Early mother-young interactions in domestic sows – nest-building material increases maternal investment

Ellen Marie Rosvold*‡, Ruth C. Newberry*, Inger Lise Andersen*

* *Norwegian University of Life Sciences, Faculty of Biosciences, Department of Animal and Aquacultural Sciences, PO Box 5003, 1432 Ås, Norway*

‡*Nord University, Faculty of Biosciences and Aquaculture, PO Box 2501, 7729 Steinkjer, Norway*

Corresponding author: Ellen Marie Rosvold. E-mail: ellen.m.rosvold@nord.no

Abstract

Nest building is important in sow preparation for motherhood. However, straw or other bulky materials can block drains, and a finer-grained material such as peat is of interest as an alternative. The main aim of this study was to evaluate effects of different nesting materials on maternal behaviour during farrowing and early lactation.

Norsvin Landrace x Swedish Yorkshire sows (n=54) were loose-housed in individual farrowing pens with wood-shavings as litter. Mean (± SE) parity was 2.9 ± 2.0 (range 1-9), and 16 were primiparous. They were provided with peat (n=18) or straw (n=17) as nesting material from two days before expected farrowing until they farrowed, or received wood shavings litter only (controls, n=18). From video recordings positive (i.e. sniffing, grunting, nudging) and negative (i.e. pushing, threatening barks, biting) communicatory behaviours from sow to piglets during farrowing (≤4 h) and on Day 1 post-partum (4 h) were registered by one-zero sampling at 1-min intervals. Nursing behaviour on Day 2 post-partum (6 h) was registered by continuous observation.

During farrowing, sows provided with straw or peat as nesting material showed a lower frequency of negative communication towards piglets compared to controls ($P<0.05$). Sows provided with straw had a higher proportion of sow-initiated nursing bouts and successful nursing bouts (i.e. with milk let-down) terminated by the piglets than sows in the peat and control groups. There were also differences in maternal behaviour across parities 1, 2-3 and ≥4 ($P<0.05$). Sows of parity ≥4 exhibited a lower frequency of negative communication during farrowing than younger sows. On Day 1 post-partum, sows of parity 2-3 performed a higher frequency of positive communication than sows of other parities. The proportion of sow-initiated nursing bouts was higher in sows of parity ≥4 than in primiparous sows, whereas the proportion of successful nursing bouts terminated by piglets was higher for primiparous than older sows. Positive sow-to-piglet communication increased with litter size during farrowing, but declined with litter size on Day 1. Proportion of sow-initiated nursing bouts increased with litter size, whereas the proportion of successful nursing bouts terminated by piglets decreased. The number of piglets without a teat during milk let-down increased with litter size ($P<0.05$).

These findings show that both peat and straw were associated with a lower rate of negative sow-to-piglet communication during farrowing compared to sows given wood shavings alone. Provision of straw, particularly, resulted in nursing behaviour indicative of increased maternal investment.

Key words: Nest building, Peat, Loose-housed sows, Maternal behaviour, Communication, Nursing behaviour

Highlights:

- Negative communication to piglets during farrowing was lower in sows provided with straw or peat before farrowing.
- Straw provided before farrowing enhanced maternal investment-related nursing behaviours.
- Parity and litter size affected maternal behaviour.
- The number of piglets without a teat during milk let-down increased with litter size.

1. Introduction

When preparing for motherhood, domestic sows are highly motivated to build a nest that protects the newborn piglets against climatic factors and predators, and facilitates the establishment of recognition and filial bonding of piglets with their mother (e.g. Wischner et al., 2009). The nest-building behaviour of sows has remained similar to that of their wild relatives (Jensen, 1986; Gustafsson et al., 1999), involving nest-seeking, digging a hollow in the ground by pawing and rooting, collecting vegetation and depositing it in the hollow and arranging the material before lying down (Jensen, 1986; 1993; Mayer et al., 2002).

Piglet mortality is still a considerable welfare and economical challenge in pig production, also in loose-housing systems, with herd mortality of live born piglets ranging from 5-28% (Rosvold et al., 2017). Most piglet deaths occur within the first few days after birth (e.g. Marchant et al., 2000; Kielland et al., 2018), with crushing and starvation as the dominant causes (Andersen et al., 2011; Kielland et al., 2018). Studies on loose-housing systems suggest that piglet survival is highly affected by maternal motivation and protectiveness (Melišová et al., 2011), and that the sow`s maternal behaviour is positively related to the performance of nest building before farrowing. For instance, nest building has been associated with increased responsiveness to piglet distress calls, increased maternal bonding and positive interactions (Cronin and van Amerongen, 1991; Cronin and Smith, 1992; Herskin et al., 1998), and a positive effect on nursing behaviour (Cronin and Smith, 1992; Herskin et al., 1999; Yun et al., 2014). Moreover, sows that spend a lot of time on nest building before farrowing are generally more careful and protective towards the piglets (Andersen et al., 2005; Yun et al., 2014). Specifically, those with a higher score for nest building were found to have a lower prevalence of crushing (Ocepek and Andersen, 2017), more positive communication with and care of the piglets, and lower overall piglet mortality (Ocepek et al., 2017b). Improved maternal behaviour (i.e. carefulness, nursing behaviour) was

accompanied by increased levels of endogenous hormones linked to maternal behaviour, including oxytocin and prolactin (Yun et al., 2013; 2014).

Communication is important for bonding, and the sow communicates with her piglets through nasal contact (i.e. sniffing and nudging) and grunting (e.g. Jensen and Redbo, 1987). A high level of such communication from sow to piglets facilitates sow-piglet bonding, and attracts the piglets to stay in close proximity to her, giving them warmth, milk and protection (e.g. Melišová et al., 2011). Moreover, Ocepek and Andersen (2018) found that sows communicating with their piglets while being active had lower piglet mortality. However, maternal aggression towards the newborn may also occur (i.e. biting, savaging), with possible fatal consequences for the piglets (e.g. Ahlström et al., 2002; Chen et al., 2008), occurring especially in the early stages of farrowing (Ahlström et al., 2002). A sow`s motivation to care for her offspring will be expressed in how she communicates with them (Ocepek and Andersen, 2017), and aggressive behaviour may be linked to a lack of preceding nest-building activity (Ahlström et al., 2002).

Nursing behaviour is an important component of maternal behaviour (Cronin and Smith, 1992), and the quality of nursing probably reflects a sow`s motivation for taking care of her young. A sow initiates nursing by lying down, exposing her udder and giving nursing grunts attracting the piglets. The piglets start massaging the udder for 1 to 3 min (pre-massage), which elicits a brief milk let-down (ca. 15 s), and is followed by another udder massage of varying duration (post-massage) depending on the sow`s udder exposure (e.g. Algers and Uvnäs-Moberg, 2007). A nursing bout can however be terminated before milk let-down (unsuccessful nursing) due to insufficient pre-massage related to an insufficient number of piglets at the udder or teat disputes between them (Illmann and Madlfousek, 1995).

Straw has been reported to have a positive effect on nest-building behaviour (e.g. Thodberg et al., 1999; Westin et al., 2015). However, many pig houses have pens with a partly slatted floor, and a slurry system for manure removal. Due to a risk of drain blockage when long straw is used, farmers hesitate to use straw and some may also consider that providing straw requires too much work for maintaining pen cleanliness. Peat is a finer grained material with structural similarities to soil, making it suitable for rooting, digging and pawing (Studnitz et al., 2007; Vanheukelom et al., 2011). These behaviours are also elements of nest building.

We have found that sows given long-stemmed straw showed more nest-building behaviour, a greater variety of nest-building elements, and fewer stereotypies pre-partum than control sows and sows given peat (Rosvold et al., 2018). They also had shorter farrowing duration and fewer stillborn piglets (Rosvold and Andersen, 2019) . The results on nest building in the peat group were intermediate, suggesting that, while straw is more effective in fulfilling the sow`s nest-building motivation, peat has some value as a nest-building material. Parity also affected nest building, with sows of parity ≥4 showing more nest-building behaviour and spending more time arranging material than younger sows (Rosvold et al., 2018).

There has been limited research on the relationship between nest-building behaviour and maternal care in sows (e.g. Herskin et al., 1998; 1999; Yun et al., 2014). The primary objective of the present work was to investigate the effects of type of nest material provided before farrowing (straw or peat vs. control given wood shavings only) on sow-piglet communication during, and shortly after farrowing, and nursing success after establishment of a stable nursing interval. Because maternal care could be affected by parity, litter size and farrowing batch, we also took these factors into account in our analyses.

We predicted that sows provided with straw as nest-building material before farrowing would show more positive (i.e. sniffing, grunting and nudging) and less negative (i.e. pushing, threatening barks and biting) communication with their piglets compared to control sows, and that the peat group would be intermediate compared to the control and straw groups. We also predicted that responses to the provision of nest-building materials before farrowing would be influenced by parity, as the young sows may need more external stimulation due to lack of maternal experience, and because their hormonal status may differ from that of older sows (Yun et al., 2014). Furthermore, we predicted that the quality of nursing bouts would be higher in the straw treatment than in the control treatment, with peat being intermediate. The evaluated indicators of nursing quality included a shorter nursing interval, a higher frequency of nursing bouts, a higher proportion of nursing bouts initiated by the sow, a higher proportion of successful nursing bouts terminated by the piglets, and fewer piglets without a teat during milk let-down.

2. Material and methods

2.1. Experimental design

The study was conducted at Mære Agricultural College in Steinkjer, Norway, in accordance with the Norwegian laws and regulations governing experiments and procedures on live animals. During three farrowing batches, 54 loose-housed sows kept in individual farrowing pens (Fig. 1), were randomly assigned to one of three treatment groups differing in nest material given before farrowing: peat, straw or control, 18 sows in each group. The sows were video recorded from two days pre-partum until three days post-partum to document the sows` pre-partum nest-building behaviour (Rosvold et al., 2018), farrowing and maternal behaviour.

2.2. Housing, management and feeding

Total area of the farrowing pens was 8.2 m^2, of which 2.9 m^2 was slatted floor, and the rest solid floor. The pen contained a creep area for the piglets equipped with heat lamps and floor heating (Fig. 1). Air temperature was recorded by two temperature loggers (Tinytag, Gemini Data Loggers, Chichester, UK) located in different parts of the farrowing room. Due to variation in the outdoor temperature, indoor temperature differed between batches. From one day before the first farrowing until four days after the last farrowing, the average temperature was 20.0°C (range 16.8°-24.7°C) for the first batch (farrowing

in May), 23.6°C (19.1°-31.8°C) for the second batch (July), and 20.5°C (17.3°-24.1°C) for the third batch (late August).

Intervention during farrowing and early lactation was kept to a minimum, but farrowing assistance was provided if piglets or placenta were retained for at least three hours. Wet straw and litter were replaced with dry litter (wood shavings) after farrowing. The sows were taken out of the pen briefly on the day after farrowing for measurement of body weight and some physical exercise, and all the piglets were subjected to tooth grinding and received iron paste orally (Pluss Jernstarter, 1.5 mL; Felleskjøpet) within the first 24 h after birth. Cross-fostering was carried out between 12-48 h after farrowing if the number of piglets exceeded the number of functional teats and if there were any suitable sows to receive piglets.

Sows were fed four times daily on lactation concentrate (FK FORMAT Laktasjon, Felleskjøpet, Steinkjer, NO) from an automatic dispenser, and once daily by the manual distribution of a farrowing concentrate (FK FORMAT Fødsel, Felleskjøpet, Steinkjer, NO), and hay (ca 0.3 kg). For further details on housing and management prior to farrowing, see Rosvold et al. (2018).

2.3. Animals

The sows were Norsvin Landrace x Swedish Yorkshire crossbreds, inseminated with semen from Duroc boars, and ranging in parity from 1 to 9 (mean ± SE: 2.9 ± 2.0) of which 16 were gilts. Due to abortion by one sow and failure of video recordings of two sows during farrowing, we obtained videos on the farrowing (Day 0) of 51 sows (n, Material groups: Control: 16, Peat: 18, Straw: 17; n, Parity groups: 1: 16, 2-3: 19, ≥4: 16), and on Days 1 and 2 post-partum from 53 sows (n, Material groups: Control: 18, Peat: 18, Straw: 17; n, Parity groups: 1: 16, 2-3: 20, ≥4: 17). Mean parity in the treatment groups control, peat and straw were 2.9 ± 0.5, 3.0 ± 0.5 and 2.9 ± 0.5 respectively.

For each sow, the total number of piglets born was the sum of live born and stillborn piglets. The number of total born piglets (mean ± SE) were 15.8 ± 1.1 in the control group, 16.8 ± 0.9 in the peat group, and 15.2 ± 0.7 in the straw group. Due to cross-fostering in some litters, the litter size on Day 1 post-partum was defined as the number of live born piglets plus piglets fostered into the litter or minus piglets fostered out of the litter. Number of live born piglets was 14.4 ± 0.9, 15.8 ± 1.0 and 14.7 ± 0.7 in the control, peat and straw groups respectively, and after cross-fostering the number of piglets was 14.4 ± 0.8, 15.4 ± 0.9 and 14.8 ± 0.6 in the control, peat and straw groups respectively. Due to piglet mortality, the litter size on Day 2 post-partum was defined as the litter size minus piglets dead on Day 1; 12.8 ± 0.5, 13.4 ± 0.7 and 13.4 ± 0.6 in the control, peat and straw groups respectively.

2.4. Provision of nest-building material

Every morning, all pens were cleaned and supplied with dry wood shavings (0.8 kg, mainly spruce, same amount to all pens irrespective of treatment). In the afternoon, each pen was again cleaned and given new litter (0.8 kg wood shavings) if necessary to replace wet and dirty litter. The wood shavings

functioned as litter for hygienic purpose and met requirements for litter in accordance with the Norwegian Regulations on Keeping of Pigs (Lovdata, 2003). Sows in the control treatment did not receive any additional material for nest building.

Additional nest-building material was provided on the solid floor to sows in the peat and straw treatments from two days before expected farrowing until farrowing. In the morning, the peat treatment group received 4 kg of peat (90% peat plus formic acid, acetic acid, potassium sorbate and coal; 75% water content, 7.6% crude fiber, and 2.4% ash; Fossli AS, Frosta, NO), and the straw treatment group received 2 kg of straw (long-stemmed barley straw). Because peat was only about half the volume of straw, the weight of peat was doubled to even out the difference (Rosvold et al., 2018). In the afternoon, a refill of 2 kg peat or 1 kg straw was provided respectively. Refills of peat were repeated each morning and afternoon until farrowing, as the peat spread out and disappeared through the slatted floor or was eaten by the sow. Straw was more likely to be retained, and further refills of straw were only given if the sow farrowed later than expected, or dirty straw needed to be replaced. Remaining straw was removed after farrowing.

2.5. Behavioural analysis

Behavioural data were collected from video recordings made using video cameras (Foscam F19821, 1280x720, Shenzhen, PRC) connected to a standard PC, that were suspended above each farrowing pen. Positive and negative forms of communication from sow to piglets, as defined in Table 1, were registered during farrowing and on Day 1 post-partum, using one-zero sampling at 1-min intervals (i.e. if a positive form of communication occurred at least once during one minute, the value was 1). Farrowing was defined as starting with expulsion of the first piglet, and registration continued for 4 h, or until the last piglet was born if the farrowing was finished earlier. On Day 1 post-partum, observations were made for 4 h in separate 1-h periods, each starting when the sow finished a meal or was otherwise active (if she ingested fewer than four meals).

Aspects of nursing behaviour, as defined in Table 2, were registered during 6 h of continuous observation in the evening of Day 2 post-partum. This timing was selected because episodic nursing bouts were well established by then and because this was a relatively undisturbed time of day when staff activity was low.

Nursing interval was the duration from one nursing bout to the next, regardless of milk let-down. Successful nursing bouts terminated by piglets, were expressed as a proportion of the total successful nursings (i.e. resulting in milk let-down). The number of piglets in a litter without a teat in their mouth during milk let-down was averaged over all observed successful nursing bouts.

2.6. Statistical methods

The statistical analyses were performed in SAS Version 9.4 (SAS Institute, Inc., Cary, NC). The effects of nest-building material (Control, Peat, Straw), parity (1, 2-3, ≥4), batch (1,2,3), litter size, and the interaction between material and parity, were analysed by a generalized model (PROC GENMOD) with Poisson distribution. Nest-building material, parity and batch were class variables and litter size was continuous variable. Pairwise means comparisons were based on differences in least square means, with Tukey adjustment for multiple comparisons. Descriptive statistics were obtained using SPSS Version 23 (IBM Corp., Armonk, NY). Wilcoxon signed-rank test was used to examine differences in positive and negative sow-piglet communication between farrowing and Day 1 post-partum.

3. Results

3.1. Nest-building materials

During farrowing, the frequency of positive communication from sow to piglets (mean ± SE % of scans) was 17.9±1.5%, ranging from 1.3 to 52.9%, and the frequency of negative communication was 2.7±0.8% (range 0.0 to 25.1%). All the sows showed positive communication during farrowing, and 21 sows (41.2%) showed negative communication. Positive communication during farrowing was not affected by nest-building material, whereas there were significant differences between sows in the three nest-building material groups in their frequencies of negative communication (Table 3). Sows in the control group had the highest levels of negative communication, the sows in the peat group the lowest, and sows in the straw group were intermediate (Table 3).

On Day 1 post-partum, the frequency of positive communication from sow to piglets (mean ± SE % of scans) was 26.9±1.1%, ranging from 10.4 to 45.8%, and the frequency of negative communication was 0.3±0.1%, with a range from 0.0 to 6.25%. All the sows showed positive communication on Day 1, while 12 sows (22.6%) showed negative communication. Nest-building materials did not affect the levels of either positive or negative communication on Day 1 (Table 3). A Wilcoxon signed-rank test showed that the level of positive communication was significantly higher on Day 1 compared to farrowing ($Z = -4.325$, $P<0.001$), and the frequency of negative communication was significantly lower on Day 1 compared to farrowing ($Z = -3.319$, $P<0.001$).

On Day 2 post-partum, the nursing interval (mean ± SE) was 42±1 min, with a variation from 21 to 69 min, and number of nursing bouts in 6 h was 8.8±0.3, ranging from 5 to 15. The percentage of nursing bouts initiated by the sow (mean ± SE%) was 28.1±3.0%, ranging from 0.0 to 85.7%, and the percentage of successful nursing bouts that resulted in milk let-down and terminated by the piglets was 56.1±5.1%, ranging from 0 to 100%. During nursing bouts, the mean number of piglets per litter not having access to a teat during milk let-down was 1.5±0.1, ranging from 0.0 to 3.7 piglets. Sows provided with straw before farrowing initiated a higher proportion of nursing bouts compared to sows in the other treatment

groups (Table 3). Sows in the straw and control groups also had a higher proportion of successful nursing bouts terminated by piglets than sows in the peat group (Table 3). Nursing intervals tended to be longer in the control than peat and straw groups (P=0.055), while the number of nursing bouts and number of piglets without access to a teat during milk let-down were not significantly affected by treatment (Table 3).

3.2. Parity

The frequency of negative communication from sow to piglets during farrowing was lower in sows of parity ≥4 compared to the other two parity groups (Table 4). On Day 1 post-partum, sows of parity 2-3 gave the highest frequency of positive communication to their piglets, whereas primiparous sows gave the lowest. The level of negative communication was not associated with parity on Day 1 (Table 4).

The proportion of nursing bouts initiated by the sow was highest for sows of parity ≥4, and lowest for first parity sows, whereas the primiparous sows had the highest proportion of successful nursing bouts terminated by the piglets (Table 4). Nursing interval, number of nursing bouts, and number of piglets without a teat during milk let-down were not associated with parity (Table 4).

There were interactions between material and parity regarding both positive and negative communication during farrowing, positive communication on Day 1 post-partum, nursing bouts initiated by the sow and successful nursing bouts ended by the piglets (Table 3, Fig. 2). Sows of parity 2-3 that received peat pre-partum performed the highest frequency of positive communication during farrowing and on Day 1 post-partum. During farrowing, sows in the control group had the highest frequency of negative communication compared to sows with peat or straw in all parities, and especially in parity 2-3 (Fig. 2). The proportion of nursing bouts initiated by the sow was highest among sows of parity ≥4 provided with peat pre-partum, and among sows in the other two parity groups provided with straw pre-partum. Primiparous sows in control and peat groups had the highest proportion of successful nursing bouts that were terminated by the piglets (Fig. 2).

3.3. Litter size

During farrowing, the frequencies of positive communication increased and negative communication decreased with litter size (Table 4, Fig. 3). The frequency of positive communication on Day 1 post-partum was also associated with litter size, declining above 14 piglets (Table 4, Fig. 3).

The proportions of nursing bouts initiated by the sow increased with litter size, whereas successful nursing bouts terminated by piglets decreased with litter size. The number of piglets without a teat during milk let-down strongly increased with litter size (Table 4, Fig. 3).

3.4. Batch

There were batch differences in the frequency of negative communication during farrowing (mean ± SE % of scans); batch 1: 2.0±1.0%, batch 2: 3.3±1.6%, batch 3: 3.0±1.5% ($\chi^2_{2,39}$ =7.9, P=0.020), and on Day 1 post-partum; batch 1: 0.1±0.0%, batch 2: 0.9±0.4%, batch 3: 0.1±0.1% ($\chi^2_{2,41}$ =18.5, P<0.001). Length of nursing intervals significantly differed between the batches; batch 1: 47±2 min, batch 2: 37±2 min, batch 3: 41±1 min ($\chi^2_{2,41}$ = 27.2, P<0.001), as did the proportion of sow-initiated nursing bouts; batch 1: 29.8±5.0%, batch 2: 31.5±5.4%, batch 3: 23.1±5.5% ($\chi^2_{2,41}$ =34.7, P<0.001). Proportions of successful nursing bouts terminated by the piglets were also different; batch 1: 61.8±9.3%, batch 2: 56.4±9.8%, batch 3: 50.1±7.8% ($\chi^2_{2,41}$ =32.8, P<0.001). With respect to number of nursing bouts, positive communication during farrowing and on Day 1, and number of piglets without a teat per nursing bout, there were no significant differences between the three farrowing batches.

4. Discussion

As predicted, sows provided with either straw or peat for nest building before farrowing showed less negative communication towards their piglets during farrowing compared to control sows without nest-building material. Thus, providing straw or peat for nest building appears to be valuable for stimulating maternal care at the time of farrowing, thereby helping piglets to get a good start in life even though the effect of material on negative communication was no longer evident by Day 1. Contrary to our prediction, peat had the greatest effect in reducing negative behaviour towards piglets in total, although not consistently across parity groups. Peat stimulates rooting to a larger extent than straw and it also initiates wallowing, which appears to have cooled the sows, but resulted in a lower overall level and variety of nest-building behaviour than straw (Rosvold et al., 2018). Our current results, therefore, suggest that different mechanisms may underlie benefits from providing straw and peat for stimulating maternal care, and that provision of both might be even more beneficial.

Negative communication included aggressive pushing with the nose, biting or biting attempts, which could lead to savaging resulting in death, although there were no documented cases of savaging in the present experiment. According to Ahlström et al. (2002), sows that exhibited savaging were more restless during farrowing. In our study, the sows in the control group not only directed more negative communication towards piglets during farrowing, but were also more restless before farrowing than the sows given straw, spending more time walking, standing or sitting, and performing stereotypies in the nest-building phase and less time resting (Rosvold et al., 2018). Ahlström et al. (2002) also suggested that there is a link between restrictive housing, prevention of nest-building behaviour and undesirable behaviour such as savaging, and that individuals expressing such behaviour may be those that are least able to cope with environmental restriction. Sows in crates have been reported to perform more threats, snapping at or biting towards piglets during the first week after farrowing than sows in pens (Cronin and Smith, 1992). Furthermore, Yun et al. (2013; 2014) observed that sows restricted to crates had lower

plasma concentrations of oxytocin and prolactin pre-partum compared to sows provided with straw and space to move. Even when loose-housed in pens, Yun et al. (2013; 2014) found lower oxytocin and prolactin levels in sows without straw compared to sows given straw before farrowing, and the sows without straw showed weaker maternal behaviour as indicated by being less careful when lying down, an effect that lasted for several days post-partum. These results support our findings regarding the positive effects of peat and especially straw as nest-building materials.

The amount of negative sow communication towards piglets during farrowing was higher in younger than older sows (parity ≥4). Our results are in correspondence with earlier studies showing that savaging is more frequent in younger than older sows (e.g. Harris et al., 2003; Chen et al., 2008). Negative sow communication was higher during farrowing than on Day 1 post-partum, possibly due to changes in hormonal status and birth-related pain and discomfort (Algers and Uvnäs-Moberg, 2007; Mainau and Manteca, 2011).

Contrary to our prediction, there was no consistent difference in positive communication with piglets between sows provided with different nesting materials. In contrast, nest-building activity has previously been associated with improved maternal behaviour (Andersen et al., 2005; Yun et al., 2014), and recently Ocepek et al. (2017b) revealed a positive correlation between scores for nest-building activity and scores for sow communication and carefulness. One reason for this discrepancy may be that we provided a limited amount of nesting material to the sows whilst, in Andersen et al. (2005) for instance, the sows had free access to straw. We also detected a nest material by parity interaction on positive communication, both during farrowing and on Day 1 that could account for differences in results between studies.

Positive sow-to-piglet communication was lower during farrowing than on Day 1 post-partum, possibly because sows are generally passive during farrowing, giving piglets opportunities to find the udder and suckle (Jarvis et al., 1999). Melišová et al. (2011) observed more positive communication on the day after farrowing than two days later. The higher level of positive communication on Day 1 compared to farrowing and Day 3 (Melišová et al., 2011) suggests that even though bonding starts right after birth, it is consolidated on Day 1.

During farrowing, positive communication increased with litter size, whereas negative communication decreased to some extent with litter size, although the sows with the highest frequencies had large litters. On Day 1 post-partum, positive communication appeared to decrease above a litter size of 14 piglets. Recently Ocepek and Andersen (2018) found that, in the first two days post-partum, positive sow-to-piglet communication while the sow was resting increased with litter size. More communication while resting was associated with higher piglet mortality, possibly due to the sows being more disturbed and stressed by the piglets at a time they should be resting. In contrast, higher level of communication while

active was positive for piglet survival (Ocepek and Andersen, 2018). We did not differentiate whether the sow was resting or active while communicating with the piglets in the current study.

As predicted and consistent with previous studies, sows provided with straw pre-partum initiated a higher proportion of nursing bouts than sows in the peat and control group, and had a higher proportion of successful nursing bouts terminated by the piglets compared to sows in the peat and the control group. Herskin et al. (1999) found that sows not provided with nest-building material tended to terminate more nursing bouts before milk let-down compared to those with access to straw, suggesting that nest-building material increases the sow`s willingness to nurse. Increased nest-building activity has been associated with elevated levels of prolactin and oxytocin, which are crucial for milk production and milk let-down, respectively, and with nursing performance during early lactation (Yun et al., 2014). When the sow terminates a nursing bout by making her udder unavailable, the amount of post-massage by the piglets may decline, which possibly could result in poorer milk production due to lower prolactin levels, reduced weight and lower productivity of the mammary glands (Algers et al., 1991; Nielsen et al., 2001; Thodberg and Sørensen, 2006). The proportions of sow-initiated nursing bouts increased with increasing parity, as also observed by Thodberg et al. (2002), whilst the proportion of successful nursings terminated by the piglets was highest among primiparous sows. Farmer et al. (1995) found that primiparous sows performed less lying on the belly after farrowing than older sows, suggesting a greater willingness to expose the udder for the piglets, possibly due to having no previous negative experience of nursing (i.e. piglets fighting at the udder). Moreover, Ocepek et al. (2016) point out that breeding goals have emphasized greater maternal investment earlier in life.

Increased litter size was associated with higher proportions of sow-initiated nursing bouts and lower proportions of successful nursing bouts terminated by piglets on Day 2 post-partum. These results do not allow conclusions regarding associations between litter size and maternal investment. As in previous studies (Andersen et al., 2011; Ocepek et al., 2017a), increased litter size resulted in a higher number of piglets without access to a teat during milk let-down.

There was a significant difference between farrowing batches in the frequency of negative sow-piglet communication during farrowing and on Day 1, with the numerically highest levels in the second batch being accompanied by a lower frequency of nest-building activity (Rosvold et al., 2018). The higher temperatures experienced at the time of observations on the second batch may explain these results.

5. Conclusions

We have found that the pre-partum provision of straw and peat as nesting materials was associated with a reduction in negative sow-to-piglet communication, and that straw improved nursing performance. These findings support the argument that the provision of appropriate nest-building material has an important impact on the maternal behaviour of sows.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors wishes to thank staff at the pig house at Mære Landbruksskole, the students Ingrid Marie Håkenåsen, Camilla Therese Skjelbred, and Geir Næss for practical help and the farrowing pen illustration. The Norwegian Research Council (NFR207804/O99), Norsvin, Animalia, Nortura and Fossli AS financed this project.

References

Ahlström, S., Jarvis, S., Lawrence, A.B., 2002. Savaging gilts are more restless and more responsive to piglets during the expulsive phase of parturition. Applied Animal Behaviour Science 76, 83-91.
Algers, B., Madej, A., Rojanasthien, S., Uvnäs-Moberg, K.J.V.R.C., 1991. Quantitative relationships between suckling-induced teat stimulation and the release of prolactin, gastrin, somatostatin, insulin, glucagon and vasoactive intestinal polypeptide in sows. Veterinary Research Communications 15, 395-407.
Algers, B., Uvnäs-Moberg, K., 2007. Maternal behavior in pigs. Hormones and Behavior 52, 78-85.
Andersen, I.L., Berg, S., Bøe, K.E., 2005. Crushing of piglets by the mother sow (Sus scrofa)—purely accidental or a poor mother? Applied Animal Behaviour Science 93, 229-243.
Andersen, I.L., Nævdal, E., Bøe, K.E., 2011. Maternal investment, sibling competition, and offspring survival with increasing litter size and parity in pigs (*Sus scrofa*). Behav Ecol Sociobiol 65, 1159-1167.
Chen, C., Gilbert, C.L., Yang, G., Guo, Y., Segonds-Pichon, A., Ma, J., Evans, G., Brenig, B., Sargent, C., Affara, N., Huang, L., 2008. Maternal infanticide in sows: Incidence and behavioural comparisons between savaging and non-savaging sows at parturition. Applied Animal Behaviour Science 109, 238-248.
Cronin, G.M., Smith, J.A., 1992. Effects of accommodation type and straw bedding around parturition and during lactation on the behaviour of primiparous sows and survival and growth of piglets to weaning. Applied Animal Behaviour Science 33, 191-208.
Cronin, G.M., van Amerongen, G., 1991. The effects of modifying the farrowing environment on sow behaviour and survival and growth of piglets. Applied Animal Behaviour Science 30, 287-298.
Farmer, C., Robert, S., Matte, J.J., Girard, C.L., Martineau, G.P., 1995. Endocrine and peripartum behavioral responses of sows fed high-fiber diets during gestation. Canadian Journal of Animal Science 75, 531-536.
Gustafsson, M., Jensen, P., de Jonge, F.H., Illmann, G., Spinka, M., 1999. Maternal behaviour of domestic sows and crosses between domestic sows and wild boar. Applied Animal Behaviour Science 65, 29-42.
Harris, M.J., Li, Y.Z., Gonyou, H.W., 2003. Savaging behaviour in gilts and sows. Canadian Journal of Animal Science 83, 819-821.
Herskin, M., Jensen, K., Thodberg, K., 1999. Influence of environmental stimuli on nursing and suckling behaviour in domestic sows and piglets. Animal Science 68, 27-34.
Herskin, M.S., Jensen, K.H., Thodberg, K., 1998. Influence of environmental stimuli on maternal behaviour related to bonding, reactivity and crushing of piglets in domestic sows. Applied Animal Behaviour Science 58, 241-254.
Illmann, G., Madlfousek, J., 1995. Occurrence and characteristics of unsuccessful nursings in minipigs during the first week of life. Applied Animal Behaviour Science 44, 9-18.

Jarvis, S., McLean, K.A., Calvert, S.K., Deans, L.A., Chirnside, J., Lawrence, A.B., 1999. The responsiveness of sows to their piglets in relation to the length of parturition and the involvement of endogenous opioids. Applied Animal Behaviour Science 63, 195-207.
Jensen, P., 1986. Observations on the maternal behaviour of free-ranging domestic pigs. Applied Animal Behaviour Science 16, 131-142.
Jensen, P., 1993. Nest building in domestic sows: the role of external stimuli. Animal Behaviour 45, 351-358.
Jensen, P., Redbo, I., 1987. Behaviour during nest leaving in free-ranging domestic pigs. Applied Animal Behaviour Science 18, 355-362.
Kielland, C., Wisløff, H., Valheim, M., Fauske, A.K., Reksen, O., Framstad, T., 2018. Preweaning mortality in piglets in loose-housed herds: etiology and prevalence. Animal, 1-8.
Lovdata, 2003. Forskrift om hold av svin (Regulations for the keeping of pigs), Norwegian Ministry of Agriculture and Food, Norway.
Mainau, E., Manteca, X., 2011. Pain and discomfort caused by parturition in cows and sows. Applied Animal Behaviour Science 135, 241-251.
Marchant, J.N., Rudd, A.R., Mendl, M.T., Broom, D.M., Meredith, M.J., Corning, S., Simmins, P.H., 2000. Timing and causes of piglet mortality in alternative and conventional farrowing systems. Veterinary Record 147, 209-214.
Mayer, J.J., Martin, F.D., Brisbin Jr, I.L., 2002. Characteristics of wild pig farrowing nests and beds in the upper Coastal Plain of South Carolina. Applied Animal Behaviour Science 78, 1-17.
Melišová, M., Illmann, G., Andersen, I.L., Vasdal, G., Haman, J., 2011. Can sow pre-lying communication or good piglet condition prevent piglets from getting crushed? Applied Animal Behaviour Science 134, 121-129.
Nielsen, O.L., Pedersen, A.R., Sørensen, M.T., 2001. Relationships between piglet growth rate and mammary gland size of the sow. Livestock Production Science 67, 273-279.
Ocepek, M., Andersen-Ranberg, I., Edwards, S.A., Fredriksen, B., Framstad, T., Andersen, I.L., 2016. Can a super sow be a robust sow? Consequences of litter investment in purebred and crossbred sows of different parities. Journal of Animal Science 94, 3550-3560.
Ocepek, M., Andersen, I.L., 2017. What makes a good mother? Maternal behavioural traits important for piglet survival. Applied Animal Behaviour Science 193, 29-36.
Ocepek, M., Andersen, I.L., 2018. Sow communication with piglets while being active is a good predictor of maternal skills, piglet survival and litter quality in three different breeds of domestic pigs (Sus scrofa domesticus). PLOS ONE 13, e0206128.
Ocepek, M., Newberry, R.C., Andersen, I.L., 2017a. Trade-offs between litter size and offspring fitness in domestic pigs subjected to different genetic selection pressures. Applied Animal Behaviour Science 193, 7-14.
Ocepek, M., Rosvold, E.M., Andersen-Ranberg, I., Andersen, I.L., 2017b. Can we improve maternal care in sows? Maternal behavioral traits important for piglet survival in loose-housed sow herds. Journal of Animal Science 95, 4708-4717.
Rosvold, E.M., Andersen, I.-L., 2019. Straw vs. peat as nest-building material – The impact on farrowing duration and piglet mortality in loose-housed sows. Livestock Science.
Rosvold, E.M., Kielland, C., Ocepek, M., Framstad, T., Fredriksen, B., Andersen-Ranberg, I., Næss, G., Andersen, I.L., 2017. Management routines influencing piglet survival in loose-housed sow herds. Livestock Science 196, 1-6.
Rosvold, E.M., Newberry, R.C., Framstad, T., Andersen, I.-L., 2018. Nest-building behaviour and activity budgets of sows provided with different materials. Applied Animal Behaviour Science 200, 36-44.
Studnitz, M., Jensen, M.B., Pedersen, L.J., 2007. Why do pigs root and in what will they root?: A review on the exploratory behaviour of pigs in relation to environmental enrichment. Applied Animal Behaviour Science 107, 183-197.

Thodberg, K., Jensen, K.H., Herskin, M.S., 2002. Nursing behaviour, postpartum activity and reactivity in sows: Effects of farrowing environment, previous experience and temperament. Applied Animal Behaviour Science 77, 53-76.
Thodberg, K., Jensen, K.H., Herskin, M.S., Jørgensen, E., 1999. Influence of environmental stimuli on nest building and farrowing behaviour in domestic sows. Applied Animal Behaviour Science 63, 131-144.
Thodberg, K., Sørensen, M.T., 2006. Mammary development and milk production in the sow: Effects of udder massage, genotype and feeding in late gestation. Livestock Science 101, 116-125.
Vanheukelom, V., Driessen, B., Maenhout, D., Geers, R., 2011. Peat as environmental enrichment for piglets: The effect on behaviour, skin lesions and production results. Applied Animal Behaviour Science 134, 42-47.
Westin, R., Hultgren, J., Algers, B., 2015. Strategic use of straw increases nest building in loose housed farrowing sows. Applied Animal Behaviour Science 166, 63-70.
Wischner, D., Kemper, N., Krieter, J., 2009. Nest-building behaviour in sows and consequences for pig husbandry. Livestock Science 124, 1-8.
Yun, J., Swan, K.-M., Farmer, C., Oliviero, C., Peltoniemi, O., Valros, A., 2014. Prepartum nest-building has an impact on postpartum nursing performance and maternal behaviour in early lactating sows. Applied Animal Behaviour Science 160, 31-37.
Yun, J., Swan, K.-M., Vienola, K., Farmer, C., Oliviero, C., Peltoniemi, O., Valros, A., 2013. Nest-building in sows: Effects of farrowing housing on hormonal modulation of maternal characteristics. Applied Animal Behaviour Science 148, 77-84.

Table captions

Table 1. Ethogram of positive and negative sow communicatory behaviours directed towards piglets as observed during farrowing and on Day 1 post-partum.

Table 2. Ethogram of nursing behaviour, as observed on Day 2 post-partum.

Table 3. Effects of nest-building material, and interactions between material and parity, on frequency of sow communicatory behaviours towards piglets during farrowing and on Day 1 post-partum and nursing behaviour on Day 2 post-partum (mean ± SE %).

Table 4. Associations of parity and litter size with frequency of sow communicatory behaviours towards piglets during farrowing and on Day 1 post-partum, and on nursing behaviour on Day 2 (mean ± SE %).

Figure captions

Fig. 1: Design of the farrowing pen (Rosvold et al., 2018).

Fig. 2. Interaction between nesting material and parity on mean (± SE) frequency of (a) positive communication from sow (n=51) to piglets during farrowing (% of scans); (b) negative communication from sow (n=51) to piglets during farrowing (% of scans); (c) positive communication from sow (n=53) to piglets on Day 1 post-partum (% of scans); d) nursing bouts initiated by the sow (n=53) on Day 2 post-partum (% of total nursing bouts); (e) successful nursing bouts terminated by piglets on Day 2 post-partum (n= 53, % of total successful nursing bouts).

Fig. 3. Association between litter size and: (a) positive communication from sow (n=51) to piglets during farrowing (% of scans); (b) negative communication from sow (n=51) to piglets during farrowing

(% of scans); (c) positive communication from sow (n=53) to piglets on Day 1 post-partum (% of scans); (d) nursing bouts initiated by the sow (n=53) on Day 2 (% of total nursing bouts); (e) successful nursing bouts terminated by piglets on Day 2 (% of total successful nursing bouts); (f) mean number of piglets per nursing bout per litter (n=53) without a teat during milk let-down on Day 2. Litter size refers to total born (live born + stillborn) piglets during farrowing, and number of piglets (live born ± cross-fostered) surviving on Days 1 and 2 post-partum.

Table 1. Ethogram of positive and negative sow communicatory behaviours directed towards piglets as observed during farrowing and on Day 1 post-partum.

Communication type	Behaviour	Definition
Positive	Sniff piglet	Sow actively directs her nose towards a piglet. Her snout is <10 cm from the piglet.
	Grunt to piglet	Sow gives short, frequent low-pitched vocalisations with head oriented towards piglets.
	Nudge piglet	Sow actively touches a piglet with her nose, may move snout gently up and down.
Negative	Push piglet	Sow moves a piglet roughly with her nose.
	Threatening barks	Sow directs sharp bark(s) towards piglet(s).
	Bite piglet	Sow bites or snaps towards a piglet.

Table 2. Ethogram of nursing behaviour, as observed on Day 2 post-partum.

Behaviour	**Definition**
Start of a nursing bout	Time point when >50% of the litter has started to actively massage the udder.
Sow-initiated nursing bout	Sow lies on side, exposing udder and/or starts grunting before piglets start massaging the udder.
Piglet-initiated nursing bout	One or more piglets is massaging the udder before sow exposes the udder and/or starts grunting.
Unsuccessful nursing bout	The nursing bout is terminated before the increase in grunting frequency and/or before the piglets` fast, rapid suckling movement (indicating intake of milk)
Successful nursing bout terminated by sow	Following milk let-down, the sow rolls over or stand up so her udder is not accessible to the piglets, while the piglets still are actively massaging.
Successful nursing bout terminated by piglets	Following milk let-down, piglets fall asleep at the udder or walk away while the sow is lying on her side with her udder exposed.
Without teat	Piglet without teat in mouth during milk let-down.

Table 3. Effects of nest-building material, and interactions between material and parity, on frequency of sow communicatory behaviours towards piglets during farrowing and on Day 1 post-partum and nursing behaviour on Day 2 post-partum (mean ± SE %).

Activity	**Material**					**Material x parity**	
	Control	**Peat**	**Straw**	χ^2	**P**	χ^2	**P**
Communication during farrowing[1,3]							
Positive, %	17.5±2.9	18.4±2.5	17.8±2.3	0.1	0.976	24.4	<0.001
Negative, %	5.3±2.1[a]	1.4±0.6[c]	1.8±0.8[b]	36.9	<0.001	27.0	<0.001
Communication on Day 1[2,3]							
Positive, %	26.6±1.7	26.3±2.0	27.9±2.2	1.1	0.582	19.5	<0.001
Negative, %	0.3±0.2	0.6±0.4	0.1±0.1	3.7	0.159	3.0	0.565
Nursing behaviour on Day 2[2]							
Nursing interval, min	44±2	40±2	41±2	5.8	0.055	4.6	0.328
Nursing bouts, n	8.3±0.5	9.4±0.6	8.8±0.4	1.1	0.565	0.1	0.999
Sow-initiated nursing bouts, %	23.5±4.3[a]	26.6±5.8[a]	34.4±5.5[b]	44.1	<0.001	72.7	<0.001
Successful nursing bouts terminated by piglets, %	58.8±8.8[a]	48.4±9.7[b]	61.3±8.3[a]	71.1	<0.001	94.3	<0.001
Piglets without teat, n	1.6±0.2	1.6±0.2	1.3±0.2	0.9	0.649	3.2	0.524

[1] Nest-building material $\chi^2_{2,39}$; Material x parity $\chi^2_{4,39}$

[2] Nest-building material $\chi^2_{2,41}$; Material x parity $\chi^2_{4,41}$

[3] 1/0 sampling

[a, b, c] Means with different letters are significantly different (P <0.05).

Table 4. Associations of parity and litter size with frequency of sow communicatory behaviours towards piglets during farrowing and on Day 1 post-partum, and on nursing behaviour on Day 2 (mean ± SE %).

Activity	**Parity**					**Litter size**	
	1	**2-3**	**≥4**	χ^2	**P**	χ^2	**P**
Communication during farrowing[1,3]							
Positive, %	18.9±3.5	17.5±2.4	17.4±1.2	3.5	0.177	3.9	0.049
Negative, %	3.4±1.6[a]	3.4±1.5[a]	1.4±0.7[b]	18.7	<0.001	6.0	0.015
Communication on Day 1[2,3]							
Positive, %	24.3±1.5[a]	29.1±1.9[b]	26.9±2.2[ab]	11.9	0.003	4.4	0.037
Negative, %	0.2±0.1	0.3±0.2	0.6±0.4	1.4	0.497	0.8	0.374
Nursing behaviour on Day 2[2]							
Nursing interval, min	42±2	42±2	42±2	1.7	0.430	0.1	0.753
Nursing bouts, n	8.8±0.6	8.8±0.5	8.9±0.5	0.2	0.915	0.1	0.829
Sow-initiated nursing bouts, %	21.4±3.8[a]	25.4±5.0[ab]	37.5±6.1[b]	67.4	<0.001	7.1	0.008
Successful nursing bouts terminated by piglets, %	83.6±5.3[a]	43.5±8.7[b]	45.0±8.4[b]	247.4	<0.001	31.8	<0.001
Piglets without teat, n	1.0±0.2	1.7±0.2	1.9±0.3	0.8	0.658	9.5	0.002

[1] Parity $\chi^2_{2,39}$; Litter size $\chi^2_{1,39}$

[2] Parity $\chi^2_{2,41}$; Litter size $\chi^2_{1,41}$

[3] 1/0 sampling

[a, b] Means with different letters are significantly different (P <0.05).

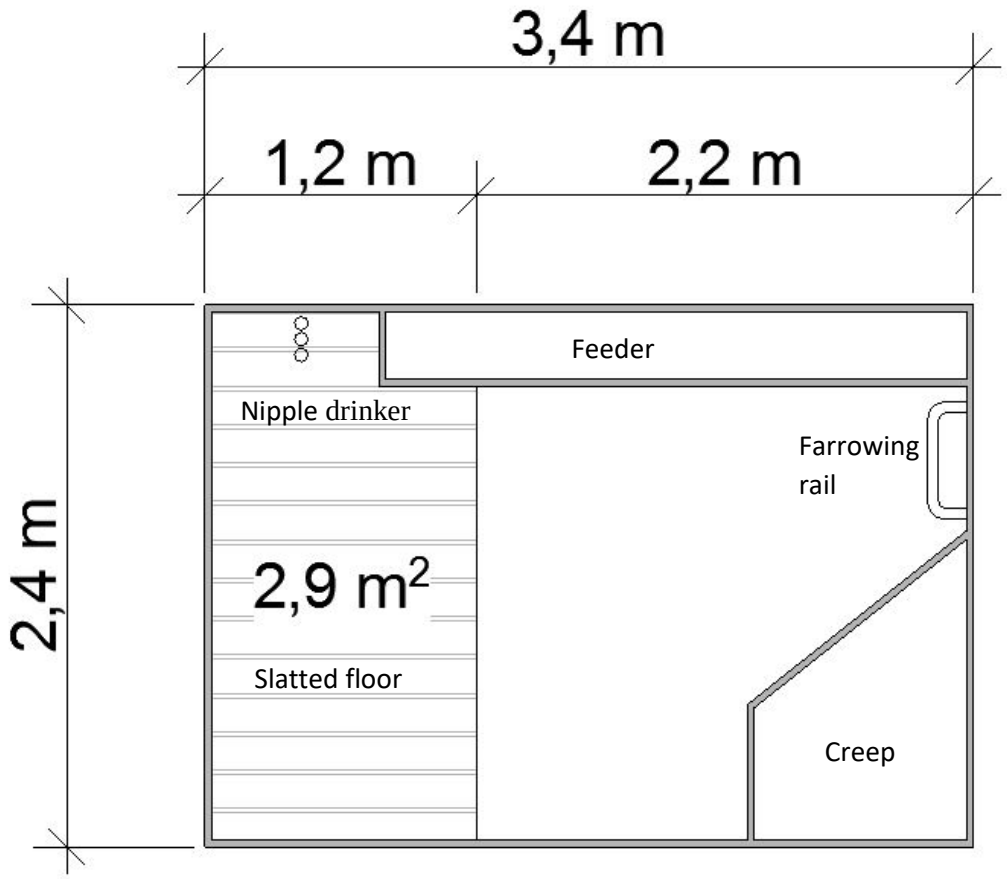

Fig. 1: Design of the farrowing pen (Rosvold et al., 2018).

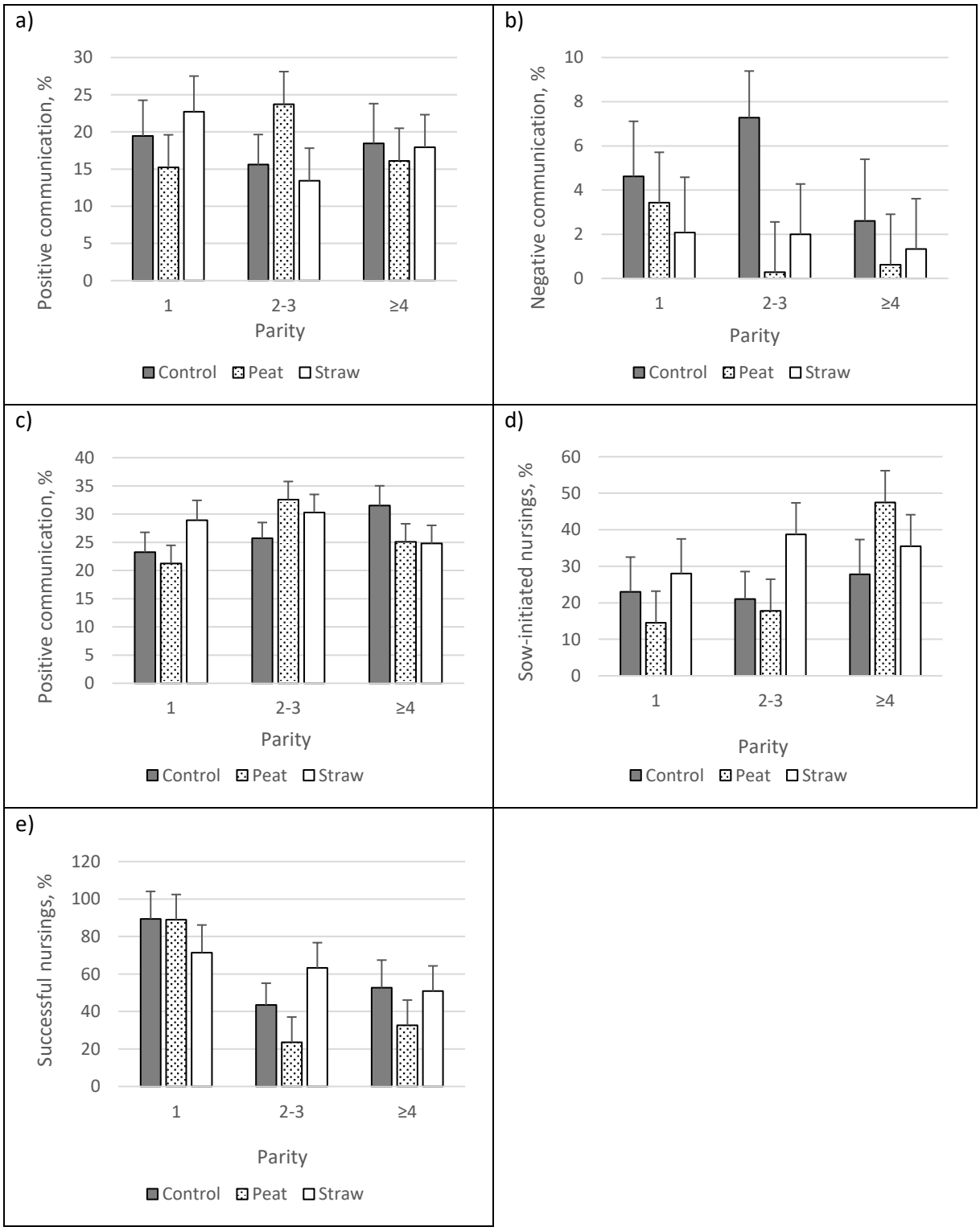

Fig. 2. Interaction between nesting material and parity on mean (± SE) frequency of (a) positive communication from sow (n=51) to piglets during farrowing (% of scans); (b) negative communication from sow (n=51) to piglets during farrowing (% of scans); (c) positive communication from sow (n=53) to piglets on Day 1 post-partum (% of scans); d) nursing bouts initiated by the sow (n=53) on Day 2 post-partum (% of total nursing bouts); (e) successful nursing bouts terminated by piglets on Day 2 post-partum (n= 53, % of total successful nursing bouts).

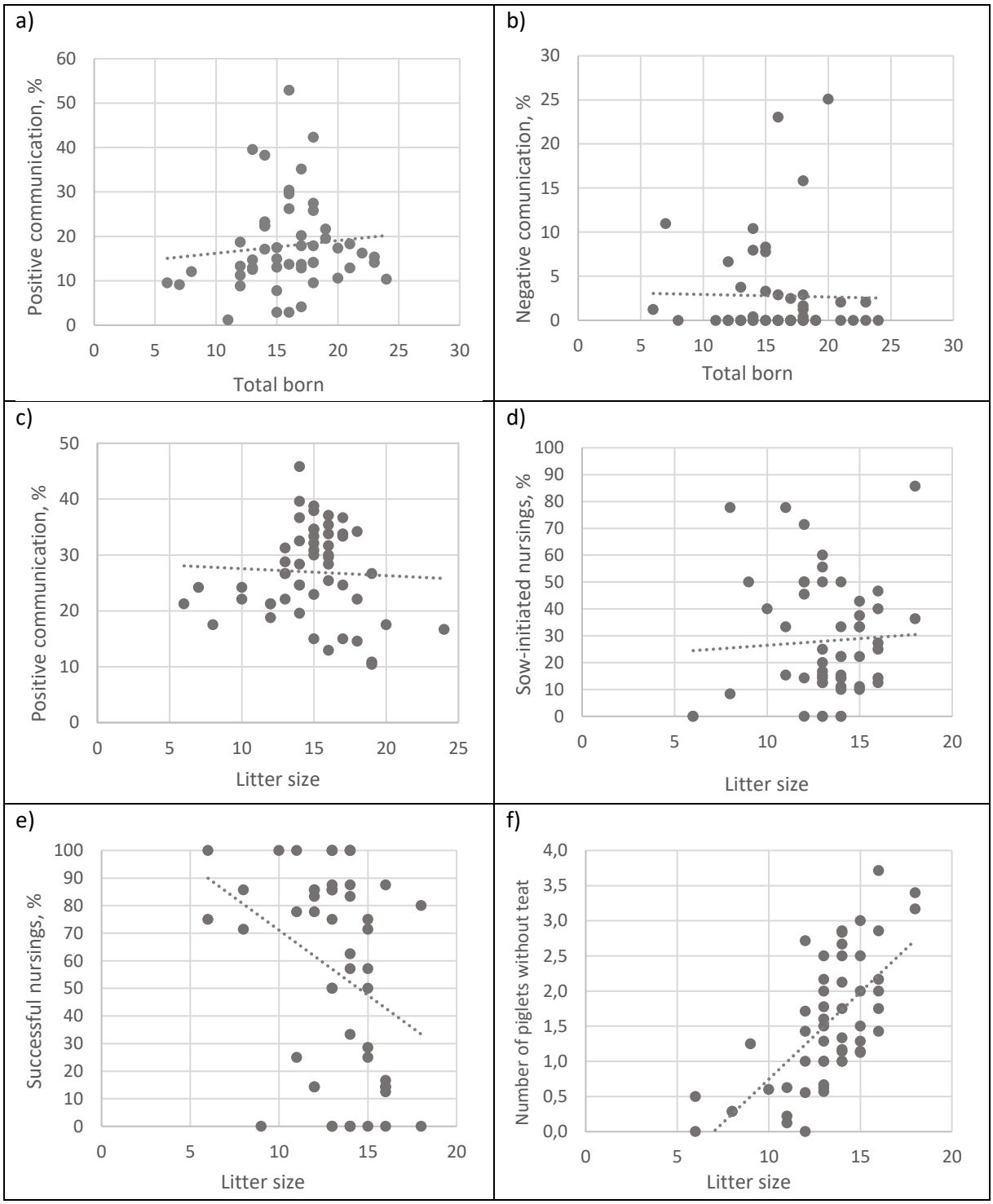

Fig. 3. Association between litter size and: (a) positive communication from sow (n=51) to piglets during farrowing (% of scans); (b) negative communication from sow (n=51) to piglets during farrowing (% of scans); (c) positive communication from sow (n=53) to piglets on Day 1 post-partum (% of scans); (d) nursing bouts initiated by the sow (n=53) on Day 2 (% of total nursing bouts); (e) successful nursing bouts terminated by piglets on Day 2 (% of total successful nursing bouts); (f) mean number of piglets per nursing bout per litter (n=53) without a teat during milk let-down on Day 2. Litter size refers to total born (live born + stillborn) piglets during farrowing, and number of piglets (live born ± cross-fostered) surviving on Days 1 and 2 post-partum.