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Monitoring trough visits of growing-finishing pigs with UHF-RFID

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ABSTRACT

Automatic monitoring of animal feeding behaviour in commercial farms is desirable as it is an important indicator for the well-being and health of animals. Low-frequency and high-frequency radio frequency identification (RFID) systems have been tested for the detection of feeding visits of growing-finishing pigs, but the suitability of ultra-high frequency (UHF) RFID for this application has not yet been shown. Therefore, the objective of this study was the validation of a UHF-RFID system, consisting of a reader, antennas and passive transponder ear tags, for the monitoring of visits of growing-finishing pigs at a short trough for liquid feeding. Consequently, (1) two antenna variants (free-form and patch antennas) were tested at different levels of antenna output power, (2) two methods to determine a bout criterion for the creation of trough visits from the RFID registrations were compared, and (3) a comparison of the RFID data with reference data from video observation was carried out. The analysis showed that the reading area exceeded the trough especially in the variants with high output power. Thus, the evaluation of the first and second rate of change of the total daily number and total daily duration of visits led to higher values for the bout criterion (50 s for both antenna variants) than the evaluation of the mean absolute deviation between video and RFID data (20 s for the free-form antenna and 30 s for the patch antennas). The trough visits observed were detected best with the patch antennas at 25 dBm output power and a bout criterion of 30 s with regard to average precision (61.1%), and correlation between the video data and RFID visits (R^2 = 0.87 for total number and 0.80 for total duration of visits). The average sensitivity of this variant was 49.7%, specificity 99.0% and accuracy 97.9%. The highest average sensitivity (79.7%) and a good correlation between video data and RFID visits (R^2 = 0.78 for total number, 0.56 for total duration of visits with a bout criterion of 50 s) were measured with the free-form antenna at 26 dBm. In conclusion, UHF-RFID can be suitable for the monitoring of trough visits of growing-finishing pigs, but the effect of ear tissue on the performance of the UHF-RFID ear tags should be reduced by further development. In addition, further research should be carried out to evaluate the potential of this technology completely for animal behaviour monitoring.

1. Introduction

Activity and behaviour measurements in livestock are important not only for scientific purposes, but also in precision livestock farming (PLF) systems, using them as input variables for control and management processes (Berckmans, 2008). Feeding behaviour is one of the most important indicators for the well-being and health of animals (Hart, 1988; Weary et al., 2009). Proof of this has been given for different diseases and animal species. González et al. (2008), for example, detected a decrease of daily feed intake, feeding time and feeding rate of dairy cows with ketosis in average 3.6 days before animal care takers observed the disease. Brown-Brandl et al. (2013) measured a significant decrease in the daily time growing-finishing pigs with pneumonia spent at the feeder. Feeding behaviour can also reflect the response of an animal to its environment (Averós et al., 2012). Influencing factors can be, for example, air temperature (Feddes et al., 1989), temperature humidity index (Brown-Brandl and Eigenberg, 2015) and type of feeder as well as feeder space allowance (Brumm et al., 2000; Gonyou and Lou, 2000). The connection of social behaviour and social constraints like degree of competition (Georgsson and Svendsen, 2002) and social rank (Cornou et al., 2008) to feeding behaviour has also been described. Automatic monitoring systems have been gaining in importance as they allow for continuous data acquisition and are less time consuming compared to direct or video observations. Many of these systems are used in single-space feeders that already make individual feed intake measurements possible (Chapinal et al., 2007; Hoy et al., 2012; Junge et al., 2012; Chizzotti et al., 2015). However, to collect feeding behaviour data on a larger scale for use in PLF systems, monitoring devices

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that can be used on-farm in commercial feeders for multiple animals and which do not interfere with the normal feeding behaviour in these facilities have to be developed. Two approaches have been shown in literature. Brown-Brandl and Eigenberg (2011) developed a feeding behaviour monitoring system based on low-frequency radio frequency identification (LF-RFID, 134.2 kHz) for use in feed-lot cattle and growing-finishing pigs. This system used multiple reader antennas and multiplexers to enable the detection of multiple animals at a time. Each antenna was placed at a single feeding space in feed bunks (cattle) and five-space dry feeders (pigs). The authors used standard passive electronic ear tags for animal identification. Maselyne et al. (2014) applied a high-frequency RFID (HF-RFID, 13.52 MHz) system to detect growing-finishing pigs at a round trough. Only one antenna was used here for each trough, applying the ability of HF-RFID systems to detect several transponders quasi-simultaneously by use of anti-collision algorithms. Hereby, feeder visits of multiple pigs feeding at the same time could be detected. Standard button ear tags with a passive disk transponder applied as an inlay on the pin of the male part of the ear tag were used in these experiments. While LF-RFID is a standard in animal identification (ISO 11784 and ISO 11785), HF-RFID has so far only been used for scientific purposes in this field of application (Reiners et al., 2009; Thurner et al., 2010). The third important RFID frequency band, ultra-high frequency (UHF, 860–960 MHz), has also been tested for application in livestock in recent years (Stekeler et al., 2011; Hogewerf et al., 2013; Adrion et al., 2015c; Hammer et al., 2015, 2016). Main advantages of this technology are the flexibly adjustable read range of more than 3 m with passive transponders as well as the ability to detect a high number of transponders per second by utilizing the high speed of communication (Ruiz-Garcia and Lunadei, 2011; Finkenzeller, 2012). These properties could facilitate various applications of UHF-RFID in animal behaviour monitoring. However, there is a negative influence of materials, in this case ear tissue, on the performance of UHF RFID transponder ear tags, mainly through absorption of radiation and a change in the resonance frequency of the transponder. This has inhibited the application of this technology in animal husbandry until a few years ago and has to be thoroughly taken into account for the development of UHF-RFID ear tags (Lorenzo et al., 2011; Adrion et al., 2015b). Applications of UHF-RFID already tested were mainly single animal identification and group identification for traceability purposes (Baadsgaard, 2012; Hogewerf et al., 2013; Pugh, 2013; Hammer et al., 2016), but activity and behaviour monitoring of individual animals in group settings with passive UHF-RFID has not yet been reported in literature.

1.1. Objectives

The experiments shown here were part of a joint research project concerned with the development of UHF-RFID ear tags for use in pigs and cattle, as well as readers and antennas for on-farm use (Federal Office for Agriculture and Food, 2012). The objective of this study was the validation of a UHF-RFID system, consisting of a reader, antennas and passive transponder ear tags, for monitoring of visits of growing-finishing pigs at a short trough for liquid feeding. To achieve this, the main tasks were (1) to test two antenna variants at different levels of antenna output power, (2) to compare two methods to determine a bout criterion for the creation of trough visits from the RFID registrations (raw data), and (3) to compare raw data and trough visits at different levels of output power with reference data from video observation to determine critical points for further development of the UHF-RFID system.

2. Materials and methods

2.1. Animals and test facility

The experiments were conducted in a growing-finishing pig barn at the Agricultural Sciences Experimental Station of the University of Hohenheim between February 4 and 16 (day 1–13), 2015. The experimental pen observed had a total size of approximately 3.30 m × 7.80 m and held 25 pigs (approximately 0.95 m^2 per animal). These pigs (10 male, 15 female) had an average weight of 110.4 ± 10.6 kg (mean ± standard deviation: SD) at the start of the experiment. Nine of the 25 pigs were sold to the slaughterhouse on day 9, increasing the space per pig to approximately 1.5 m^2. The pen was equipped with a slatted floor in the defecation area and the other two-thirds of the pen had a slatted floor with reduced perforation, functioning as a lying and feeding area. The feeding of the pigs was carried out with a sensor-controlled liquid feeding system at a metal short trough (1.50 m × 0.37 m, five feeding spaces of 30 cm each). The animal to feeding place ratio was 6:1 from day 1–9, and 4:1 for the rest of the experiment. However, from day 9 on all feeding spaces of the trough were still occupied during the main feeding times as before day 9, ensuring comparable conditions for the registration of the pigs during feeding. Feed was given at six feeding times, split into two meals each (6:00, 6:20, 9:00, 9:20, 12:00, 12:20, 15:00, 15:20, 18:00, 18:50, 21:40 and 22:00). Seven of these 12 meals were included in the daily monitoring time of this experiment from 11:00 to 22:00. On day 7 the meals at 15:00 and 15:20 were left out due to technical problems with the feeding system, but the data acquisition went on during this time. There were three additional nipple drinkers on the opposite side of the pen. A playing device, which consisted of a straw-filled metal container with a trough and a free-hanging wooden beam, was placed on the long side of the pen in the fully slatted area.

Eight focal pigs were chosen out of the 25 pigs (genetics: German Landrace x Pietrain, sex: 7 females, 1 male) with an average weight of 99.9 ± 8.3 kg (mean ± SD) at the beginning of the test period. They were tagged with UHF transponder ear tags in the right ear. No larger number of ear tags was available for this experiment due to the complexity of the ear tag production at this phase of the project. The eight animals were marked individually with colour for video observation and the ear tags were checked with a handheld reader and visually for signs of damage on each test day. Two ear tags lost their function during the experiment (on day 7 and day 11). These two ear tags showed signs of biting already several days before they stopped working and also much less readings of these tags could be detected during that time. The exact time of the first damage could not be determined exactly, thus, these two animals were completely excluded from the data analysis.

The experimental procedures were approved by the regional authorities in Baden-Württemberg, Germany, and were carried out in accordance with EU Directive 2010/63/EU for animal experiments.

2.2. UHF-RFID system

The transponders used had a planar inverted F-shaped antenna design (Fujimoto and Morishita, 2013) and were equipped with an Impinj Monza 4® chip. The transponder antenna was made of a copper layer on polyimide foil. The outer dimensions of the transponders, approximately 30 mm × 40 mm, were shaped to fit into a pig ear tag, but they were grouted into the female part of a cattle ear tag (Primaflex®, Caisley International GmbH, Bocholt, Germany) because only an injection mold for cattle ear tags was available at this stage of the project (Fig. 1).

Two reader antenna variants were tested for monitoring the feed trough. The first one was a Locfield® free-form antenna (Cavea Identification GmbH, Olching, Germany). It had a total length of 3 m with an active part of 2 m. This type of antenna is made of a coaxial cable (diameter 5 mm, attenuation 0.28 dBm/m at 800 MHz). The antenna was mounted parallel to and approximately 0.1 m above the back side of the trough (Fig. 2). The antenna was shielded by plastic pipe (32 mm outer diameter, 27 mm inner diameter, PVC) to protect it from water, dirt and biting of the pigs. The field strength of this antenna

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