Test of a UHF-RFID system for health monitoring of finishing pigs

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Abstract

Due to increasing herd sizes, the demand for automatic health and activity monitoring systems for individual animals is getting stronger. The aim of this study is to fulfill this task by using a validated ultra-high frequency radio frequency identification system (UHF-RFID) to monitor the visiting events (time, frequency, duration) of finishing pigs at so-called hotspots in a pen. This contribution presents initial analyses as a step toward this goal.

Two groups of finishing pigs (33 in total) were tagged with UHF-RFID transponder ear tags and were kept in two pens of an outdoor climate stable equipped with UHF readers at the trough, the drinker, the playing material and the door to a yard area. Over a period of nearly 12 weeks, the visiting events of each pig at these locations were monitored via a monitoring software. Additionally, their health status (lameness, tail lesions, skin lesions, diarrhea, coughing and shortness of breath) was observed twice a week.

The average daily duration of visits at the trough across all 33 pigs was 145 min. The pig with the shortest duration was, on average, 101.3 min per day at the trough, the one with the longest duration 203.7 min. Though there was no difference in the average feeding duration of healthy pigs and pigs classified as sick in general, a finer classification showed that pigs that were declared as lame (123.9 min) or coughing (113.3 min) had shorter daily visiting time at the trough. When looking at the single RFID events, all pigs showed circadian rhythms of activity on every hotspot. Lame pigs displayed a longer night-time break on days with lameness than on healthy days. Also, the influence of the fattening day on the duration at the trough was regarded.

The results promise a possibility to detect lameness based on monitored changes of behavior patterns. Further analyses are planned, e.g. on other hotspots and pigs with observed diarrhea with the objective of forecasting diseases.

Keywords: health, behavior, monitoring, fattening pigs, ultra-high frequency, radio frequency identification

1. Introduction

Due to increasing herd size per production unit health monitoring is becoming a growing challenge in modern pig husbandry. Hence, systems for automatic animal health and activity monitoring would be of great help to the farmer. Observing anomalous behavior could be a promising method for the detection of health impacts. Pigs' visits at different hotspots in the pen (e.g. at the trough) can be registered by using RFID (Radio Frequency Identification) for electronic animal identification (Adrion et al., 2015; Maselyne et al., 2014a; Maselyne et al., 2015). Analyzing a pig's duration and frequency of visits at a hotspot may lead to conclusions on the animal's health. The use of UHF technology (ultra-high frequency) instead of LF (low frequency) enables a simultaneous identification without separation and a larger reading range (Adrion et al., 2015; Barge et al., 2013). The aim of this study was to develop an automatic health and activity monitoring system based on UHF-RFID and the visiting events at the trough, the drinker, the door to the yard area and the playing material. This contribution shows initial analyses in order to examine the suitability of different indicator variables and covariates with influence on the pigs' behavior for the modelling that serves as basis for a monitoring system.

2. Materials and Methods

The study was carried out in Germany in an outdoor climate stable with insulated lying boxes and a yard area ("Pig-Port 3") for pigs. Two mixed-gender groups of finishing pigs (33 in total) were tagged with UHF-RFID transponder ear tags and kept in two similarly structured pens (Figure 1). The pigs (German Landrace, DanBred, Saddlebag pigs) weighed on average 55 kg at the beginning of the tests and were fattened to a final weight of about 120 kg. Each pen was divided into different functional areas, namely into the resting area with solid surface and minimal litter, the fully slatted feeding and drinking area with a wet feeder and three nipple drinkers and the fully slatted yard area where the pigs usually defecate. A metal chain with a piece of wood and a plastic tube was located in the yard area and used as playing material. The hotspots feeding area (trough), drinking area (drinker), door to the yard area (door) and playing area (toy) in both pens were equipped with UHF antennas (high gain patch antennas at the trough, drinker and the toy, cable antennas in plastic tubes at the door). The readers used in this UHF-RFID system were functional models (deister electronic GmbH, agrident GmbH, Barsinghausen, Germany) with a multiplexer for 4 antennas, a maximum output power of 29 dBm and an operation frequency of 865.7 MHz. The UHF ear tags were developed within the research project especially for the use with pigs. The transponders were equipped with an Impinj Monza 4® chip and had a PIF

antenna design (Planar Inverted F-Shaped Antenna; Adrion et al.; 2015). They were sized approx. 30 x 40 mm and grouted into a flexible plastic ear tag (Primaflex®, Caisley International GmbH, Bocholt, Germany).

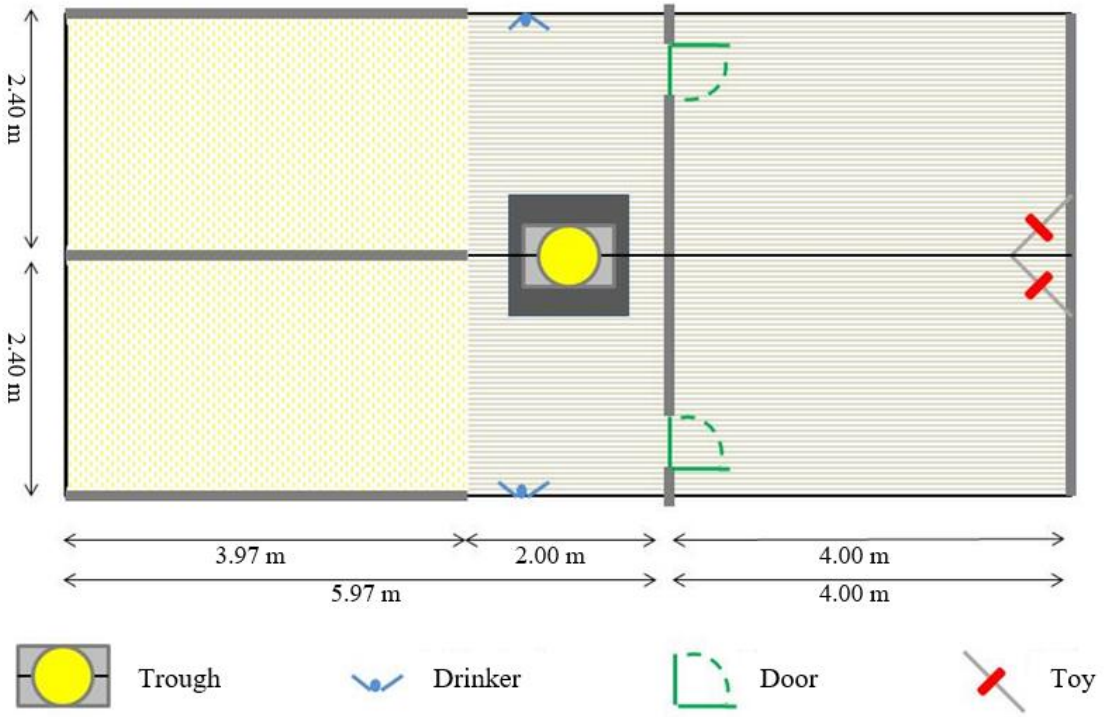

Figure 1. Floor plan of the two test pens for the study.

Preliminary tests were carried out to figure out the most suitable antenna power for each hotspot to detect an animal's visit correctly. For each hotspot four different settings of the antenna power (23-28 dBm) were tested by validating the RFID events with video recordings of 8 focal pigs. It should be clarified, that the video analysis was based on the pigs' location in the reading range and not on any interaction with the hotspots such as feeding at the trough. The aggregation of RFID events – i.e. by which criteria single readings are summed up to events – was optimized for each hotspot and each tested antenna power. These visiting events were compared to the video recordings (at least two hours of high activity for each hotspot and each tested antenna power) with statistical measures such as true positive rate (sensitivity) and true negative rate (specificity). For example, a positive event (video event) was classified as true, if the pig in question was registered at the hotspot some time during this event (RFID event). Based on these results, the antenna powers and RFID event aggregation parameters for each hotspot were selected as follows for the main study (Table 1). Sensitivity was very good at the trough and the toy, however, at the drinker and the door potential for further optimization of the antenna field was revealed.

Table 1. Antenna power and RFID event aggregation for every hotspot in the main study.

Hotspot	Antenna power [dBm]	RFID event aggregation		Statistical measures*			
		Maximum gap between two single readings [s]	Minimum duration of event [s]	Sensitivity [%]	Specificity [%]	Precision [%]	Accuracy [%]
Trough	24	50	1	92.0	97.5	97.2	94.8
Drinker	24	60	1	79.0	92.0	90.1	85.7
Toy	24	30	1	100.0	97.8	97.4	98.8
Door	26	30	0	48.5	93.0	86.9	71.1

*Sensitivity = true positive rate, Specificity = true negative rate, Precision = positive predictive value

The main study ran for about 12 weeks. During this period the UHF-RFID system consisting of UHF ear tags, UHF antennas, readers and a monitoring software (Phenobyte GmbH, Ludwigsburg, Germany) that recorded and aggregated occurring RFID events ran constantly (except on one day due to a broken USB interface). Also temperature and humidity inside and outside the building were permanently logged by dataloggers (testo 175H, Testo AG Lenzkirch, Germany). Furthermore, the health status of the pigs was observed twice a week in addition to the usual daily control by the farm

manager. The rating of the health status included lameness, tail lesions, skin lesions, diarrhea, coughing and shortness of breath – each divided into 2 to 4 grades of severity. Apart from this, the management in the test pens was the same as in the other pens on this farm, so that the test was carried out under conditions of good agricultural practice.

Only complete trial days were used for the analysis. That means, each day a pig could be monitored completely by the UHF-RFID system, beginning with the day after the trial started until the day before the pig was removed from the stable for slaughter, was considered for the calculations, apart from days with incomplete data because of technical reasons. The following analyses were performed to assess the possibility of an early detection of diseases on the basis of RFID events by combining these events with the health conditions. Basis of these analyses were the aggregated RFID events at every hotspot and the resulting daily mean values of the duration and frequency of visits. Based on the ratings of health status, the pigs were classified into two groups. Pigs that showed any lameness or diarrhea or a higher grade of coughing or skin lesions were classified as sick. Other pigs were declared as healthy.

3. Results and Discussion

The daily mean values of the duration and frequency of visits at the different hotspots are summarized in Table 2. On average, the frequency at the trough was 35.0 visits per day with an average duration of 145.0 minutes. The average visiting events at the drinker were 26.6 times per day with a duration of 24.7 minutes. The toy was the least frequented hotspot with on average 9.9 visits per day (8.2 min d^{-1}). The door was the hotspot with the shortest average duration (5.7 min d^{-1}), but was visited relatively often (23.3 visits d^{-1}). The minima and maxima are obtained from every single daily mean value of every pig. However, regarding the minima and maxima of daily mean values grouped by pigs, a strong inter-animal variability is reflected. For example, the pig with the shortest average daily duration at the trough was 101.3 min per day at this hotspot, the one with the longest daily duration was there on average 203.7 min. The variability between the pigs was particularly large at the drinker with an average daily visiting time between 8.0 min and 56.0 min. Maselyne et al. (2014b) also found variations within and between finishing pigs for the daily duration of different behaviors. The average daily durations of feeding (99.4 min) and drinking (15.8 min) were shorter than in this study here, but were only observed during the day between 7 AM and 9 PM.

Table 2. Daily mean values (MV) of duration and frequency of visits (n = 2365, pigs×complete trial day).

Hotspot	Parameter	MV	Min.	Max.
Trough	Duration [min d^{-1}]	145.0	22.0	344.8
	Frequency [1 d^{-1}]	35.0	7	103
Drinker	Duration [min d^{-1}]	24.7	0.2	174.7
	Frequency [1 d^{-1}]	26.6	1	82
Toy	Duration [min d^{-1}]	8.2	0	173.0
	Frequency [1 d^{-1}]	9.9	0	62
Door*	Duration [min d^{-1}]	5.7	0.01	133.3
	Frequency [1 d^{-1}]	23.3	1	106

*n = 2205 due to technical defect

In the present study, the pigs were classified into two groups based on the observed health status: sick and healthy. Figure 2 shows the average daily visiting time at the trough based on different health conditions (only health observation days were considered for this figure). The daily mean value of pigs classified as sick was 145.2 min, 141.5 min of pigs classified as healthy. As the figure implies, there is a clear difference between the average daily duration at the trough of pigs that were lame (123.9 min) or coughing (113.3 min) and healthy pigs. For example, pig 43 had the most lameness days with 4 out of 24 health observation days. The average duration and number of visits of this pig at the trough per day were both higher on days were no lameness was detected (104 compared to 87 min and 32 compared to 23 visits). The fact that the drinking or feeding behavior of pigs can be affected by lameness or other diseases is supported by the findings in other studies (Madec et al., 1986; Junge, 2015; Weary et al., 2009). Pigs with diarrhea and skin lesions had an average daily feeding time of 147.8 min respectively 145.6 min. Consequently, they hardly showed any difference to the mean value of healthy pigs (141.5 min). Though the results seem to suggest that lame and coughing pigs eat less, they are not necessarily indicative due to the small quantity of occurrences of diseases. Nevertheless, the results are very promising. They allow the assumption, that lameness and cough could be detected by an RFID system based on the visiting events at the trough. Further studies with an UHF-RFID monitoring system are needed to confirm this assumption.

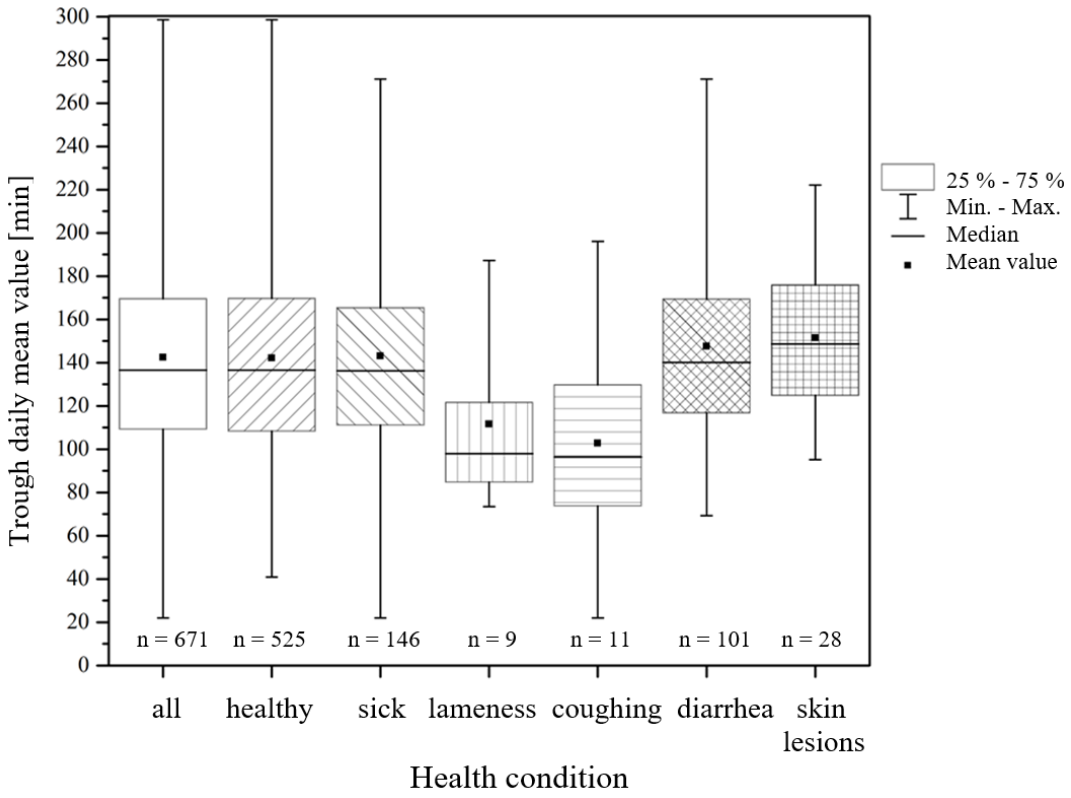

Figure 2. Average daily visiting time at the trough based on different health conditions.

When looking at the single visiting events instead of the mean values per day, the data indicates circadian rhythms for the visits of every hotspot, which is also supported by other studies. For example, Ingram and Dauncey (1985) found that the peak of food intake was significantly greater in the light than in the dark and water intake was correlated very strongly with that. Overall, the activity of pigs in the present study is greater during the day and there is often a night-time break of several hours where there is no visiting event at any hotspot. Despite that, a night time break that is longer than usual could be an indicator for diseases, because sick animals may tend to be sleepy or inactive and less motivated to move (Hart, 1988). For example, in 6 out of 10 times where lameness was detected in the present study, the night time break at the trough was found to be more than 8 h long on the day of health observation or ±1 day. This was the case on only 14 % of the days where no lameness was observed at these pigs. This circumstance should be further investigated by studies with a larger number of animals and with minimized potential sources of error by eliminating time gaps in health observation.

With regard to possible interrelations between health condition and frequency or duration of visits at a hotspot, other influencing variables must not be forgotten, such as atmospheric humidity and temperature or the age and thus the weight of the pigs. As an example, figure 3 shows the decreasing trend over time of the duration of visits at the trough of every pig (daily mean values) in relation to the time of fattening. In contrast to that, Brown-Brandl et al. (2013) observed increasing time at the feeders until day 95-105 of age with a maximum of only 76.7 min d^{-1}. In general, a possible influence on the results by aspects of the social behavior and interaction (social facilitation) must not be forgotten, but could not be investigated in this study yet. For example, if a pig fed ad libitum sees another pig eating, it will be motivated to eat again (Deen, 2010).

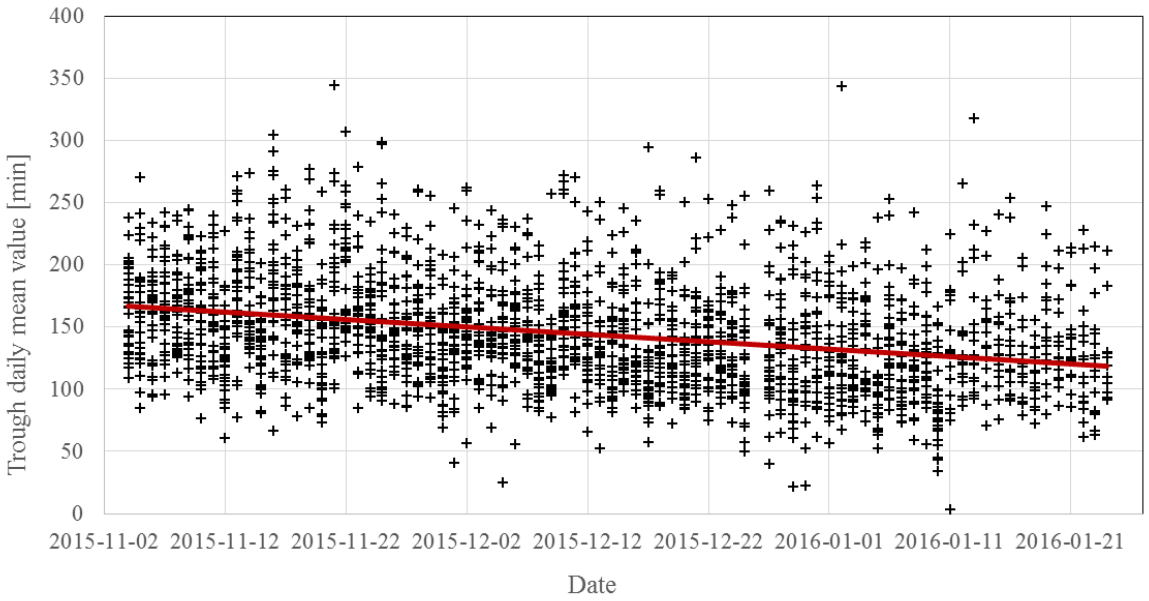

Figure 3. Daily mean value of duration of visits at the trough of every pig and trend over fattening time.

4. Conclusions

The present study shows much potential in finding sick finishing pigs based on UHF-RFID detection. The RFID events display the behavior of the pigs represented by the daily duration and frequency of stay at the trough, the drinker, the toy and the door. The analysis of the data and correlations so far indicate that lameness and coughing could be detected automatically through this method. The analysis of the single RFID events and circadian rhythms seem to be very promising to find suitable variables for disease detection. Further studies and additional analyses of the data are planned at other hotspots and involving influencing variables such as atmospheric humidity and temperature. It will be investigated, for example, whether other diseases can be detected by regarding drinking events or how visiting events on different hotspots are correlated to each other. The influence of social facilitation is another point of interest. The aim is to develop a prediction model based on a UHF-RFID system which could be used for early detection of diseases in finishing pigs.

Acknowledgements

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