Nest-building behaviour and activity budgets of sows provided with different materials

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Abstract

Domestic sows are still highly motivated to build a nest before farrowing. Many pig houses have slurry systems that do not allow use of long straw or other bulky materials that could block the drains, which provides an incentive to investigate the functionality of finer-grained materials for nest building. The objective of this study was to evaluate the effects of providing peat or straw on the overall amount of nest-building behaviour, number of different behavioural elements performed during nest building, and behavioural time budget of sows in the nesting period before farrowing.

Fifty-four hybrid sows (Norwegian Landrace x Yorkshire) ranging in parity from 1 to 9 (mean ± S.E., 2.9 ± 2.0), of which 16 were gilts, were loose-housed in individual farrowing pens. From two days before expected farrowing until farrowing the sows received nest-building material, with refills if necessary: peat (4 kg, 2 kg refills, n=18), straw (2 kg, 1 kg refills, n=17), or served as controls (n=16). Behaviour in the last 12 hours before onset of farrowing was instantaneously scan sampled at 5-min intervals from video recordings of each sow.

Sows provided with straw or peat engaged in nest-building behaviour in a higher proportion of scans compared to the sows in the control group ($P < 0.001$), and the sows in the straw group displayed the highest number of nest-building elements ($P < 0.001$). Sows in the straw group also lied more ($P < 0.001$) and performed less stereotypic behaviour ($P < 0.001$) than sows in the other two groups. Overall, total nest-building behaviour increased to a peak at 6-4 hours before farrowing and declined in the final three hours ($P < 0.001$). The number of different nest-building elements followed the same pattern ($P = 0.032$). Sows of parity ≥4 (n=16) exhibited more nest-building behaviour compared to gilts and sows of parity 2-3 ($P < 0.001$).

Our results demonstrate that both straw and peat stimulated more nest building compared to the control condition. However, straw elicited more complex nest-building behaviour, increased lying time and

reduced time spent on stereotypies in the 12 h before farrowing, suggesting that straw has a better function as nest-building material than peat.

Keywords: Nest building; Sow; Peat; Straw; Maternal behaviour; Loose-housed sows

Highlights:

- Nest-building behaviour was studied in the 12 hours before farrowing in loose-housed sows.
- Peat and straw were compared as nest-building materials to each other and to a control group without extra added material.
- Straw stimulated the highest frequency of nest-building behaviour.
- Straw stimulated the highest number of nest-building elements.
- Straw resulted in the most lying and least stereotypic behaviour prior to farrowing.

1. Introduction

Although pigs are domesticated and most live indoors sheltered from climatic factors and predators, sows are still motivated to build a nest before farrowing (e.g. Wischner et al., 2009). In a semi-natural environment, the sow leaves the group a day before farrowing to seek a suitable nest site (Jensen, 1986). In the initial nest-building phase, the sow digs a depression in the ground by pawing with the front legs and rooting with the snout. Subsequently she collects and carries vegetation such as grass and branches to the nest site, and arranges the material before she lies down to rest (Jensen, 1986; 1993; Mayer et al., 2002). Nest building has been reported to be most intensive during the last 12 h before farrowing (Castrén et al., 1993; Jensen, 1993). The onset of nest building behaviour is associated with a rise in prolactin levels (Castrén et al., 1993), which is induced by a decrease in progesterone and an increase in prostaglandins (Algers and Uvnäs-Moberg, 2007). Nest construction is dependent on external stimuli such as nesting materials (Jensen, 1993), and Jensen (1989) suggested that sows could learn to build a better nest with age or experience, though elements of nest-building behaviour occur even when sows are provided with a pre-made nest (Arey et al., 1991). However, Andersen et al. (2014) found that crated sows spent less time nest building, and showed more behaviours related to restlessness and frustration, than sows loose-housed in pens despite being provided with the same amount of straw. Also, the research by Hansen et al. (2017) showed that loose-housed sows performed a higher proportion of nest-building behaviour in the nesting period compared to confined sows. This indicates that suitable materials and ability to move are both important for the full expression of nest-building behaviour.

Previous studies have investigated the effects of different materials or environmental stimuli on nest building. These have included straw, cloth tassels, branches, sawdust, sand bedding, and a pen cover, with long-cut straw and branches stimulating the most nest-building behaviour (Widowski and Curtis, 1990; Cronin et al., 1993; Thodberg et al., 1999; Damm et al., 2000; Damm et al., 2010; Westin et al., 2015). Many pig houses have slurry systems that will not allow use of long straw or other materials that

could block the drains. Some farmers also consider that when straw is provided, too much labour is needed to maintain pen cleanliness. Therefore, peat is of interest as a nest-building material in regions where it is readily available, and where straw is of variable availability. The combined effects of providing peat bedding covered with a thin layer of straw along with racks of straw and branches were investigated in one study (Damm et al., 2002). However, reports on the effectiveness of peat as a nest-building material in the absence of straw are lacking. The structure of peat is very similar to soil, and peat is used as an environmental enrichment for pigs as it is suitable for rooting, digging and pawing (Studnitz et al., 2007; Vanheukelom et al., 2011), which are also elements of nest building.

Our objective was to study the effects of providing peat, straw or no nest-building material (control) on the overall amount of nest-building behaviour, number of different nest-building elements performed, and the activity budget of sows in the nest-building period before farrowing. The study was conducted under loose-housing conditions that allowed sows freedom of movement to express nest-building behaviour. We predicted that provision of either peat or long-stemmed straw would result in more nest-building behaviour, and a larger variety of nest-building behavioural elements, than when no nesting material was added. Due to the structural differences between straw and peat, with straw enabling the construction of a more complex nest, we expected to observe more nest-building behaviour and a larger number of nest-building elements in the straw treatment. Consequently, sows with access to straw were predicted to spend less time on other activities, including stereotypies, and lie more than sows in the other treatments. Finally, based on previously reported correlations between nest-building and sow parity, body size and age (Jensen, 1989; Widowski and Curtis, 1990; Mayer et al., 2002), we predicted that time spent in nest-building behaviour would increase with parity.

2. Material and methods

2.1 Experimental design

During three farrowing batches, 54 loose-housed sows kept in individual farrowing pens were video recorded from two days pre-partum until the start of farrowing to document the sows` pre-partum nest-building behaviour and activity budget. The sows were randomly assigned to one of three treatment groups differing in nest-building material: peat, straw and control (no nest-building material), with 18 sows in each group. The final sample sizes were 18, 17 and 16 respectively, due to failure of video recordings of two sows and abortion by one sow.

2.2 Animals and housing

The study took place at Mære Agricultural College in Steinkjer, Norway. The sows were Norwegian Landrace x Yorkshire, ranging in parity from 1 to 9 (mean ± S.E., 2.9 ± 2.0), of which 16 were gilts. They were inseminated with semen from Duroc boars. Approximately 3 to 4 weeks before farrowing, they were moved from group gestation pens to individual farrowing pens with an area of 8.2 m^2, of

which 2.9 m^2 was slatted flooring (Figure 1). According to standard practice in Norway, no farrowings were artificially induced, and no laxatives were added to the diet prior to farrowing.

The farrowing unit was insulated, and mechanically ventilated. The room temperature was regulated to 20°C, and the pen creep area was equipped with heat lamps and floor heating kept at 35°C. The indoor air temperature was measured by two temperature loggers (Tinytag, Gemini Data Loggers, Chichester, UK) placed in different parts of the farrowing unit. Due to variation in the outdoor temperature, indoor temperature differed between the batches. From one day before the first farrowing until the last farrowing (8 days), the average temperature was 19.0°C (range 17.3°-20.2°C) for the first batch in May, 22.4°C (19.1°-29.8°C) for the second batch in July, and 20.4°C (17.3°-24.1°C) for the third batch at the end of August.

The sows had access to natural light through windows. Consequently, during the summer, it remained light indoors through most of the night. Room lights were on throughout the working day, and only switched on during the night for additional visibility if needed when assisting sows during farrowing.

Before farrowing, the sows were fed twice a day by automatic distribution with a standard lactation concentrate (FK FORMAT Laktasjon, Felleskjøpet, Steinkjer, NO) at approximately 08:30 and 16:00 h, and once during the day with a farrowing concentrate given by hand (FK FORMAT Fødsel, Felleskjøpet, Steinkjer, NO). Once daily, hay (ca 0.3 kg) was distributed to the sows.

2.3 Distribution of nest-building material

In accordance with Castrén et al. (1993), nest-building material was provided from two days before expected farrowing. In the morning, the pens were cleaned and dry wood shavings provided as litter (0.8 kg, mainly from spruce, same amount to all pens). Then either 4 kg of peat (90 % peat with added formic acid, acetic acid, potassium sorbate and coal; 75 % water content, 7.6 % crude fibre, and 2.4 % ash; Fossli AS, Frosta, NO) or 2 kg of straw (long-stemmed barley straw) were added to the peat and straw treatment pens respectively. Because peat was only about half the volume of straw, the amount was doubled to even out this difference. Sows in the control group did not receive any more material than what was provided as litter. In the afternoon the procedure was repeated, with a new provision of litter (0.8 kg wood shavings) to each pen if necessary to replace wet and dirty litter, and a refill of 2 kg peat to peat pens and 1 kg straw to straw pens. The pen cleaning procedure with provision of new litter was done every day until farrowing. Refills of peat were repeated each morning and afternoon until farrowing, as the peat was spread out in the pen because of wallowing and rooting, and disappeared as it was eaten by the sow and went through the slatted floor. Further refill of straw was only necessary if the sow`s farrowing occurred later than expected and dirty straw needed to be replaced.

2.4 Video recording and analysis

To record nest building behaviour, a video camera sensitive to low light (Foscam F19821, 1280x720, Shenzhen, PRC) was suspended above each farrowing pen and connected to a standard PC. Video analysis started at 12 h before the start of farrowing (defined by the birth of the first piglet), since this is the most active period of the nest building (Castrén et al., 1993; Jensen, 1993; Andersen et al., 2005), with instantaneous scan sampling at 5-min intervals until the sow gave birth to the first piglet. One trained observer (EMR), who made frequent checks for intra-observer reliability during data collection, scored mutually exclusive sow behaviours as defined in Table 1. Wallowing was included in the ethogram because it was observed in sows who had received peat in a pilot study, but occurred too rarely for statistical analysis.

"Total nest-building behaviour" was the % of time spent on any nest-building behavioural element observed, whereas "number of nest-building elements" was the number of the various types of nest-building behavioural elements observed (i.e. if both rooting and carrying were observed within an hour, the number was two).

2.5 Statistical methods

A generalized linear mixed model in SAS Version 9.4, (SAS Institute, Inc., Cary, NC), with Poisson or Gamma distribution, was used to analyse the effects on each behaviour of the following main effects and interactions: material (control, peat, straw), time period (hours 12-10, 9-7, 6-4, 3-1 pre-partum), parity (1, 2-3, ≥4), material x time period and material x parity, and batch (1-3) as a random effect. A similar model without time period was used to analyse data from the final hour before farrowing. Descriptive statistics were obtained using SPSS Version 22 (IBM Corp., Armonk, NY).

3. Results

3.1 Behavioural time budget during the last 12 h before farrowing

Overall, the sows were lying in around 60 % of the scans, and standing in fewer than 20 % (Figure 2). Around 14 % of observations were dedicated to nest-building behaviour. The sows were moving in 2.4 % of scans, and were observed eating wood shavings, peat or straw material (not defined as nest-building behaviour) in 2.7 % of scans. The sows showed stereotypic behaviour in fewer than 2 % of the observations.

3.2 Nest-building activity in the last 12 h before farrowing

3.2.1 Nest-building materials

There were significant differences in the levels of most nest-building variables between sows in the control, peat and straw groups (Table 2). Sows in the straw group expressed the highest total nest-building behaviour, and displayed the highest number of nest-building elements in the 12 h before farrowing. Sows in the control group performed the least total nest-building behaviour, and the fewest

nest-building elements, and the peat group results were intermediate. The frequency of pawing was highest among sows in the control group, closely followed by the peat group, and lowest in the straw group. Sows provided with peat had the highest frequency of rooting behaviour observations, followed by sows in the control group and the straw group, respectively. Pushing and arranging material was observed with highest frequency in the straw group, and lowest in the peat group. Carrying material was observed only among the sows provided with straw.

3.2.2 Time periods

Nest-building behaviour varied over the 12 h before farrowing in all treatment groups. Collated over 1-h intervals, nest building peaked in the third hour pre-partum in the control group, the fifth hour in the straw treatment group and the sixth hour in the peat treatment group (Figure 3). On average, sows provided with straw had the highest frequency of total nest-building behaviour each hour from 9 h pre-partum until farrowing, except in the sixth and fourth hours pre-partum when sows in peat treatment group had numerically higher means.

Based on statistical analysis of the data in 3-h periods (12-10 h, 9-7 h, 6-4 h and 3-1 h), the highest total nest-building behaviour and number of different nest-building elements was observed between 6-4 h before farrowing (Table 3). The nest-building elements pawing, rooting and carrying material had the highest frequency in the same time period. The frequency of total nest-building behaviour was lowest at 12-10 h and 3-1 h before farrowing. The number of nest-building elements was also lowest in the time period 12-10 h. Pawing was observed with lowest frequency at 12-10 h before farrowing, whereas rooting was observed with lowest frequency at 3-1 h before farrowing.

Interactions between material and period were found in total nest-building behaviour, rooting and pushing (Table 3, Figure 3). Sows in the straw treatment group performed the highest frequency of total nest-building behaviour in each 3-h period except the 12-10 h period. The peat group expressed the highest frequency of rooting in all the four time periods, and especially in the 12-10 and 6-4 h time periods. The straw group had the highest frequency of pushing material in all time periods, with the differences between treatment groups being most pronounced in the 12-10 and 3-1 h time periods.

3.2.3. Parity

Total nest-building behaviour, pawing, rooting and pushing material were highest among sows of parity ≥4, whereas gilts had the lowest frequency of total nest-building behaviour (Table 4). Sows of parity 2-3 carried material the most, and this behaviour was not registered among gilts. Interactions were found between material and parity in total nest-building behaviour, pawing, rooting, and pushing (Table 4, Figure 4). In the straw and peat treatment groups, the sows of ≥4 parity showed more total nest-building behaviour than the gilts, whereas this change with parity was not observed in the control group. Sows with straw showed more pawing with increasing parity, although they showed the lowest frequency of pawing overall. Sows of parity 2-3 pawed most when not given nest-building material, whereas sows of

parity ≥4 pawed most if they received peat. Sows of parity ≥4 also exhibited the highest frequency of rooting if given peat. Gilts receiving straw were those exhibiting the most pushing of the material, whereas older sows with straw performed this behaviour with about half of the frequency compared to the gilts, though still tending to perform it more than sows in the other treatment groups.

3.2.4. Farrowing batch

The experiment was repeated in 3 batches, with 17 sows in each batch. The frequency of total nest-building behaviour was lowest in batch 2 (12.8 ± 1.2 % of observations), whilst the frequencies were almost equal in batches 1 (15.2 ± 1.5 %) and 3 (15.4 ± 1.2 %; $\chi^2_2 = 16.35$, P <0.001).

3.3 Other activities the 12 h pre-partum

The sows provided with straw had the highest frequency of lying, and lowest frequency of moving and standing (Table 2). The opposite was found amongst the sows in the peat group, and the sows in the control group were in between for moving and lying. Sows in the peat and control groups had similar frequencies of standing. In total, 33 (64.7 %) sows performed different types of stereotypies, with the highest frequencies occurring among sows in the control and peat groups (Table 2). Wallowing accounted for 0.2 ± 0.1 % of scans overall. It was only observed among the sows that received peat, and was performed by four (22.2 %) of these sows, mostly shortly after the material was provided.

At 9-7 h pre-partum, the sows performed the most moving and standing activity, and had the lowest frequency of lying (Table 3). In the last three hours pre-partum, the opposite was observed, and the sows lied more than 70 % of the time. The frequency of eating material was highest in the first three hours of the observation period, and decreased as the sows came closer to parturition. Stereotypies followed the same pattern, although the frequency was similar in the periods 12-10 h and 9-7 h. The highest frequency of wallowing was observed in the first three hours of the observation period (0.1 ± 0.1 % of scans).

Interactions were found between material and time periods for the behaviours "move" and "stereotypies" (Table 3, Figure 5). Although moving tended to decline in all treatment groups in the last three hours before farrowing, the sows provided with straw performed the least moving during this period. Sows in the straw group showed a consistent decrease in performing stereotypies whereas sows in the peat group showed an increase at 9-7 h, and then a large drop at 6-4 h. Sows in the wood-shavings group showed a slight increase at 6-4 h and then a drop during the last three hours.

Gilts showed the lowest frequency of moving and standing, and highest frequency of lying (Table 3). As parity increased, there was an increased frequency of moving and standing activity, whilst lying decreased with increasing parity group. The frequency of stereotypies was lowest among the gilts, doubled in the parity 2-3 group, and doubled again in the group of parity ≥4. Gilts also tended to exhibit the lowest frequency of eating material.

Interaction effects were found between material and parity for the behaviours "move", "stand" and "lie" (Table 3, Figure 6). Sows in the peat group showed a large increase in moving with increasing parity, while sows in the control group showed a slight decrease. For standing, the highest frequency was observed at parity ≥4 for sows with peat and at parity 2-3 for sows in the control group. For lying, there was a drop in frequency from first parity to parity 2-3, and then an increase at parity ≥4, in the control group. This response was the opposite to that for standing frequency.

3.4 Activities in the last hour before farrowing

In the last hour before farrowing, lying was observed in 79.9 % of scans, and standing in 7.5 %. Only four sows moved in the last hour before farrowing, which constituted 1.1 % of scans. Eating material was seen in 1.0 % of the scans, and stereotypies in 0.7 %. Overall, average total nest-building behaviour was 10.0 %, and rooting was the nesting element most frequently seen (7.5 %), followed by arranging material (1.3 %), pawing (0.8 %) and pushing material (0.3 %). Carrying material was not seen in the last hour before farrowing, and the mean number of nest-building elements observed per sow was 0.9.

There were differences between sows in the three material groups in lying (χ^2_2=14.09, P <0.001), standing (χ^2_2 = 24.87, P <0.001) and total nest building (χ^2_2=23.06, P <0.001; Figure 7). Between parity groups, only standing and total nest building were significantly different (χ^2_2=11.28, P=0.004; χ^2_2=23.25, P <0.001). Gilts showed the highest frequency of standing (8.9 ± 2.7 %), followed by sows of parity ≥4 (7.3 ± 2.3 % of observations), and parity 2-3 (6.6 ± 1.8 %). However, in total nest-building behaviour, the sows of parity 2-3 had the highest frequency (12.3 ± 2.7 %), followed by sows of parity ≥4 (9.9 ± 1.7 %), and gilts (7.3 ± 1.8 %).

There was an interaction between material and parity in the behaviour "stand" the last hour prior farrowing (χ^2_4=54.75, P <0.001). In the control group, sows of parity 2-3 had the highest frequency of standing (8.3 ± 2.6 %), followed by gilts (5.0 ± 2.1 %), and sows of parity ≥4 had the lowest frequency (2.1 ± 2.1 %). Gilts in the peat group had the highest frequency of standing (12.5 ± 6.4 %). They were followed by sows of parity ≥4 (11.1 ± 4.7 %), and parity 2-3 (5.6 ± 2.8 %). In the straw group gilts exhibited standing the most (8.3 ± 3.7 %), followed by sows of parity ≥4 (6.9 ± 3.4 %) and parity 2-3 (5.6 ± 4.1 %).

4. Discussion

As predicted, there was a higher frequency of total nest-building behaviour in the straw and peat groups compared to the control group. The number of nest-building elements was, as predicted, highest in the straw group, and only slightly higher in the peat group compared to the control group. Sows in the control group showed the most pawing and sows in the peat group showed the most rooting. These results indicate that the sows altered their behaviour according to available substrates, with pawing enabling movement of loose dry wood shavings and rooting enabling the formation of a depression in the moist peat. Sows in the straw group were more engaged in pushing and arranging material, and were

the only ones that carried material. The high frequency of pushing and arranging material in addition to carrying reflects that the quality of the straw gave more opportunities to manipulate and construct a nest than peat and a small amount of wood shavings. The many nest-building elements seen in the straw group also tell us that these sows moved forward to the second phase of nest building, which is dependent on materials (Jensen, 1993). The results show that straw stimulated nest building to a larger extent than the other materials, and gave the sow a possibility to construct a more complex nest.

From 12 hours before farrowing, total nest-building behaviour increased, reaching a peak 6-4 h before farrowing, and then ceased during the last three hours, which is in accordance with previous findings (Castrén et al., 1993; Jensen, 1993; Andersen et al., 2005). The number of different nest-building elements seen was also highest at 6-4 h before farrowing. The frequency of total nest-building behaviour and other activities was reduced as the sows approached farrowing, and in the last hour before farrowing the sows were usually calm and lied a lot except for shorter periods or occasionally when they got up and rearranged the nest. These observations are in accordance with Jensen (1986), who observed that all the sows rose and performed some extra nest building right before farrowing.

As predicted, time spent on nest building also increased with increasing parity (i.e. ≥ 4. Parity). In a recent study by Hansen et al. (2017), sows of parity 2-3 had longer bouts of nest building, and tended to spend more time on this activity compared to gilts. Jensen (1989) found a correlation between the amount of nesting material the sows gathered and increasing parity in sows in a semi-natural environment, and suggested that experience played a certain role in nest-building behaviour. Also, Mayer et al. (2002) found that larger and older sows, living wild, walked a much longer distance to collect their nesting material and built larger nests compared to smaller and younger sows. It has been suggested that multiparous sows are more likely to build a nest than primiparous sows, even without previous experience of nest building (Widowski and Curtis, 1990). Previous experiments have indicated that pre-partum concentrations of prolactin were greater with increasing parities (Farmer et al., 1995; Yun et al., 2014), which in addition to experience may contribute to increased nest building in older sows. In another study by Jensen (1993), sows of higher mean parity showed less carrying and arranging material. Those sows, however, had been assigned to a treatment without access to straw during the nest-building phase, so the lower levels might reflect the environmental treatment rather than parity. The present study shows an overall increase in total nest-building behaviour with higher parities, especially when the sows were provided with straw, and to some extent peat, whereas the sows in the control group exhibited almost the same amount of total nest-building behaviour in parity 1 and ≥ 4. Therefore, these results suggest that the performance of nest building increases with parity if the sows receive an appropriate nesting material.

As predicted, sows in the straw group lied more and spent less time on activities other than nest building compared to sows in the peat and control groups. There was also, as predicted, a lower frequency of

stereotypies in the straw group compared to the other groups. These findings indicate that straw is a better material to satisfy the need for nest building, and also leads to sows that are calmer close to farrowing. Sows without straw performed more stereotypies, and this may indicate that they had a higher level of frustration when unable to build a proper nest. As the frequency of stereotypies increased with higher parities, this may indicate that the degree of frustration was greater in these sows when they were not supplied with suitable nest-building material. It may also indicate that older sows have more internal motivation to build a nest, perhaps related to higher prolactin concentrations (Farmer et al., 1995; Yun et al., 2014).

Sows provided with peat had a lower frequency of total nest-building behaviour and number of nest-building elements compared to the sows with access to straw. For instance, no carrying was seen, and almost no arranging either. Peat is therefore not of full value as a nest-building material to the farrowing sows, considering that their behaviour is derived from their wild ancestry when it was presumably adaptive to build a nest suitable for concealing vulnerable newborn piglets from predators and providing them with thermal protection. However, it seems that peat is an excellent environmental enrichment for sows as it stimulates more rooting and wallowing behaviour. As the peat contained moisture, wallowing in it could have cooled the sows, which may have helped them to combat heat stress associated with late pregnancy and parturition. There have been reports of increased wallowing in pre-farrowing sows which likely were related to heat-stress (Buckner et al., 1998). Across all treatments, the relatively high summer temperatures experienced by the second batch of sows likely explain their lower nest building frequencies.

Conclusions

In conclusion, straw resulted in more time spent on nest building, increased lying time and less stereotypies, compared to peat and no nest-building material (control). Straw is considered to be a better material than peat for nest-building. As a practical implication, we recommend that future slurry systems are designed to allow farmers to use straw to facilitate nest building before farrowing.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Table captions

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418 **Table 1.** Nest building and other mutually exclusive behaviours recorded during the last 12 h before
419 farrowing.

Behaviour	Definition
Nest building	
Paw	Make digging movements in substrate material or against the floor with a forefoot.
Root	Make digging movements in substrate material or against the floor with the snout.
Push	Push substrate material with the snout.
Carry material	Carry substrate material in the mouth while taking at least two steps.
Arrange material	Collect substrate material with the mouth, deposit and move collected material without walking, lying down or attempting to lie down in the collected material.
Other	
Move	Walk/ take steps along floor, not performing any of the other behaviours.
Stand	Stand upright with all four feet on the floor or sit with hind end on floor, not performing any of the other behaviours.
Lie	Lie in sternal or lateral recumbency on the floor, not doing any of the other behaviours.
Eat material	Chew and/or swallow substrate material.
Perform stereotypies	Bite, chew or lick pen equipment repetitively, weave head from side to side, sham chew, lick inside of feeder although empty.
Wallow	Roll or rub head or body in substrate material.

420

421 **Table 2.** Mean ± S.E. % of scans engaged in different activities in the last 12 h pre-partum according to
422 nest-building material.

Activity	**Material**				
	Control *(n=16)*	**Peat** *(n=18)*	**Straw** *(n=17)*	χ^2_2	**P-value**
Total nest-building behaviour, %	12.3±1.1	14.5±1.3	16.5±1.4	30.78	<0.001
No. of nest-building elements	2.7±0.2	2.9±0.2	3.9±0.2	15.11	<0.001
Paw, %	2.3±0.4	2.1±0.4	1.3±0.3	21.17	<0.001
Root, %	8.9±0.8	11.8±1.1	7.1±0.8	86.86	<0.001
Push, %	0.8±0.3	0.4±0.2	1.9±0.3	77.34	<0.001
Carry material, %	0.0±0.0	0.0±0.0	0.7±0.3	- [1]	- [1]
Arrange material, %	0.3±0.1	0.1±0.1	5.6±0.8	6.82	0.033
Move, %	2.4±0.4	2.9±0.4	2.0±0.3	20.20	<0.001
Stand, %	19.8±1.7	20.3±1.5	15.4±1.3	44.90	<0.001
Lie, %	60.8±2.6	57.8±2.4	62.1±2.5	24.62	<0.001
Eat material, %	2.7±0.7	2.3±0.4	3.2±0.9	0.41	0.815
Perform stereotypies, %	2.2±0.4	2.1±0.4	0.8±0.2	46.74	<0.001

423 [1]Number of observations too low to analyse.

Table 3. Mean ± S.E. % of scans engaged in different activities across four time periods in the 12 h pre-partum, and interactions between material and period.

Activity	Time period prior farrowing						Material x period	
	12-10 h	9-7 h	6-4 h	3-1 h	χ^2_3	P-value	χ^2_6	P-value
Total nest-building behaviour, %	13.1±1.5	15.0±1.5	16.8±1.7	13.0±1.2	29.78	<0.001	33.72	<0.001
No. of nest-building elements	2.6±0.2	3.2±0.3	3.7±0.3	3.1±0.2	8.88	0.032	3.52	0.741
Paw, %	1.0±0.3	2.1±0.4	2.6±0.5	1.8±0.4	39.09	<0.001	11.91	0.064
Root, %	9.9±1.3	8.6±1.0	10.4±1.3	8.3±0.9	12.25	0.007	18.73	0.005
Push, %	0.9±0.3	1.2±0.4	1.1±0.3	1.0±0.3	6.19	0.103	17.09	0.009
Carry material, %	0.0±0.0	0.2±0.1	0.5±0.4	0.2±0.1	- [2]	- [2]	- [2]	- [2]
Arranging material[1], %	1.3±0.5	2.9±0.8	2.2±0.6	1.6±0.5	0.01	1.000	0.01	1.000
Move, %	2.5±0.4	3.1±0.5	2.7±0.4	1.5±0.4	39.72	<0.001	26.85	<0.001
Stand, %	22.1±1.8	22.9±1.8	17.9±1.6	11.3±1.2	247.42	<0.001	6.77	0.343
Lie, %	54.2±2.9	53.4±2.6	60.3±2.8	72.4±2.3	200.84	<0.001	8.28	0.218
Eat material[1], %	5.8±1.3	3.2±0.7	1.1±0.3	0.8±0.3	12.53	0.006	1.53	0.910
Perform stereotypies, %	2.3±0.5	2.3±0.6	1.3±0.3	0.8±0.3	48.52	<0.001	31.14	<0.001

[1]Gamma distribution

[2]Number of observations too low to analyse

Table 4. Mean ± S.E. % of scans engaged in different activities in the last 12 h pre-partum by sow parity and interactions between nesting material and parity.

Activity	**Parity**					**Material x parity**	
	1 ***(n= 16)***	**2-3** ***(n=19)***	**≥4** ***(n=16)***	χ^2_2	**P-value**	χ^2_4	**P-value**
Total nest-building behaviour, %	13.2±1.1	13.7±1.2	16.7±1.5	19.20	<0.001	15.38	0.004
No. of nest-building elements	2.9±0.2	3.0±0.2	3.6±0.3	4.00	0.135	2.56	0.633
Paw, %	1.6±0.3	1.7±0.3	2.4±0.4	11.47	0.003	24.36	<0.001
Root, %	8.9±0.9	8.9±0.9	10.3±1.2	9.63	0.008	18.82	0.001
Push, %	1.1±0.3	0.8±0.2	1.3±0.4	12.90	0.002	28.91	<0.001
Carry material, %	0.0±0.0	0.4±0.3	0.2±0.1	- [1]	- [1]	- [1]	- [1]
Arranging material, %	1.6±0.4	2.0±0.5	2.5±0.7	0.31	0.858	0.13	0.935
Move, %	1.9±0.3	2.5±0.3	2.9±0.4	13.15	0.001	38.07	<0.001
Stand, %	15.8±1.4	19.1±1.6	20.6±1.4	41.49	<0.001	114.66	<0.001
Lie, %	66.9±2.2	59.8±2.3	53.6±2.7	93.11	<0.001	73.98	<0.001
Eat material, %	1.6±0.4	3.4±0.6	3.0±1.0	5.39	0.068	3.23	0.520
Perform stereotypies, %	0.7±0.2	1.4±0.3	3.0±0.6	105.98	<0.001	5.18	0.269

[1]Number of observations too low to analyse.

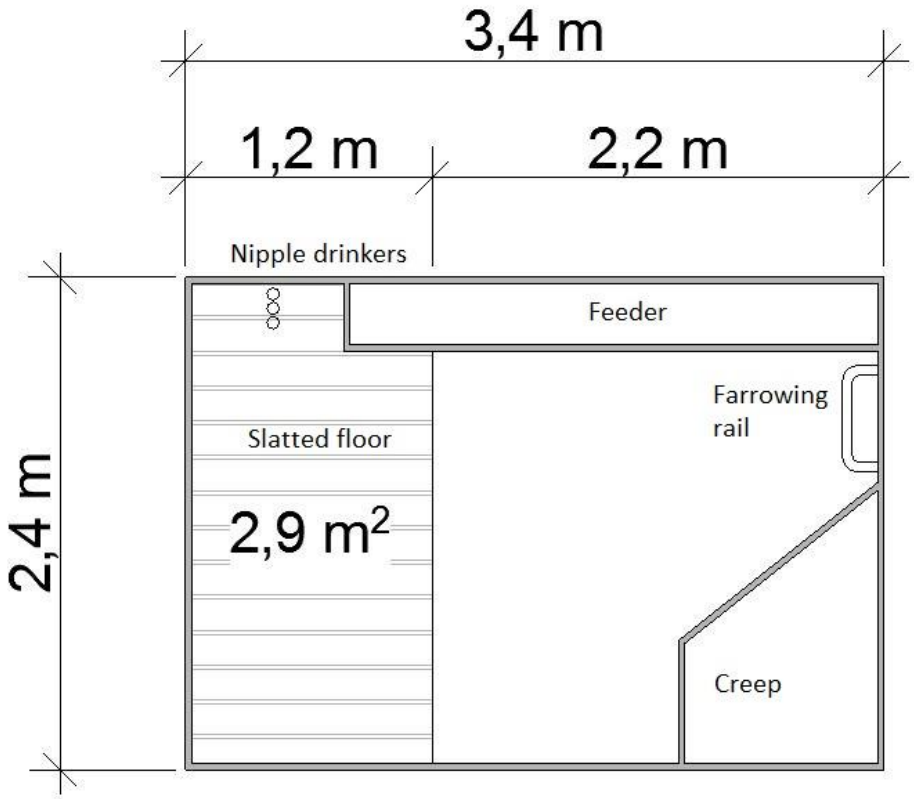
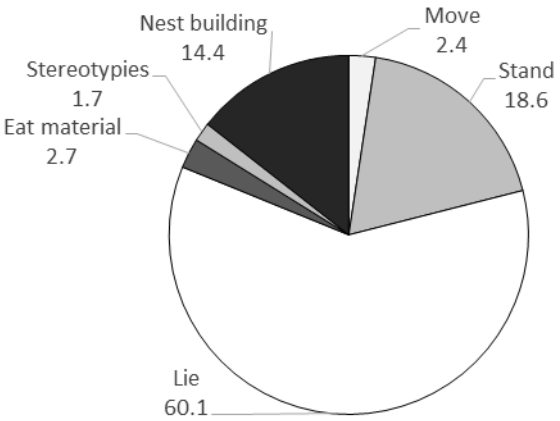


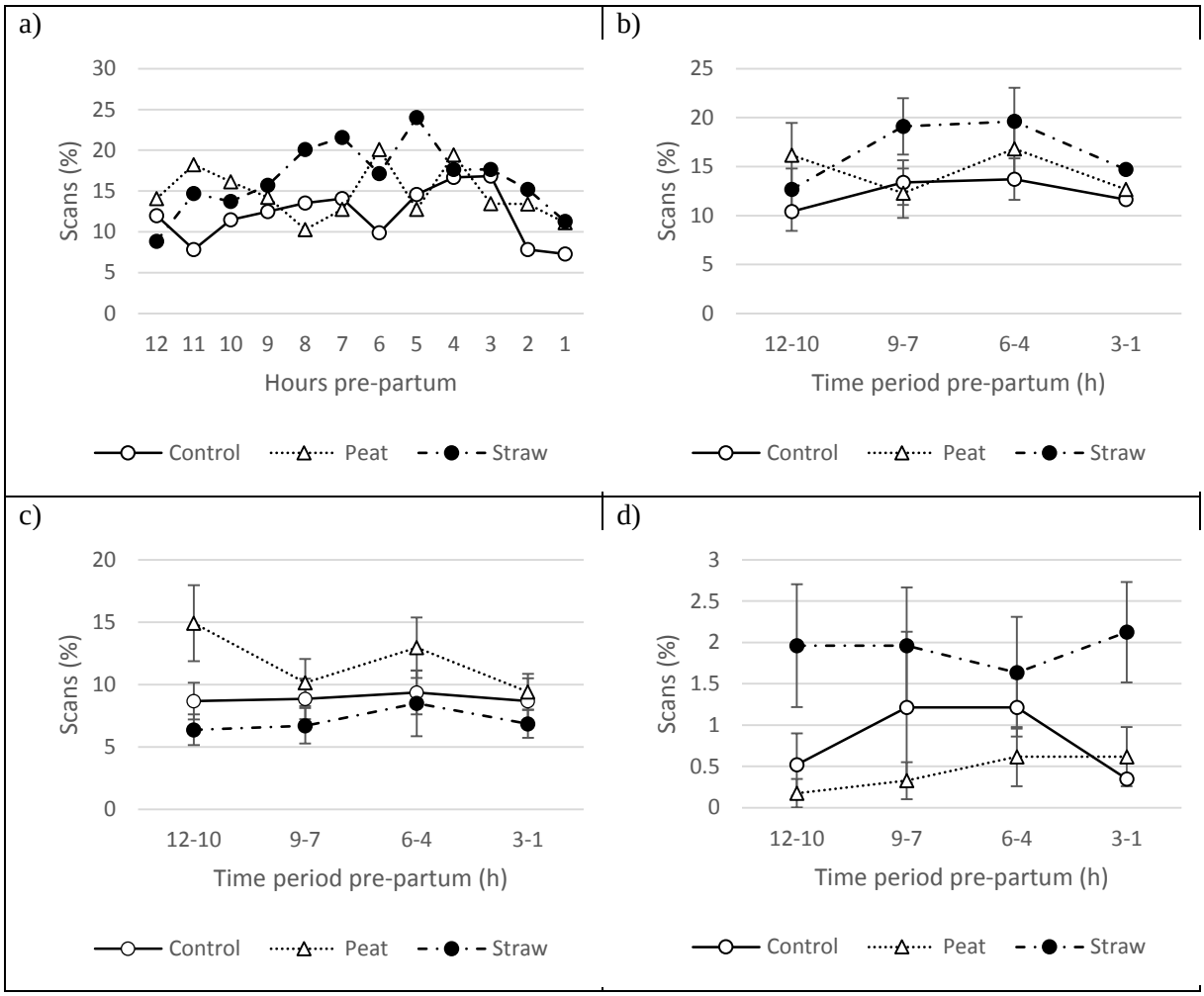
Figure 1. The design of the farrowing pen.

434



435

436 **Figure 2.** Sow behavioural time budget (mean % of scans) in the last 12 h before farrowing.



437

438 **Figure 3**. (a) Mean percentage of scans per hour engaged in total nest-building behaviour in the 12 h
439 before farrowing in the different nesting material groups (n=51 sows). (b-d) Effect of interaction
440 between 3-h time period and nesting material on mean (± SE) percentage of scans engaged in (b) total
441 nest-building behaviour, (c) rooting, and (d) pushing material.

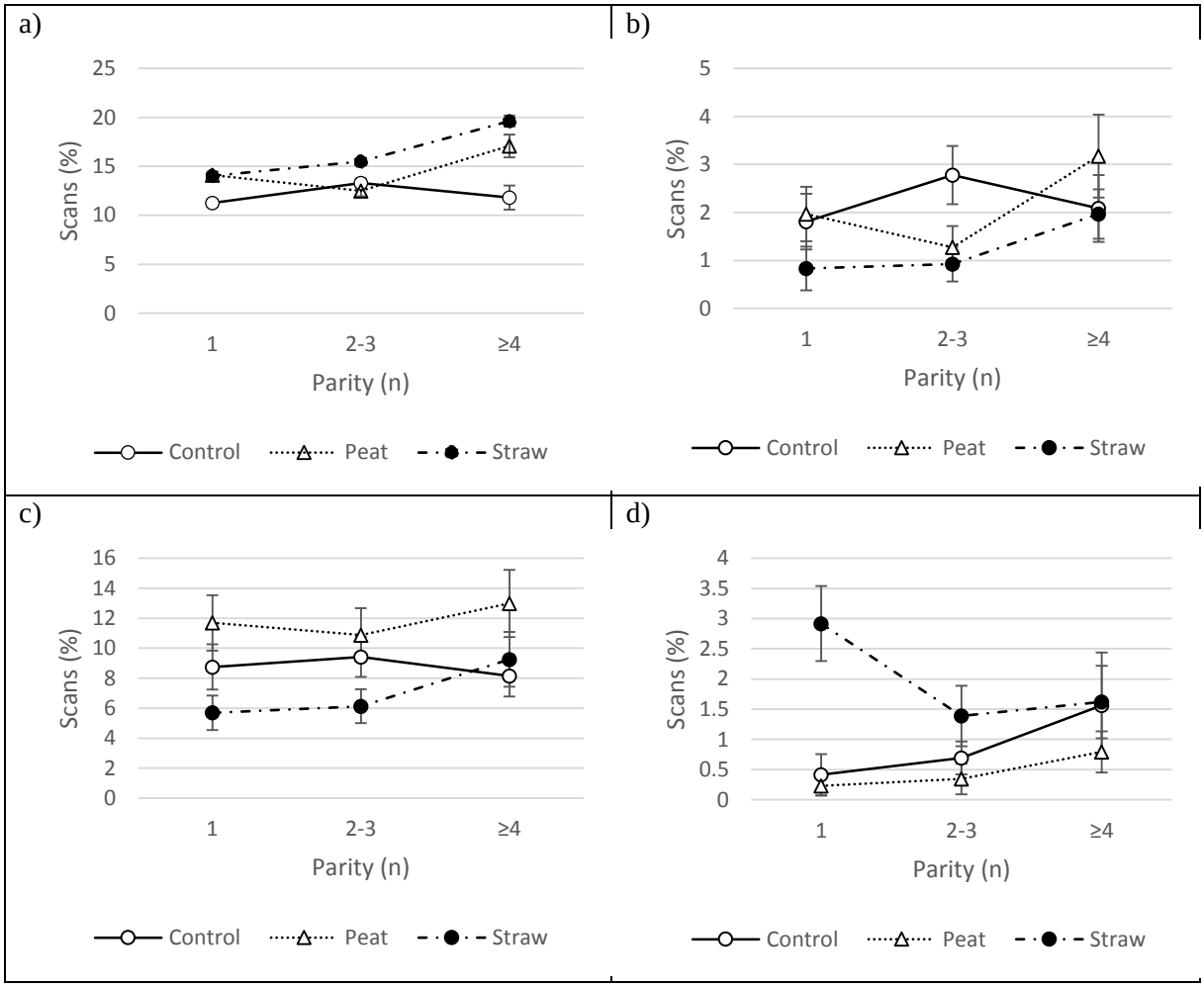


Figure 4. Effect of interaction between parity and nesting material on mean (± SE) percentage of scans engaged in (a) total nest-building behaviour, (b) pawing, (c) rooting, and (d) pushing material.

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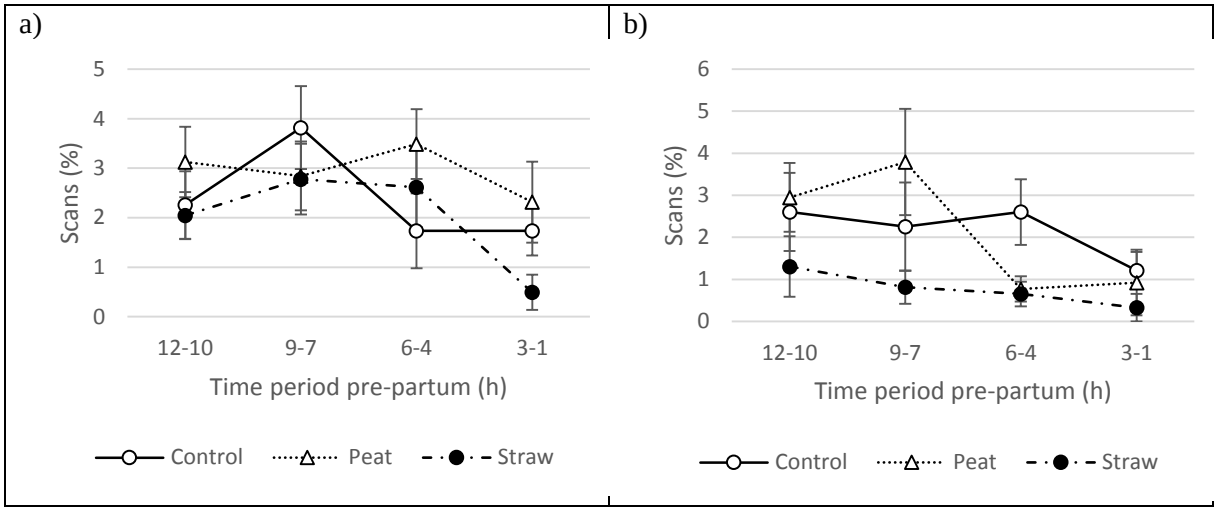
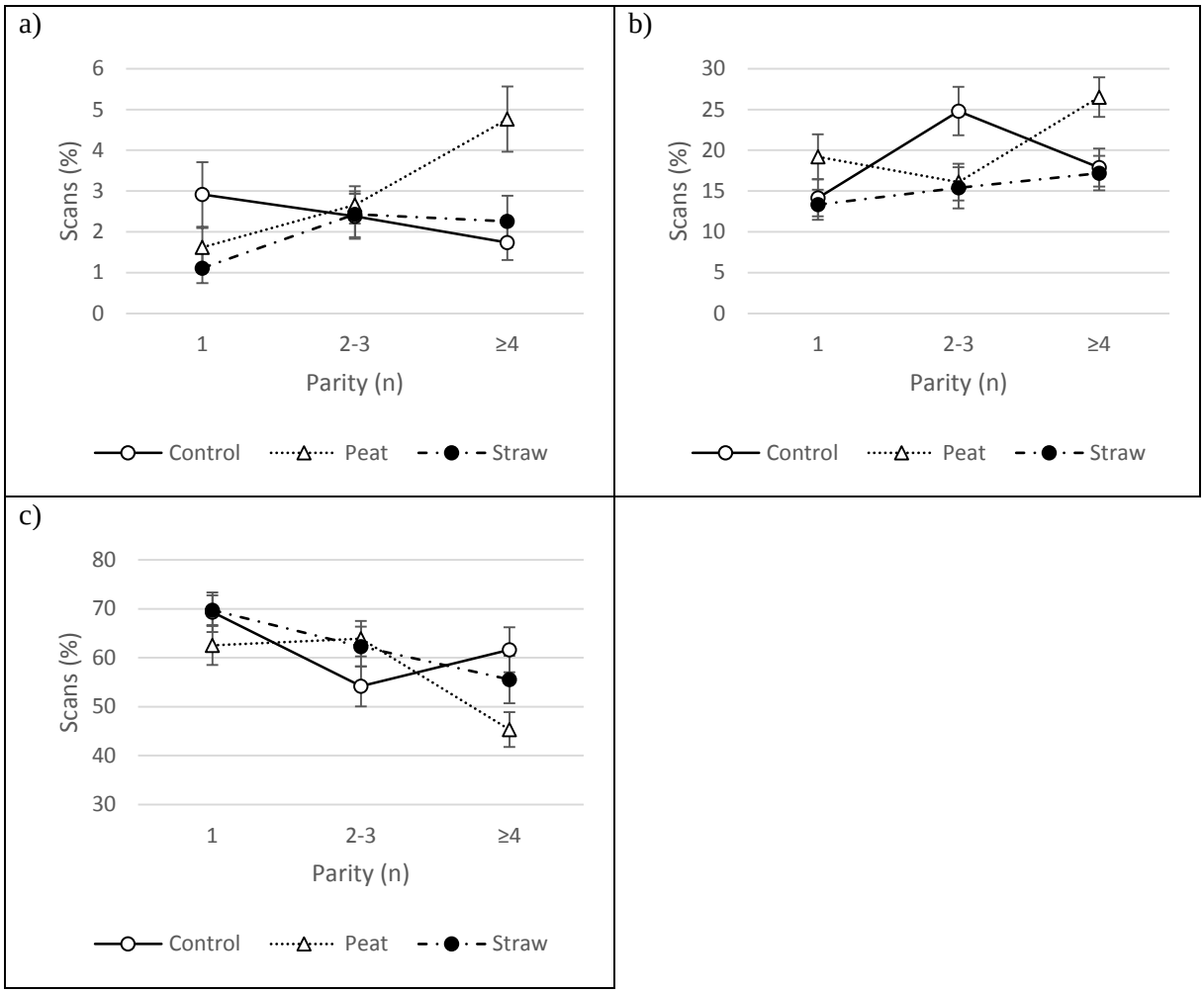


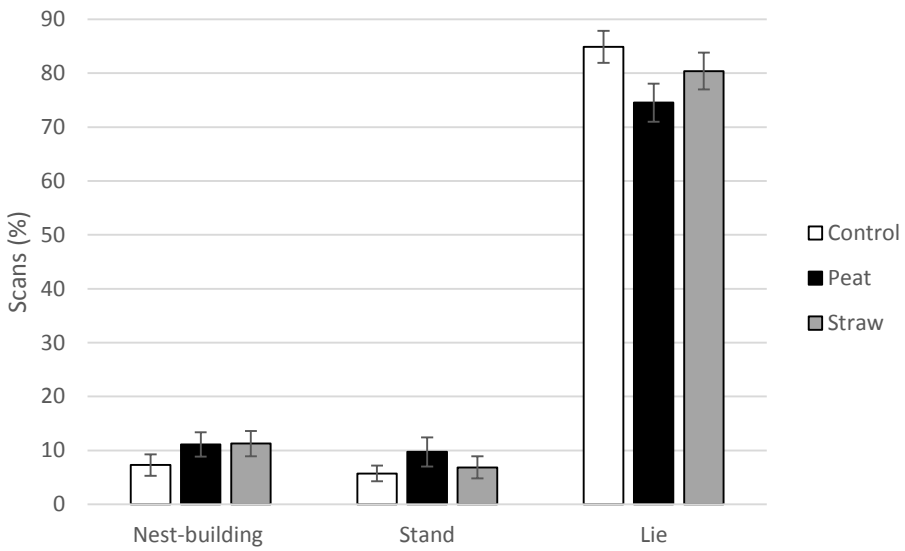
447

448 **Figure 5.** Effect of interaction between 3-h time period and nesting material on mean (± SE)
449 percentage of scans engaged in (a) moving, and (b) stereotypies.



450

451 **Figure 6.** Effect of interaction between parity and nesting material on mean (± SE) percentage of scans
452 engaged in (a) moving, (b) standing, and (c) lying.



453

454 **Figure 7.** Mean (± SE) percentage of scans engaged in different activities in the final hour before
455 farrowing. Effect of nesting material on total nest-building behaviour, standing and lying.