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Monitoring body temperature and activity in sows using a sensor-based telemetric system

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Abstract

Improving estrus detection accuracy could improve sow conception rates, leading to higher production efficiency. Current observation-based estrus detection practices are labor intensive and less accurate. Around estrus, body temperature and activity change. Therefore in this study a telemetric monitoring system for body temperature and activity was tested. Firstly Templant2 sensors (TeleMetronics) were validated under lab conditions for temperatures from 35°C to 45°C, using a water basin with a Julabo heater and a P600 thermometer. Activity measurements were validated with the sensors attached to a stick, simulating sow movements. Secondly, sensors were attached externally to 4 gilts and 4 sows for 30 minutes, testing functionality. Thirdly, activity of sows was recorded manually for 3 days around estrus. Results showed that under lab conditions temperature results of sensors, heater and thermometer were highly correlated (linear regression, R^2=0,96; slope 1,1). Simulated activities corresponded consistently with peaks in sensor values. Activity was measured reliably with the sensor attached externally to the sows. On the farm, sows showed more activity (manual observations, $P<0.05$ for standing up, lying down, sitting down and walking) the day before insemination. We conclude that monitoring activity and body temperature is a promising tool for estrous detection in sows.

Keywords: pigs, estrus detection, temperature, activity

Introduction

Estrus detection in sows is important in pig husbandry. Financial losses due to non-productive days can be high, and estrus detection is taking up approximately 30% of the overall labor input. (Freson et al., 1998). Failure to accurately detect estrus has the greatest impact on farrowing rate and litter size (Kraeling and Webel, 2015). In current European and American practice, sows are artificially inseminated and estrus detection is done manually (Knox, 2016). The primary estrus detection method is the Back Pressure Test (BPT, Willemse and Boeder, 1966), where sow movement is assessed by the producer or animal caretaker when pressure is applied to the back and sides. The sow is considered in estrus when she shows a full standing reflex, meaning that the sow is immobile in response to back pressure (Cornou, 2006).

Precision Livestock Farming technology may improve estrus detection accuracy and increase sow conception rates, leading to higher production efficiency and less labor. Different techniques have been tested so far, based on monitoring physical activity or temperature (Cornou, 2006). Mean daily activity of sows peaks just before standing estrus (Freson et al., 1998, Cornou, 2006). The activity of sows kept in individual sow pens can be measured by using infrared sensors mounted on the pen, in front of the sow. For group housed sows, automated recording of visits to the boar pen with a 'ticket window', or a separate detection area where the sow can have nose contact with a boar and the number of visits is scored automatically, is possible. Another possibility to measure activity, is using an accelerometer on the back of the sow (Cornou, 2006; Ostersen, 2010). Sensitivity of the tested systems varied from 53% to 87%, while sensitivity of manual estrus detection is reported to be 93% (Cornou, 2006). Body temperature of sows deviates around estrus. This physiological trait can be measured automatically with a sensor implanted in the ear base or inserted in the vagina, or by infrared thermography of the vulvar area. Ear base temperature seems to rise before standing estrus (approx. +1 °C), while vaginal temperature seems to drop (appr. -0.5 °C) (Cornou, 2006). Vulvar temperature seems to rise before estrus (Simões et al., 2014) and drop before ovulation (-1.5 °C) (Scolari et al., 2011). However, results from different studies show conflicting results (Cornou et al., 2006; Soede et al., 1997).

Assuming that around estrus, body temperature and activity of sows change, in this study a sensor-based telemetric system that monitors both body temperature and activity was tested. We hypothesized that combining activity and temperature measurements will improve sensitivity of automated estrus detection in sows. The aim of this study was twofold: first, to test whether Templant2, a telemetric monitoring system for body temperature and activity, functioned reliably under lab and farm conditions, and second, to study changes in behavior around estrus in sows kept in cubicles. This pilot study was the first step in developing an automated estrus detection system for sows based on temperature and activity.

Material and methods

In this study, Templant2 sensors (TeleMetronics Biomedical[1], Wageningen, The Netherlands) were used, containing an NTCS0603E3104FXT Thermistor temperature-sensitive resistor (VISHAY), a BMA250 accelerometer (Bosch), a PIC18LF14K22 controller (Microchip), a 40 MHz crystal (LFIQXC42) radio transmitter and a 170 mAh battery (Varta). Five levels of sensitivity of the activity sensor could be set (S001 to S005), with a trigger level ranging from 7.82 mg (S001) to 23.46 mg (S005). Every exceedance of the trigger level was recorded as one count for activity. Sampling interval was set to 15 seconds.
In Phase 1, the temperature measurements of the sensors were validated under lab conditions, using a water basin with a Julabo heater and a validated P600 thermometer. Temperature was recorded in degrees Celsius. A constant temperature was tested as well as rising temperatures, roughly around the biological range of the sow's body temperature, starting at 35 °C and increasing to 45 °C. The validation test with the Templant2 sensor was performed twice, with slightly different time periods used for the increase in temperature (Table 1). Temperature results of the sensors and the validated thermometer were compared using a linear regression analysis.
Activity measurements of the sensors were validated by attaching the sensor to a stick and simulating sow movements by moving the stick with the sensor: Walking (moving the sensor slowly backward or forward), Standing up (moving the sensor upward), Lying down or Sitting down (moving the sensor downward), Standing, Sitting or Lying (holding the sensor in the same position) (Table 1). Activity was recorded in counts/second. All five levels of sensitivity were tested (S001 to S005). All tests were performed twice, with two similar sensors. Linear regression was used to test whether active behaviors showed higher counts than holding the sensor stationary, and to test the influence of sensitivity level.

Table 1: Measurement protocols of Templant2 temperature and activity sensors under lab conditions

Temperature sensor Test 1		**Temperature sensor Test 2**		**Activity sensor**	
Temperature (°C)	Time (Min)	Temperature	Time (Min)	Time (Min:Sec)	Simulated activity

[1] In March 2017, the activities of TeleMetronics Biomedical have been taken over by Noldus Information Technology.

From	*To*		*From*	*To*			
						0:00	Lie down
20	35	15	20	35	15	0:15	Lie
35	35	5	35	35	5	0:30	Lie
35	38.8	15	35	38.8	15	0:45	Lie
38.8	38.9	10	38.8	39.6	15	1:00	Lie
38.9	39.0	10	39.6	38.8	15	1:15	Sit down
39.0	39.1	10	38.8	40.5	15	1:30	Sit
39.1	39.2	10	40.5	42	15	1:45	Stand up
39.2	39.3	10	42	45	15	2:00	Stand
39.3	39.4	10	45	45	5	2:15	Stand
39.4	39.5	10				2:30	Walk forward
39.5	39.6	10				2:45	Stand
39.6	38.8	15				3:00	Stand
38.8	40.5	15				3:15	Walk backward
40.5	42	15				3:30	Stand
42	45	15				3:45	Sit down
45	45	5				4:00	Lie down
						4:15	Lie
						4:30	Lie
						4:45	Stand up
						5:00	Lie down

In Phase 2, sensors were attached to a neck collar or taped to the back of 3 sows for 30 minutes. Activity was measured with the sensor and recorded manually using an ethogram containing the following behaviors: Sit down, Sit, Lie down, Lie, Stand up, Stand, Head movement, Walk, Unrest. Different sensitivities were tested to determine which sensitivity would reflect movements of the sow most accurately. A total of 12 tests were performed with 4 similar sensors. Sow 1 had the sensor attached to neck and back with sensitivities S004 and S005 (4 tests); sow 2 had the sensor attached to neck and back with sensitivity S003 (2 tests) and sow 3 had the sensor attached to neck and back with sensitivity S003, S004 and S005 (6 tests). Univariate Analysis of Variance was used to determine whether active behaviors were related to higher sensor counts and influenced by sow number and sensor location.

Activity for 3 days around estrus was recorded manually for 4 gilts and 4 sows using video analysis with The ObserverXT (Noldus Information Technology). The following behaviors were recorded: Stand up, Lie down, Sit down, Walk forward and Walk backward. From each 24 hours, 2 hours during the day and 2 hours during the night were scored, with a total of 12 hours per sow. Time periods were chosen outside feeding times and when no personnel was around and were categorized in 1) the day before insemination, 2) the day of insemination and 3) no estrus (>1 day before or after insemination). Insemination

dates were recorded by the farm personnel. Activity on the non-estrus day was compared to the day before estrus with a 1-sided paired T-test.
The Templant2 sensors were not yet robust enough in this phase to record and transfer data for three days in a row, so manual observations of activity and sensor measurements were not yet combined in this pilot study.

Results and Discussion

Temperature results of sensors, heater and thermometer correlated highly under lab conditions in both tests (Figure 1a and 1b). Results from the linear regression showed an R^2 of 0.96 and 0.97 and a slope of 1.09 and 1.07 in both tests.

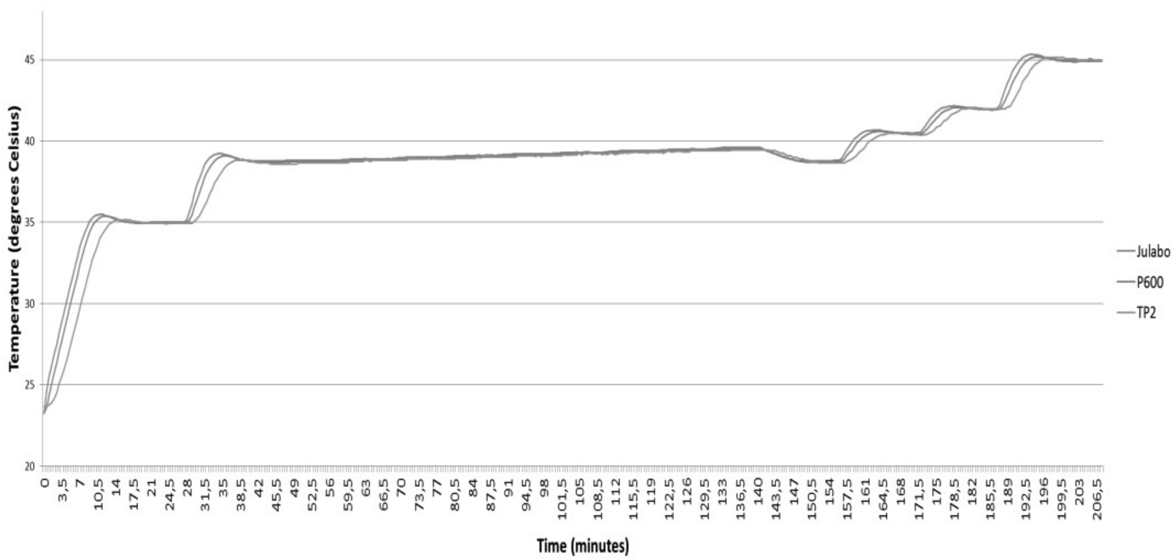


Figure 1a: Validation test of Templant2 temperature sensor under lab condition, test 1.

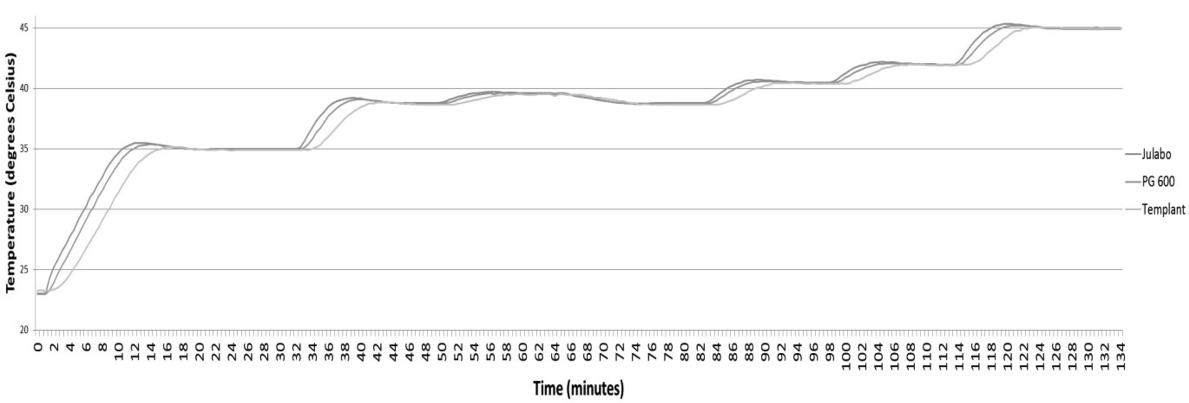


Figure 1b: Validation test of Templant2 temperature sensor under lab condition, test 2.

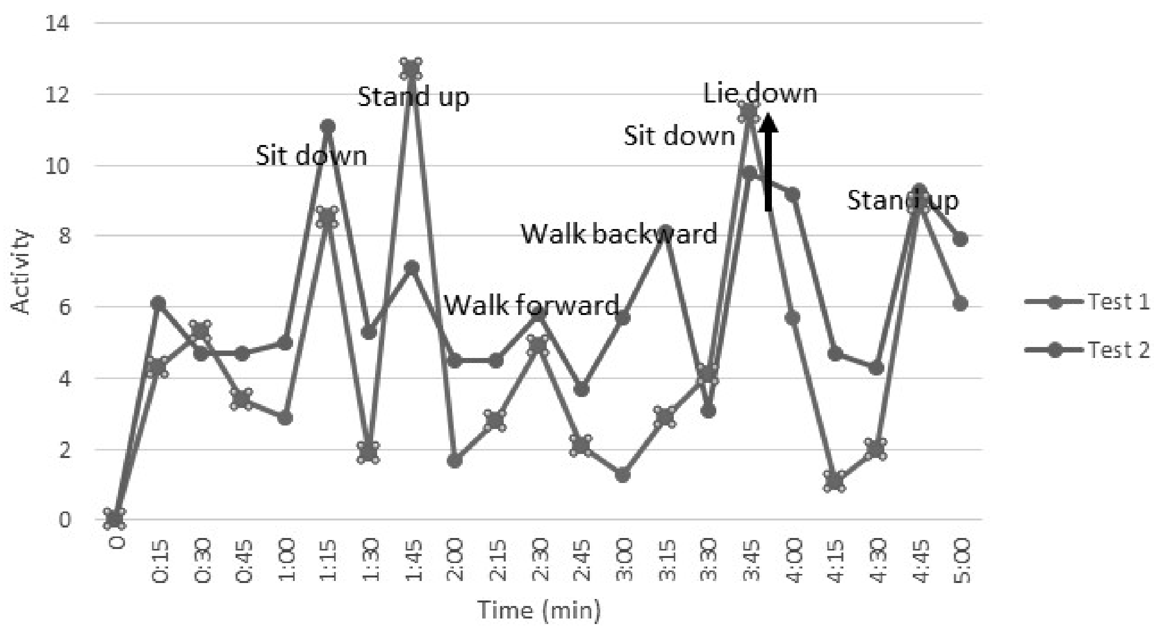
To test the activity sensor, sow movement was simulated with the sensor on a stick and sensitivities S001, S002, S003, S004 and S005. Sensor activity counts when the stick was moved, simulating the active behaviors Sit down, Stand up, Walk, Lie down, were higher than when the sensor was stationary, simulating the inactive behaviors Lie, Sit, Stand (P=0.010). Sensitivity influenced mean results (P=0.027), with the highest mean counts and standard deviations for S001 and S005 (Table 2).

Table 2: Simulating sow behaviors (active/inactive) with the sensor on a stick: activity counts for different sensitivities S001 to S005

Sensitivity	**Sensor count overall (mean ± stdev)**	**Sensor count, inactive (mean ± stdev)**	**Sensor count, active (mean ± stdev)**
S001	17.7 ± 7.9	14.6 ± 6.9	25.4 ± 4.2
S002	8.6 ± 4.6	6.4 ± 3.4	12.9 ± 3.4
S003	5.2 ± 3.1	3.7 ± 1.9	8.3 ± 2.7
S004	3.4 ± 3.7	2.1 ± 3.0	6.1 ± 3.7
S005	14.5 ± 50.0	9.4 ± 46.9	24.8 ± 56.2

An example of the test simulating the sow movements with the sensor on a stick is shown in Figure 2.

Figure 2: Simulated sow movements and activity measured with Templant2 sensor on a stick, sensitivity S003; active movements are noted in the graph.



Under farm conditions, sow activity was measured for 30 minutes by attaching the sensor to the back and the neck of three sows in a series of tests with different sensitivities set in the sensor.

For sensitivity S003, the sensor was attached to the neck and back of sows 2 and 3, in 4 tests. Mean activity was 145.0 ± 75.8 when the sensor was attached to the back of the sow, and 265.1 ± 194.1 when attached to the neck. When the sow was actively moving (Walk,Stand up, Lie down, Unrest, Head movement), mean activity for the sensor on the back was 184.5 ± 84.2 and for the sensor on the neck 333.5 ± 207.5; when the sow was not moving (Lie, Stand), mean activity for the sensor on the back was 116.4 ± 54.0 and for the sensor on the neck 146.1 ± 79.9. With this sensitivity, all sow movements gave a sensor count.

For sensitivity S004, the sensor was attached to the neck and back of sows 1 and 3, in 4 tests. Mean activity was 50.5 ± 69.2 when the sensor was attached to the back of the sow, and 253.5 ± 400.9 when attached to the neck. When the sow was actively moving, mean activity for the sensor on the back was 78.2 ± 100.6 and for the sensor on the neck 269.3 ± 268.2; when the sow was not moving, mean activity for the sensor on the back was 34.7 ± 35.8 and for the sensor on the neck 216.0 ± 627.7. With this sensitivity, 4 of 15 events (Lie down or Stand up) did not give any sensor count (0).

For sensitivity S005, the sensor was also attached to the neck and back of sows 1 and 3, in 4 tests. Mean activity was 21.5 ± 42.2 when the sensor was attached to the back of the sow, and 96.0 ± 159.9 when attached to the neck. When the sow was actively moving, mean activity for the sensor on the back was 40.7 ± 57.7 and for the sensor on the neck 135.5 ± 184.6; when the sow was not moving, mean activity for the sensor on the back was 6.1 ± 7.2 and for the sensor on the neck 23.9 ± 52.0. With this sensitivity, 6 of 15 events (Lie down or Stand up) did not give any sensor count (0).

For all tests, the sensors showed higher activity counts for active than for inactive behaviors (P=0.000 for S003, P=0.042 for S004 and P=0.000 for S005; overall P=0.000). Sow number did influence sensor results, with sow nr 1 showing the lowest mean count of 66.8 ± 118.5, sow nr 2 showing a mean count of 155.2 ± 95.5 and sow nr 3 showing the highest mean count of 210,9 ± 277.4. This means that sows vary in individual activity levels. As a consequence, for an activity based estrus detection system, the sow's own mean (or predicted) activity levels should be taken as standard and not the mean activity level of the herd. Sensitivity settings influenced mean count as well (P=0.016), with S003 showing the highest and S005 showing the lowest mean count. All sensitivity levels showed a clear difference between active and inactive behavior, but it seems that level S003 is the most reliable, with low standard deviations and no missed events.

An example of sensor results with the sensor attached to the neck of sow nr 3, with sensitivity S003, is shown in Figure 3.

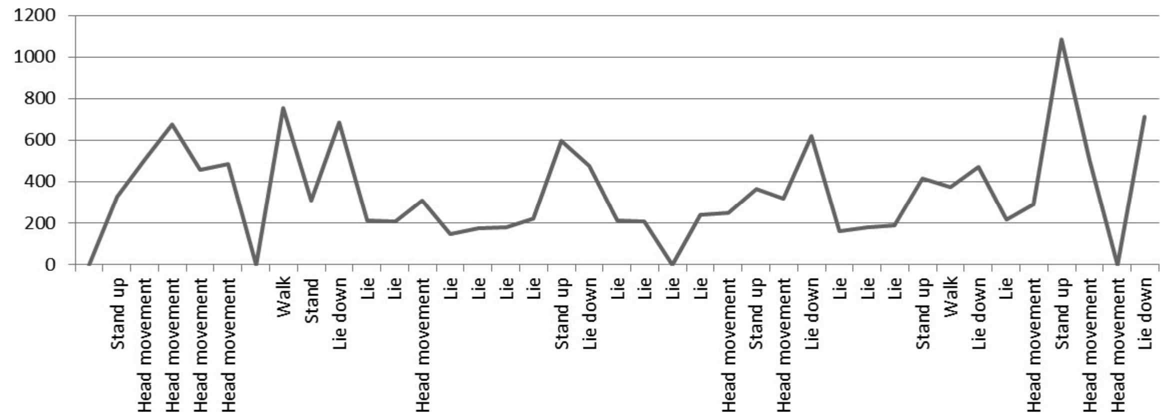


Figure 3: Movements recorded for 30 minutes with the Templant2 sensor attached to the neck of a sow (sensitivity S003).

During the manual observations (4 hours/day), sows showed more activity on the day before insemination ($P<0.05$ for standing up, lying down, sitting down and walking backward). All sows and gilts showed an increase in activity on the day before estrus, which makes activity a good predictor for estrus (Figure 4). The increase in activity from no estrus to the day before estrus was 2.4 ± 2.6 for Standing up ($P=0.03$), 4.6 ± 4.4 for Lying down ($P=0.02$), 3.3 ± 3.7 for Sitting down ($P=0.03$), 4.7 ± 4.9 for Walking backward ($P=0.02$) and 2.6 ± 3.8 for Walking forward ($P=0.06$).

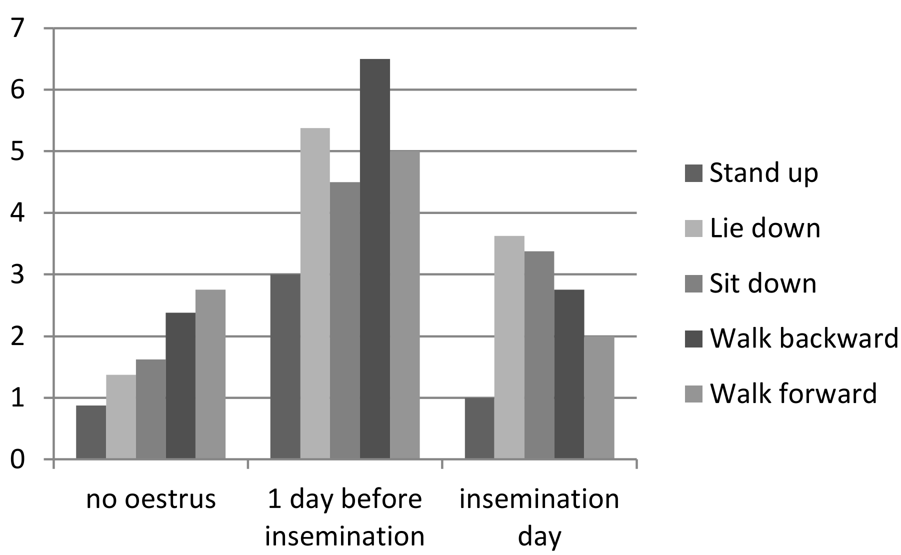


Figure 4: Mean activity around estrus for 4 sows and 4 gilts

In this study we could not yet use the Templant2 sensors internally, so we could only test activity in sows and not the combination of activity and temperature. In a follow-up study (Johnson and Shade, 2017) with an improved version of the Templant2 sensors used intra-vaginally in 12 gilts, temperature decreased (-0.26°C) and activity increased (+38%) significantly at the onset of estrus, with both parameters measured reliably with the sensors. This is a promising development for an estrus detection system based on activity and temperature combined.

Conclusions

Temperature could be measured reliably with the Templant2 sensor under lab conditions, and activity could be measured reliably under lab as well as under farm conditions. Templant2 activity sensors functioned best with sensitivity S003; with that sensitivity, no events (i.e. movements of the sow) were missed and the standard deviation was low. Sensor counts were significantly higher during active behaviors; a marked increase in sensor count was shown every time the sow moves, especially when standing up or lying down. Sows in cubicles showed more activity the day before insemination, which is at the start of the estrus period. This increase in activity consists mainly in more standups and more times lying down; as mentioned above, these are the same activities that Templant2 can measure reliably. We conclude that monitoring activity with Templant2 is a promising tool for estrus detection in sows. In future research, combining automated activity and temperature measurements in one system will be validated for estrus detection in sows.

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