Using movement sensors to detect the onset of farrowing

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\begin{abstract}
Farrowing is an important economic phase in pig production. In modern pig herds the lack of surveillance at farrowing is a current animal health and welfare problem. One of the clearest signals of impending farrowing is the sow’s increased activity caused by nest-building behaviour. Six farrowing crates were equipped with a system to monitor sow activity. Each crate was equipped with a photocell (E3F2, Omron Europe, The Netherlands) placed at a height of 0.6 m. In three crates, a thin-film ferroelectret force sensor (L-series, Emfit Ltd., Finland) was also installed under the sows. The force sensor measured the overall movement of the sows and the photocells were used to detect whether they were lying down or standing up.

The mean time sows spent standing was significantly higher in the 24-h interval prior to farrowing than in all the other 24-h intervals monitored ($p<0.05$). The force sensor recorded a significantly higher number of peaks in the 24-h interval prior to farrowing than in all the other 24-h intervals monitored ($p<0.05$). Thus, our results indicate that these sensors can serve to measure sow activity with impending parturition and both sensors can provide similar information.

\end{abstract}

1. Introduction

Over the past few decades, in order to optimise sow fertility research in the field of animal reproduction has focused mainly on ovulation and pregnancy rates. During each farrowing, however, an average of one piglet is lost due to problems in the process of parturition, and an additional piglet is lost within a few days after birth (Edwards, 2002). Therefore, focusing research on farrowing is not only economically important but it can improve the health and welfare of the dam and her offspring. On the 764 farms included in the national litter-recording scheme in Finland, total piglet mortality averaged 22.4\% (the mortality of live-born piglets was 13.9\%) in 2001 (Sternberg, 2002). For sows, 2768 treatment cases for farrowing problems on 942 farms included in the health recording scheme were recorded that same year (Rautala, 2002). Moreover, 15.4\% of all veterinary treatments in the herds participating in the scheme were due to post partum dysgalactia syndrome (PPDS). These data clearly show that problems during and shortly after parturition can seriously compromise animal health and affect the production economy of pig farms.

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In modern pig herds, the lack of surveillance at farrowing is a current problem. Increased intensity of pig production has inevitably raised challenges during farrowing. Large litter sizes may result in delivery problems often associated with dystocia (Smith, 1997). Also, in large litters some of the piglets are more likely to be weaker and to require assistance soon after birth. Parturition should therefore be closely supervised in order to minimize losses due to problems with sows or piglets. Some studies have demonstrated that human supervision at farrowing can halve the piglet perinatal mortality (Holyoake et al., 1995; White et al., 1996). However, constant human supervision of all the farrowing sows has not been considered feasible, due to the high cost of labour and the working hours required.

Currently, research is being carried out in the field of automatic growth control of pigs (Parsons et al., 2007). However, systems for automatically detecting farrowing do not exist today. Prediction of the onset of farrowing with a degree of accuracy could improve herd management and consequently improve the supervision of parturition. In sows, certain physiological and behavioural parameters are clear signals of impending parturition. Some of these parameters have been studied around farrowing, including the rise in body temperature (King et al., 1972; Elmore et al., 1979), the rise in respiratory rate (Hendrix et al., 1978) and behavioural changes (Hartsock and Barczewski, 1997; Bradshaw and Broom, 1999). All these changes occur 24–36 h before farrowing starts. Thus, monitoring the variation in these parameters during the last days of pregnancy could likely serve to predict the onset of farrowing. One of the clearest signals of approaching farrowing is the increased activity due to nest-building behaviour. Hartsock and Barczewski (1997) found that rooting, pawing, turning and walking behaviour in sows kept in pens or crates begins to increase 24 h prior to farrowing.

The aim of our study was to test different movement sensors to measure changes in the farrowing-related activity of crated sows. These sensors could also be used to develop an automatic alarm system to help farmers to predict the onset of parturition. This would allow for more effective work organisation, reduce losses due to farrowing complications and weak piglets, and thus improve animal welfare.

2. Materials and methods

2.1. Animals and measurements

Six farrowing crates were equipped with a system to monitor sow activity. Altogether, 18 sows were placed in the crates a week before the expected farrowing and were fed twice daily at approximately 10:00 and 17:00. During pregnancy, the sows were kept loose-housed in groups of 15–20 animals. The crates were 800 mm wide and 2 m long. Three crates were equipped with a thin-film ferroelectret force sensor (L-series, Emfit Ltd., Finland) sealed between two rubber carpets placed on the floor under the sows. The Emfit L-series force sensor is a cellular, biaxially oriented polypropylene film coated with metal electrodes. A force affecting the sensor causes a change in film thickness resulting in a change in the charge of the film, which can be measured as a voltage signal (Paajanen et al., 2000). The signal is proportional to the force acting on the sensor, which operates linearly (Pastell et al., 2006). Thus, when the sow is not moving, the sensor produces no signal and the movement appears as peaks in the data. A photocell (E3F2, Omron Europe, The Netherlands) and a reflector, both placed at a height of 0.6 m, were also installed in each of these three crates. The other three crates were equipped with photocells only. The beam of the photocell was pointed so that the sows intercepted it while standing up and did not while lying down.

The force sensor measured the overall movements of the sows, whereas the photocells were used to detect whether the sow was lying down or standing up. All sensors were connected to two USB data acquisition units (NI USB-6008, National Instruments, USA), using a single-ended connection for the photocells and a differential connection for the force sensors. The data were logged continuously with a dedicated computer programme made with LabView® v7.1 (National Instruments, USA). The measurement rate for the photocells was set at 10 Hz and at 50 Hz for the force sensors. The appropriate frequencies were determined experimentally by comparing the movements of the animals to the measured data, and were set so that all movements were identified with the system.

A video recording system was installed to assess the exact start of each parturition. We place three video cameras were placed on the wall 3 m behind the farrowing crate in order to obtain a good view and to determine the birth of the first piglet. Cameras were connected to a Digital Video Recorder (TP-S1016DR, Topica, Taiwan), which stored the images on a hard disk. The herd’s lights were turned off from 18:00 to 06:00 during this period; we used two small spot lights to enable video recording.

2.2. Data analysis

A total of ten sows were successfully monitored using the photocells, and four of these were with force sensors. The parity of these sows ranged from one to six, with an average ± SD of 3.4 ± 1.5 (n = 10). Of all the 18 sows monitored, eight sows were excluded from the analysis due to technical failures. The main cause of exclusion was a loss of signal, such as incorrect pointing of the photocell beam towards the reflector or substantial damage to the force sensor. We excluded the sows when the loss of signal exceeded 20% of the entire interval, ranging from 120 h before to 72 h after farrowing. For the sows in the study, the loss of data averaged 9%.

The time when the sow was lying down and standing up appears in the raw data from the photocell (Fig. 1). When the sow was lying down, the signal was close to 0 V, but when she was standing up and intercepted the photocell beam, the signal approached 1.5 V. The duration of standing (min h⁻¹) and the frequency of getting up and lying down (number h⁻¹) were calculated.

The overall movement of the sow was measured with the force sensor and appears as peaks in the raw data (Fig. 1). The intensity of the peaks is proportional to the force applied on the sensor (Pastell et al., 2006). There was some amount of...
drifting in the force sensor data due to temperature changes, and so it was detrended in 24-h sections by subtracting the average value from the data. The activity was simply analysed by calculating the frequency of peaks (peaks h\(^{-1}\)) exceeding 0.1 V. This limit was imposed so that very small movements of the sow, while lying down or standing, would not be considered a proper activity.

The exact onset of farrowing was verified by examination of the video recording. Therefore, considering the beginning of farrowing as 0, all the previous and subsequent periods of time were divided into intervals of 24 h.

The video recording was used to validate the efficiency of the sensors. Random video intervals of 1 min each hour, each day for each sow, were verified to confirm whether the presence of a recorded signal or peak corresponded effectively to standing or movements. Similarly, random video intervals of 1 min were verified to confirm whether the absence of a signal or a peak was effectively due to the absence of standing or movements.

### 2.3. Statistical analysis

The data from the photocells, as the mean duration of standing (min h\(^{-1}\)) and the mean frequency of getting up and lying down (number h\(^{-1}\)), as well as the data from the force sensor, such as the mean frequency of peaks exceeding 0.1 V (peaks h\(^{-1}\)), were subjected to one-way analysis of variance with repeated measurements (GLM repeated measurements). Regarding the photocell, the within-subject factor was considered to be the mean duration of standing (min h\(^{-1}\)) or the mean frequency of getting up and lying down (number h\(^{-1}\)) for all the 24-h intervals before and after farrowing. For the force sensor, the within-subject factor was the mean frequency of peaks exceeding 0.1 V (peaks h\(^{-1}\)) for all the 24-h intervals before and after farrowing. Parity was included in the model as a covariate. Statistical analysis was performed with SPSS\textsuperscript{®} software, version 15.0 (SPSS\textsuperscript{®} Inc., Chicago, IL, USA).

### 3. Results and discussion

The mean duration of standing was significantly higher in the 24-h interval prior to farrowing than in all the other 24-h intervals monitored (\(p<0.05\); \(n=10\); Fig. 2).

The mean frequency of the getting up and lying down movements was significantly higher in the 24-h interval prior to farrowing than in all the other intervals (\(p<0.05\); \(n=10\); Fig. 3), except for the last two intervals after farrowing (\(p>0.05\)).

The force sensor recorded a significantly higher number of peaks in the 24-h interval prior to farrowing than in all the other 24-h intervals monitored (\(p<0.05\); \(n=4\); Fig. 4).

A representative sample of the raw data of the force sensor and the photocell with one sow during a 24-h period appears...
in Fig. 1. This shows that both sensors produced comparable information about the activity of the animal. When the sow was standing up (detected by the photocell signal), the force sensor recorded a high frequency of peaks. The similarity of the information about the activity of the sow, obtained from both sensors, is demonstrated in Fig. 5.

For the photocells, 98.3% of all the verified random video intervals with a recorded signal corresponded to sows standing. Of all the verified random video intervals without a recorded signal, 100% of the data corresponded to sows not standing.

For the force sensor, the presence of a peak corresponded to a real overall movement of the sows for 99.7% of all the verified intervals; an absence of peaks corresponded to an absence of movement in 100% of all the verified intervals.

Therefore, we were able to successfully record the activity of sows in farrowing crates using photocells and force sensors.

From 4 to 2 days before farrowing, sow activity averaged less than 8 min h\(^{-1}\). Except for the feeding times, before farrowing the sows spent most of the time lying down. As the farrowing approached, the activity of sows increased slightly. However, it is more than doubled the day before farrowing. This is in agreement with the results of several studies that have described the presence of nest-building behaviour in sows (Hartsock and Barczewski, 1997; Bradshaw and Broom, 1999).

Our results show that the photocells and the force sensor can be used to develop an activity-based system to predict farrowing in crated sows. The future implications of the wide use of such a system are promising. At present, especially in large herds, most farrowing occurs with no supervision. Since the gestation length in the sow can range from 105 to 125 days (Sasaki and Koketsu, 2007), parturition is difficult to predict in practice. The sows should be checked at regular intervals during many days before the expected farrowing, which is costly in terms of labour. The prediction of farrowing using movement sensors could help the farmers to improve their surveillance during these hours, thus benefiting the sows, the piglets and the economy.

Although there are other physiological parameters that could serve as predictors of farrowing (such as body

![Fig. 3 - The mean frequency and standard deviation of standings (number h\(^{-1}\)) by all the sows (n = 10) recorded with the photocell sensors, during the different 24-h intervals before and after farrowing (black arrow).](image)

![Fig. 4 - The mean and standard deviation of overall movements (peaks h\(^{-1}\)) recorded by the force sensors in all sows (n = 4), during the different 24-h intervals before and after farrowing (black arrow).](image)

![Fig. 5 - The activity of one sow on 4 days before farrowing, calculated from the force sensor (+) and the photocell (●). The sow is clearly active mainly around the two feeding times (10:00 and 17:00).](image)
temperature and respiratory rate) we think that the increased activity due to nest-building behaviour is more reliable and can be measured under practical conditions. Measuring other parameters in connection with movement may improve the predictability of the beginning of farrowing but more information is required on the accuracy of these parameters and how costly they are to measure.

Some of the sensors used in this study, such as the photocells, are inexpensive and can easily be installed in the farrowing crates without disturbing the animal. Moreover, the reliability of monitoring sow movements is also supported by the tendency for crated sows to show extremely habitual behaviour. During the experiment, sows were shown to be rather inactive throughout the entire day, until the nest-building behaviour began. Except for feeding times, the sows spent most of their time lying down during the 5 to 2 days before farrowing. In the data from both sensors, we found a high activity count every day around the feeding times, but activity was very low during the rest of the day. The situation was completely different during the 24-h interval before farrowing, during which a clear increase was observed in activity independent of the feeding times.

Visual verification of the data reveals that the information obtained from both sensors is comparable. Although additional studies are needed, it appears that the activity of sows in crates could be effectively monitored with only one of these two sensors. The photocells were easier to fit in the farrowing crate, were cheaper, and encountered fewer technical problems than the force sensors. If protected from urine the force sensor itself is durable although the connectors appear to be weak points and will need extensive protection in further usage. As a result the photocells should be the first choice for the future development of an electronic system to predict farrowing.

4. Conclusions

An activity-monitoring system for sows in farrowing crates using photocells and force sensors has been established. Our results indicate that the system can reliably measure the activity of crated sows. The results of this work enable the development of a system to predict the onset of parturition, perhaps combined with other parameters such as the respiratory or the body temperature.

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