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Original article

Changes in reticulorumen content temperature and pH according to time of day and yearly seasons

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Abstract

The monitoring of rumen content temperature can be useful for the evaluation of cow health condition and heat. The aim of this research was to evaluate the influence of the circadian rhythm (time of day) and season on reticulorumen acidity (pH) and temperatures (RT) in lactating dairy cows. The research was performed on ten 2nd – lactation, clinically healthy Lithuanian Black and White fresh dairy cows (up to 1 day after calving). The cows were milked twice daily at 05:00 and 17:00. The cows were kept in a loose housing system, and were fed a feed ration throughout the year at the same time, balanced according to their physiological needs. Cow feeding took place every day at 06:00 and 18:00. The pH and temperature of the contents of cow reticulorumens were measured using specific smaXtec boluses manufactured for animal care.

The temperature starts rising 6 hours after the evening feeding and milking, whereas 1 hour after the morning milking, it starts decreasing. The lowest temperature observed in the springtime was 38.81±0.001, and the highest was in autumn 39.17±0.001. The pH starts decreasing 3 hours after the morning feed, whereas 4 hours after the evening feed, it starts increasing. The lowest pH was observed in the summertime – 5.99±0.001, and the highest was in autumn and springtime – 6.18±0.001.

In conclusion the reticulorumen temperature in lactating cows was found to be influenced by the circadian rhythm and season. The acidity of the reticulorumen content changes similar to the temperature. The pH of the reticulorumen contents was also found to be influenced by the circadian rhythm and season.

Key words: reticulorumen, pH, temperature, yearly seasons

Introduction

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. The SmartBolus (TenXSys Inc., Eagle, ID) system used a reticulorumen bolus to automatically record and transmit dairy cow temperatures (Liang et al. 2013). Unlike the telemetric system,

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the conventional system requires cow cannulation; therefore, the current study provided a non-invasive alternative for measuring ruminal temperature and the prediction of Reticulorumen pH (RpH). Remote rumen temperature monitoring is a potential method for early disease detection in beef cattle (Rose-Dye et al. 2014). Radiotelemetry has the potential to improve the detection of SARA and fever on farms (Alzahal et al. 2011). Over the past several years, many efforts have been made to measure ruminal pH using an indwelling system, which has contributed to an improved understanding of the ruminal pH dynamics in cows with SARA (Strabel et al. 2007, Alzahal et al. 2008, Bewley at al. 2008, Kaur et al. 2010, Hook et al. 2011). Ruminal temperature rises during the early phase of disease, estrus, and the onset of calving (Bewley et al. 2008). For example, a radiotelemetric bolus was able to detect an increase in body temperature due to bovine respiratory disease and bovine viral diarrhea (Bewley et al. 2008). A negative correlation has been observed between ruminal pH and ruminal temperature in cows with SARA. Rumen temperature boluses appear to have potential as a tool for detecting temperature changes associated with adverse health events such as exposure to bovine respiratory disease and BVDV (Rose-Dye et al. 2014). The ruminal temperature decreased the day before parturition and increased at estrus in spring-calving beef cows, and has a potential use as a predictor of parturition and estrus (Cooper-Prado et al. 2014). Continuous monitoring of the ruminal pH using a newly invented radio-transmission pH-measurement system could be applied for the detection and prevention of SARA in the field and pathophysiological research into SARA, including ruminal zymology and bacteriology, which have previously been determined by sampling the ruminal fluid and measuring the ruminal pH (Sato 2016). The ambient temperature, milk production and breed influence the reticulorumen temperature (Liang et al. 2013). We did not find sufficient information about the influence of circadian rhythm and season on the reticulorumen pH in lactating dairy cows.

The aim of this research was to evaluate the influence of the circadian rhythm (time of day) and season on the reticulorumen acidity (pH) and temperatures (RT) in lactating dairy cows.

Materials and Methods

Location, animals and experimental design

The experiment was caarried out on a dairy farm in the the east region of Europe at 56 00 N, 24 00 E. It was selected on ten 2nd – lactation, clinically healthy (an average rectal temperature of 38.8°C, rumen motility 5-6 times per 3 min, without signs of mastitis, lamenesis or metritis) Lithuanian Black and White fresh dairy cows (up to 1 day after calving). The herd consisted of 400 dairy cows in total. The cows were milked twice daily at 05:00 and 17:00.

The cows were kept in a loose housing system, and were fed a feed ration throughout the year at the same time, balanced according to their physiological needs. Cow feeding took place every day at 06:00 and 18:00. The cows were not inseminated during the study.

Measurements

The pH and temperature of the contents of cow reticulorumens were measured using specific smaXtec boluses manufactured for animal care. SmaXtec animal 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 was 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) was collected by means of an analogue to digital converter (A/D converter) and stored in an external memory chip. Due to its dimensions (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 01/12/2014 to 01/12/2015. All data was obtained by smaXtec messenger® computer software.

Data analysis and statistics

The statistical characteristics of the sample (n) – arithmetic mean (M) and standard error (SE), were calculated using the „R 2.1.0" package (http://www.r-project.org/). The relationships between the traits were analysed using Pearson's coefficient of correlation and regression analysis. The results were considered statistically significant when $p \leq 0.05$.

A linear model was created to describe and predict the behaviour of the complex systems and to analyse the experimental data:

$$Y_{ijklm} = \mu + T_i + M_j + H_k + A_l + MH_{jk} + HA_{kl} + \\ + MA_{jl} + MHA_{jkl} + e_{ijklm}$$

where:
Y_{ijklm} = dependent variable (reticulorumen pH or temperature for the l cow in the j month and the k time point); μ = general mean, T_i – covariable (reticulorumen temperature for the pH model and pH for the temperature model), M_j – month of year (fixed effect, 12 classes). H_k – time (fixed effect, 24 classes). A_l – animal (fixed effect, 10 classes), MH_{jk} – interaction M x H, HA_{kl} – interaction H x A, MA^{jl} – interaction M x A, MHA_{jkl} – interactions M x H x A, e_{ijklm} – residual error.

Results

The results of the descriptive statistics and correlation analysis are presented in Table 1. We estimated a significant ($p<0.01$) positive correlation between the pH and temperature of the contents of cow reticulorumens, but the relationship was very slight.

Table 1. Statistical characteristics of investigated traits.

Traits	M	SE
pH	6.13	0.001
Temperature °C	38.87	0.004
pH – Temperature	r	P
	0.073	0.01

The research showed that from 23:00 to 05:00 the average temperature of the contents of cow reticulorumens (39.07 ± 0.001) was 0.31 higher compared to 06:00 to 22:00; from 06:00 to 11:00 the temperature decreased by the linear regression equation: $y = 40.687 + -0.21x$, $R^2 = 0.922$, and from 12:00 to 05:00 it increased: $y = 38.419 + 0.0431x$, $R^2 = 0.9477$ (Fig. 1)

The pH average of the contents of cow reticulorumens by hours of the investigation ranged from 6.02 to 6.31 ($p<0.0001$). Our research has shown a decrease of pH from 9 h to 18 h by linear regression equation: $y = -0.0307x + 6.544$; $R^2 = 0.9237$, stabilization for a period of four hours and increase from 22 h: $y = 5.9867 + 0.0269x$, $R^2 = 0.9789$. Polynomial of degree 5 was used to describe pH changes from 6 h (Fig. 2). The average pH from 6 h to 22 h was 6.13 ± 0.001 (0.03 higher than from 23 h to 05 h). The pH was found to start decreasing 3 hours after the morning feed, whereas 4 hours after the evening feed it was found to start increasing again.

The investigation revealed that the lowest (38.81 ± 0.001) temperature of the reticulorumen was in the spring, and the highest (39.17 ± 0.001) was in the autumn ($p<0.0001$). The analysis showed that from June to November, the temperature of the contents of cow reticulorumens increased ($y = 38.267 + 0.0897x$, $R^2 = 0.9556$), and from December to May, it decreased ($y = 39.031 + -0.0469x$, $R^2 = 0.6285$). The highest temperature (39.27 ± 0.001) was recorded in November, and the lowest (38.76 ± 0.001) was in April ($p<0.0001$) (Fig. 3). The investigation has shown that the lowest pH of the contents of cow reticulorumens was recorded in the summer – 5.99 ± 0.001, while the highest was in the autumn and spring – 6.18 ± 0.001 ($p<0.0001$), (Fig. 4). Statistical analysis revealed that the pH decreased from March to July ($y = 6.334 + -0{,}08x$, $R^2 = 0.9368$); increased from September to December ($y = 0.03x + 6.088$, $R^2 = 0.7979$) and in January – February, fell to 6.12- 6.14. The lowest pH was determined in July (5.93 ± 0.001), and the highest (6.25 ± 0.001) was in March and December ($p <0.0001$).

The result of the linear model showed that all the investigated effects and their interactions significantly ($p<0.0001$) influenced the pH ($R^2 = 0.999$) and temperature ($R^2 = 0.999$) of contents of reticulorumens and help to understand the behaviour of the complex systems of the experimental data.

Discussion

In agreement with Lefcourt et al. (1999), the daily maximum RT was significantly greater than the daily minimum RT in all seasons. The reticulorumen temperatures decrease after water intake and return to the baseline temperature within 0.3 to 3.5 hr (Cunningham et al. 1964, Bewley et al. 2008). In the present study, the mean ruminal temperature at 1 hr intervals in cows fed the RAI diet increased markedly and reached its highest level 13 hr after the morning feed (4.5 hr after the evening feed), and the values decreased by the next morning feed. Therefore, the ruminal temperature may increase and ruminal pH decrease simultaneously by rapid fermentation and VFA production after an RAI diet feed (Wang et al. 2012). The ruminal temperature in cows decreased 3-4 and 9-10 hr after the morning feed, indicating drinking bouts (Stone 2004, Alzahal et al. 2008). AlZahal et al. (2008) reported a significant increase in rumen tempera-ture due to feeding high amounts of grain in comparison to a mixed hay diet. In the pres-

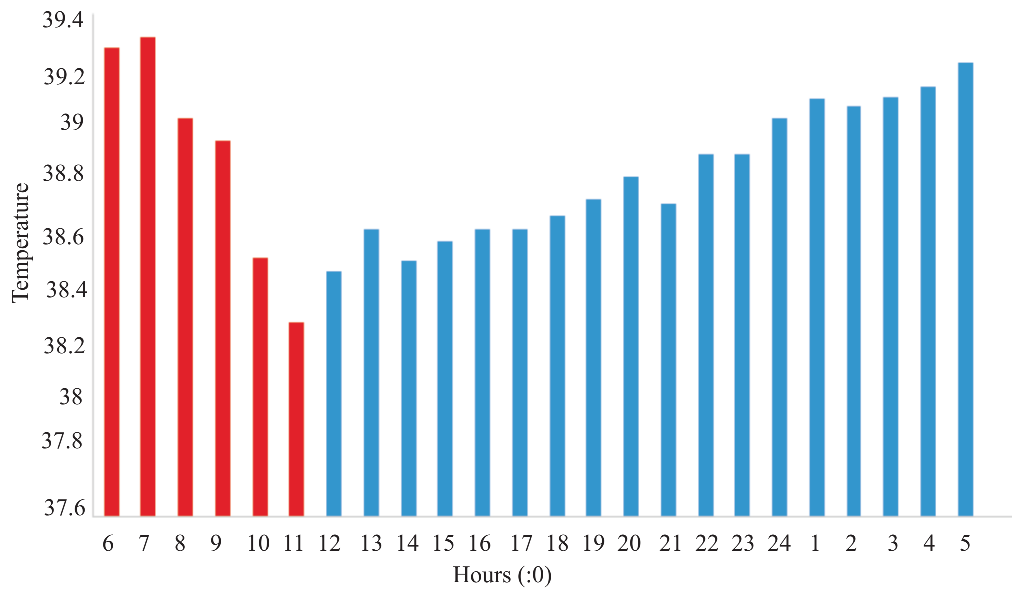

Fig. 1. Influence of time (hours) on the average temperature changes in cow reticulorumens.

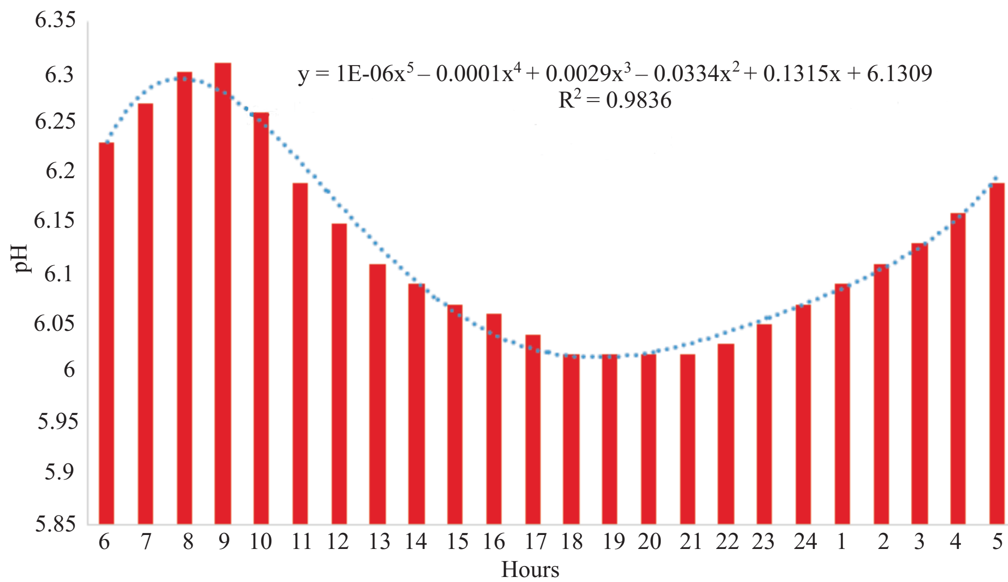

Fig. 2 Influence of time (hours) on the pH changes in cow reticulorumens.

ent study, the reticulorumen temperature starts rising 6 hours after the evening feed and milking, whereas 1hour after the morning milking, it starts decreasing. Rhythmiticy changes of body temperature observed by Joel Bitman (1984). It is noticed, in the present study, that body temperature decreases in similar intervals.

The devices used for the evaluation showed a moderate linear relationship and an agreement in pH measurement with the applied manual method, a fact that could be due to a lack of accuracy in the manual pH determination (Lohölter et al. 2013). The ruminal pH profiles may not be predictable by only measuring ruminal temperature, because decreases in the ruminal pH were preceded by increases in the ruminal temperature, and the pH levels were associated with ruminal fermentation (Kimura et al. 2012). Circadian changes in pH have been measured in the rumen of cannulated cattle using an indwelling ruminal pH system (Dado L. 1993, Strabel et al. 2007, Alzahal et al. 2008, Kaur et al. 2010, Hook et al. 2011). Based on such studies, ruminal pH values were lowest at 5-8 hr after feeding a total mixed ration or 2-5 hr after consuming concentrate for component feeding (Enemark et al. 2003, Commun et al. 2009).

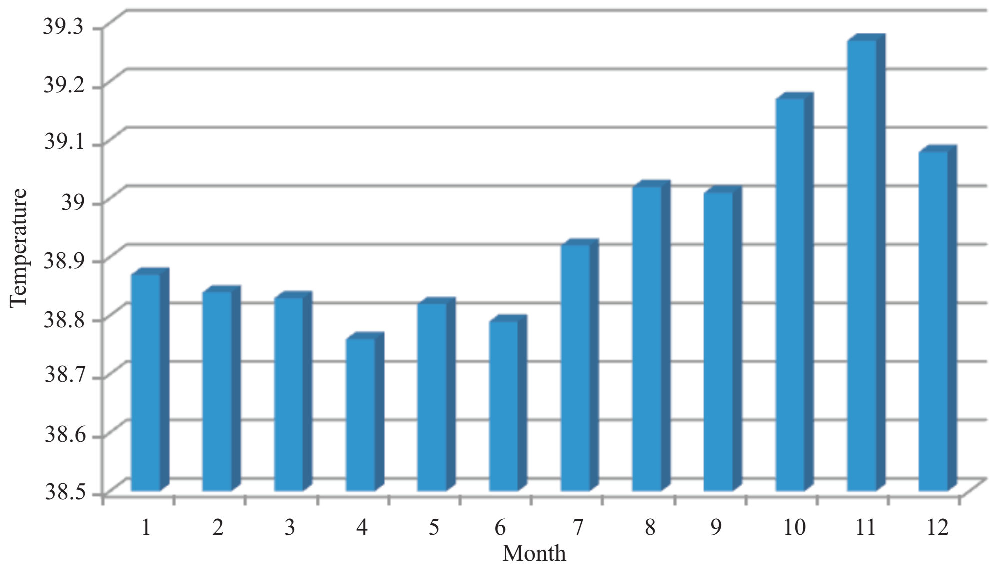

Fig. 3. Influence of season on the temperature changes in cow reticulorumens.

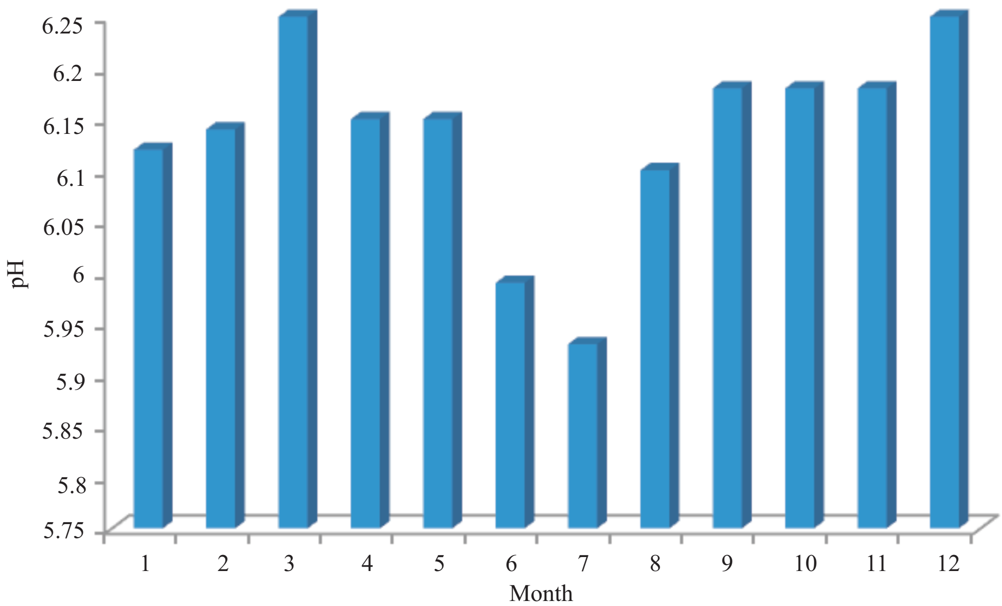

Fig. 4. Influence of season on the pH changes in cow reticulorumens.

Season also had a profound effect on the circadian body temperature rhythm but there was little difference between the breeds of dairy cows (Kendall and Webster 2009). This is important for assessment of the health condition by temperature. However, these changes may also reflect a biological change in the core body temperature associated with changing seasons. The seasonal body temperature baseline may be useful for interpretation of the differences in body temperature and used for cow management by season. At a minimum, these differences indicate the need to adjust the thresholds used for management purposes by season (Liang et al. 2013). The summer RT was significantly greater than the spring, autumn, or winter RT (Liang et al. 2013). The summer months may be associated with heat stress. A heat-stressed cow is prone to rumen acidosis, and many of the lasting effects of warm weather (laminitis, low milk fats, etc.) can probably be traced back to a low rumen pH during the summer months (Baumgard et al. 2014).

Conclusion

The reticulorumen temperature in lactating cows was found to be influenced by the following factors: circadian rhythm (the temperature starts rising 6 hours after the evening feeding and milking, whereas 1 hour after the morning milking, it starts decreasing), and season (the lowest temperature observed in the springtime was 38.81 ± 0.001, and the highest was in autumn, 39.17 ± 0.001.

The pH of the reticulorumen contents was found to be influenced by the circadian rhythm (the pH starts decreasing 3 hours after the morning feed, whereas 4 hours after the evening feed, it starts increasing) and season (the lowest pH was observed in the summertime – 5.99±0.001, and the highest was in autumn and springtime – 6.18±0.001).

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