Animal Reproduction Science 180 (2017) 50–57

Contents lists available at ScienceDirect

Animal Reproduction Science

journal homepage: www.elsevier.com/locate/anireprosci

Estrous detection by monitoring ventral tail base surface temperature using a wearable wireless sensor in cattle

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ARTICLE INFO

Article history:
Received 9 January 2017
Accepted 3 March 2017
Available online 11 March 2017

Keywords:
Body surface temperature
Wearable wireless sensor
Estrous detection
Ovulation
Cattle

ABSTRACT

In the present study, the ventral tail base surface temperature (ST) was monitored using a wearable wireless sensor for estrus detection in cattle. Relationships among ST, behavioral estrus expression, ovulation, and changes in hormone profiles during the estrous cycle were examined. Holstein Friesian or Japanese Black female cattle were used in summer (August–September), autumn (October–November) and winter (January–February; three animals per season). On Day 11 of the estrous cycle (Day 0 = the day of ovulation), the sensor was attached to the surface of the ventral tail base and ST was measured every 2 min until Day 11 of the next estrous cycle. Hourly maximum ST values were used for analysis. To exclude circadian rhythm and seasonal effects, ST changes were expressed as residual temperatures (RT = actual ST − mean ST for the same hour on the previous 3 days). Obvious circadian rhythms of the ST were observed and daily changes in the ST significantly differed among seasons. There was no significant seasonal difference, however, in the RT. The mean RT increased significantly ~24 compared with ~48 h before ovulation. The mean maximum RT was 1.27 ± 0.30 °C, which was observed 5.6 ± 2.4 h after the onset of estrus, 2.4 ± 1.3 h before LH peak, and 26.9 ± 1.2 h before ovulation. The ST of the ventral tail base could be monitored throughout the estrous cycle and could detect a substantial change around the time of expression of behavioral estrus. Calculation and analysis of the RT could be useful for automatic estrous detection.

1. Introduction

Estrous detection is one of the most important factors for improving reproductive performance in the dairy and beef cattle industries and is generally accomplished by visual observation of estrous signs, such as standing to be mounted when in estrus (López-Gatius, 2012; Shahinfar et al., 2014). However, the duration of estrus and standing for mounting events have been decreasing, coinciding with increasing emphasis on the milk production trait in dairy cows (Lopez et al., 2004). Various sensor systems for automatic detection of estrus, such as pedometers, neck-mounted collars to measure physical activity, and pressure sensing devices to measure standing estrus, have been developed (Roelofs and Van Erp-van der Kooij, 2015). Moreover, several studies have indicated an association

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http://dx.doi.org/10.1016/j.anireprosci.2017.03.002
0378-4320/

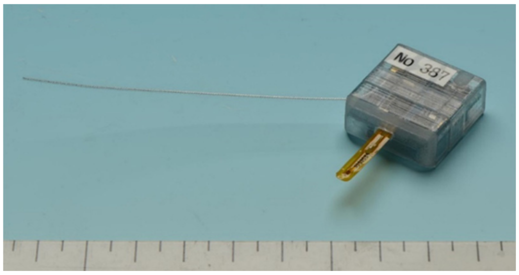

Fig. 1. Wearable wireless sensor for monitoring the body surface temperature.

between body temperature and estrus in cattle, with an increase of 0.3–1.0 °C in vaginal temperature during the estrous phase of the estrous cycle (Mosher et al., 1990; Redden et al., 1993; Kyle et al., 1998; Suthar et al., 2011; Sakatani et al., 2016). The rate of estrous detection is greater when monitoring the vaginal temperature every hour, rather than using a pedometer (Sakatani et al., 2016). Thus, monitoring the body temperature throughout the estrous cycle could be effective for detecting estrus accurately and improving the timing of artificial insemination.

A wearable wireless sensor has been developed for measurement of the body surface temperature (ST) at the ventral tail base in calves (Nogami et al., 2013, 2014). Monitoring the ST in this way would likely be less stressful to the animal and a less invasive procedure than measuring vaginal temperature. The changes in the ST, however, throughout the estrous cycle in adult female cattle are still unknown.

The aim of the present study was to develop a new procedure for estrous detection by monitoring the ventral tail base ST during the estrous cycle in female cattle. Relationships were examined among ST, estrous behavior, ovulation, and changes in hormone profiles throughout the estrous cycle in different seasons of the year, and the overall efficacy of estrous detection using ST was evaluated.

2. Materials and methods

2.1. Design of the wireless sensor

A wireless sensor nodes was designed which can be attached to the base of the ventral surface of a cow's tail. The sensor nodes were divided into two parts, a main unit and a 25.0-mm-long thermistor (103JT-025, SEMITEC Corporation, Tokyo, Japan). The main unit contains the micro control unit, transmitter, and battery. The main unit, without the connector, measures 20.0 × 20.0 × 4.3 mm. The size of the main unit with the temperature unit and the case is 25.0 × 25.0 × 9.6 mm, and it weighs 7.7 g when the battery is inserted (Fig. 1). In the present research, the battery was a CR2032 (3.0 g).

The operating frequency of the transceiver was chosen to be 920 MHz. The distance to the receiver was approximately 100 m when there were no obstacles present. The measurement and transmission interval was set to 2 min, and the lifetime of the sensor nodes was > 6 months using the CR2032 battery.

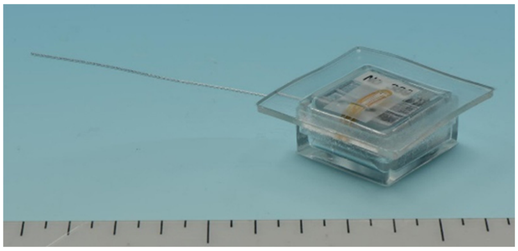

Fig. 2. Wearable wireless sensor covered with urethane gel.

Fig. 3. Position of the wearable wireless sensor attached to the lower surface of the ventral tail base.

2.2. Animals and experimental design

All the procedures employed in this study were approved by the Institutional Care and Use Committee for Laboratory Animals of the National Institute of Animal Health, NARO (Protocol No. 15-012). Nine female cattle (five Holstein Friesian heifers, one Japanese Black heifer, and three Japanese Black cows; 2.7 ± 0.8 years old) with normal estrous cycles were used in summer (August–September), autumn (October–November) and winter (January-–February; three animals per season). All cattle were housed in tie-stall barns under natural conditions of sunlight and temperature at the National Institute of Animal Health. Distances from the receiving antenna to the animal were 3.0–15.0 m. All experimental procedures and data collection were conducted from August 2015 to February 2016.

After switching on the device, the sensor was covered with urethane gel (Fig. 2) to prevent damage to the tail skin. The soft cover measured 29.0 × 29.0 × 11.6 mm (the upper side was 45.0 × 45.0 mm) and it was 2.0 mm thick. On Day 11 of the estrous cycle (Day 0 = the day of ovulation), the wearable wireless sensor was attached to the surface of the ventral tail base for measuring ST (Fig. 3). The sensor was wrapped with elastic medical bandage (SRPH50, Nichiban Co., Ltd., Tokyo, Japan) and then surrounded with a hook and loop fastener to stabilize its position. In addition, it was suspended by elastic webbing with hook and loop fasteners from the back of each animal and then was wrapped with elastic medical bandage (SRPH75, Nichiban Corp.) to cover the sensor, fastener and elastic webbing (Fig. 4). The ST was measured every 2 min until Day 11 of the subse-