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Straw vs. peat as nest-building material - the impact on farrowing duration and piglet mortality in loose-housed sows

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Abstract

Provision of nest-building material pre-partum is required by farm animal legislation in Norway, but as some farmers have problems with straw in the slurry system, alternative and finer-grained substrates could be of interest. The aim of the present study was to examine the effects of providing different nest-building materials before farrowing (peat and long-stemmed straw) on farrowing duration and piglet mortality. Sows of Norsvin Landrace x Swedish Yorkshire were loose-housed in individual farrowing pens with their litter throughout the entire lactation period, and provided with peat (n=18), long-stemmed straw (n=17), or controls (n=18), from two days before expected farrowing until farrowing. Parity ranged from 1 to 9 (mean ± SE: 2.9 ± 2.0), of which 16 were gilts. The farrowing was video recorded, and the farrowing duration registered from first to last piglet born. Dead piglets were subjected to a post mortem.

Sows provided with long-stemmed straw pre-partum had shorter farrowing duration compared to sows provided with peat or controls ($P < 0.001$). The percentage of stillborn piglets was also lowest among sows in the straw group compared to the other two groups ($P < 0.001$). Sows of parity ≥4 had longer farrowing duration than gilts and sows of parity 2-3 ($P < 0.001$). Farrowing duration ($P < 0.001$) and the percentage of stillborn piglets increased ($P < 0.001$) with an increasing number of total born piglets. Moreover, increased litter size resulted in a higher pre-weaning mortality ($P = 0.016$).

The present study shows that provision of nest-building material before farrowing is important for the birth process of the sow as it reduces farrowing duration and percentage of stillborn piglets compared to controls without relevant substrate. Although peat gave better results than the control treatment, our results suggest that long-stemmed straw is a more appropriate nest-building material.

Keywords: Nest building, Nest-building material, Loose-housed sows, Farrowing duration, Stillbirth, Piglet mortality

Highlights:

- Farrowing duration was shorter for loose-housed first parity and older sows provided with nest-building material before farrowing.
- Loose-housed sows provided with long-stemmed straw had lower percentage of stillborn piglets.
- Nest-building material had no significant effect on live born mortality.

1. Introduction

Sows are highly motivated to build a nest before farrowing (e.g. Wischner et al., 2009), and previous studies have found that providing nest-building material, such as straw, has a positive effect on nest-building behaviour (e.g. Thodberg et al., 1999; Westin et al., 2015b; Rosvold et al., 2018). When the sows are allowed to go through a process of nest building, stress is reduced (i.e. hormonal changes; e.g. Yun and Valros (2015)), and maternal behaviour improves, which may indirectly affect piglet survival (Cronin and van Amerongen, 1991; Herskin et al., 1998; Thodberg et al., 1999; Andersen et al., 2005; Yun et al., 2013; 2014). Only a few studies have actually documented a direct relationship between nest-building performance and piglet survival (Ocepek and Andersen, 2017). There are also a few studies showing reduced farrowing duration and reduced incidence of stillbirths when the sow is allowed to express nest-building behaviour with access to relevant material (Thodberg et al., 1999; Westin et al., 2015a; 2015b).

Even though straw is a material with positive impact, many farmers hesitate to use it due to the risk of bedding falling through the slatted floor and blocking the drains in the slurry system, and because of more labour needed to maintain pen cleanliness. Peat is finer grained with structural similarities to soil, and suitable for rooting, digging and pawing (Studnitz et al., 2007; Vanheukelom et al., 2011), which also are elements of nest-building behaviour. Therefore, peat is of interest as a nest-building material.

The aim of the present project was to investigate the effects of two different nest-building materials on farrowing duration and piglet mortality in individually loose-housed sows. We predicted that provision of peat or long-stemmed straw to sows before farrowing would result in a shorter farrowing duration and a lower piglet mortality compared to sows without access to nest-building material. Due to more positive behavioural effect pre-partum of straw vs. peat (i.e. slightly larger variety of nest-building behaviours, more nest building and a lower frequency of stereotypies; Rosvold et al. (2018)), we also predicted stronger effects of straw than peat on farrowing duration and piglet mortality.

2. Materials and methods

The present study was conducted in accordance with the Norwegian laws and regulations controlling experiments and procedures on live animals (Nara, 2015).

2.1. Experimental design

During three farrowing batches, 54 sows, kept loose in individual farrowing pens, were randomly (but balanced for parity) assigned to one of three treatment groups differing in nest-building material: peat, long-stemmed straw or control. There were 18 sows in each treatment group and 18 sows in each batch (6 sows per treatment per batch). The sows were video recorded from two days pre-partum until three days afterwards to document the sows` pre-partum nest-building behaviour, farrowing duration, activity and maternal behaviour. Due to abortion by one sow and failure of video recordings during farrowing of two sows, we collected information about litters and piglet mortality in 53 sows, and farrowing duration of 51 sows.

2.2. Animals, housing and feeding

The study took place at Mære Agricultural College in Steinkjer, Norway, from May to September 2014. The sows were Norsvin Landrace x Swedish Yorkshire, ranging in parity from 1 to 9 (mean ± SE: 2.9 ± 2.0), of which 16 were gilts. Mean parity in the treatment groups control, peat and long-stemmed straw were 2.9 ± 0.5, 3.0 ± 0.5 and 2.9 ± 0.5 respectively, and mean parity in the three farrowing batches were 2.7 ± 0.4, 3.3 ± 0.6, and 2.9 ± 0.4 respectively. The sows were inseminated with semen from Duroc boars. The sows were moved from group gestation pens (concrete floor covered with wood-shavings, and sows provided with rooting material and roughage daily) to individual farrowing pens at 3 to 4 weeks before farrowing. The farrowing pens had an area of 8.2 m^2, of which 2.9 m^2 was slatted flooring (Fig. 1) in one farrowing room with four rows of pens (20 pens in total). The different material treatments were distributed in all four pen rows. According to standard practice in Norway, none of the farrowings were artificially induced, and no laxatives were added to the diet prior to farrowing.

The farrowing room was insulated, and mechanically ventilated. The room temperature was regulated to 20°C, and the pen creep area was equipped with floor heating kept at 35°C and heat lamps, which were removed when the piglets were one week of age. The indoor air temperature was measured by two temperature loggers (Tinytag, Gemini Data Loggers, Chichester, UK) placed in different parts of the farrowing room. Due to variation in the outdoor temperature, indoor temperature differed between the batches. From one day before the first farrowing until four days after the last farrowing (12 days), the average temperature was 20.0°C (range 16.8°-24.7°C) for the first batch in May, 23.6°C (19.1°-31.8°C) for the second batch in July, and 20.5°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 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). In accordance with Norwegian legislation, hay (ca 0.3 kg) was distributed to all the sows once every day through the pre-farrowing and lactation periods. After farrowing and through the whole lactation period the sows were fed four times a day by the automatic distribution, and the first 7 days after farrowing once daily by hand.

After farrowing, wet straw and litter were replaced with dry litter (wood shavings). The sows were taken out of the pen on the first day after farrowing for getting some physical exercise and weight measurement. All the piglets were tooth grinded and they received iron paste orally within the first 24 h after birth (Pluss Jernstarter, 1.5 mL; Felleskjøpet). Peat enriched with iron (Pluss Smågristorv, Felleskjøpet) was also provided to all piglets daily from three days after birth (1/2 L, which increased to 1 L per litter within the first two weeks), and concentrate (FK FORMAT Kvikk, Felleskjøpet, Steinkjer, NO) from three days of age. The male piglets were surgically castrated within the first two weeks after birth. Cross-fostering was done between 12-48 h after farrowing. Litter size in this study is thus defined as: number of live born piglets + piglets fostered on – piglets fostered off. Weaning was done at around 5 weeks of age.

2.3. Post mortem examination of dead piglets

From farrowing until weaning dead piglets were subjected to a post mortem to determine cause of death, and categorized into stillborn (lungs sink when laid in water), crushed (physical signs of crushing were bruising to the body, fractions, haemorrhage or crushed internal organs), starvation (no milk in stomach), and other causes. Piglets that suffered from injuries or starvation, and not able to survive, were euthanized by the staff.

2.4. Distribution of nest-building material

Nest-building material was provided from two days before expected farrowing. In the morning, the farrowing pens were cleaned and dry wood shavings provided, which had a function as litter for hygienic purposes (0.8 kg, mainly from spruce, same amount to all pens irrespective of treatment, in accordance with Norwegian legislation). Then either 4 kg of peat (90% peat with added formic acid, acetic acid, potassium sorbate and coal; 75% water content, 7.6% crude fiber, and 2.4% ash; Fossli AS, Frosta, NO) or 2 kg of long-stemmed straw (barley) were added to 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 for nest building (Rosvold et al., 2018). 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 or 1 kg long-stemmed straw to the respective treatment groups. 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 was later than expected and dirty straw needed to be replaced.

2.5. Video recordings

A video camera sensitive to low light (Foscam F19821, 1280x720, Shenzhen, PRC), was suspended above each farrowing pen and connected to a standard PC to record the farrowing process. Farrowing was defined as started when the first piglet was expelled and ended with the birth of the last piglet.

2.6. Statistical analysis

SAS Version 9.4 (SAS Institute, Inc., Cary, NC) was used to perform statistical analyses. The effects of nest-building material (Control, Peat, Straw), parity (1, 2-3, ≥4), batch (1,2,3), litter size (continuous variable), and the interaction between material and parity and the interaction between material and batch, were analysed by a general linear model (PROC GLM) for the following, normally distributed variables: live born, litter size, mortality of live born, percentage of crushed piglets. A generalized model (PROC GENMOD) with Poisson distribution for not normally distributed variables (farrowing duration, stillborn, weaned, starvation and other causes) were also used. Descriptive statistics were obtained using SPSS Version 23 (IBM Corp., Armonk, NY).

3. Results

3.1. Farrowing duration

Mean farrowing duration was 349.9 ± 34.0 min (mean ± SE), ranging from 90-1235 min (n=51). Provision of straw resulted in significantly shorter farrowing duration than peat, whereas the longest was observed in the control group (Table 1). Farrowing duration increased with parity, as gilts (n=16) spent 262.6 ± 48.7 min on the birth process, sows of parity 2-3 (n=20) spent 362.1 ± 52.4 min, and parity ≥4 sows (n=17) 422.9 ± 71.6 min ($\chi^2_{2,35}$ = 810.75, P <0.001).

There was a significant interaction between material and parity (Table 1, Fig. 2), where sows in the control group of parity ≥4 had the longest farrowing duration, and gilts in the straw group had the shortest. Farrowing duration was quite similar between sows in the peat and straw group in parity 1 and ≥4, but a little longer in the latter group, and among sows in parity 2-3, those that received peat had the longest duration.

Increased number of total born piglets (live born + stillborn) increased the farrowing duration ($\chi^2_{1,35}$ = 226.83, P <0.001; Fig. 5a). Farrowing duration differed between the three batches (mean ± SE), 359.8 ± 57.1 min, 257.6 ± 27.6 min, and 432.4 ± 76.5 min respectively ($\chi^2_{2,35}$ = 765.07, P <0.001), and sows in batch 3 had the longest duration. There was also a significant interaction between material and batch on farrowing duration (Table 1). In the control group the farrowing duration (mean ± SE) in the three farrowing batches was 272.6 ± 79.6 min, 306.7 ± 40.6 min and 761.4 ± 186.5 respectively, in the peat

group 451.5 ± 118.5 min, 231.0 ± 51.9 min and 285.7 ± 14.7 respectively, and in the straw group 340.8 ± 90.9 min, 230.6 ± 52.3 min and 305.0 ± 64.1 min respectively.

3.2. Piglet mortality

3.2.1. Overall production and piglet mortality results

The 53 sows gave birth to 845 piglets in total; 15.9 ± 0.5 (mean ± SE) total born per litter (ranging from 6 to 24). Of these 794 were live born (15.0 ± 0.5) and 51 stillborn (0.9 ± 0.2). Stillbirths occurred in 28 litters (52.8%), and the mean percentage of stillborn piglets (% of total born) was 5.7 ± 1.0% (ranging from 0-28.6%).

The total mortality of live born piglets (% of litter size) was 18.0 ± 1.9%, ranging from 0-55%, and 14.2 ± 1.7% of the piglets died of crushing, 2.8 ± 0.8% of starvation and 1.0 ± 0.3% of other causes. Within the first three days after farrowing, 68.6% of the mortality had occurred. Total number of weaned piglets per sow was 12.0 ± 0.3 (ranging from 6-15).

In 20 out of 53 litters (37.7%), the mortality of live born piglets was >20% (ranging from 21.1% to 55.0%). In 14 litters (26.4%) the total mortality of live born piglets was <8%, and in eight litters there was no mortality (Fig. 3).

3.2.2. Effects of nest-building materials and parity on piglet mortality

Sows provided with straw had the lowest percentage of stillborn piglets, significantly lower than peat and controls, and sows provided with peat had lower percentage of stillborn piglets than controls (Table 1). Nest-building material had no significant influence on total mortality of live born piglets or on the different mortality causes. The number of live born piglets, litter size and the number of piglets at weaning were not significantly different between the treatments.

Parity had no effect on stillbirths, total piglet mortality, any of the mortality causes or number of weaned piglets. The number of live born piglets increased with increasing parity; Parity 1: 13.1 ± 0.7, Parity 2-3: 15.7 ± 0.7, Parity ≥4: 16.0 ± 0.9 ($F_{2,14}$ = 4.70, P = 0.015), and also litter size; Parity 1: 13.1 ± 0.7, Parity 2-3: 15.5 ± 0.6, Parity ≥4: 15.8 ± 0.9 ($F_{2,14}$ = 4.72, P = 0.015).

There was an interaction between material and parity regarding percentage of stillborn piglets (Table 1, Fig. 4). Sows of parity ≥4 provided with long-stemmed straw pre-partum had the lowest percentage of stillborn piglets, whereas first parity sows in the control group had the highest (Fig. 4). There was also a tendency for an interaction between material and parity on mortality of live born piglets (Table 1).

3.2.3. Litter size and piglet mortality

Increased number of total born piglets resulted in increased percentage of stillborn piglets ($\chi^2_{1,37}$ = 21.74, P <0.001; Fig. 5b). The litter size (live born ± cross-fostered) was 14.9 ± 0.4 piglets (6-24), and increased litter size resulted in increased mortality of live born piglets ($F_{1,15}$ = 6.37, P = 0.016; Fig. 5c),

and a tendency to more crushed piglets ($F_{1,15}$ = 3.35, P = 0.075). Starvation and other causes of death were not significantly influenced by litter size. Increased litter size resulted in a higher number of weaned piglets ($\chi^2_{1,37}$ = 8.96, P = 0.003).

3.2.4. Batch and piglet mortality

Total born piglets in the three farrowing batches were 15.9 ± 0.8, 14.8 ± 0.9 and 17.1 ± 0.9 respectively, not significantly different. Farrowing batch had a significant effect on percentage of stillborn piglets (mean % ± SE), highest in the first batch; batch 1: 6.6 ± 1.8%, batch 2: 4.7 ± 1.9%, batch 3: 5.7 ± 1.4% ($\chi^2_{2,37}$ = 17.34, P < 0.001). An interaction effect between material and batch on stillbirths was found (Table 1). In the control group the percentage of stillborn piglets (mean ± SE) in the three farrowing batches was 9.5 ± 4.3%, 4.7 ± 2.3% and 10.2 ± 3.0% respectively, in the peat group 5.6 ± 2.6%, 7.5 ± 4.6% and 4.8 ± 1.9% respectively, and in the straw group 4.7 ± 2.2%, 1.3 ± 1.3% and 2.1 ± 1.4% respectively.

There were significant differences in live born mortality between the three batches, 13.7 ± 2.9%, 22.2 ± 4.0%, and 18.4 ± 2.7% respectively ($F_{2,15}$ = 3.99, P = 0.027), highest in the second batch, and significant differences regarding crushing in the three batches, 10.5 ± 2.7%, 18.7 ± 3.7%, and 13.8 ± 2.4% respectively ($F_{2,15}$ = 3.57, P = 0.038), also highest in the second batch. With respect to starvation, other causes of death and number of weaned piglets there were no significant differences.

4. Discussion

Nest building is a part of the sow`s preparation for motherhood. Although nest-building behaviour is largely motivated by internal processes, relevant external stimuli, such as straw, provided at least from around 12 hours pre-partum (Castrén et al., 1993; Andersen et al., 2005), will encourage the sows to spend more time on nest building and express a larger variety of behavioural elements (Westin et al., 2015b; Rosvold et al., 2018). As predicted, the presence of nest-building material resulted in a lower percentage of stillborn piglets compared to the control group, in accordance with previous studies (Westin et al., 2015a), but the effects of material differed between sows of different parity. Percentage of stillborn piglets were lowest for multiparous sows provided with long-stemmed straw, whereas sows in the peat and control groups had a quite similar percentage of stillborn piglets, suggesting that straw is a better material for nest building in experienced sows. However, for first parity sows, the percentage of stillborn piglets did not differ much between the peat and the straw treatment, suggesting that type of material is less crucial for stillbirths in these sows.

As predicted, farrowing duration was shorter for sows provided with nesting material than sows in the control group. However, the effects of material was not significant for sows of parity 2 and 3, and the reason for this is unclear. A large number of different studies have documented an association between farrowing duration and the probability of stillbirths (Borges et al., 2005; van Dijk et al., 2005; Canario

et al., 2006; Oliviero et al., 2010; Björkman et al., 2017; Thorsen et al., 2017). The risk of hypoxia is higher during a prolonged farrowing, because of damage or occlusion of the umbilical cord, or a placental detachment, which in turn gives a higher risk for stillbirths (van Dijk et al., 2006). Oxytocin release is of importance for effective contractions of the uterus and rapid birth of the piglets (Algers and Uvnäs-Moberg, 2007), and the process of nest building in sows results in elevation of oxytocin levels and a reduction of stress hormones (Yun et al., 2013). It is likely that this is the mechanism explaining why we have these effects on stillbirths and farrowing duration. The control sows had the longest mean farrowing duration, and it is possible that the lack of opportunity to fulfil the behavioural need of nesting induced stress, which in turn led to a prolonged farrowing. These sows also had the highest frequency of stereotypies before farrowing (Rosvold et al., 2018), indicating more frustration and stress.

In accordance with some previous studies (Cronin et al., 1993; Björkman et al., 2017), farrowing lasted longer in sows of higher parities in the present study. Aging of the uterus in older sows may reduce muscle tone (Marchant et al., 2000; Borges et al., 2005; Canario et al., 2006) and lead to less efficient expulsions and prolong the farrowing process. Another explanation could be that the farrowing duration also increased with a larger number of piglets born, as seen in earlier research (Rens and Lende, 2004; van Dijk et al., 2005), and sows of higher parities gave birth to larger litters in the present study.

In the present study, provision of nest-building material did not affect survival of live born piglets in contrast to a recent study by Swan et al. (2018), and to previous work were a high level of nest-building behaviour pre-partum was associated with lower piglet mortality (Cronin and van Amerongen, 1991), and with no crushing (Andersen et al., 2005). It is possible that the effect on mortality is more dependent on how much time the sows spend on nest building, as loose-housed sows with a high score for nest-building activity had a lower mortality of live born piglets and a higher number of piglets weaned (Ocepek and Andersen, 2017; Ocepek et al., 2017b). Effects of nest-building material are also likely to depend on the amount and the timing of provision. In the present study, we had a limited amount of material. It is possible that free access to nest-building material, with individual needs taken into account, would have given stronger effects, as other studies used ad libitum access from a hayrack the last 24 to 48 hours before expected parturition (e.g. Andersen et al., 2005; Ocepek and Andersen, 2017). Use of hayrack can simplify management of straw as the sow can pull out the amount she needs without spoiling too much on the floor. Parity had no significant effect on mortality of live born piglets in the present study, in accordance with a few studies (Knol et al., 2002; Carney-Hinkle et al., 2013), while others have documented the opposite (e.g. Marchant et al., 2000; Weber et al., 2009; Andersen et al., 2011; Westin et al., 2015a). It is difficult to explain the divergent results on live born mortality with respect to parity, other that the causes are highly multifactorial.

A higher number of piglets born increased the percentage of stillborn piglets in the present study, which agrees with previous work (Marchant et al., 2000; Borges et al., 2005; Canario et al., 2006). According to Herpin et al. (2001), larger litters are associated with a longer farrowing duration and a higher risk of hypoxia. Live born piglet mortality and the incidence of crushing (tendency) increased with increasing litter size, in accordance with previous work (Weary et al., 1998; Marchant et al., 2000; Pedersen et al., 2006; Weber et al., 2009; Andersen et al., 2011; Ocepek et al., 2017a). Consistent with earlier work (e.g. Andersen et al., 2011; Kielland et al., 2018), the main cause of death in the present study was crushing. Crushing often occurs immediately after the sow has nosed or oriented towards the piglets, and therefore being aware of their presence. Maternal infanticide by crushing is thus not accidental in many cases, but related to a less protective mothering style (Andersen et al., 2005), and can be considered as a strategy of litter reduction in pigs, especially in larger litters (Andersen et al., 2011; Ocepek et al., 2017a). High litter size also results in more piglets failing to access a teat during a nursing bout, due to a higher sibling competition in larger litters, which is a risk for starvation-related piglet mortality (Andersen et al., 2011; Ocepek et al., 2017a).

Farrowing duration was longer in the third and first batch. It is possible that a higher number of total born piglets in these batches was a contributing part of the result. Live born mortality and crushing were higher in the second batch when the temperature was substantially higher than in the other two. More piglets tend to be crushed during the hot season (Weber et al., 2009). Moreover, when surrounding temperatures are above the sow`s upper critical temperatures, her appetite is reduced, with a negative consequence for milk production (Quiniou and Noblet, 1999; Cabezón et al., 2017), which is in turn negative for piglet performance (Silva et al., 2018).

The mortality of live born piglets was 18% in the present study, in accordance with Kielland et al. (2018) of 18.2%, and slightly lower than the results from Westin et al. (2015a) of 19.5%. The result is higher than the national average in 2014 of 14.2% (Ingris, 2015), and may be explained by the higher number of live born piglets in our study compared to the national average; 15.0 vs. 13.2 piglets (Ingris, 2015). Almost 70% of the mortality occurred within the first three days after birth, corresponding with previous studies (e.g. Marchant et al., 2000; Westin et al., 2015a; Kielland et al., 2018).

5. Conclusions

The results of our study showed that provision of long-stemmed straw or peat to loose-housed sows before farrowing resulted in a shorter farrowing duration compared to controls in sows of most parities. The percentage of stillborn piglets were lower for sows provided with long-stemmed straw compared to both peat and control. The results in the present study thus strengthens the conclusion that long-stemmed straw is best suited as nest-building material.

Conflict of interest

The authors have no conflicts of interest to declare.

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414

Figure captions

Table 1. Litter traits and mortality causes (mean ± SE): effects of nest-building material, the interaction between nest-building material and parity, and the interaction between nest-building material and batch.

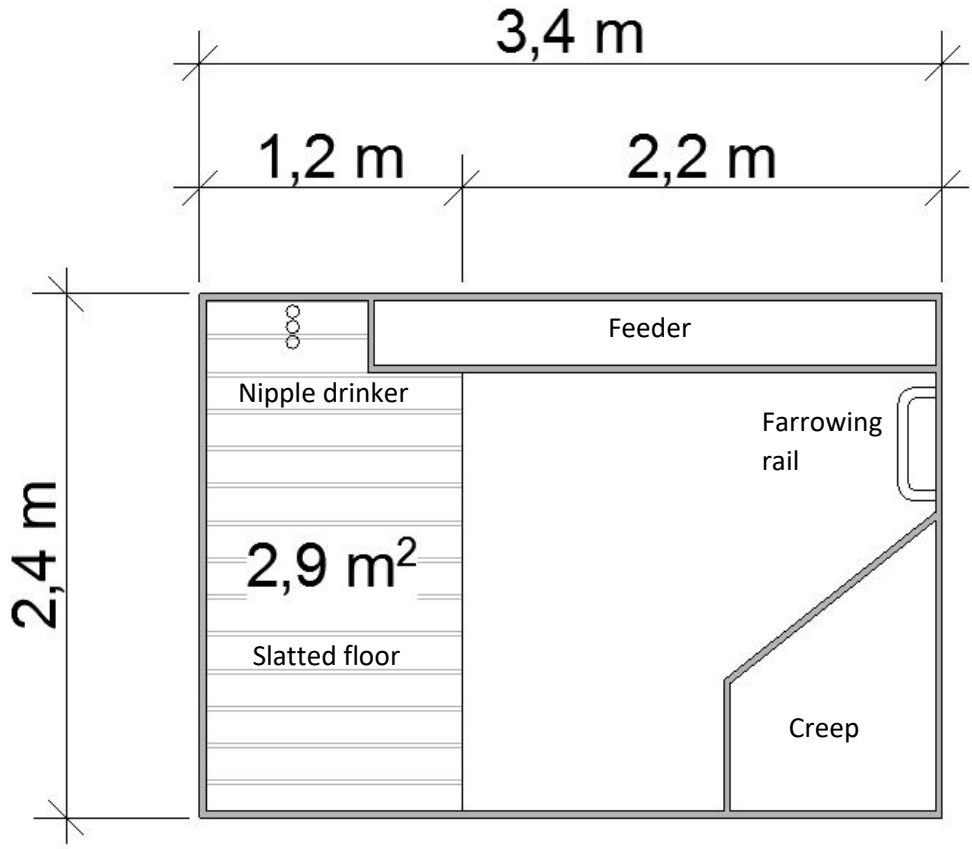
Fig. 1. The design of the farrowing pen.

Fig. 2. The interaction between material and parity regarding farrowing duration, min (mean ± SE).

Fig. 3. Frequency distribution of the mortality of live born per sow (%), n=53.

Fig. 4. The interaction between material and parity regarding stillborn piglets (mean % ± SE).

Fig. 5. (a) Farrowing duration (min) in relation to total born piglets (live born + stillborn), n=51. (b) Stillborn piglets (mean %) with respect to total born piglets, n=53 litters. (c) Mortality of live born piglets (%) with respect to litter size (live born ± cross-fostered), n=53 litters.



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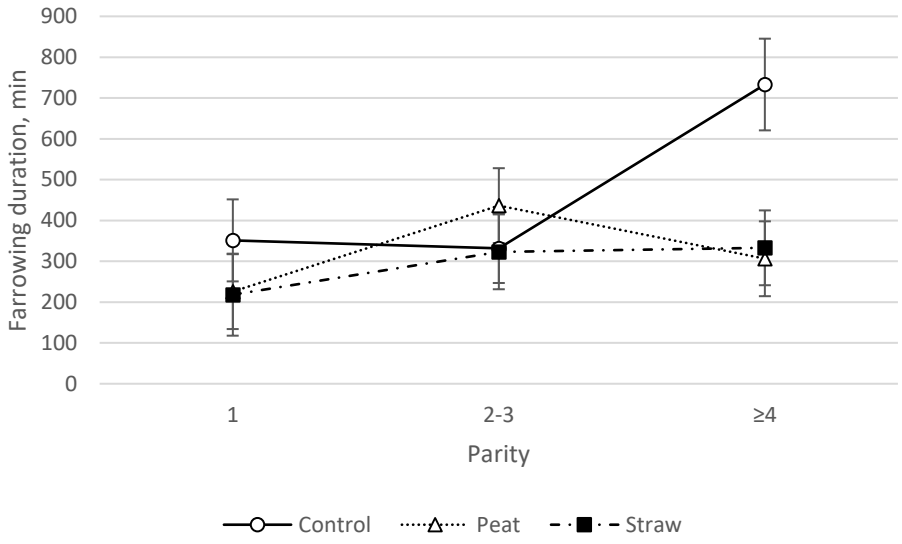
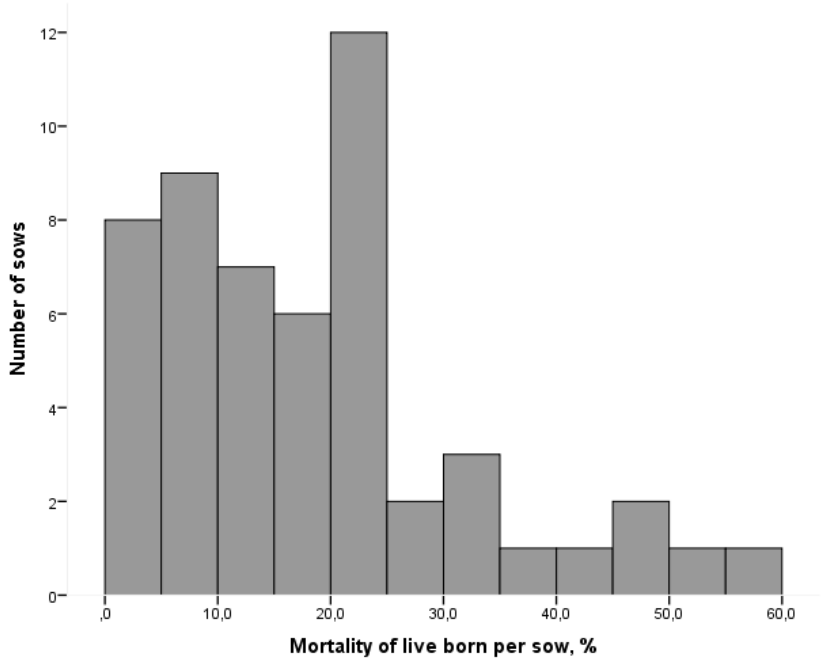


Fig. 2. The interaction between material and parity regarding farrowing duration, min (mean ± SE).



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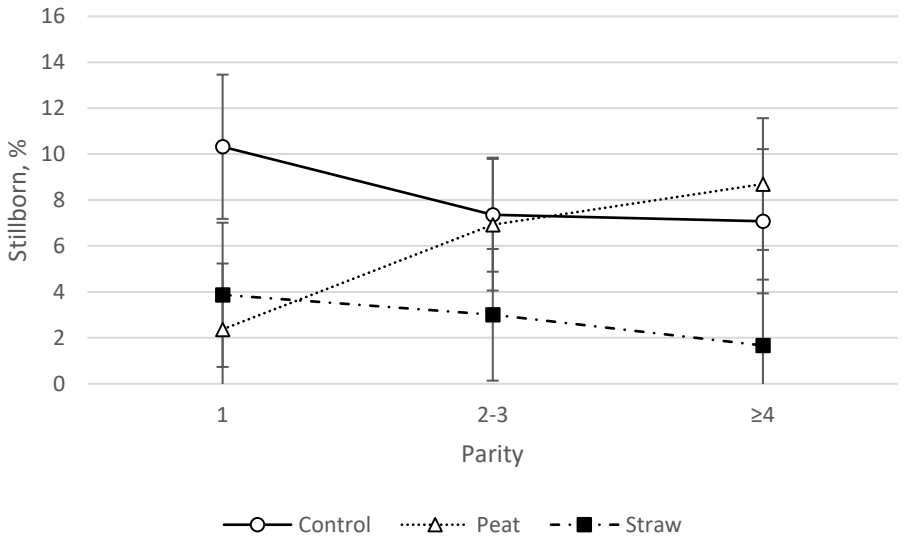

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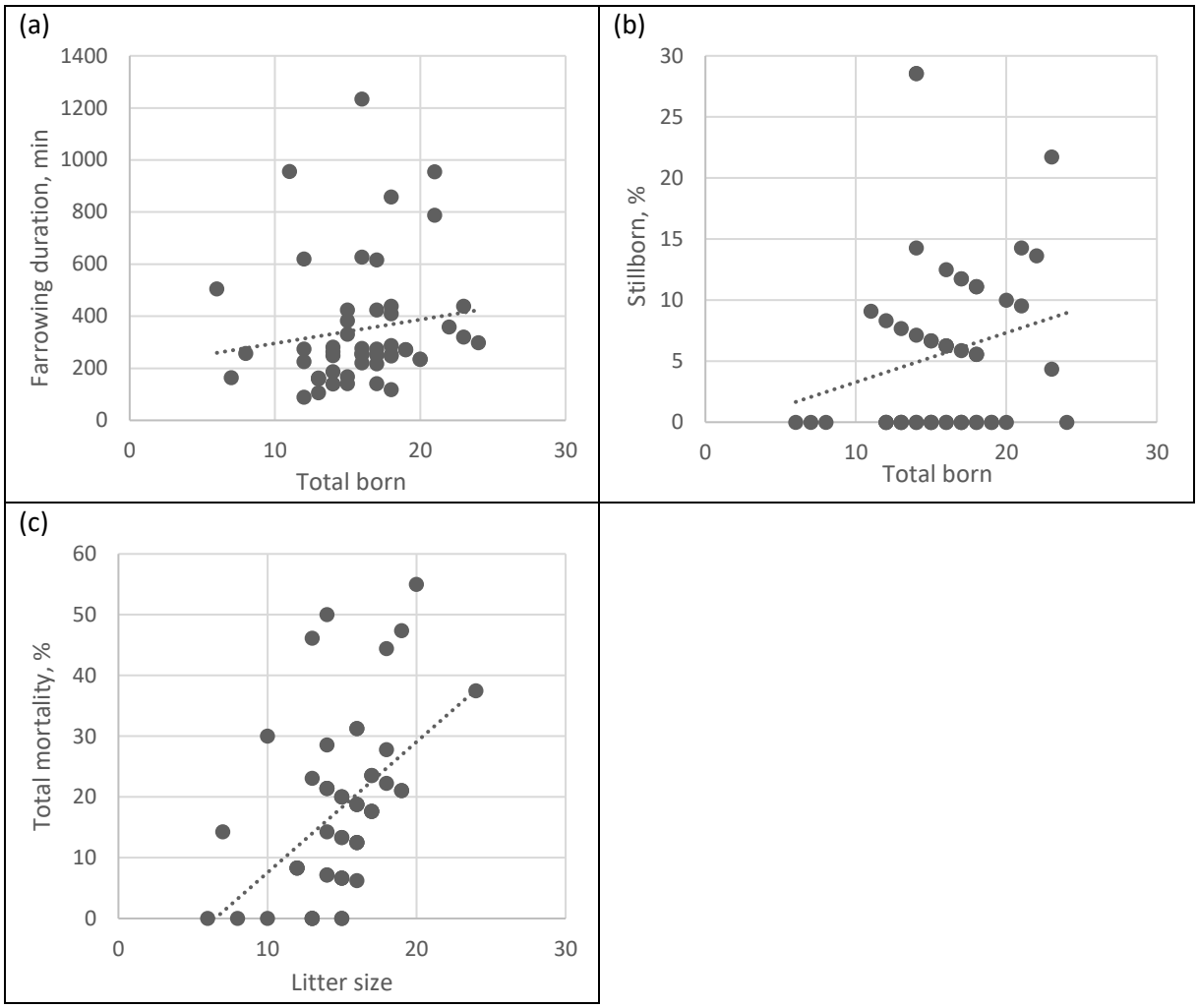

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Table 1. Litter traits and mortality causes (mean ± SE): effects of nest-building material, the interaction between nest-building material and parity, and the interaction between nest-building material and batch.

	Material					Material x Parity		Material x Batch	
	Control (n=18)	**Peat (n=18)**	**Straw (n=17)**	**$\chi^2_{2,37}$**	**P-value**	**$\chi^2_{4,37}$**	**P-value**	**$\chi^2_{4,37}$**	**P-value**
Farrowing duration, min	438.1±82.6[a] (n=16)	322.7±46.7[b] (n=18)	295.8±41.1[c] (n=17)	262.72[1]	<0.001	307.31[2]	<0.001	991.28[2]	<0.001
Stillborn, %[3]	8.1±1.9[a]	6.0±1.8[b]	2.8±1.0[c]	44.79	<0.001	39.22	<0.001	20.09	<0.001
Live born	14.4±0.9	15.8±1.0	14.7±0.7	$F_{2,14} = 1.06$	0.3573	$F_{4,14} = 1.09$	0.3764	$F_{4,14} = 1.94$	0.1229
Litter size[4]	14.4±0.8	15.4±0.9	14.8±0.6	$F_{2,14} = 0.72$	0.493	$F_{4,14} = 0.69$	0.601	$F_{4,14} = 1.52$	0.215
Weaned	11.7±0.6	11.9±0.6	12.3±0.5	0.44	0.803	2.27	0.687	1.26	0.8688
Live born mortality,%[5]	16.8±3.8	21.1±3.1	16.1±2.8	$F_{2,15} = 0.56$	0.574	$F_{4,15} = 2.27$	0.080	$F_{4,15} = 1.05$	0.395
Crushed,%	12.4±3.2	16.3±2.8	14.0±2.7	$F_{2,15} = 0.43$	0.654	$F_{4,15} = 1.29$	0.293	$F_{4,15} = 0.98$	0.432
Starvation,%	3.3±1.6	3.7±1.6	1.4±0.7	-[6]	-[6]	-[6]	-[6]	-[6]	-[6]
Other causes,%	1.1±0.6	1.1±0.6	0.7±0.5	-[6]	-[6]	-[6]	-[6]	-[6]	-[6]

[1] $\chi^2_{2,35}$

[2] $\chi^2_{4,35}$

[3] % of total born (live born + stillborn).

[4] Litter size: live born ± cross-fostered piglets.

[5] % of litter size.

[6] Number of observations too low to analyse.

[a-c] Means with superscripts are significantly different (P <0.01).