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Pilot study to monitor body temperature of dairy cows with a rumen bolus

A.H. Ipema, D. Goense, P.H. Hogewerf, H.W.J. Houwers, H. van Roest*

Animal Sciences Group of Wageningen UR, P.O. Box 65, 8200 AB Lelystad, The Netherlands

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ABSTRACT

A bolus containing a mote (temperature sensor, processor and radio) was placed in the rumen of a fistulated cow to monitor body temperature. Rumen temperature was measured every minute and stored in the internal buffer of the mote. The measured temperature was also transmitted to a base station by the mote every minute. A relay mote mounted on the cows' left front leg assisted transmission of the information from rumen to the base station. Cow behaviour affected the success rate of data transmission. The base station received more than 50% of the transmitted data when the cow was standing. Success rate was lower than 40% when the cow was lying down. Rumen temperature varied diurnally with night-time temperatures higher than day-time temperatures. Drinking events resulted in distinct decreases of the rumen temperature. It is concluded that for the application of internal sensor motes wireless communication through the body and living environment of the animal works but improvements are possible. Research should also focus on the interpretation of sensor data on mote level for optimizing data recording frequency and transmission of data to dairy management practice.

1. Introduction

Monitoring of dairy cows is performed mainly for operational control of farm processes. It is expected that these control activities will gain importance because of public concern about food safety, animal health and animal welfare. This also implies a growing need for collecting accurate data from individual animals in a herd. On the other hand, average herd size is increasing so the herdsman has less time available per individual cow. Sensors can be used for the collection of data per individual cow. For this reason, several research groups and companies are working on the development of wireless sensor systems. Recent developments and future perspective for these systems in agriculture and food industry are described by Wang et al. (2006). Data from a combination of capsule-based pH and temperature sensors could be used by farmers to optimize feeding patterns, to detect illness, and to manage breeding (Cumming et al., 2006). Research about monitoring rumen pH by wireless telemetry has been reported by Mottram et al. (2006).

In this paper the results of an experiment with a temperature sensor built into a bolus placed in the rumen of a cow is described. The main objective was to demonstrate that capsule-based wireless technology could work in cattle. An essential basic part of these systems are motes. A mote is a unit comprising sensor(s), a processor and a mode of communication. The mode of communication of the motes placed into the animal's body is an important aspect in practice. It is also of utmost importance to study the types of data required in order to optimize sensor use.

* *Corresponding author*. Tel.: +31 320 29 35 65; fax: +31 320 23 80 22.
E-mail address: bert.ipema@wur.nl (A.H. Ipema).
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2. Materials and methods

The experimental set up consisted of a Personal Computer (PC; Pentium 3 processor of 800 MHz), a base station, an antenna and two motes attached to a cow.

Communication with the base station was via a RS232 port. The base station (Mib510) was powered by 5 V and was permanently connected with a Mica2 mote (Crossbow Technology Inc., 2007) with antenna which served as interface between the base station and the motes attached to the cow.

These motes had a 5 V battery energy supply, CC1000 radio chip and a small antenna for FM radio communication at 433 MHz. The chip, antenna, battery and temperature sensor were built into a bolus, a small plastic pipe 3.5 cm (inner diameter) and 10.6 cm long. The weight of the bolus with contents was 106 g. The bolus was placed in the rumen of a fistulated cow, 8 days prior to calving. The signal strength of the radio in the rumen mote was expected to be too weak to reach the antenna of the base station. Therefore an additional mote was attached to the left front leg of the cow. This mote was used to relay the signal from the rumen mote to the base station.

PC, base station with Mica2 mote and download antenna were all placed on a table in an observation room with stone walls approximately 15 m from the calving pen. The distance between the transmitting mote in the rumen and receiving mote at the front leg of the cow was less than 2 m.

Measurements were terminated 1 day post-calving. The data recording and transmitting frequency of the motes was set at approximately once per minute. An internal logging device mounted in the rumen mote buffered all sensor temperature measurements. After removal of the bolus from the rumen this buffer with all recorded was read out by the base station.

During the experiment the cow was housed in a calving pen (30 m^2) with a layer of straw as bedding on a concrete floor. The pen had iron fencing and was equipped with a water trough and a forage-feeding trough. Cow behaviour in the pen was recorded on a time-lapse video system.

Technical research aspects focussed mainly on the reliability of the direct radio transmission from the rumen mote via front leg mote to the base station. For an uninterrupted period of 60 h the reception rate of the transmitted temperature measurements was analysed. Relations with the behaviour of the animal were studied. Animal behaviour was classified as lying, standing, foraging and drinking events for 5 min periods based on the video recordings.

The effects on mean hourly temperatures were analysed further. The mean hourly temperatures were calculated based on all recordings that were read out from the logging device in the bolus mote after removal from the rumen. Effects of time of the day (h), water drinking and cow activity were statistically analysed on the basis of the mean hourly data. For this statistical analysis each day was divided into 6 periods of 4 h. Water drinking events in a certain hour was registered as a 'no', 'yes' or 'in previous hour'. Hourly cow activity was expressed in 3 classes of lying times per hour: <15 min, 15–45 min and >45 min. All three factors were included in the statistical model.

3. Results

Cow behaviour was analysed for a period of 60 h in the week prior to calving. The cow was lying down for 54% of the time, standing 18%, foraging 26% and drinking water 2% of the time.

The numbers and percentages of directly received (real-time) temperature measurements during different activities are given in Table 1.

On average 44% of measurements were received directly by the base station. The percentage of measurements received directly was higher during standing and foraging than during lying. For standing and foraging 61% and 58%, respectively, of the measurements were received on-line. Only 25% of measurements were received directly when lying on the left side. Lying on the right side gave better results (36%).

Intervals between successful communications could be longer than 1 min due to failed transmissions. About 5% of the intervals between consecutive communications were longer than 5 min and 0.5% longer than 1 h. The longest observed interval was 122 min.

The mean, minimum and maximum per hour were calculated from 60 temperatures (once a minute) and are given in Fig. 1. Environmental conditions in the barn were monitored continuously. Mean ambient temperature was 18 °C with a minimum of 14 °C and a maximum of 24 °C. Minimum temperatures were measured around 06:00 h and maximum temperatures around 15:00 h.

A certain rhythm was observed in the temperature of the bolus as displayed in Fig. 1. Temperatures were lower during the day than during the night. Further analyses showed that rumen bolus temperatures were highest between 20:00 and 00:00 h (40.2 °C) and between 00:00 and 04:00 h (40.3 °C) and lowest between 08:00 and 12:00 h (39.5 °C) and between 12:00 and 16:00 h (39.4 °C). The means between the periods with highest and lowest temperatures differed significantly ($p < 0.05$).

Water drinking in a certain hour significantly affected the mean rumen temperature in that and in the subsequent hour. Mean values in these hours declined with 0.4 °C and 0.7 °C,

Table 1 – Number of temperature sensor measurements and directly received measurements for different activities

Activity	Number of measurements	Number directly received	% Directly received
Standing (incl. water drinking)	695	402	58
Lying on left side	952	239	25
Lying on right side	1004	364	36
Foraging	914	557	61
All	3565	1562	44