Monitoring fattening pig's behaviour by RFID registrations

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Abstract

RFID identification can be used for health and welfare monitoring if tagged animals are recorded at drinking and feeding places. In an experiment, RFID readings from 144 fattening pigs (12 pens each with 12 pigs, one drinker and two feeders) were recorded with four readers (each with eight antennas) during almost four months. Tag readings were combined in visits and subsequently visits in meals. A model for the number of meals per pig per day was developed generating alerts when the number was less than expected. Most cases of culled pigs corresponded with alerts, but the sensitivity depended on the chosen setting. The related specificity was only high enough when a high threshold was chosen.

Keywords: RFID, pigs, eating behaviour, drinking behaviour, health and welfare monitoring.

Introduction

Pig identification with RFID ear tags can be used in pig production to certify antibiotics-free meat production, as is done by KDV (Sustainable Pork Value Chain, sustainable-pork.com). This RFID identification can also be used for health and welfare monitoring if tagged animals are recorded by readers at certain locations in the barn (Ruiz-Garcia and Lunadei, 2011, Maselyne *et al*., 2018). In a previous research a good correspondence between tag readings and animal behaviour was found in two cycles in a pen with 12 weaned pigs (de Mol *et al*., 2019). In the current research LF RFID readings in one cycle were available for 12 pens each with 12 fattening pigs. Recordings per animal can be used for individual monitoring of pigs. The goal of this experiment was the analysis of the individual patterns of the number of visits for monitoring by generating alerts when the number is deviating. These alerts are true in case of the culling or treatment of animals and false for healthy animals.

Materials and methods

Twelve pens with fattening pigs were involved in this experiment at the Dutch Swine Innovation Centre (VIC Sterksel) in the Netherlands.The experimental period started at March 11 2020 and ended at July 1 2020, this is from the start till the end of the fattening period. Each pig was equipped with an LF RFID tag in the right ear. Each pen was equipped with one drinker and two (combined) feeders (Figure 1). Four readers, each with eight antennas were available to register the tag readings at each drinker and feeder (equipment provided by Agrident, agrident.com). For four drinkers and all 24 feeders one specific antenna was available. Four antennas were applied for tag

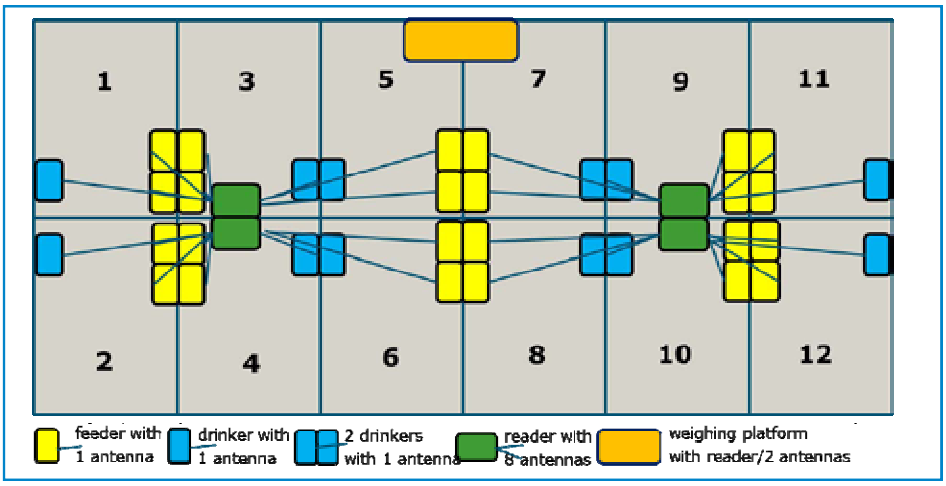

Figure 1. Layout of the barn with 12 pens each with one drinker and two feeders; 4 readers, each with 8 antennas; one weighing platform (with reader) connecting pens 5 and 7.

readings from two drinkers in neighbouring pens. In this way it was possible to register the visits of all drinkers and feeders (n=36) with 32 antennas (connected to four readers).

One weighing platform (Thomas® Animal Weighing system, www.hotraco-agri.com) was installed at a passage that was created at the back end of two neighbouring pens (Figure 1). Weight recordings were available anonymously and an additional reader with two antennas was installed on this weighing platform to register tag readings. Reference weight recordings by weighing by hand were available once a month.

Recordings of climate data (temperature, relative humidity, $CO_2$and NH_3) were also available (equipment provided by Hotraco, www.hotraco-agri.com).

Video recordings at selected spots were available for validation. Treatments, cullings and other management data could be used for the analysis of the monitoring results.

Readings of the RFID tags were recorded continuously. The tag readings became available as one csv file per reader per day with on each line:an identification, a time stamp and an antenna number. The combination of reader and antenna number identified a drinker, feeder or weigher. Tag readings were combined to visits by applying a bout criterion of 20 seconds (Maselyne *et al.*, 2016). Visits were combined to meals by applying a meal criterion of 900 seconds(Tolkamp and Kyriazakis, 1999).Data were stored in an Access database. A procedure for reading the csv files was made where the tag readings of the same pig and same location were combined in visits with the time stamp of the first reading as starting time, the time stamp of the last time stamp as ending time and the number of readings included as an additional characteristic of the visit. In another procedure visits were combined in meals. This processing resulted in three types of readings, visits and meals: 1 = drinking, 2 = eating and 3 = weighing (only possible in the combined pen). The number of visits and meals per pig per day was used to develop a model for monitoring the pigs.

Results

Recorded visits were available per pig and per type. This is visualized in Figure 2 where the visits in one pen during a 6 hour period are shown. Tag readings were combined in visits. Visits can be to the drinker, to one of the feeders or to the weigher (not relevant for Pen 2 depicted in Figure 2). In general periods with activity from all pigs in the pen alternate with periods of rest where general activity is low. Evening and night periods appeared to be quieter (but not without activity).

The average weight by hand of the pigs was 35 kg at March 26 and 123 kg at June 17. Due to technical problems (mostly network problems) readings were missing for 28% of the days (uptime less than 20 hours per day).This missing percentage varied between readers from 11% to 49%. The data from the other days were used to get an indication of the usability of RFID readings for monitoring. Visits at one feeder were mostly combined with visits at the other feeder, therefore visits at the two feeders were combined in the further analysis. In total almost 17 million tag readings were recorded (Table 1), resulting in almost 1,3 million visits (131 readings per visit) and 266 thousand meals (5 visits per meal).The number of tags was at the same level for all antennas, the number of visits was higher for the antennas serving two drinkers and the number of meals was twice as high for these antennas. These results indicate that one antenna can be used to register the relevant readings of two drinkers.

Visits and meals are a characteristic of the behaviour of a pig. So, monitoring of the pig's behaviour can be based on monitoring the number of meals, the average interval between meals or the maximum interval between meals. Pigs with a decreased number of meals or with increased intervals should be alerted for inspection by the farmer. For these variables the daily level is predicted with a statistical model, e.g., for the number of meals given in Equation 1, where the number of meals today (d) is predicted by the number yesterday (d-1), the number on the day before yesterday (d-2) and the average number of the other animals in the same pen today.

$$\text{NrMeals}(d) = \alpha_1 + \alpha_2\,\text{NrMeals}(d-1) + \alpha_3\,\text{NrMeals}(d-2) + \alpha_4\,\text{AvgNrMeals}(d) \quad (1)$$

Equation 1 was based on the analysis of the correlations of the number of meals with other variables that might be related. From this analysis it was concluded that it is not relevant to include climate variables in this equation. The values of the parameters

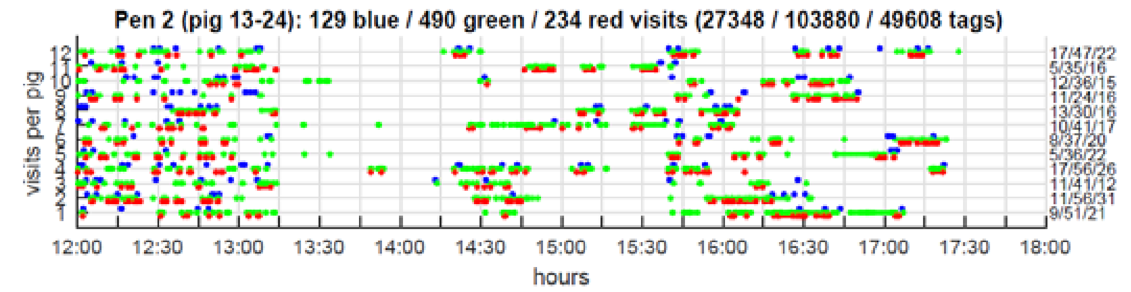

Figure 2. Example of all visits in Pen 2 between 12:00 and 18:00 hr om March 11, 2020; each line represents visits of one pig: blue visits correspond with readings at drinking nipple, green and red visits correspond with reading at one of the feeding throughs.

Table 1 Percentage of days with uptime less than 20 hours, number of readings, visits and meals per reader (reader 213 is on the weighing platform).

	Reader 209	Reader 210	Reader 211	Reader 212	Reader 213	Total
Days Uptime < 20 Hrs	49%	26%	24%	30%	11%	28%
Readings	31675394	46228483	43866491	44780502	1660406	168211276
Visits	227302	349709	327865	331887	43166	1279929
Meals	39688	71770	68736	63989	22262	266445

α_1, α_2, α_3 and α_4 might vary between pigs and might be time dependent. Therefore, a Kalman filter is used to fit these parameter values per pig on-line (de Mol *et al.*, 1999), resulting in updated parameter values per pig per day, together with a variance-covariance matrix for these values that can be used to calculate confidence intervals. Alerts are generated when the difference between predicted and real level for a pig on a day is too big, that is when the error is outside a confidence interval. Several options were considered: a 95%, 99% or 99.9% confidence interval.

The alerts were analysed in two ways:

- Alerts are true in case of a recorded case of culling or treatment: each case is either true positive (TP) or false negative (FN), resulting in the sensitivity: TP/(TP+FN), the percentage of detected cases.
- Alerts outside culling or treatment periods are false: each day in then either true negative (TN) or false positive (FP), resulting in the specificity: TN/(TN+FP),the percentage of healthy days without alert.

An example of the monitoring process for one pig is depicted in Figure 3. For each day the expected value was calculated based on Equation 1 using the parameter values from the Kalman model. The outcomes of the Kalman model made it also possible to calculate the confidence interval and to give alerts when the real value is outside the confidence interval. Sensitivity and specificity results for all pigs are included in Table 2 and Table 3.

Discussion

It was difficult to calculate the sensitivity as there were only a few cases of culled or treated pigs, furthermore some cases were in a period were most data were missing(so insufficient input for model) and there was one case only a few days after the start of the experiment (limited time for the model to adapt). However, in most cases of culling alerts at various levels were generated in the period before culling. Results for the treatment cases were not included, as these were only a limited number (n=11), for a great part(n=5) in the period before the culling of a pig.

For sensitivity there is no clear difference between the results of different variables. This is different for specificity, it is lower in case of the average or maximum interval between meals compared with the number of meals. The specificity is high for the

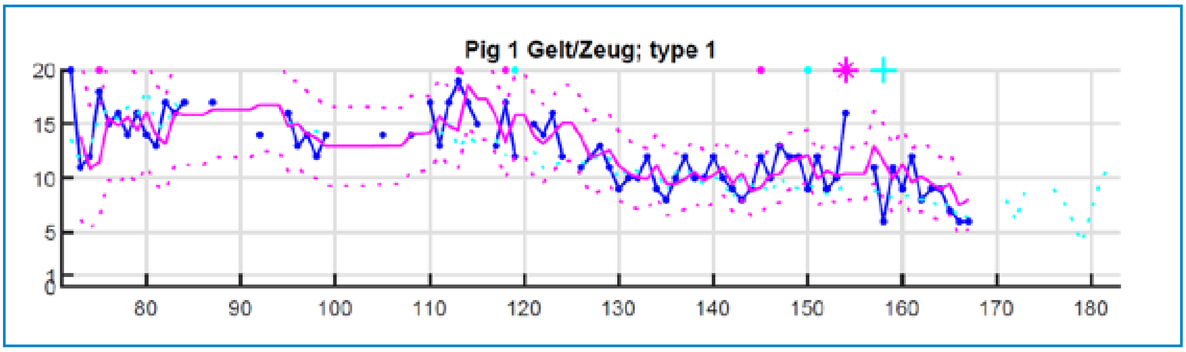

Figure 3. Example of monitoring per pig with results per day: blue solid line is number of meals, dotted cyan is average number for this pen, solid magenta line is fitted value (with dotted magenta line as 95% confidence interval) and alerts in top line when value is outside confidence interval (cyan for decreased values, magenta for increased; dot sign for 95%, plus sign for 99% and asterisk sign for 99.9% confidence interval).

Table 2. Sensitivity results based on number of meals per day, average interval between meals and maximum interval between meals for five cases of culled pigs (= outside 95%, ** = outside 99% and *** = outside 99.9% confidence interval).*

		Case 1[1]	Case 2	Case 3[2]	Case 4[2]	Case 5[2]
Decreased number	Type 1 (drinking)	*	**	*	***	-
of meals	Type 2 (eating)	**	***	*	*	**
	Type 3 (weighing)	n/a	**	**	n/a	n/a
Increased average	Type 1 (drinking)	***	***	-	*	***
interval between	Type 2 (eating)	-	-	-	-	***
meals	Type 3 (weighing)	n/a	***	**	n/a	n/a
Increased maximum	Type 1 (drinking)	***	**	-	**	***
interval between	Type 2 (eating)	***	-	**	-	***
meals	Type 3 (weighing)	n/a	***	***	n/a	n/a

[1] Case in the beginning of experiment
[2] Missing data in culling period

Table 3. Specificity results based on number of meals per day, average interval between meals and maximum interval between meals for all pig days outside treatment or culling periods.

			Confidence interval		
		Valid days	95%	99%	99.9%
Decreased number	Type 1 (drinking)	9380	94.6%	98.4%	99.6%
of meals	Type 2 (eating)	9115	95.4%	98.8%	99.7%
	Type 3 (weighing)	2245	94.7%	97.9%	99.5%
Increased average	Type 1 (drinking)	9293	90.9%	93.9%	96.1%
interval between	Type 2 (eating)	9040	90.2%	93.8%	96.2%
meals	Type 3 (weighing)	2051	91.6%	94.2%	95.8%
Increased maximum	Type 1 (drinking)	9293	89.7%	94.3%	97.1%
interval between	Type 2 (eating)	9040	90.6%	94.5%	97.0%
meals	Type 3 (weighing)	2051	91.5%	94.7%	97.5%

number of meals but might only be high enough for practical application in case of the 99.9% confidence interval. For practical application one should balance between wanted sensitivity and acceptable specificity.

Other variables should be studied as well, for example the visits per pig per day can be analysed in the same way. Other aspects that need further study are the influence of the group level on the individual pattern and the within-day pattern of the pig behaviour.

Two pens were different as they were connected by a weighing platform, the specific results also need further study: combining anonymous weights with RFID readings, differences in visiting patterns to the weighing platform compared with visits to the drinker and feeders.

Similar data are available from two other fattening round in the same pens, one in 2019 and one later in 2020. Comparing the results of these rounds with the present results might strengthen the conclusions.

Conclusions

We conclude that RFID readings can also be used for health and welfare monitoring in fattening pigs. Comparing the number of meals (or the average and maximum interval) per pig per day with the expected level results in alerts that can be useful is daily management. Sensitivity results were difficult to quantify, but alerts were given in most cases. Specificity was lower when results were based on average or maximum interval compared with average number of meals.

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