

1 Nest-building behaviour and activity budgets of sows provided with 2 different materials

3 Ellen Marie Rosvold*‡, Ruth C. Newberry*, Tore Framstad**, Inger-Lise Andersen*

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

6 ** Norwegian University of Life Sciences, Department of Production Animal Clinical Sciences, PO Box 8146,
7 0033 Oslo, Norway

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

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

10 Abstract

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

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

23 Sows provided with straw or peat engaged in nest-building behaviour in a higher proportion of scans
24 compared to the sows in the control group ($P < 0.001$), and the sows in the straw group displayed the
25 highest number of nest-building elements ($P < 0.001$). Sows in the straw group also lied more ($P < 0.001$)
26 and performed less stereotypic behaviour ($P < 0.001$) than sows in the other two groups. Overall, total
27 nest-building behaviour increased to a peak at 6-4 hours before farrowing and declined in the final three
28 hours ($P < 0.001$). The number of different nest-building elements followed the same pattern ($P = 0.032$).
29 Sows of parity ≥ 4 ($n=16$) exhibited more nest-building behaviour compared to gilts and sows of parity
30 2-3 ($P < 0.001$).

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

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

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

36 Highlights:

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

43 1. Introduction

44 Although pigs are domesticated and most live indoors sheltered from climatic factors and predators,
45 sows are still motivated to build a nest before farrowing (e.g. Wischner et al., 2009). In a semi-natural
46 environment, the sow leaves the group a day before farrowing to seek a suitable nest site (Jensen, 1986).
47 In the initial nest-building phase, the sow digs a depression in the ground by pawing with the front legs
48 and rooting with the snout. Subsequently she collects and carries vegetation such as grass and branches
49 to the nest site, and arranges the material before she lies down to rest (Jensen, 1986; 1993; Mayer et al.,
50 2002). Nest building has been reported to be most intensive during the last 12 h before farrowing
51 (Castrén et al., 1993; Jensen, 1993). The onset of nest building behaviour is associated with a rise in
52 prolactin levels (Castrén et al., 1993), which is induced by a decrease in progesterone and an increase
53 in prostaglandins (Algers and Uvnäs-Moberg, 2007). Nest construction is dependent on external stimuli
54 such as nesting materials (Jensen, 1993), and Jensen (1989) suggested that sows could learn to build a
55 better nest with age or experience, though elements of nest-building behaviour occur even when sows
56 are provided with a pre-made nest (Arey et al., 1991). However, Andersen et al. (2014) found that crated
57 sows spent less time nest building, and showed more behaviours related to restlessness and frustration,
58 than sows loose-housed in pens despite being provided with the same amount of straw. Also, the research
59 by Hansen et al. (2017) showed that loose-housed sows performed a higher proportion of nest-building
60 behaviour in the nesting period compared to confined sows. This indicates that suitable materials and
61 ability to move are both important for the full expression of nest-building behaviour.

62 Previous studies have investigated the effects of different materials or environmental stimuli on nest
63 building. These have included straw, cloth tassels, branches, sawdust, sand bedding, and a pen cover,
64 with long-cut straw and branches stimulating the most nest-building behaviour (Widowski and Curtis,
65 1990; Cronin et al., 1993; Thodberg et al., 1999; Damm et al., 2000; Damm et al., 2010; Westin et al.,
66 2015). Many pig houses have slurry systems that will not allow use of long straw or other materials that

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

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

88 2. Material and methods

89 2.1 Experimental design

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

96 2.2 Animals and housing

97 The study took place at Mære Agricultural College in Steinkjer, Norway. The sows were Norwegian
98 Landrace x Yorkshire, ranging in parity from 1 to 9 (mean \pm S.E., 2.9 ± 2.0), of which 16 were gilts.
99 They were inseminated with semen from Duroc boars. Approximately 3 to 4 weeks before farrowing,
100 they were moved from group gestation pens to individual farrowing pens with an area of 8.2 m², of

101 which 2.9 m² was slatted flooring (Figure 1). According to standard practice in Norway, no farrowings
102 were artificially induced, and no laxatives were added to the diet prior to farrowing.

103 The farrowing unit was insulated, and mechanically ventilated. The room temperature was regulated to
104 20°C, and the pen creep area was equipped with heat lamps and floor heating kept at 35°C. The indoor
105 air temperature was measured by two temperature loggers (Tinytag, Gemini Data Loggers, Chichester,
106 UK) placed in different parts of the farrowing unit. Due to variation in the outdoor temperature, indoor
107 temperature differed between the batches. From one day before the first farrowing until the last
108 farrowing (8 days), the average temperature was 19.0°C (range 17.3°-20.2°C) for the first batch in May,
109 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
110 end of August.

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

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

118 2.3 Distribution of nest-building material

119 In accordance with Castrén et al. (1993), nest-building material was provided from two days before
120 expected farrowing. In the morning, the pens were cleaned and dry wood shavings provided as litter (0.8
121 kg, mainly from spruce, same amount to all pens). Then either 4 kg of peat (90 % peat with added formic
122 acid, acetic acid, potassium sorbate and coal; 75 % water content, 7.6 % crude fibre, and 2.4 % ash;
123 Fossli AS, Frosta, NO) or 2 kg of straw (long-stemmed barley straw) were added to the peat and straw
124 treatment pens respectively. Because peat was only about half the volume of straw, the amount was
125 doubled to even out this difference. Sows in the control group did not receive any more material than
126 what was provided as litter. In the afternoon the procedure was repeated, with a new provision of litter
127 (0.8 kg wood shavings) to each pen if necessary to replace wet and dirty litter, and a refill of 2 kg peat
128 to peat pens and 1 kg straw to straw pens. The pen cleaning procedure with provision of new litter was
129 done every day until farrowing. Refills of peat were repeated each morning and afternoon until
130 farrowing, as the peat was spread out in the pen because of wallowing and rooting, and disappeared as
131 it was eaten by the sow and went through the slatted floor. Further refill of straw was only necessary if
132 the sow`s farrowing occurred later than expected and dirty straw needed to be replaced.

133 2.4 Video recording and analysis

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

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

147 2.5 Statistical methods

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

154 3. Results

155 3.1 Behavioural time budget during the last 12 h before farrowing

156 Overall, the sows were lying in around 60 % of the scans, and standing in fewer than 20 % (Figure 2).
157 Around 14 % of observations were dedicated to nest-building behaviour. The sows were moving in 2.4
158 % of scans, and were observed eating wood shavings, peat or straw material (not defined as nest-building
159 behaviour) in 2.7 % of scans. The sows showed stereotypic behaviour in fewer than 2 % of the
160 observations.

161 3.2 Nest-building activity in the last 12 h before farrowing

162 3.2.1 Nest-building materials

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

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

173 *3.2.2 Time periods*

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

180 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
181 nest-building behaviour and number of different nest-building elements was observed between 6-4 h
182 before farrowing (Table 3). The nest-building elements pawing, rooting and carrying material had the
183 highest frequency in the same time period. The frequency of total nest-building behaviour was lowest
184 at 12-10 h and 3-1 h before farrowing. The number of nest-building elements was also lowest in the time
185 period 12-10 h. Pawing was observed with lowest frequency at 12-10 h before farrowing, whereas
186 rooting was observed with lowest frequency at 3-1 h before farrowing.

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

193 *3.2.3 Parity*

194 Total nest-building behaviour, pawing, rooting and pushing material were highest among sows of parity
195 ≥ 4 , whereas gilts had the lowest frequency of total nest-building behaviour (Table 4). Sows of parity 2-
196 3 carried material the most, and this behaviour was not registered among gilts. Interactions were found
197 between material and parity in total nest-building behaviour, pawing, rooting, and pushing (Table 4,
198 Figure 4). In the straw and peat treatment groups, the sows of ≥ 4 parity showed more total nest-building
199 behaviour than the gilts, whereas this change with parity was not observed in the control group. Sows
200 with straw showed more pawing with increasing parity, although they showed the lowest frequency of
201 pawing overall. Sows of parity 2-3 pawed most when not given nest-building material, whereas sows of

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

206 *3.2.4. Farrowing batch*

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

210 *3.3 Other activities the 12 h pre-partum*

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

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

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

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

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

241 3.4 Activities in the last hour before farrowing

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

248 There were differences between sows in the three material groups in lying ($\chi^2_2=14.09$, $P < 0.001$),
249 standing ($\chi^2_2 = 24.87$, $P < 0.001$) and total nest building ($\chi^2_2=23.06$, $P < 0.001$; Figure 7). Between parity
250 groups, only standing and total nest building were significantly different ($\chi^2_2=11.28$, $P=0.004$; $\chi^2_2=23.25$,
251 $P < 0.001$). Gilts showed the highest frequency of standing (8.9 ± 2.7 %), followed by sows of parity ≥ 4
252 (7.3 ± 2.3 % of observations), and parity 2-3 (6.6 ± 1.8 %). However, in total nest-building behaviour,
253 the sows of parity 2-3 had the highest frequency (12.3 ± 2.7 %), followed by sows of parity ≥ 4 ($9.9 \pm$
254 1.7 %), and gilts (7.3 ± 1.8 %).

255 There was an interaction between material and parity in the behaviour “stand” the last hour prior
256 farrowing ($\chi^2_4=54.75$, $P < 0.001$). In the control group, sows of parity 2-3 had the highest frequency of
257 standing (8.3 ± 2.6 %), followed by gilts (5.0 ± 2.1 %), and sows of parity ≥ 4 had the lowest frequency
258 (2.1 ± 2.1 %). Gilts in the peat group had the highest frequency of standing (12.5 ± 6.4 %). They were
259 followed by sows of parity ≥ 4 (11.1 ± 4.7 %), and parity 2-3 (5.6 ± 2.8 %). In the straw group gilts
260 exhibited standing the most (8.3 ± 3.7 %), followed by sows of parity ≥ 4 (6.9 ± 3.4 %) and parity 2-3
261 (5.6 ± 4.1 %).

262 4. Discussion

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

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

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

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

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

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

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

325 **Conclusions**

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

330 **Conflicts of interest**

331 The authors have no conflicts of interest to declare.

332 **Acknowledgements**

333 The Norwegian Research Council, Norsvin, Animalia, Nortura and Fossli AS financed this project. The
334 authors wish to thank staff in the pig house at Mære Landbruksskole, especially Mona Langås and Bjørn
335 Åge Fjeset. We also wish to thank Einar Morten Røset and Geir Næss for practical help during the
336 experiment. Geir Næss also made the illustration of the farrowing pen.

337 **References**

338 Algers, B., Uvnäs-Moberg, K., 2007. Maternal behavior in pigs. *Hormones and Behavior* 52, 78-85.

339 Andersen, I.L., Berg, S., Bøe, K.E., 2005. Crushing of piglets by the mother sow (*Sus scrofa*)—purely
340 accidental or a poor mother? *Applied Animal Behaviour Science* 93, 229-243.

341 Andersen, I.L., Vasdal, G., Pedersen, L.J., 2014. Nest building and posture changes and activity budget
342 of gilts housed in pens and crates. *Applied Animal Behaviour Science* 159, 29-33.

343 Arey, D.S., Petchey, A.M., Fowler, V.R., 1991. The preparturient behaviour of sows in enriched pens
344 and the effect of pre-formed nests. *Applied Animal Behaviour Science* 31, 61-68.

345 Buckner, L.J., Edwards, S.A., Bruce, J.M., 1998. Behaviour and shelter use by outdoor sows. *Applied*
346 *Animal Behaviour Science* 57, 69-80.

347 Castrén, H., Algers, B., de Passillé, A.M., Rushen, J., Uvnäs-Moberg, K., 1993. Preparturient variation
348 in progesterone, prolactin, oxytocin and somatostatin in relation to nest building in sows. *Applied*
349 *Animal Behaviour Science* 38, 91-102.

350 Cronin, G.M., Schirmer, B.N., McCallum, T.H., Smith, J.A., Butler, K.L., 1993. The effects of providing
351 sawdust to pre-parturient sows in farrowing crates on sow behaviour, the duration of parturition and
352 the occurrence of intra-partum stillborn piglets. *Applied Animal Behaviour Science* 36, 301-315.

353 Damm, B.I., Bildsøe, M., Gilbert, C., Ladewig, J., Vestergaard, K.S., 2002. The effects of confinement
354 on periparturient behaviour and circulating prolactin, prostaglandin F2 α and oxytocin in gilts with
355 access to a variety of nest materials. *Applied Animal Behaviour Science* 76, 135-156.

356 Damm, B.I., Heiskanen, T., Pedersen, L.J., Jørgensen, E., Forkman, B., 2010. Sow preferences for
357 farrowing under a cover with and without access to straw. *Applied Animal Behaviour Science* 126, 97-
358 104.

359 Damm, B.I., Vestergaard, K.S., Schrøder-Petersen, D.L., Ladewig, J., 2000. The effects of branches on
360 prepartum nest building in gilts with access to straw. *Applied Animal Behaviour Science* 69, 113-124.

361 Farmer, C., Robert, S., Matte, J.J., Girard, C.L., Martineau, G.P., 1995. Endocrine and peripartum
362 behavioral responses of sows fed high-fiber diets during gestation. *Canadian Journal of Animal*
363 *Science* 75, 531-536.

364 Hansen, C.F., Hales, J., Weber, P.M., Edwards, S.A., Moustsen, V.A., 2017. Confinement of sows 24h
365 before expected farrowing affects the performance of nest building behaviours but not progress of
366 parturition. *Applied Animal Behaviour Science* 188, 1-8.

367 Jensen, P., 1986. Observations on the maternal behaviour of free-ranging domestic pigs. *Applied*
368 *Animal Behaviour Science* 16, 131-142.

369 Jensen, P., 1989. Nest site choice and nest building of free-ranging domestic pigs due to farrow.
370 *Applied Animal Behaviour Science* 22, 13-21.

371 Jensen, P., 1993. Nest building in domestic sows: the role of external stimuli. *Animal Behaviour* 45,
372 351-358.

373 Mayer, J.J., Martin, F.D., Brisbin Jr, I.L., 2002. Characteristics of wild pig farrowing nests and beds in
374 the upper Coastal Plain of South Carolina. *Applied Animal Behaviour Science* 78, 1-17.

375 Studnitz, M., Jensen, M.B., Pedersen, L.J., 2007. Why do pigs root and in what will they root?: A
376 review on the exploratory behaviour of pigs in relation to environmental enrichment. *Applied Animal*
377 *Behaviour Science* 107, 183-197.

378 Thodberg, K., Jensen, K.H., Herskin, M.S., Jørgensen, E., 1999. Influence of environmental stimuli on
379 nest building and farrowing behaviour in domestic sows. *Applied Animal Behaviour Science* 63, 131-
380 144.

381 Vanheukelom, V., Driessen, B., Maenhout, D., Geers, R., 2011. Peat as environmental enrichment for
382 piglets: The effect on behaviour, skin lesions and production results. *Applied Animal Behaviour*
383 *Science* 134, 42-47.

384 Westin, R., Hultgren, J., Algers, B., 2015. Strategic use of straw increases nest building in loose
385 housed farrowing sows. *Applied Animal Behaviour Science* 166, 63-70.

386 Widowski, T.M., Curtis, S.E., 1990. The influence of straw, cloth tassel, or both on the prepartum
387 behavior of sows. *Applied Animal Behaviour Science* 27, 53-71.

388 Wischner, D., Kemper, N., Krieter, J., 2009. Nest-building behaviour in sows and consequences for pig
389 husbandry. *Livestock Science* 124, 1-8.

390 Yun, J., Swan, K.-M., Farmer, C., Oliviero, C., Peltoniemi, O., Valros, A., 2014. Prepartum nest-building
391 has an impact on postpartum nursing performance and maternal behaviour in early lactating sows.
392 Applied Animal Behaviour Science 160, 31-37.

393

394 [Table captions](#)

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

397 **Table 2.** Mean \pm S.E. % of scans engaged in different activities in the last 12 h pre-partum according to
398 nest-building material.

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

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

403 [Figure captions](#)

404 **Figure 1.** The design of the farrowing pen.

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

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

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

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

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

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

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

Behaviour	Definition
<i>Nest building</i>	
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.
<i>Other</i>	
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 \pm S.E. % of scans engaged in different activities in the last 12 h pre-partum according to
 422 nest-building material.

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

423 ¹Number of observations too low to analyse.

424 **Table 3.** Mean \pm S.E. % of scans engaged in different activities across four time periods in the 12 h pre-
 425 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 \pm 1.5	15.0 \pm 1.5	16.8 \pm 1.7	13.0 \pm 1.2	29.78	<0.001	33.72	<0.001
No. of nest-building elements	2.6 \pm 0.2	3.2 \pm 0.3	3.7 \pm 0.3	3.1 \pm 0.2	8.88	0.032	3.52	0.741
Paw, %	1.0 \pm 0.3	2.1 \pm 0.4	2.6 \pm 0.5	1.8 \pm 0.4	39.09	<0.001	11.91	0.064
Root, %	9.9 \pm 1.3	8.6 \pm 1.0	10.4 \pm 1.3	8.3 \pm 0.9	12.25	0.007	18.73	0.005
Push, %	0.9 \pm 0.3	1.2 \pm 0.4	1.1 \pm 0.3	1.0 \pm 0.3	6.19	0.103	17.09	0.009
Carry material, %	0.0 \pm 0.0	0.2 \pm 0.1	0.5 \pm 0.4	0.2 \pm 0.1	- ²	- ²	- ²	- ²
Arranging material ¹ , %	1.3 \pm 0.5	2.9 \pm 0.8	2.2 \pm 0.6	1.6 \pm 0.5	0.01	1.000	0.01	1.000
Move, %	2.5 \pm 0.4	3.1 \pm 0.5	2.7 \pm 0.4	1.5 \pm 0.4	39.72	<0.001	26.85	<0.001
Stand, %	22.1 \pm 1.8	22.9 \pm 1.8	17.9 \pm 1.6	11.3 \pm 1.2	247.42	<0.001	6.77	0.343
Lie, %	54.2 \pm 2.9	53.4 \pm 2.6	60.3 \pm 2.8	72.4 \pm 2.3	200.84	<0.001	8.28	0.218
Eat material ¹ , %	5.8 \pm 1.3	3.2 \pm 0.7	1.1 \pm 0.3	0.8 \pm 0.3	12.53	0.006	1.53	0.910
Perform stereotypies, %	2.3 \pm 0.5	2.3 \pm 0.6	1.3 \pm 0.3	0.8 \pm 0.3	48.52	<0.001	31.14	<0.001

426 ¹Gamma distribution

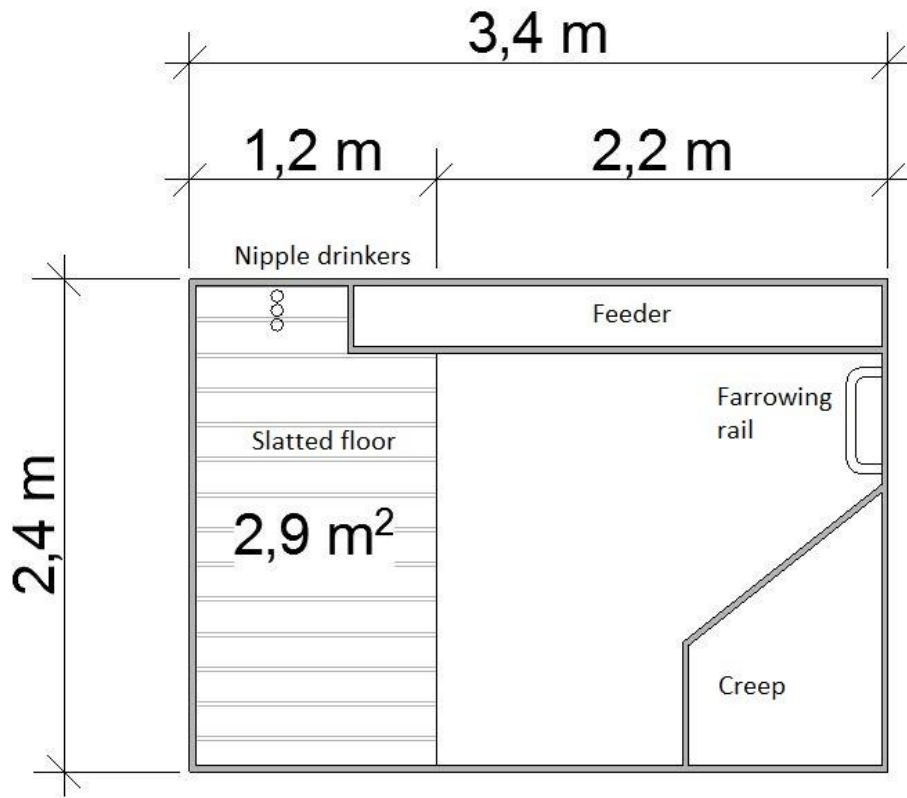
427 ²Number of observations too low to analyse

428

429 **Table 4.** Mean \pm S.E. % of scans engaged in different activities in the last 12 h pre-partum by sow
 430 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 \pm 1.1	13.7 \pm 1.2	16.7 \pm 1.5	19.20	<0.001	15.38	0.004
No. of nest-building elements	2.9 \pm 0.2	3.0 \pm 0.2	3.6 \pm 0.3	4.00	0.135	2.56	0.633
Paw, %	1.6 \pm 0.3	1.7 \pm 0.3	2.4 \pm 0.4	11.47	0.003	24.36	<0.001
Root, %	8.9 \pm 0.9	8.9 \pm 0.9	10.3 \pm 1.2	9.63	0.008	18.82	0.001
Push, %	1.1 \pm 0.3	0.8 \pm 0.2	1.3 \pm 0.4	12.90	0.002	28.91	<0.001
Carry material, %	0.0 \pm 0.0	0.4 \pm 0.3	0.2 \pm 0.1	- ¹	- ¹	- ¹	- ¹
Arranging material, %	1.6 \pm 0.4	2.0 \pm 0.5	2.5 \pm 0.7	0.31	0.858	0.13	0.935
Move, %	1.9 \pm 0.3	2.5 \pm 0.3	2.9 \pm 0.4	13.15	0.001	38.07	<0.001
Stand, %	15.8 \pm 1.4	19.1 \pm 1.6	20.6 \pm 1.4	41.49	<0.001	114.66	<0.001
Lie, %	66.9 \pm 2.2	59.8 \pm 2.3	53.6 \pm 2.7	93.11	<0.001	73.98	<0.001
Eat material, %	1.6 \pm 0.4	3.4 \pm 0.6	3.0 \pm 1.0	5.39	0.068	3.23	0.520
Perform stereotypies, %	0.7 \pm 0.2	1.4 \pm 0.3	3.0 \pm 0.6	105.98	<0.001	5.18	0.269

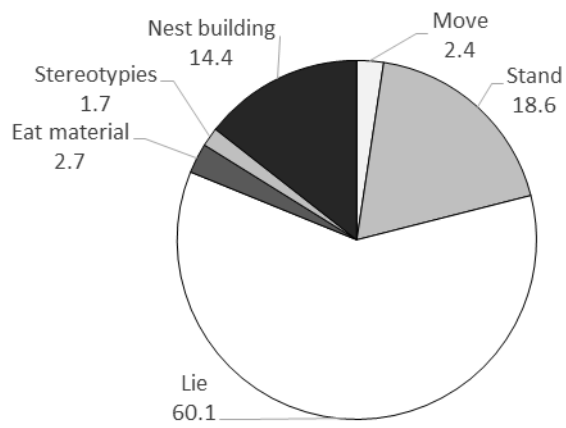
431 ¹Number of observations too low to analyse.



432

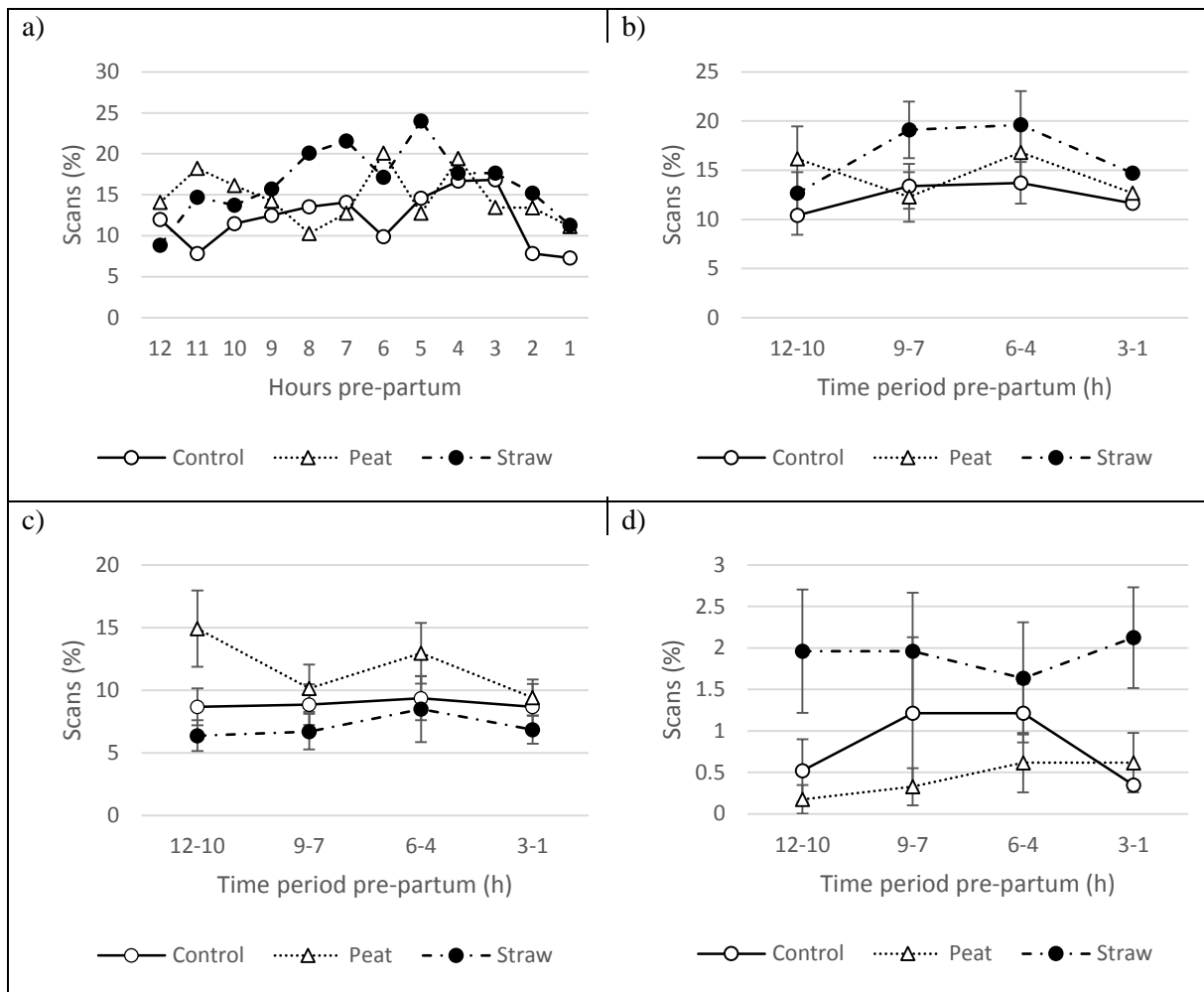
433 **Figure 1.** The design of the farrowing pen.

434



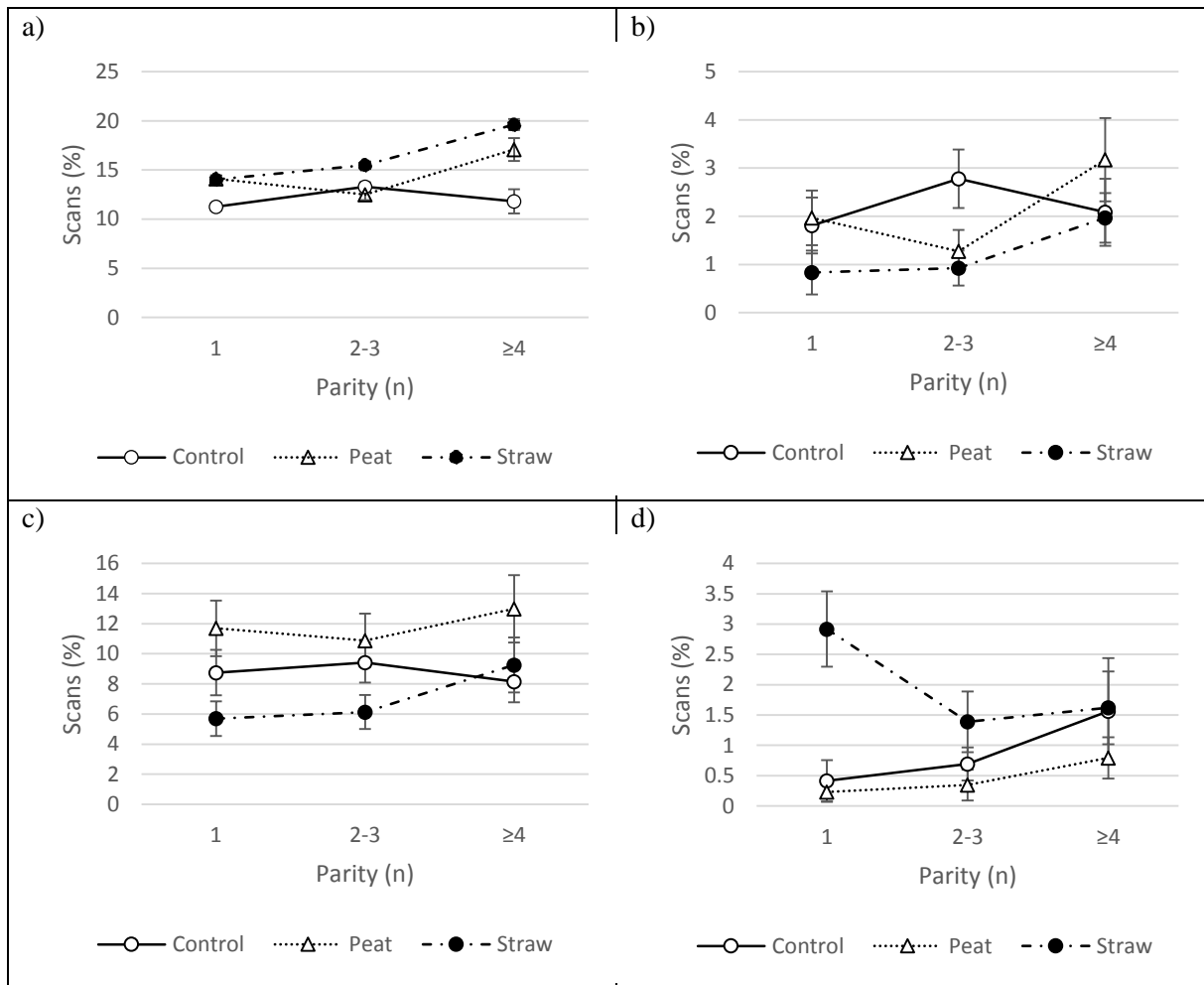
435

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

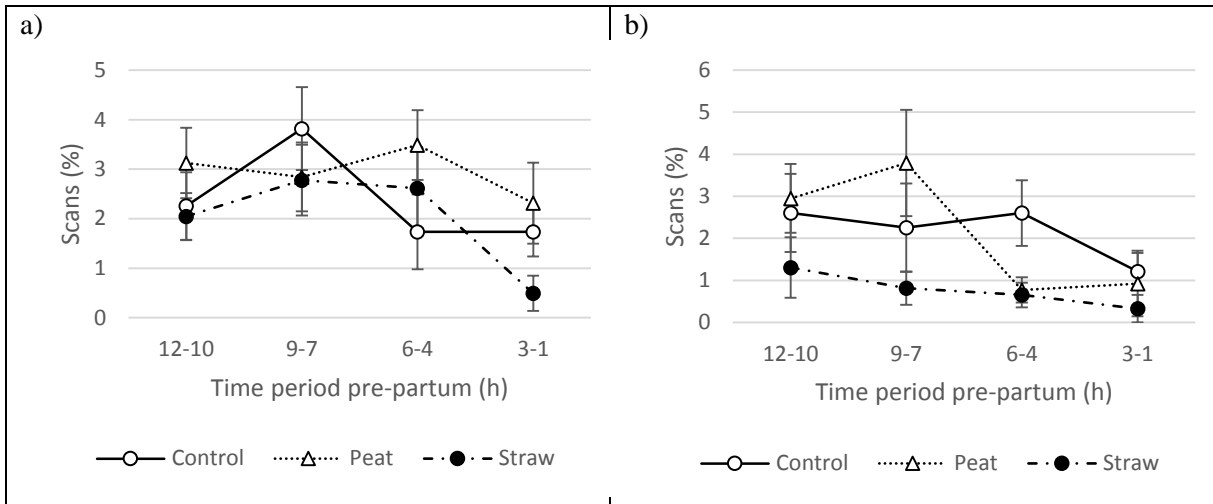


437

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 (\pm SE) percentage of scans engaged in (b) total
 441 nest-building behaviour, (c) rooting, and (d) pushing material.

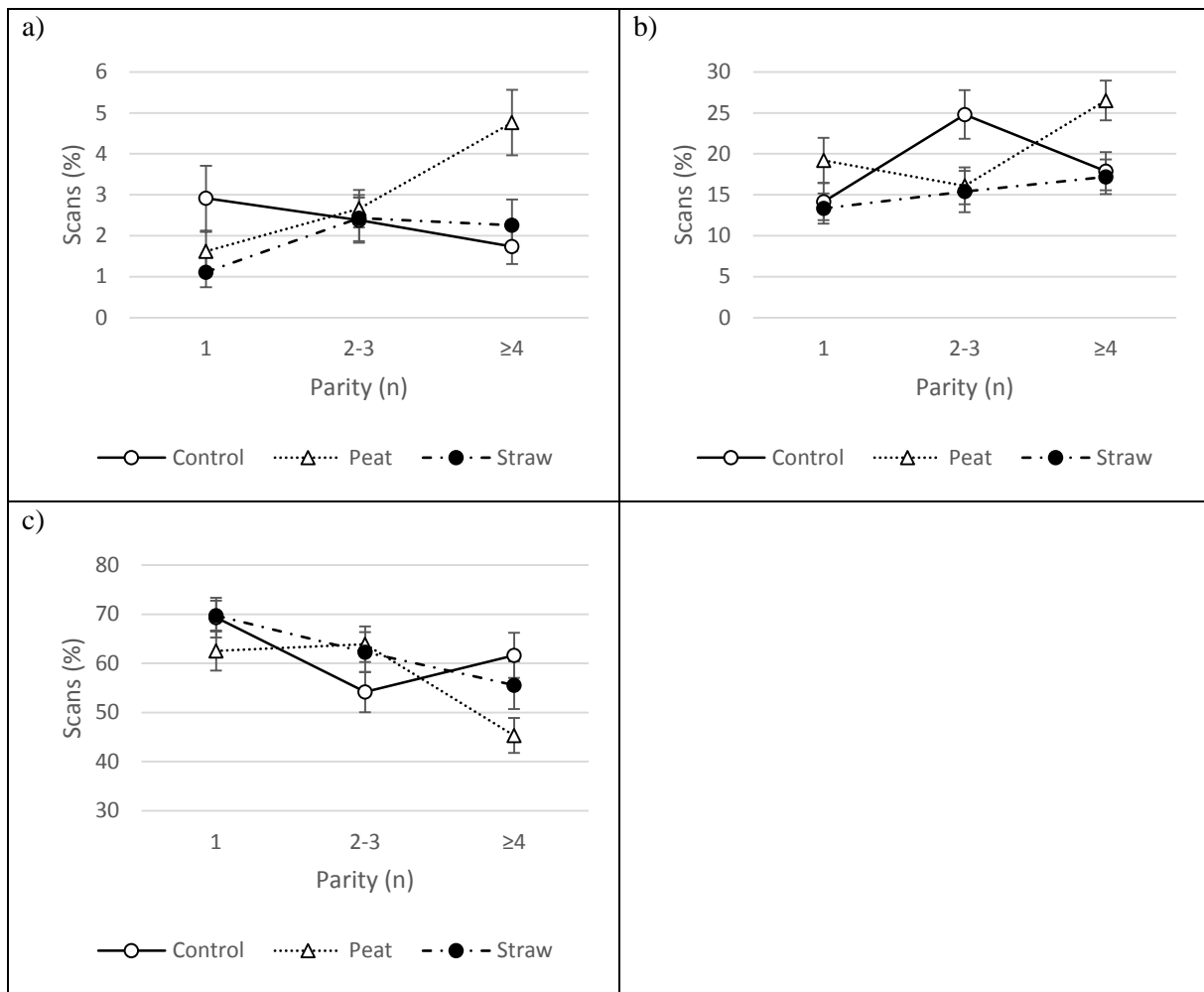


444 **Figure 4.** Effect of interaction between parity and nesting material on mean (\pm SE) percentage of
 445 scans engaged in (a) total nest-building behaviour, (b) pawing, (c) rooting, and (d) pushing material.



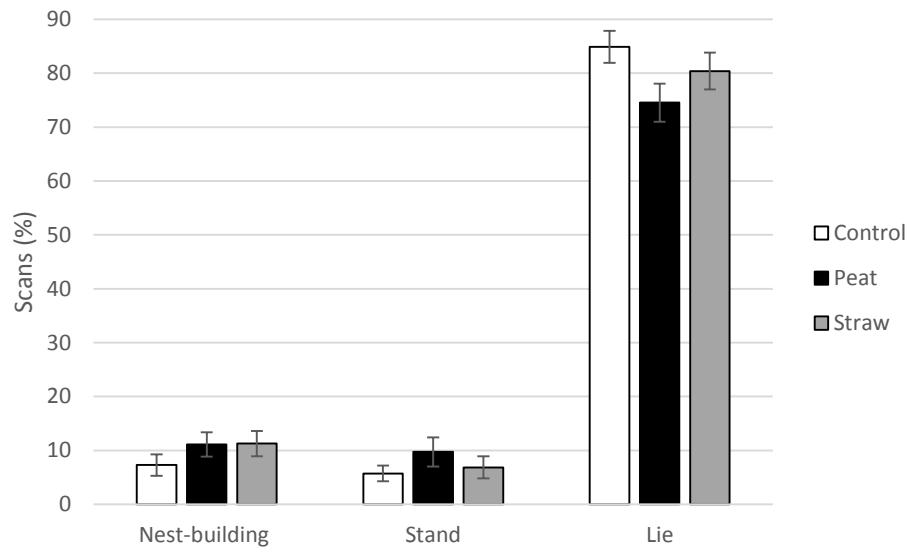
447

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



450

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



453

454 **Figure 7.** Mean (\pm 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.