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Application of a chewing sensor (RumiWatch) for automatic heat detection in dairy cows: a pilot study

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Abstract

Automatic heat detection is gaining interest in dairy farming, particularly as fertility problems have high prevalence in intensive livestock systems. A pilot study at Agroscope Tänikon research station was conducted to determine the feasibility of automatic heat detection in dairy cows using a novel sensor-based health and activity monitoring system (RumiWatchSystem, Itin+Hoch GmbH, Liestal, Switzerland). The aim of the study was to assess the suitability of the system's chewing sensor for automatic detection of heat and to investigate changes in behavioral parameters between peri-estrus vs. estrus days. In total, 10 estrus events were monitored at Agroscope Tänikon research stable (Ettenhausen, Switzerland). Results of this study are intended to serve for further enlargement of the system's functionality and for set-up of additional analysis functions. Experimental animals were equipped with chewing sensors two weeks before the calculated estrus day. Estrus events were verified by several reference methods (visual observation, pedometers, color markers). Behavioral changes in ruminating, eating, and motion activity during estrus cycles were analyzed and compared for all monitored estrus cycles (n=10). Three reference days before and after the day of estrus, and the day of estrus itself were compared in the evaluation. Overall results were generated by calculating the average change in activity parameters for all experimental animals (n=7). Results indicate that estrus significantly influences ruminating and eating activity in dairy cows. Motion activity of the head clearly increased by +34.5% compared to non-estrus days. On average, decrease in number of ruminating chews was -18.3% and -23.7% in number of eating chews when comparing the day of estrus versus the reference (peri-estrus) period. Number of ruminating boluses decreased by -16.0% at the day of estrus. These behavioral changes can be reliably measured by the RumiWatchSystem. Based on the findings of this study, several parameters of ruminating, eating, and motion behavior were identified as potentially significant indicators for automatic heat detection in dairy cows. The chewing sensor used in this study has the potential to become a suitable tool for heat detection, as it constantly measures relevant behavioral parameters for reliable estrus detection, e.g. ruminating activity (Reith and Hoy 2012). Further research and development works serve for implementation and validation of a function for automatic heat detection as part of the health monitoring system (RumiWatch). Particularly in a systematic approach when used in combination with a pedometer, very high heat detection rates may be achievable.

Keywords: automatic measurement, heat detection, rumination

1. Introduction

Today's dairy farming is marked by increased herd sizes, high milk yield, and lower time-budget for individual animal control. This may result in missed cases or lower rates of detected estrus events in dairy cows and economic losses due to prolonged calving interval and service period. Van Eerdenburg et al. (2002) reported detection rates of visual observation below 50% at larger herd sizes. Hence, techniques for automatic heat detection are gaining interest for farmers. Several studies have shown significant changes in locomotory behavior induced by estrus in dairy cows (Arney et al. 1994, Roelofs et al. 2005). Technical solutions for automated detection of estrus based on measurement of intensity of motion behavior and pedometric activity are extensively available. For pedometers and accelerometers used to monitor changes in physical activity at estrus, Firk et al. (2002) described detection rates of 80-90%. In contrast, changes in ingestive behavior due to estrus have been rarely studied. Reith and Hoy (2012) quantified changes in ruminating activity in the peri-estrus period. They reported a reverse dynamic of ruminating activity with a gradual decrease staring 2 days before onset of estrus (Reith and Hoy 2012). Monitoring parameters of ingestive behavior may enable to achieve higher estrus detection rates.

A pilot study at Agroscope Tänikon research station was conducted to determine the feasibility of automatic heat detection by measuring parameters of ruminating and eating activity in dairy cows. The objective was to assess the suitability of the RumiWatchSystem (Itin+Hoch GmbH, Liestal, Switzerland) for automatic detection of heat and to investigate changes in parameters of ingestive behavior from peri-estrus days compared to the estrus day. Results of this study serve for further enlargement of the system's functionality and for set-up of additional analysis functions. In its current state of development, an analysis algorithm for estrus detection is not yet implemented to the system.

2. Materials and methods

2.1 Investigation methods

RumiWatchSystem (Itin + Hoch GmbH, Liestal, Switzerland) is a sensor-based system enabling automatic measurement of rumination, feed intake, water intake and locomotion. It incorporates a noseband sensor, data logger with on-line data analysis, pedometer and evaluation software. The noseband sensor consists of a vegetable oil-filled silicone tube with a built-in pressure sensor placed in the casing of a halter over the bridge of the cow's nose (Fig. 1). The curvature of the noseband is altered by the cow's jaw movement, causing a pressure change in the silicone tube. The pressure sensor is connected to a data logger and accelerometer placed in a protective casing on the right side of the halter. A second casing on the left side of the halter serves for storage of power supply. The data logger registers the pressure in the noseband sensor and the motion activity of the head at a constant logging rate of 10 Hz and saves the raw data to a SD Memory Card. Selectable formatting of the memory card allows a recording period up to four months. The data are transmitted wireless or using a SD Memory Card to a computer operating the evaluation software ("RumiWatch Manager"). The low-energy system has a focus on long-term (months to several years) operating time at minimized energy consumption.

Automatic measurement of jaw movements is based on a generic algorithm without animal specific learning data. The system allows individual jaw movements to be recorded. Incoming pressure data are automatically classified as "ruminating", "eating", "drinking" or "other activity". Detailed on-line analysis enables quantification of total ruminate time, number of boli and chews per bolus while ruminating. Equivalent analysis is conducted for additional behavior parameters (feed intake, water intake). Additionally, an indicative value for identification of periodically increased motion activity of the head is calculated based on the measurements of the accelerometer contained in the noseband sensor. Cow's motion states are measured via a three-dimensional accelerometer that functions as a pedometer. Data logger, data storing and transmission, logging rate and energy management are identical to the previously described noseband sensor. Pedometer analysis algorithm allows classification und quantification of different motion states, i.e. walking, lying, and standing with an indication on periodically increased intensity of motion behavior (activity index). In the present study, the noseband sensor was the experimental method, whereas the pedometer served as a reference method.

Reference methods for estrus verification were Kamar Heatmount Detectors (Kamar Products Inc., Zionsville, USA), RumiWatch pedometers (Itin+Hoch GmbH, Liestal, Switzerland) and visual observation. Kamar Heatmount Detectors are a pressure sensitive device intended to be activated by standing heat behavior. The detector is glued onto the tail head of the observed cow. If pressure from the brisket of a mounting cow is exerted on the contained pressure tube, the mounting event is indicated by a stain form white to red. Pedometers were applied to identify period with increased locomotory activity of the animal, as these changes in activity are a clear indication of heat in cattle (Arney et al. 1994). Visual observation of the experimental animals aims at definite identification of the estrus day and adequate time for insemination. Behaviors like mounting and flehming, and physiological changes, e.g. swelling of the lips of the vulva and bleeding off provide information on the state of estrus. The chosen reference methods were intended to detect an occurring estrus event and to clearly identify the day of estrus.

Figure 1: Dairy cow equipped with RumiWatch® noseband sensor (left) and Kamar® Heatmount Detector (right)

2.2 Animals, housing, and management

The study was conducted at research station Agroscope Tänikon (Ettenhausen, Switzerland). A total number of 55 dairy cows (Brown Swiss, Red Holstein x Fleckvieh) were kept in a loose housing system with cubicles, solid flooring, and half-automated manure removal. All cows were milked in a 2x3 auto-tandem milking parlor (GEA Farm Technologies Suisse AG, Ittigen, Switzerland) twice a day at 4:00 am and 4:00 pm. A mixed ration with different proportions of concentrate and forage was provided by an automated feeding system (Pellon Group Oy, Ylihärmä, Finland) up to eight times per day. Cows had permanent access to an outdoor paddock with slatted flooring. Average milk-yield of the herd was 8327 kg (Brown Swiss) and 9227 kg (Red Holstein x Fleckvieh) per 305-day-lactation.

2.3 Experimental set-up

Experimental animals (n=7 multiparous cows, 154±65 days in milk) were equipped with RumiWatch noseband sensors and pedometers from two weeks before until two weeks after the calculated estrus day. Measurement data of the sensors were transferred to a computer operating the specific evaluation software several times per day. Estrus was defined as the day when cows were detected in estrus by the technical reference methods (Kamar Heatmount, Detector, RumiWatch pedometer) and by visual observation for verification. Pedometer data and Kamar detectors were checked several times per day. Visually observed estrus events or indicative behaviors were noted in a protocol daily by researchers and farm staff. In this study, the day of estrus detection was identical with the day of insemination. In total, 10 estrus events were monitored at Agroscope Tänikon research stable (Ettenhausen, Switzerland) between April 29th and July 8th 2013. Out of 7 experimental animals, 3 cows were not inseminated at first observed heat. Hence, a second estrus cycle could be observed for each of these animals.

2.4 Data analysis:

Recorded 10-Hz raw data were transferred from the noseband sensors to a personal computer using the RumiWatch Manager software (version 0.9.6, Itin+Hoch GmbH, Liestal, Switzerland) and prepared for analysis using the RumiWatch Converter software (version 0.7.0.0, Itin+Hoch GmbH, Liestal, Switzerland). Considered measurement parameters of the RumiWatch noseband sensor for this analysis were number of ruminating chews per 24 hours, number of eating chews per 24 hours, number of ruminating boluses per 24 hours, and intensity of motion activity of the head per 24 hours. Changes in ruminating, eating, and motion activity were analyzed and compared for all monitored animals (n=7) and estrus cycles (n=10). Three reference days before (days -3 to -1) and after the day of estrus (+1 to +3), and the day of estrus itself (0) were compared in the evaluation. Calculated parameters were the mean, absolute change, and percentage change for the reference period (pooled 24-h average value for days -3 to -1 and +1 to +3) und the day of estrus (day 0).

3. Results and discussion

Results indicate that estrus significantly influences ruminating and eating activity in dairy cows. Motion activity of the head clearly increased by +34.5% compared to non-estrus days. On average, decrease in number of ruminating chews was -18.3% and -23.7% in number of eating chews when comparing the day of estrus versus the reference period (peri-estrus, days -3 to -1 before and +1 to +3 after the day of estrus). Number of ruminating boluses decreased by -16.0% at the day of estrus. Results for all analyzed behavioral parameters are shown in Table 1.

Table 1: Changes in behavioral parameters between the reference period and day of estrus (N=10 estrus cycles, n=7 cows, reference period is days -3 to -1 before and +1 to +3 after the day of estrus)

Parameter	**Dimension**	**Reference period [Ø]**	**Day of estrus [Ø]**	**Difference**	**Change [%]**
Ruminating chews	n	25’999	21’229	-4’770	-18.3
Eating chews	n	34’991	26’692	-8’299	-23.7
Ruminating boluses	n	470	395	-75	-16.0
Motion activity	RMS	1’649	2’219	+570	+34.5

RMS = Root mean square of the variance of accelerations

Figure 2 illustrates the dynamics in ruminating, eating, and motion behavior around the day of estrus. Values are shown in relation to the value measured at the day of estrus being the 100% reference. Results in Figure 2 represent an average value calculated from 10 monitored estrus cycles.

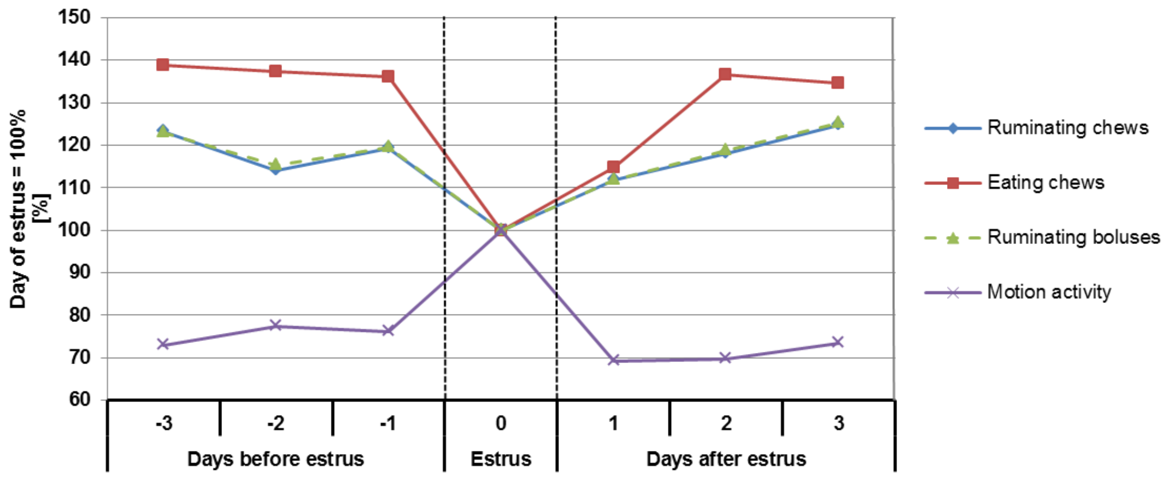

Figure 2: Changes in behavioral parameters between reference period and day of estrus

During data acquisition, all sensors worked reliably. Visual observation of heat events required intensive presence of the observers but allowed detection of all occurring estrus events and identification of the definite estrus day (day 0). The additional reference methods (Kamar Heatmount Detectors, RumiWatch pedometers) provided suitable support for verification of estrus events.

Based on the findings of this study, several parameters of ruminating and eating behavior were identified as potentially significant indicators for automatic heat detection in dairy cows. Observed tendencies for a decrease in ruminating activity from the peri-estrus towards the estrus day are similar to the results reported by Reith and Hoy (2012). Reverse dynamic of rumination with a gradual decrease starting 2 days before onset of estrus can also be found in recordings from this pilot study. These behavioral changes may be reliably measured by RumiWatch, as the parameters of ingestive behavior that can indicate heat are fully implemented to the monitoring system. Nonetheless, an analysis algorithm for estrus detection was not yet developed for this system, as a more extensive sample is required.

4. Conclusions

The chewing sensor used in this study has the potential to become a suitable tool for heat detection, as it constantly measures relevant behavioral parameters for reliable estrus detection, e.g. ruminating activity (Reith and Hoy 2012). Particularly in a systematic approach when used in combination with a pedometer, very high heat detection rates may be achievable. This ability is of particular relevance in commercial dairy farming. From a scientific point of view, application of the described chewing sensor and its analysis routines may enable closer characterization of changes in ingestive behavior by the onset of heat. Further research and development works serve for implementation and validation of a function for automatic heat detection as part of the health monitoring system (RumiWatch). Therefore, an extensive sample size in terms of farms, animals, and estrus cycles is required.

5. Acknowledgements

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