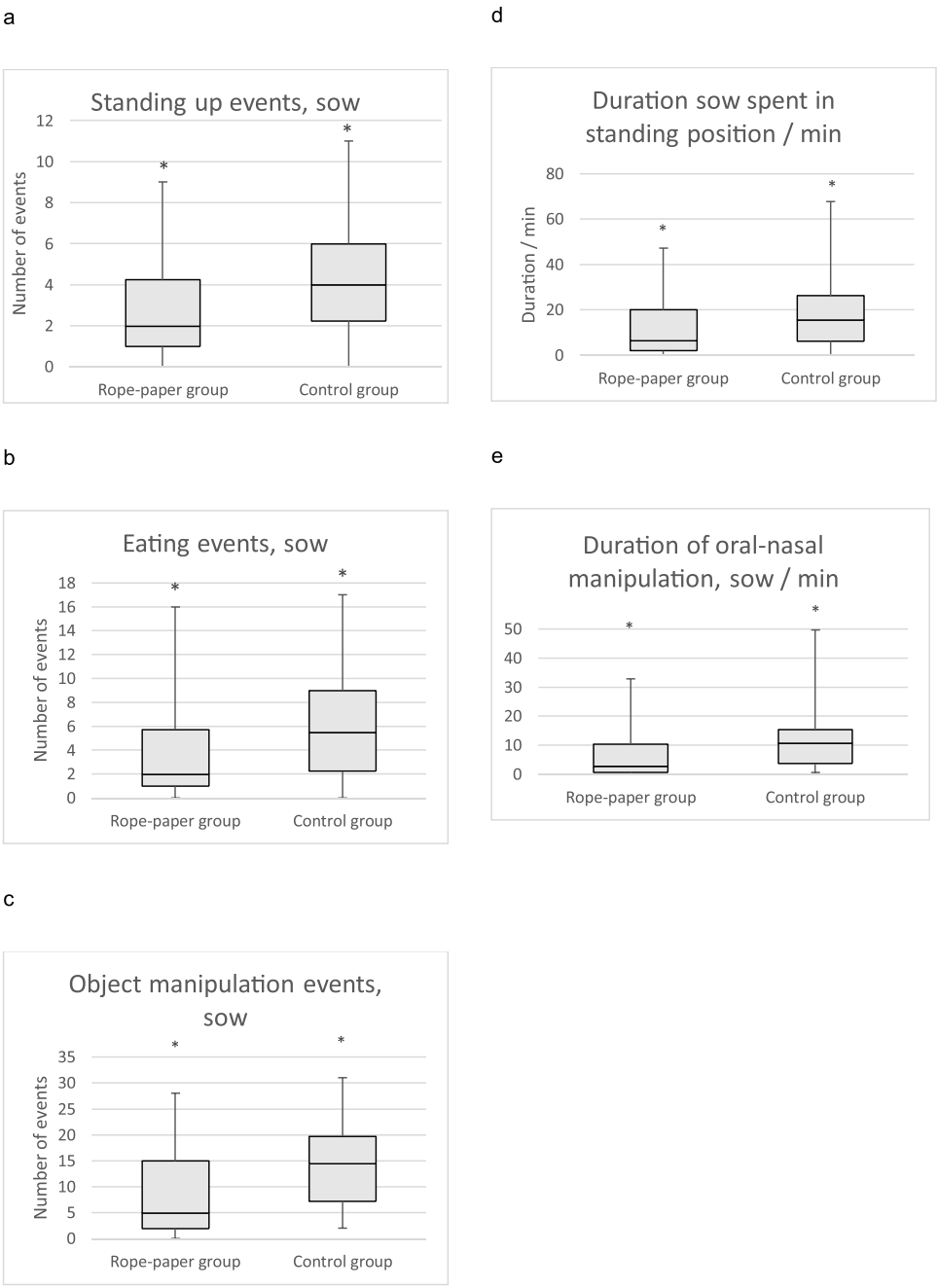

Fig. 5. a– e Treatment effect on sow behaviour. Sows in the Control group stood, ate and manipulated objects more often and spent more time in the standing position and performing oral-nasal manipulation than the Rope-Paper group during the last week of lactation (piglet age $\geq$ 14 days). The parameters were analysed by applying nonparametric Mann-Whitney *U* test . Parameters differing ($p < 0.05$) are indicated with *, median with interquartile range and 95 % CI.

et al. (2006) found no differences in general activity of piglets with chewable materials. In fact, they noted that piglets with shredded paper spent more time inactive. Further, Yang et al. (2018) also did not observe a difference in the number of contacts with littermates, or in the number of fresh skin lesions in piglets raised with or without chewable materials, wood-bark in a box or hanging objects, respectively. The differences in the results of the studies presented, may be also because in our study the piglets in the Control group received also wood shavings.

Synchronization of general activity and inactivity among sucklers is described in a study from Docking et al. (2008). They predict that materials that are available only temporarily, such as wood shavings or newspaper in our study, would lead to higher degrees of synchronization (Docking et al., 2008). In our study we did not observe the synchronization of other behaviours of the piglets than udder massage. The Rope-paper piglets did not synchronize their behaviour directed towards the udder. Still, it is possible that the general activity and inactivity were actually more synchronized than we observed, since our observation period was during the hours which piglets are known to be most active (Webster, 1998). However, Docking et al. (2008) did not observe sow behaviour or sow directed behaviour. In our study one possible explanation is that the sucklers in the Rope-Paper group synchronized their active and inactive behaviour to a higher extent than the control group and therefore did not disturb the sow continuously. This has potentially made the sows experience less frustration and therefore manipulate objects, stand up and interrupt eating less frequently. Still, the effects of the changes in the piglet behaviour on the sow stress and welfare remain unclear.

In conclusion, the sows in enriched pens relative to control pens may

Table 4
Number and severity of teat lesions. Teat lesions were evaluated once a week. The lesions were scored according to severity, and the median number of the scored lesions (score 1 representing light injury, score 3 representing severe injury, see Table 3 b) as well as the median of the sum of all lesions in all teats are presented. No differences between the treatment groups were found.

	Summed lesions per sow Med (Min– Max)	Median number with Score 1 (Min– Max)	Median number with Score 2 (Min– Max)	Median number with Score 3 (Min– Max)
Week 1	2 (0–22)	0 (0–3)	1 (0–11)	1 (0–11)
Week 2	3 (0–12)	2 (0–7)	0 (0–7)	0 (0–3)
Week 3	1 (0–12)	1 (0–8)	0 (0–10)	0 (0–1)
Week 4	3 (0–14)	2 (0–7)	0 (0–10)	0 (0–2)
Week 5	3 (0–17)	2 (0–8)	0 (0–11)	0 (0–2)

have experienced less stress due to changes in piglet behaviour and/or due to direct effects of access to newspaper. The present study design does not provide information to investigate these mechanisms, however, it could be assumed that both are involved.

4.3. Nutritive nursing

We observed no differences in weight gain of the piglets or in successful nutritive nursing. This is in line with the findings of Yang et al. (2018). However, our study covered only the lactation period. According to De Jonge et al. (1996), differences in weight of piglets kept in a barren environment during lactation may first appear at 23 weeks of age. In their study, the difference was found in individual weight development of piglets from the same treatment group, and no difference emerged in individual weight development of piglets that were socialized in an enriched environment. Therefore, De Jonge et al. (1996) suggested the difference to arise from less efficient food conversion of the piglets in the poorer environment.

We also do not know whether the piglets actually got more milk as a result of more active udder manipulation. Even if the milk intake was potentially greater in the Rope-Paper group, it is possible that no differences in weight gain were found because of the higher gross -activity and therefore higher energy consumption of the piglets in the Rope-paper group.

4.4. Skin lesions of the sow and udder health

Our finding of more rapid injury progression of the skin is noteworthy. In our study despite the discovery of more frequent manipulation of the udder and sow body, the injury progression of the sow skin was milder in the Rope-Paper group. We assume that in the Control group the piglets were biting the sow in a more damaging way.

Being bitten by piglets may cause pain and discomfort to the sow even if the bite does not lead to skin ulceration. This was not evaluated in our study and no difference in udder or teat lesions was apparent. The incidence of skin lesions in the udder is known to be higher in sows kept in farrowing crates (Verhovsek et al., 2007) and decrease over time during lactation (Lohmeier et al., 2019). Both studies did not evaluate the skin lesions in the body or the healing process. It is known that the amount of tail and / or ear biting does not always correlate with the lesion severity (Chou et al., 2020). Eventhough the teeth of the piglets were not clipped in our study, the piglets may not have had the ability to bite through the sow skin, since we found no differences in the lesion occurrence between the treatment groups. However, the existing damages in the sows' skin may have attracted the piglets, which is known to be a factor influencing tail biting (Fraser, 1987; van Putten, 1969). This might have caused the slower healing process of the existing lesions in the sows' skin within the Control group.

Nevertheless, this may explain the differences in sow behaviour between the treatment groups and supports the theory of the piglet manipulation pattern being different in the treatment groups, causing more discomfort to the sow if no chewable material is available for the piglets. Our finding is in line with Lewis et al. (2006), who found no differences in udder or teat lesions in sows whose litters had access to ropes or shredded paper. Also, contradictory to our findings, their study showed no differences in sow behaviour between the treatment groups (Lewis et al., 2006). However, Lewis et al. (2006) provided the materials from above the piglets. Further, their observation method was instantaneous scan sampling, while we observed the sows from videos continuously, which might have caused discrepant results (Lewis et al., 2006).

In our study the Rope-Paper group had a possibility to perform greater range of behaviours which propably led to a higher satisfaction of their behavioural need to chew, explore and root as also suggested by Schmitt et al. (2020). Therefore, the piglets in the Control group may have had a stronger need to perform chewing behaviour in the environment without chewable materials, as also described by Petersen et al. (1995). In addition to the piglets of the Control group biting the sow more powerfully, manipulation directed towards pen mates may have been greater. Findings from Telkänranta et al., 2014 support this speculation, since the Rope-Paper group had less severe tail-biting lesions after weaning, which is in line with findings from Schmitt et al. (2020). Since the manipulative behaviour during nursings does not include chewing (Algers and Jensen, 1985; Gill and Thomson, 1956) it is possible in our study that the piglets did not direct chewing towards the udder, but towards the skin on the sow body.

5. Conclusion

In our experiment the piglets that had access to chewable materials from birth made more contact with the sow during lactation, but still the sow performed less stress-related behaviour. We suggest that this is at least partly due to the piglets being less harmful in their biting behaviour causing less pain and discomfort for the sow.

Chewable material given to piglets during the early weeks of life has potentially a positive effect on sow behaviour and potentially on piglet behaviour. Based on our findings, the use of chewable materials during lactation is recommended, although the aetiology of the findings is unclear and further research is needed.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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