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Original article

Can reticulorumen ph, temperature and cow activity registered before calving act as biomarkers of diseases after calving?

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Abstract

The aim of this study was to determine if reticulorumen ph, temperature and cow activity registered before calving can serve as indicators of diseases after calving.

The cows were selected according to those fitting the profile of having had two or more lactations (on average 2.9±0.13 lactations), from 60 to 0 days before and the first 30 days after calving, and being clinically healthy. The clinical examination (identification of diseases after calving) was performed from 60 days before calving to 60 days after calving. Diseases after calving were diagnosed based on clinical symptoms specific to these diseases. The pH and temperature of the contents of the cow reticulorumens and cow activity were measured using specific smaX-tec boluses manufactured for animal care.

We found that the highest pH and temperature before calving can serve as biomarkers of healthy cows after calving. The lowest reticulum temperature before calving can serve as an indicator of MF after calving. A positive correlation of reticulum pH and temperature before calving can serve as biomarkers of PR. Decreasing cow activity before calving can serve as an indicator of diseases after calving. For calving prognosis, temperature of the reticulorumen can be used; it decreased 6–7 days before calving.

Key words: cow, diseases after calving, biomarkers, reticulorumen

Introduction

The peripartum period in dairy cows is characterized by a period of negative energy balance, reduced dietary matter intake (DMI), insulin resistance, lipolysis, and weight loss of varying severities (Koster and Opsomer 2013). In dairy cows, the periparturient or transition period is marked by nutritional, metabolic, hormonal, and immunological changes that have an impact on the incidence of infections and metabolic diseases (Goff and Horst 1997). During this period, cows are in a state of negative energy balance that occurs because the demand for nutrients for milk production increases rapidly and exceeds the supply

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of nutrients provided by food intake (Bauman and Currie 1980). Metabolic changes can lead to hypocalcemia, ketosis, displaced abomasum, and hepatic lipidosis (Bobe et al. 2004, Leblanc et al. 2005). During the transition period, dairy cows experience a natural state of immunosuppression, which can increase their susceptibility to uterine and mammary infections (Sheldon 2004). Parturition is associated with a decrease in the number of polymorphonuclear leukocytes (Sheldon 2004), along with a weakening of these cells' phagocytosis capacity and a decrease in their ability to fight bacteria (Kehrli et al. 1989). This period is also marked by a decreased responsiveness of blood lymphocytes to stimulation with mitogenic agents and by decreased immunoglobulin production by B cells (Nonnecke et al. 2003). The interaction between health status and parity affected all metabolites during the transition period (Ruprechter et al. 2018).

Precision technologies are often integrated into dairy farms to monitor individual animal health. One precision technology used is a bolus that is inserted into a cows' reticulorumen to monitor reticulorumen temperature (Cantor et al. 2018). Preventative health measures may reduce the impact of animal disease and improve animal health, cow longevity, and milk production (Romer 2011). One way to intervene prior to the emergence of clinical symptoms of a disease is by using constant measures to detect slight deviations, such as using a reticulorumen temperature transponder inserted into a cow's reticulorumen to detect changes in core body temperature. Temperature monitoring technologies such as reticuloruminal temperature transponders take multiple temperature measurements (AlZahal et al. 2011), providing the precision of identifying deviations from an individual cow's temperature and circadian rhythm (Bitman et al. 1984).

According to our past reports, measurements of reticuloruminal pH may be useful as a predictor of the likelihood of reproductive success (Antanaitis et al. 2018). Real-time observation of temperature and pH levels in the reticulorumen in fresh dairy cows allows the evaluation of the risk of SARA and provides the opportunity to determine the prophylactic effect of these capsules (Antanaitis et al. 2019). According to Cantor et al. (2018), temperature monitoring via the reticulorumen is an effective means of monitoring a dairy herd for water intake.

In the literature we found no information on how certain parameters such as reticulorumen ph, temperature and activity, registered before calving, can serve as biomarkers of diseases after calving. We hypothesized that reticulorumen ph, temperature and cow activity registered before calving can serve as biomarkers of some diseases after calving.

The aim of this study was to determine if reticulorumen ph, temperature and cow activity registered before calving can serve as indicators of diseases after calving.

Materials and Methods

Location, animals and experimental design. The study was conducted during the summer period from 01.05.2019 to 01.06.2019. The experiment was carried out on a dairy farm in the central region of Europe at 56 00 N, 24 00 E. Lithuanian Black and White dry dairy cows (n=30) were selected according to those fitting a profile of having had two or more lactations (on average 2.9±0.13 lactations), from 60 to 0 days before and the first 30 days after calving, and being clinically healthy. The clinical examination (identification of diseases after calving) was performed every day (at 10:00 a.m.) from 60 days before calving until 60 days after calving.

Clinical mastitis (CM) group (n=9 and 4808 records)

Clinical mastitis cases were characterized by clinical signs, including abnormal appearance of milk (watery, flakes, fibrin clots, and so on; mild), abnormal appearance of milk with swollen or painful quarter, and abnormal appearance of milk, swollen or painful quarter and the cow demonstrating systemic signs of illness (fever, decreased appetite, dehydration, and so on; severe). Treatment and management protocols for CM cows were assigned to individual cows based on clinical signs category and pathogen identification.

Milk fever group (MF) (n=4 and 4808 records)

The animals were in sternal recumbency with typical S-shaped curve on the neck, weakness and inappetence. On clinical examination, the general health condition was found to be poor. The body temperature was subnormal and pulse was undetectable.

Placental retention (PR) (n=6 and 5580 records)

The cows that did not expel their placenta within 12 h were diagnosed with PR.

Healthy group (H) (n=11 and 5472 records)

Without any clinical sign of disease after calving. Cows that expelled their placenta within 12 h after parturition were included in the healthy cow group

Table 1. Descriptive statistic by disease during the study period.

	pH		Temperature		Activity	
CM (n=9)	6.30	±0.01[a]	39.43	±0.01[a]	5.74	±0.05[a]
MF (n=4)	6.53	±0.01[b]	39.30	±0.02[b]	11.33	±0.06[b]
PR (n=6)	6.28	±0.01[a]	39.33	±0.01[b]	14.16	±0.13[c]
H (n=11)	6.31	±0.01[a]	39.48	±0.02[a]	7.85	±0.04[d]

[a,b,c,d] Values within rows with different superscripts differ significantly at p<0.05.

Table 2. Correlation between evaluated traits by disease of cows during the study period.

Disease	pH - temperature		pH - activity		Activity - temperature	
	r	P	r	P	r	P
CM (n=9)	0.055	0.001	-0.052	0.001	-0.125	0.001
MF (n=4)	0.030	0.133	-0.152	0.001	-0.051	0.011
PR (n=6)	0.059	0.001	0.069	0.001	-0.161	0.001
H (n=11)	0.120	0.001	-0.335	0.001	-0.188	0.001

We differentiated the clinical status of the cows as healthy or sick within the period of the investigation.

The cows were kept in a loose housing system and fed total mixed ration (TMR) throughout the year at the same time, balanced according to their physiological needs. Feeding took place every day at 06:00 and 18:00.

Measurements

The pH temperature of the contents of the reticulorumens and cow activity were measured using specific smaX-tec boluses manufactured for animal care. SmaX tecanimal care technology® enables the continuous real-time display of data such as ruminal pH and temperature. According to the directions of the manufacturer, the boluses were inserted into the reticulorumens of the cows investigated with the help of a specific tool. The data were measured with the help of specific antennas (smaXtec animal care technology®). For monitoring the reticuloruminal pH, an indwelling and wireless data transmitting system (smaXtec animal care GmbH, Graz, Austria) was used. The system was controlled by a microprocessor. The data (pH, temperature) were collected using an analogue-to-digital converter (A/D converter) and stored in an external memory chip. Due to its dimension (length: 12 cm, width: 3.5 cm, weight: 210 g), this indwelling system can be orally administered to an adult cow and is shock-proof and resistant to rumen fluid. Calibration of the pH-probes was performed using pH 4 and pH 7 buffer solutions at the beginning of the experiment. The data were read every 10 minutes, daily. The study was conducted from 01/05/2019 to 01/06/2019. All data were obtained by smaXtec messenger® computer software.

Statistical analysis of the data was performed using the SPSS 20.0 program package (SPSS Inc., Chicago, IL, USA). Using the descriptive statistics obtained, normal distributions were assessed for all variables by means of the Kolmogorov–Smirnov test. The differences in the mean values of the normal distributed variables were analysed using Student's t-test. A probability of less than 0.05 was considered significant (*p*-value<0.05).

Results

The average pH of healthy cows differed significantly (by 3.37%) from the pH of the MF group (p<0.05). Cows in this group showed the highest pH of the reticulum - 3.52% higher than the CM group and 3.83% higher than the PR group (p<0.05). The group of healthy cows showed the highest level of reticulum temperature which was 0.13–0.46% higher than in other groups (p<0.05). The lowest values of the reticulum temperature were shown by MF cows.

For the arithmetic average of cow activity, we found a much more marked difference between the groups. Healthy cows showed a 30.72–44.56% lower activity than the MF and PR group and were 36.76% more active than the CM group (p<0.05). The highest level of activity was determined in PR-cows, the lowest (2.47 times lower) in the CM group (p<0.05). The data are presented in Table 1. Reticulum pH and temperature were slightly positively related in all groups of cows. However, we noticed that statistically significant correlation coefficients were calculated in the groups CM, PR and H (r=0.055–0.120, p=0.001). The analysis

Fig 1. Changes in evaluated traits by disease during the study period.

showed that the pH of the reticulum statistically reliably correlated with the activity of the cows—positively in the PR group (r=0.069, p=0.001) and negatively in the CM, MF and H groups (r=0.052–0.335, p=0.001). The temperature of the reticulum was negatively related to the activity of the cows (r = 0.051–0.188, p=0.011–0.001). In the group of healthy cows, we calculated the highest positive correlation between pH and reticulum temperature and a negative correlation of cow activity with pH and reticulum temperature (Table 2). Changes in the calculated characteristics during the experimental period are shown in Fig. 1. In all groups of sick cows, we found a sharp decrease in their activity of 3–4 days before calving, while the activity of healthy cows increased. The temperature of the reticulum sharply decreased in all groups of cows 6–7 days before calving in groups H, MF and PR, and on day 4 in the CM group. In the PR group, the reticulum temperature increased 2 days before calving. After comparing the differences in the estimated characteristics of the cows with the values on the day of calving, we found the highest level of reticulum temperature in CM and PR cows 12 days before calving (2.04–2.48% higher), and in MF cows 18–6 days before calving (2.04–2.16% higher), with a sharp drop in temperature on day 6 before calving. The reticulum pH decreased linearly in MF cows during the entire experiment period; in CM cows it increased by 3.59% on the 12th day before calving, and again in CM cows by 1.53% on the 2nd day before calving. In all groups of sick cows, activity on the 12th day before calving increased sharply and was high in MF and PR cows and decreased in CM and healthy cows (Fig. 2).

Discussion

The temperature and pH of the contents of the reticulorumen of cattle can be monitored using sensors placed in a rumen bolus (Antanaitis et al. 2018). The measurements of reticuloruminal pH may be useful as a predictor of the likelihood of reproductive success (Antanaitis et al. 2018). The aim of the present investigation was to determine if reticulorumen pH, temperature and cow activity registered before calving can serve as indicators of diseases after calving. According to our results we found that healthy cows before calving showed the highest pH and temperature of the reticulum. The highest level of activity was in PR cows, the lowest in the CM group before calving. Reticulum pH and temperature were positively related in all groups

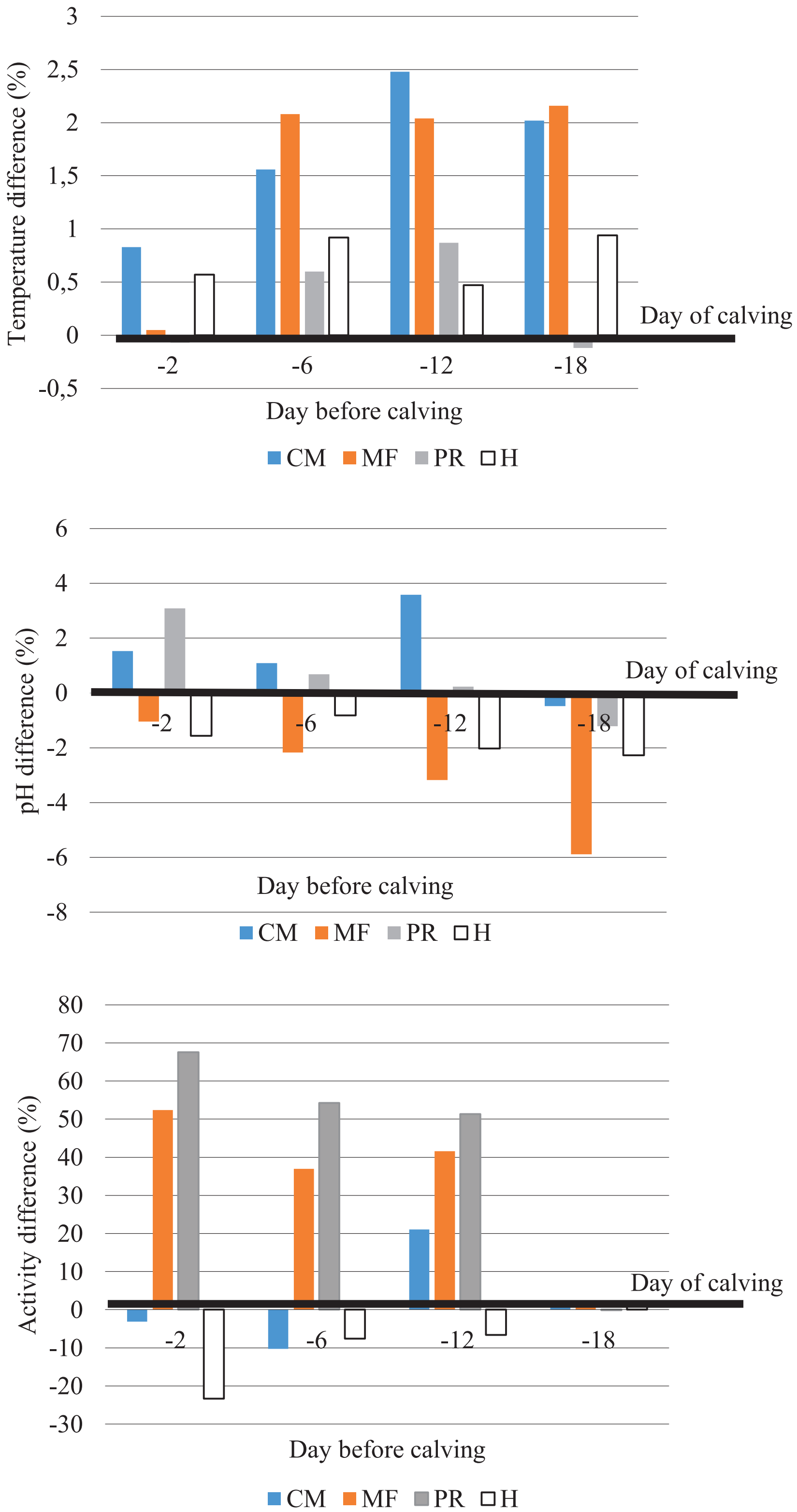

Fig.2. Difference (%) in evaluated traits compared to day of calving.

of cows. In our study the reticulum was statistically reliably correlated with the activity of the cows positively in the PR group and negatively in the CM, MF and H groups. The temperature of the reticulum was negatively related to the activity of the cows. In all groups of sick cows, we found a sharp decrease in the activity of animals 3–4 days before calving, while the activity of healthy cows increased. The temperature of the reticulum sharply decreased in all groups of cows 6–7 days before calving in groups H, MF and PR, and on day 4 in the CM group. In the PR group, the reticulum temperature increased 2 days before calving. AlZahal et al. (2011) continuously monitored ruminal pH and temperature in dairy cows and determined that low ruminal pH is associated with increased ruminal temperature. In another study, Cooper-Prado et al. (2011) state that ruminal temperature decreased the day before parturition. For optimum fermentation of the diet and fibre digestion, ruminal pH should be between 6.0 and 6.4 because the cellulolytic bacteria, which allows the digestion of fibre, are inhibited when pH is less than 6.0 (AlZahal et al. 2009). The increase in the acidity (decrease of pH) of the contents of the reticulorumen increases its temperature and the temperature of the contents of the abomasum. Through measurement of the reticulorumen temperature, it is possible to predict the health status (Antanaitis et al. 2016). The automatic monitoring of core body temperature in dairy cattle could be useful for the identification of illness, heat stress, general physiological stress and estrus. Body temperature is associated with rumen content temperature. Activity was generally lower among sick cows, cows with ketosis, left displaced abomasum, and digestive disorders (Edwards et al. 2004). Kuźma et al. (1996) reported that cows with PR showed a high level of ketone bodies (KB) and free fatty acids (FFA) in the last week before parturition. The activity of an animal and variation in milk production are considered to reliably indicate pathological changes taking place in the body. The increase in animal activity before the detection of a disease might be associated with increasing stress (Antanaitis et al. 2015). Cows spent less time lying and ruminated and drank less when the udder was severely swollen and when they had a high fever (Siivonen et al. 2011). According to our past studies, the reticulorumen temperature and pH in lactating cows are influenced by the circadian rhythm and season (Antanaitis et al. 2016). The rumen pH is an important parameter for estimating the nutritional and metabolic status of dairy cows (Enemark 2007, Danscher et al. 2015). Reticulorumen pH depression has been associated with the initiation of a chain of metabolic and microbial alterations and dysbiosis in the rumen, which are implicated in multiple metabolic health disorders in dairy cows (Khafipour et al. 2009, Steele et al. 2011).

We found the lowest values of reticulum temperature were shown by MF cows. According to Radostits et al. (2007), cows with clinical milk fever have cold extremities. It is wellknown that decreased temperature of the ear (Guterbock 2004, Radostits et al. 2007) and skin (Larsen et al. 2001) are clinical symptoms indicative of hypocalcemia in periparturient dairy cows. Therefore, it is common practice for veterinarians and farmers to use ear temperature determined by manual palpation as an estimate of the presence or absence of milk fever (i.e., calcium status) in a periparturient cow. To our knowledge, however, the temperature of the ear skin has never been validated as a potential predictor of calcium status (Venjakob et al. 2016). Cows with hypocalcemia also had a lower skin surface temperature on the coxal tubers (Radostits et al. 2007) and a lower rectal temperature (Larsen et al. 2001). Monitoring cow health by using temperature-sensing reticular boluses is an alternative to rectal temperature monitoring that is easy to use and requires minimal manpower. In another study, conducted by Bewley et al. (2008), ruminal temperature (RT) was found to be strongly correlated with rectal temperature ($r = 0.645$), with RT being on average approximately 0.45 ± 0.33°C higher than rectal temperature (Adams et al., 2013). Factors that influence RT include ambient temperature, recumbency, stage of gestation, estrus, feed and water intake, and the overall health of the cow (Adams et al. 2013). The decrease of reticuloruminal temperature shortly before parturition concurs with previous reports that ruminal temperature and body temperature of cows decreased by 0.33°C or between 0.4 and 1.0°C before parturition, respectively (Humer et al. 2015). Athough ruminal or reticular temperatures are about 0.5°C higher than rectal temperatures (Simmons et al. 1965), they have been shown to be effective measures of core body temperature (Hicks et al. 2001). The decrease in temperature shortly before parturition may be caused by endocrine and behavioral changes during the periparturient period (Humer et al. 2015). Ruminal temperature decreased the day before parturition, increased at estrus in spring-calving beef cows and has potential use as a predictor of parturition and estrus (Cooper-Prado et al. 2011).

Conclusions

The increases of reticulorumen pH and temperature before calving can serve as biomarkers of healthy cows after calving. The decreases of reticulum temperature before calving can serve as an indicator of MF after calving. A positive correlation of reticulum pH and temperature before calving can serve as biomarkers of PR. Decreasing cow activity before calving can serve as an indicator of diseases after calving. For calving prognosis, temperature of the reticulorumen can be used; it decreased 6–7 days before calving.

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