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Reproductive Management by the Continuous Body Temperature Measurement in Cattle: Focusing on the Reproductive Hormonal Change

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ABSTRACT

Proper reproductive management, breeding and calving is essential for the good farm management. Recently the conception rate of cattle is decreasing. One reason is the weak estrous behavior which makes difficult to breed at the appropriate time. Therefore, the efficient detection system of estrus without observation has been desired. On the other hands, calving accidents such as the dystocia and stillbirth directly affect farm management. Farmers need to monitor cows at any hour of day or night to avoid accidents. Therefore, the automatic detection of calving has been also desired. Estrus and calving are regulated by reproductive hormones. The measurement of hormonal levels is the most precise way to understand the estrus and calving. However, the measurement of hormones costs and is difficult at the farm. Recently, various studies demonstrated the relationship between hormonal levels and the body temperature. Here, we used the continuous vaginal temperature measurement to detect the estrus and the calving timing. First, we evaluated the estrus detection by the vaginal temperature and the effect of hormone administration on the vaginal temperature. We found that the vaginal temperature rose at the estrus and by utilizing and measuring this, we could detect estrus with high accuracy. In addition, the vaginal temperature change reflected the progesterone level. These findings successfully demonstrated that the vaginal temperature measurement is effective for detecting estrus. Second, we evaluated the utility of the continuous vaginal temperature measurement using commercial thermometer for detecting the calving timing. The vaginal temperature decreased around 24 h prior to the calving time. Interestingly, the prolonged duration of calving was also associated with calving assistance and dystocia. Our findings indicated that the continuous measurement of vaginal temperature could become a good indicator for predicting not only the onset of calving but also the calving accidents. Thus, the vaginal temperature well reflects the reproductive hormone, progesterone level. The measurement of vaginal temperature would be a good tool for reproductive management in cattle.

Keywords: Cattle, estrus, parturition, progesterone, vaginal temperature

INTRODUCTION

Recently, the management scale of livestock farm has been expanding. Concomitantly, the time of reproductive management is decreasing. This lack of management time would lead to decrease the pregnancy rate due to the missing of the estrus detection and increase of calving accidents.

The estrus detection is essential for the proper artificial breeding. Generally, the detection of estrus is based on the detection of standing heat by the observation. The dairy cattle have been shown lower estrus symptoms and shorter estrus duration according to the increase of milk yield (Dobson *et al.* 2008). Environmental factors such as heat stress also decrease the rate of estrus detection (Sakatani *et*

al. 2012). The decrease of standing heat rate and duration make difficult to detect the estrus by the observation. The utilization of automated sensor would detect the estrus precisely and reduce the labor and cost. Widely prevalent estrus detection methods are to detect the activity increase by the pedometer or accelerometer. However, these signs are sometimes affected by the social order of herd and other external factors (Sakatani *et al.* 2016, Palmer *et al.* 2012). It is necessary to detect estrus unaffected by external factors. Reproductive activities including estrus are regulated by reproductive hormones. Therefore, the measurement of hormonal levels is most accurate marker for detecting estrus. However, it is impractical at farm and the marker alternative to the activity including standing heat or activities are desired.

Calving accident directly hit farmers' finance by death of cows or calves and damage of maternal body which decreases the milk yield or reproductive recovery. Therefore, calving management is also important for maintaining stable farm management. There are several symptoms at calving as the relaxation of pelvic ligaments, udder edema and vaginal mucus discharge. These are found by the observation and clear symptoms of calving. However, these signs are not suitable for predicting the onset or the time of calving. As farm scale becomes larger, the management of calving becomes important and a greater problem. Because night time calving requires extra labor for farmers. The increase of calf size causes the high risk of dystocia and the increase of calving accidents (Mee 2008). Therefore, the efficient and effective reproductive management techniques for calving monitoring has been desired. Calving is also regulated by reproductive hormone. The cortisol secreted by the calf is a trigger of calving. It regressed the pregnant corpus luteum. The uterus contraction following oxytocin and PGF2α secretion from uterus induces the expulsion of calf.

The daily measurement of body temperature has been used to understand the estrus cycles in humans and to predict the day of calving. Thus, it is thought that the measurement of body temperature well-reflect the physiological activity such as hormonal levels. Here, we evaluated whether the continuous measurement of vaginal temperature using wireless is useful for detecting the estrus and onset of calving in Japanese black cattle.

Changes of body temperature and reproductive hormone level

Body temperature reflects various physiological phenomenon such as the inflammatory reaction, metabolic heat production by feed intake or the exercise and hormonal changes. The measurement of body temperature has been thought as one of estrus detection methods (Redden *et al.* 1993). The measurement of body (rectal) temperature continuously is difficult without restraint in cattle. However, the measurement of vaginal temperature enabled to continuous temperature measurement (Redden *et al.* 1993). Several studies demonstrated the elevation of body temperature on the day of estrus or during estrus (Redden *et al.* 1993, Piccione *et al.* 2003, Fisher *et al.* 2008, Suthar *et al.* 2011, Sakatani 2012). The transient increase of body temperature at the day of estrus would associate with LH surge (Fisher *et al.*2008). The start and peak points were synchronized between the body temperature and LH surge (Fisher *et al.*2008). Interestingly, this temperature increases were observed in cows kept in not only free-stall but also tie-stall. Thus, the body temperature increase at estrus would be regulated mainly by hormonal level. The increase of activity during estrus would enhance the increase of body temperature.

On the other hands, it is well-known the periodic variation of temperature during estrus. It might be related to progesterone levels secreted by the corpus luteum (Suthar *et al.* 2012, Sakatani *et al.* 2016). Thus, the periodic variation of body temperature might reflect the ovarian function in cattle. Therefore, we evaluated the effect of hormonal treatments on vaginal temperatures in cycling Japanese black cows. Cows which has the functional corpus luteum was treated PGF2α (2 mL i.m., Estrumate, MSD, Tokyo, Japan) which regressed corpus luteum. The vaginal temperature decreased significantly at 15 h after PGF2α treatment compared with that of day 7 after estrus as the functional corpus luteum existed (Sakatani *et al.* 2016). The lower vaginal temperature kept until the beginning of estrus. All PGF2α treated cows showed the estrus within 72 h after PGF2α treatment. However, the vaginal temperature did not decrease when the exogenous progesterone existed. The slow-released progesterone (Eazi-Breed, CIDR, Zoetis Japan, Tokyo, Japan) placed into vagina following artificial corpus luteum regression by PGF2α treatment. In the presence of CIDR, the temperature kept high value although the corpus luteum regressed. Once CIDR was removed from the vagina after 6 days insertion, the vaginal temperature started decreasing and was lower than that before PGF2α treatment (Sakatani *et al.* 2016). These results indicated that the periodic variation of body temperature during estrus cycles due to the progesterone level. Thus, the presence of progesterone keeps the body temperature high, and the low progesterone level by corpus luteum regression decreases the body temperature. Therefore, the continuous measurement of vaginal temperature is a good indicator of understanding the progesterone levels.

Detection of estrus by body temperature measurement

The periodic body temperature change is associated with progesterone levels. Moreover, the transient temperature elevation during estrus might be associated with LH surge. The rectal temperature elevated at the day of estrus (Walton and King 1986). Measurement of rectal temperature is a good method to detect the day of estrus but not suitable for detecting the beginning of the estrus which is important to breed artificially at the optimal time. Therefore, the automatic continuous monitoring is required to detect the beginning of estrus. Measurement of activity is popular and widespread in all over the world. However, the detection of activity was sometimes affected by several factors such as environments, rearing condition and social orders in the herd (Sakatani *et al.*, 2012, Sakatani *et al.* 2016, Palmer *et al.* 2012). It is thought that the body temperature measurement is less affected by the rearing condition and social orders, because it reflect the hormonal levels.

The duration of estrus was not different between the vaginal temperature measurement and activity measurement (Sakatani *et al.*2016). Also, it was no different between the beginning points of vaginal temperature elevation and standing heat which is the golden standard of the estrus detection (Higaki *et al.* 2019). Thus, it suggested that the measurement of vaginal temperature is effective for detecting the beginning of estrus. And it would become an indicator of breeding at optimal time.

In addition, continuous vaginal temperature measurement might be less affected by environments compared with activity. The estrus detection rate by activity was lower in summer than winter (Sakatani *et al.* 2012, 2016). Cows with natural estrus showed lower estrus detection rate than that in synchronized cows when utilizing the pedometer (Sakatani *et al.* 2016). The activity of cattle decreased under high ambient temperature and high humidity. In contrary, the activity was increased by insect avoidance behavior at the day time in summer when cows were in the outside paddock or pasture (Sakatani *et al.* 2016). Thus, the detection rate of activities is highly affected by environmental conditions. However, the vaginal temperature measurement showed the high estrus detection rate (more than 90%) with stability in Japanese Black cows (Sakatani *et al.* 2016). The changes of vaginal temperature during estrus would reflect the hormonal level and be insusceptible to environmental conditions different from the measurement of activity.

Although the estrus detection rate was not different between natural and synchronized estruses, estrus synchronized cows showed the higher temperature difference between estrus and non-estrus than those of natural estrus cows (Sakatani *et al.* 2016). Forced corpus regression leads the clear estrus behavior by enhanced secretion of estradiol 17β and LH (Larson and Ball 1992, MacDougall 2010). Consequently, the enhanced estradiol 17β and LH surge also induce the body temperature. The measurement of body temperature would detect the estrus with high fidelity in synchronized cows.

Prediction of calving by body temperature measurement

Calving starts at the secretion of cortisol from the fetus. It induces the secretion of PGF2α from the placenta and leads to pregnant corpus luteum regression. The pregnant corpus luteum regression starts 1 to 2 days before calving. Therefore, it could be a good indicator for predicting calving that detecting the regression of the pregnant corpus luteum by monitoring progesterone levels. The body temperature of pregnant cows decreased one day before calving (Lammoglia *et al.* 1997). This decline of body temperature was associated with decrease of the progesterone level along with the pregnant corpus luteum regression (Lammoglia *et al.* 1997). Therefore, measurement of rectal temperature twice daily (morning and evening) has been applied to detect the day of calving. One day before calving, the rectal temperature decreased significantly. It is useful way to know the day of calving, but it is unable to predict the time of calving and difficult to apply at the big farm. Therefore, the continuous measurement of body temperature, measurement of vaginal temperature might be a good indicator for detecting calving.

The wireless vaginal temperature sensor is commercially available in several countries. It has been demonstrated that the continuous measurement of vaginal temperature is useful to detect the calving (Aoki *et al.* 2005, Burfeind *et al.* 2011). Advantages of vaginal temperature sensor is to detect not only the onset of calving by decrease of the temperature, but also the rupture of allantoic sack. Because the rupture of allantoic sack pushes the vaginal temperature sensor out from the vagina and the temperature drops as the ambient temperature. This enable for farmers to present the calving and to provide the appropriate assistance as necessary. The vaginal temperature starts decrease two days prior to calving. Setting threshold of relative temperature decrease enables to predict the calving around one day before calving. The experiment was performed at the commercial Japanese Black beef cattle farm which kept 500 cows. Total 625 calving with vaginal temperature data were recorded. When the threshold of relative temperature change was set at 0.4ºC, the average temperature decrease point was

21:59 (hh:mm) before the first rupture of membrane. Average time from first rupture of membrane to calving was 2:06. The median of these two were 22:27 and 1:18, respectively (Sakatani *et al.* 2018). The detection rates of these two time were 88.3% and 99.4% (Sakatani *et al.* 2018). Thus, the calving detection by measurement of vaginal temperature shows quite high rate and it is possible at around 24 h before calving by setting the threshold at -0.4ºC.

In addition, these durations were affected by several factors. Dystocia, gestation period and parities were associated with duration from temperature decrease to the first rupture of membrane. Dystocia, gestation period, calf body weight and calf sex were also associated with the duration from first rupture of membrane to the calving. Interestingly, each duration became longer dependent on the necessity of assistance ($P<0.05$, Sakatani et al. 2018). Body weight of calves and male calf rate also increased dependent on the calving assistance necessity. Proper calving assistance is very important to reduce the calving accidents. This result indicated that the measurement of vaginal temperature has a potential of detecting the necessity of calving assistance or dystocia.

Future perspective

The measurement of continuous body temperature is also useful for health management. It is easy to detect infectious diseases or injuries associated with fever and it makes possible early medical treatment. On the other hand, there is a concern from the aspect of hygiene for measurement of vaginal temperature. Detecting estrus needs the insertion of thermometer into vagina for long time. It has a possibility to induce the discharge from vagina and the infection of the vagina or uterus. It is not suitable for inserting the thermometer into damaged vagina at soon after calving. Therefore, it needs more non-invasive and wireless measurement of deep body temperature. The possibilities of continuous temperature measurement of body surface or subcutaneous implanted thermometer were demonstrated by several articles (Miura *et al.* 2017, Koyama *et al.* 2018, Lee *et al.* 2016). Even measurement of skin surface temperature was evaluated for reproductive management (Miura *et al.* 2017, Koyama *et al.* 2018). However, it still has several technical problems and has not been on sale at a market yet.

These evidences imply that the continuous measurement of body temperature is useful for reproductive management without restraint. Measurement of vaginal temperature sensor has already been commercial used. It is mainly used for calving detection. It might be applied for detecting not only calving and estrus but also the reproductive problems like ovarian dysfunction (follicular cyst, non-ovulation) or detecting the calf size or calving assistance. More non-invasive and easy set up measurements and the combination of artificial intelligence would make it more precise and applicable reproductive management tool. Further evaluation is needed.

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