

Original Article

Differences in ruminal temperature between pregnant and non-pregnant Korean cattle

Dae Hyun Kim^{1,4}, Jae Jung Ha¹, Jun Koo Yi¹, Byung Ki Kim¹, Woo-Sung Kwon², Bong-Hae Ye³, Seung Ho Kim⁴ and Yoonseok Lee^{4,5,*}

¹Livestock Research Institute, Yeongju 36052, Korea

²Department of Animal Science and Biotechnology, Kyungpook National University, Sangju 37224, Korea

³Division of Livestock Policy, Province of Gyeongsangbuk-Do, Andong 36759, Korea

⁴Department of Biotechnology, College of Agriculture & Life Science, Hankyong National University, Anseong 17579, Korea

⁵Center for Genetic Information, College of Agriculture & Life Science, Hankyong National University, Anseong 17579, Korea

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*Correspondence

Yoonseok Lee

E-mail: yoonseok95@hknu.ac.kr

ORCID

<https://orcid.org/0000-0003-4803-5192>

ABSTRACT In recent years, various methods of measuring body temperature have been developed using wireless biosensors to facilitate an early detection of pregnancy and parturition in cows. However, there are no studies on real-time monitoring of cattle body temperature throughout pregnancy. Therefore, we investigated the daily mean ruminal temperature in pregnant cows throughout pregnancy using a ruminal bio-capsule sensor and then evaluated the temperature variation between pregnant and non-pregnant cows. In pregnant cows, the mean and standard deviation of ruminal temperature was $38.86 \pm 0.17^\circ\text{C}$. Ruminal temperature in pregnant cows slowly decreased until 180 to 190 days after artificial insemination and after that, the temperature increased dramatically until just before parturition. Furthermore, the means ruminal temperature was significantly different between pregnant and non-pregnant cows. The mean and standard deviation of ruminal temperature were as follows: $38.68 \pm 0.01^\circ\text{C}$ from days 80 to 100, $38.78 \pm 0.02^\circ\text{C}$ from days 145 to 165, $38.99 \pm 0.45^\circ\text{C}$ from days 200 to 220, $39.14 \pm 0.38^\circ\text{C}$ from days 250 to 270 before parturition. Therefore, our results could provide useful data for early detection of pregnancy and parturition in Korean cows.

Keywords: Korean cattle, pregnant cow, ruminal bio-capsule sensor, ruminal temperature

INTRODUCTION

Recently, Information & communications technology (ICT) has been used to increase reproductive performance, and improve breeding management and disease detection in the livestock industry (Cooper-Prado et al., 2011; Lee et al., 2016; Sakatani et al., 2018; Higaki et al., 2019). Early detection of estrus and pregnancy in breeding cows is an important factor influencing reproductive performance. Currently, there are many physiological in-

dicators to detect the occurrence of estrus and pregnancy.

Among these indicators, several studies have reported that changing body temperature in cows is associated with reproductive performance. A study showed that body temperature increased in pregnant cows and changing of body temperature highly correlates with physiological mechanisms (Suthar et al., 2012). Furthermore, body temperature in lactating dairy cattle is higher than that in pregnant cows because of metabolic heat generation. It was shown that body temperature in pregnant cows was

higher than that in non-pregnant cows during fertilization after artificial insemination (Gil et al., 2001). Vaginal temperature in pregnant dairy cows changes depending on the stage of pregnancy (Scanavez et al., 2017). At pregnancy day 180, vaginal and rectal temperatures in pregnant cows were relatively higher than that in non-pregnant cows, and these temperatures immediately decreased before parturition (Burfeind et al., 2011; Cooper-Prado et al., 2011; Suthar et al., 2012; Ricci et al., 2018).

Recently, a technology has been developed to detect temperature changes in real-time by inserting a sensor into the rumen of a cow through the bolus system. Various studies using implantable sensors to detect change in milk production, ruminal pH, feed intake rate, and vaccination have been conducted (Gasteiner et al., 2012; Gasteiner et al., 2015; Kim et al., 2017a; Ammer et al., 2018; Villot et al., 2018).

Use of thermometers, the most common method of measuring core body temperature, is limited and cannot be used to measure body temperature in real-time. Several wearable sensors have been developed for real-time monitoring of cattle body temperature (Gasteiner et al., 2012; Gasteiner et al., 2015; Kim et al., 2017a; Ammer et al., 2018).

Therefore, the aim of this study was to record the daily body temperature throughout the pregnancy period using a ruminal wearable sensor, and to investigate the differences in body temperature between pregnant and non-pregnant cows.

MATERIALS AND METHODS

Animals and management

The animal experiment was approved by the IACUC (Institutional Animal Care and Use Committee) of the Gyeongsangbuk-do Livestock Research Institute and all applicable national laws and policies regarding the care and use of animals were performed during the experi-

ment. One hundred twelve mature Hanwoo cows (37 pregnant and 75 non-pregnant cows) were included in the study. During the experiment, cows were housed in a stanchion barn with sufficient space and were given feed according to the Korean feeding standards program. Rice straw, mineral blocks, and water were fed *ad libitum*. The breeding management information on the experimental animals by group used in this study are shown in Table 1. No abnormalities in the ovaries and uterus were found through ultrasound examination.

Real-time measurement of ruminal temperature using wearable bio-capsule sensor

In order to monitor ruminal temperature in real-time, cows were orally administered the ruminal wireless bio-capsule sensor (LiveCare, UlikeKorea, Korea). Recently, this sensor has been validated in a dairy cattle experiment with rumen-cannulated cows (Kim et al., 2017b). The sensor measured ruminal temperature every 10 min and transmitted the data in real-time to a basis station using the LiveCare system. The size of the sensor was 125 mm in length with a diameter of 36 mm and the weight was 200 g when the battery was inserted. The ruminal temperature was collected according to the method reported by Kim et al., 2017b.

Detection of pregnancy

Pregnancy was detected at 40 days after artificial insemination using transrectal ultrasonography (HONDA HS-101V, HONDA, Japan) and reconfirmed at days 100 and 200 of pregnancy.

Statistical analysis

Data on ruminal temperature from the ruminal wireless bio-capsule sensors were downloaded into Excel spreadsheets. The data were analyzed to determine the pattern of ruminal temperature in cows and compared between pregnant and non-pregnant cows using the 'ggplot' pack-

Table 1. The breeding management information of pregnant and non-pregnant cows

Group	No. of cows	Mean \pm SD*		
		Ruminal temperature	Month of breeding	Parity
Pregnant cows	37	38.86 \pm 0.17	34.0 \pm 1.84	1.2 \pm 0.14
Non-pregnant cows	75	38.72 \pm 0.08	34.3 \pm 2.39	0.9 \pm 0.12
Total	112	38.76 \pm 0.06	34.1 \pm 1.45	1.1 \pm 0.10

*Standard deviation.

age of the R program (version: 3.6.2, Foundation for Statistical Computing, Vienna, Austria). Ruminal temperature $< 37.5^{\circ}\text{C}$ were considered as a consequence of water consumption (Bewley et al., 2008; Cooper-Prado et al., 2011) and excluded from analyses.

The daily mean ruminal temperature was calculated throughout pregnancy. Furthermore, for comparison of body temperature, the means were calculated at four different periods of pregnancy: days 80 to 100, days 145 to 165, days 200 to 220, and days 250 to 270. So, the daily mean ruminal temperature at four periods was compared by one-way ANOVA and Tukey's HSD tests. The results were reported as the mean \pm standard deviation (SD) and differences with $p < 0.05$ were considered significant.

RESULTS

Pattern of the daily mean ruminal temperature in Hanwoo cow

We determined the daily mean ruminal temperature for the entire period of pregnancy using data collected from wireless bio-capsule sensors. The pattern of the daily mean ruminal temperature in cows ($n = 112$) is presented in Fig. 1. The body temperature was measured every 10 min using a wireless bio-capsule sensor and then the daily mean was calculated.

As shown in Fig. 1, the mean and standard deviation of ruminal temperature was $38.76 \pm 0.06^{\circ}\text{C}$, and the maxi-

mal and minimal temperatures were 39.05°C and 38.61°C , respectively. All cows were vaccinated with FMD (Foot and Mouth Disease) vaccine on February 1, 2019. After FMD vaccination, a rapidly increasing ruminal temperature was confirmed in all cows because of inflammation and acute-phase reaction. The daily mean and standard deviation of ruminal temperature in pregnant cows was $38.86 \pm 0.17^{\circ}\text{C}$ and that in non-pregnant cows was $38.72 \pm 0.08^{\circ}\text{C}$.

Comparison of ruminal temperature in pregnant cows with that in non-pregnant cows

Differences in ruminal temperature between pregnant and non-pregnant cows is shown in Fig. 2. In this study, since the gestation period was different in all pregnant cows, gestation periods were sorted by parturition day using the R program.

As shown in Fig. 2, the mean ruminal temperature in pregnant cows was gradually decreased compared to non-pregnant cows at 245 days after artificial insemination. In addition, the mean ruminal temperature between pregnant and non-pregnant cows showed the highest difference at 100 days before parturition. Since then, the mean ruminal temperature in pregnant and non-pregnant cows was similarly maintained from 180 to 190 days before parturition ($p < 0.05$). The mean ruminal temperature in pregnant cows was increased compared with non-pregnant cows until 190 to 280 days just before parturition.

Overall, we found that the mean ruminal temperature

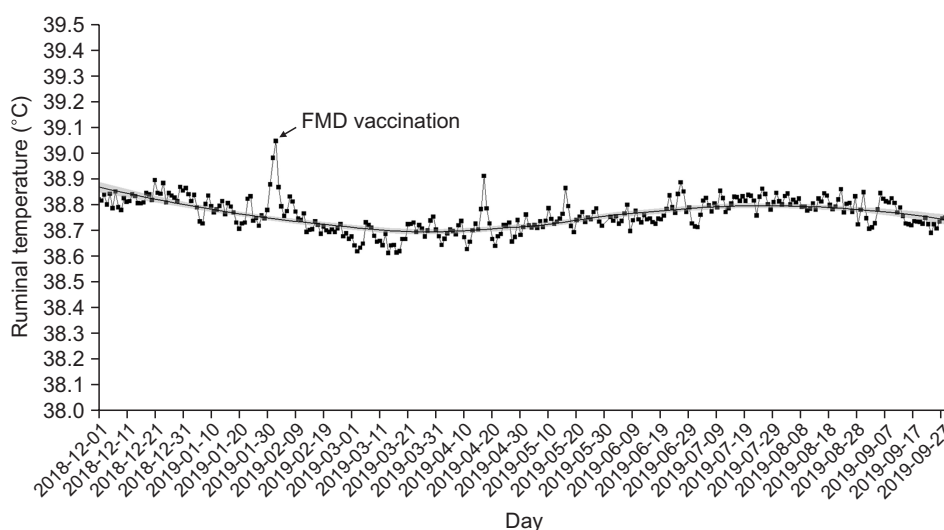


Fig. 1. The pattern of daily mean of ruminal temperature in Hanwoo cows ($n = 112$). The mean and standard deviation of ruminal temperature. The black line connected by the black round dot (●) represents the average daily ruminal temperature. Black lines with shades depict polynomial regression lines. The black diagonal line indicates when the FMD vaccine was administered.

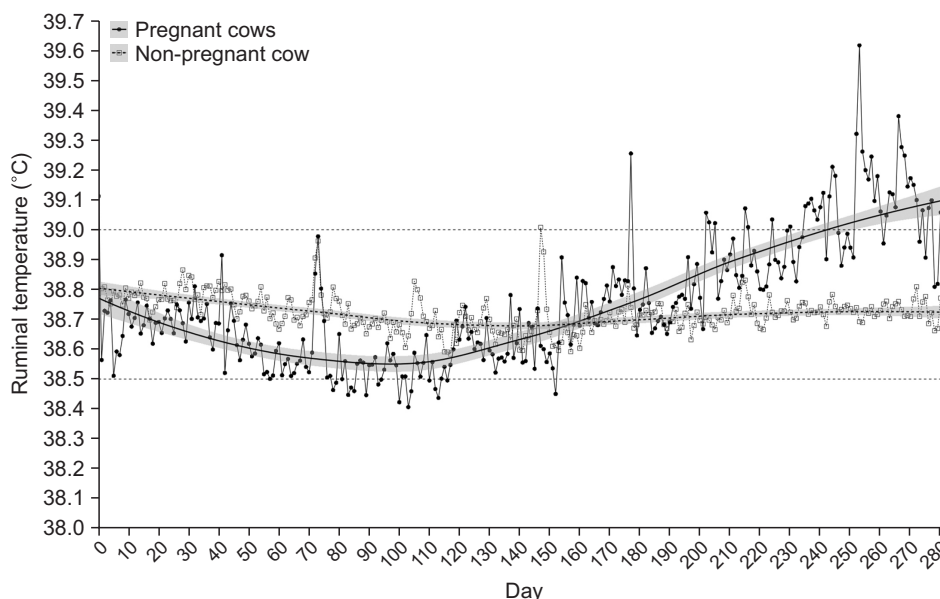


Fig. 2. The difference in the daily pattern of ruminal temperature between pregnant and non-pregnant cows throughout pregnancy. The mean and standard deviation of ruminal temperature. The black line connected by the black round dot represents the average daily ruminal temperature in pregnant cows. The dashed line and solid line represent ± 2 standard deviation and average temperature in non-pregnant cows. Shaded black lines and dotted lines represent polynomial regression lines. The black diagonal line indicates when the FMD vaccine was administered. Thick horizontal black bars represent mean ruminal temperatures at four different periods: days 80 to 100 (I), days 145 to 165 (II), days 200 to 220 (III), and days 250 to 270 (IV). Means without a common letter represent significant differences ($p < 0.05$).

Table 2. The probability value of ruminal temperature in pregnant and non-pregnant cows at four periods after artificial insemination

Day after artificial insemination	Ruminal temperature (Mean \pm SD*)	
	Pregnant	Non-pregnant
80–100	38.68 ^a \pm 0.01 ^a	38.68 \pm 0.04
145–165	38.78 ^b \pm 0.02 ^b	38.69 \pm 0.04
200–220	38.99 ^c \pm 0.45 ^c	38.71 \pm 0.05
250–270	39.14 ^d \pm 0.38 ^d	38.66 \pm 0.03
p-value	0.000	0.151

*Standard deviation.

^{a,b,c,d}Means with different letters are significantly different at $p < 0.05$.

between pregnant and non-pregnant cows for four different pregnancy periods was significantly different. The probability value, mean and standard deviation of ruminal temperature in pregnant and non-pregnant cows is shown in Table 2. The mean and standard deviation were as follows: $38.672 \pm 0.007^\circ\text{C}$ from days 80 to 100, $38.785 \pm 0.010^\circ\text{C}$ from days 145 to 165, $39.006 \pm 0.010^\circ\text{C}$ from days 200 to 220, and $39.126 \pm 0.010^\circ\text{C}$ from days 250 to 270 after artificial insemination.

DISCUSSION

In this study, we investigated the daily variation in mean ruminal temperature in pregnant cows throughout pregnancy using a wireless bio-capsule sensor system, and then evaluated the differences in ruminal temperature between pregnant and non-pregnant cows. Our results showed that the ruminal temperature in pregnant cows gradually decreased at 180–190 days after artificial insemination and since then, it dramatically increased until just before parturition.

However, the results were inconsistent with previous several studies. Gil et al. (2001) suggested that the mean rectal temperature in pregnant cows ($39.09 \pm 0.22^\circ\text{C}$) was higher than that in non-pregnant cows ($38.63 \pm 0.14^\circ\text{C}$) at 5–12 days of gestation. This could be due to the differences in temperature measurement sites described by Lee et al. (2016).

In addition, at 180 days after artificial insemination, the vaginal and rectal temperatures in pregnant cows were increased by 0.3°C and 0.2°C , respectively than that in non-pregnant cows, although these differences were not significant (Suthar et al., 2012). Although the observed ruminal temperature in pregnant cows was higher than

that in non-pregnant cows from days 180 to 190 before parturition, the estimated mean between pregnant and non-pregnant cows was similar.

Notably, our study identified that ruminal temperature in pregnant cows was gradually increased from day 180 to just before parturition. During the period from day 180 to just before parturition, the increase in ruminal temperature led to an increase in the level of progesterone, which in turn increased the core temperature due to its thermogenic effect (Cooper-Prado et al., 2011).

Furthermore, the ruminal temperature in pregnant cows during the luteal phase was higher than that in non-pregnant cows (cycling cows) due to increased metabolic activity and physiological changes for foetal development following higher feed intake (Kendall and Webster, 2009).

In our study, the ruminal temperature gradually decreased before parturition. Cooper-Prado et al. (2011) reported that the decreased ruminal temperature before parturition was attributable to abnormal feeding rates and endocrine changes via secretion of hormones during pregnancy.

CONCLUSION

The dramatic change in the ruminal temperature of pregnant cows is interesting because this is the first study to monitor the real-time pattern of ruminal temperature and its differences between pregnant cows and non-pregnant cows. Therefore, the ruminal temperature in pregnant cows were found to significantly vary at four different periods of pregnancy. We believe that our findings will provide useful information for early detection of pregnancy and parturition in Korean cows.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Conceptualization: Dae Hyun Kim, Jae Jung Ha, Yoonseok Lee

Data curation: Seung Ho Kim, Yoonseok Lee

Formal analysis: Dae Hyun Kim, Jae Jung Ha, Jun Koo Yi

Funding acquisition: Bong-Hae Ye, Byung Ki Kim, Woo-Sung Kwon

Investigation: Dae Hyun Kim, Jae Jung Ha

Methodology: Dae Hyun Kim, Woo-Sung Kwon, Yoonseok Lee

Project administration

Resources: Gyeongbuk Provincial Government

Software: Seung Ho Kim, Yoonseok Lee

Supervision: Yoonseok Lee

Validation: Seung Ho Kim, Yoonseok Lee

Visualization: Seung Ho Kim, Yoonseok Lee

Writing - original draft: Dae Hyun Kim, Yoonseok Lee

Writing - review & editing: Dae Hyun Kim, Yoonseok Lee

AUTHOR'S POSITION AND ORCID NO.

DH Kim, PhD,

<https://orcid.org/0000-0002-4820-4438>

JJ Ha, PhD,

<https://orcid.org/0000-0001-6785-6346>

JK Yi, PhD,

<https://orcid.org/0000-0003-2593-6529>

BK Kim, PhD,

<https://orcid.org/0000-0003-3127-6643>

WS Kwon, Professor,

<https://orcid.org/0000-0002-0848-7189>

BH Ye, BS,

<https://orcid.org/0000-0002-7941-2053>

SH Kim, BS,

<https://orcid.org/0000-0003-1334-0154>

Y Lee, Professor,

<https://orcid.org/0000-0003-4803-5192>

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