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Relationship of ruminal temperature with parturition and estrus of beef cows[1]

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ABSTRACT: Spring-calving Angus cows (n = 30) were used to evaluate changes in ruminal temperature (RuT) related to parturition and estrus. Cows were synchronized and inseminated by a single sire. Temperature boluses (SmartStock, LLC, Pawnee, OK) were placed in the rumen at 7.0 ± 0.2 mo of gestation. Boluses were programmed to transmit RuT every 15 min. Cows (BW = 623 ± 44 kg, BCS = 4.9 ± 0.4) calved during 3 wk, and estrus was synchronized at 77 ± 7 d after calving with $PGF_{2\alpha}$. Cows were observed every 12 h to detect estrus. Daily average ambient temperatures ranged from 2 to 22°C during parturition (February to March) and 17 to 25°C during estrus (May to June). Ruminal temperature from 7 d before to 3 d after parturition and 2 d before to 2 d after visual detection of estrus was analyzed using MIXED (SAS Inst., Inc., Cary, NC). Ruminal temperatures < 37.72°C were attributed to water consumption and excluded from analyses. Day did not influence ($P = 0.36$) RuT from d -2 to -7 before parturition (38.94 ± 0.05°C). Ruminal temperature decreased ($P < 0.001$) from d -2 to d -1 before parturition (38.88 ± 0.05 to 38.55 ± 0.05°C, respectively). Ruminal temperature was not influenced ($P = 0.23$) by day from 1 d before to 3 d after parturition (38.49 ± 0.05°C). Ruminal temperature at 0 to 8 h after detection of estrus (38.98 ± 0.09°C) was greater ($P < 0.001$) compared with RuT at the same daily h the day before (38.37 ± 0.11°C) or the day after estrus (38.30 ± 0.09°C). Ambient temperature did not influence ($P > 0.30$) RuT at parturition or estrus. Ruminal temperature decreased the day before parturition and increased at estrus in spring-calving beef cows and has potential use as a predictor of parturition and estrus.

Key Words: beef cows, estrus, parturition, temperature

INTRODUCTION

Body temperature is related to physiological functions such as parturition and estrus in mammals. Decreases in body temperature of cows before parturition range from 0.4 to 1.0ºC (Wrenn et al., 1958; Lammoglia et al., 1997). Dystocia is a problem in beef cattle (Patterson et al., 1987), and death of some calves could be prevented by obstetrical assistance (Bellows et al., 1987). Prevention of dystocia requires frequent observations or the use of a system to predict parturition. Prediction of parturition will allow supervision of cows and increase survival of calves.

Accurate estrus detection can increase pregnancy rate with AI. Calving interval, milk production, and profitability are affected by estrus detection of dairy cows (Pecsok et al., 1994). Rate of genetic improvement of beef herds can be increased with the use of AI. Inadequate estrus detection and labor required for estrus detection are major reasons why AI is used infrequently in beef production (Kyle et al., 1998). Vaginal temperature increases 0.3 to 0.8°C during estrus in dairy cows (Bobowiec et al., 1990; Fisher et al., 2008) and beef cows (Kyle et al., 1998) and the increase persists for 7 to 12 h in dairy cows (Redden et al., 1993; Fisher et al., 2008) and beef cows (Kyle et al., 1998).

Development of ruminal boluses and telemetry allows frequent recording of temperature of cows with minimal physical impact on animals, behavior, and body temperature. Frequent recording of ruminal temperature (RuT) may be required to detect the increase in body temperature during estrus. The objective of this study was to evaluate changes in RuT associated with parturition and estrus in spring-calving beef cows. We hypothesized that RuT would decrease before parturition and increase at estrus, and that RuT could be used to predict these events in beef cows.

MATERIALS AND METHODS

Animals and Management

The Oklahoma State University Animal Care and Use Committee approved all the experimental procedures used in this study. Estrous cycles of Angus multiparous, spring-calving, cows (n = 30; 5 to 8 yr of age) were synchronized by treatment with $PGF_{2\alpha}$ (Lutalyse, 25 mg, intramuscularly; Pfizer and Upjohn Co., New York, NY). Cows were observed twice daily for estrus and were inseminated at 12 h after first observed in estrus with semen from a single Angus sire. If a cow did not exhibit estrus after treatment, the cow was treated a second time with $PGF_{2\alpha}$ 11 d later and observed for estrus and artificially inseminated. During the last 2 mo of gestation, cows grazed native prairie pasture (*Andropogon scoparius, Andropogon gerardii*) and received 1.4 kg of a 38% CP supplement. Ruminal boluses (SmartStock, LLC, Pawnee, OK) were orally inserted into the rumen of each cow, using a custom balling gun at 7.0 ± 0.2 mo of gestation. The ruminal bolus data collection system (http://www.smartstock-usa.com/index.htm) consisted of 4 components: (a) a radio-frequency RuT sensor bolus (8.25 cm x 3.17 cm; 114 g), (b) an antenna in the cow pen for data collection from boluses, (c) a receiver antenna for transmitted data, and (d) a personal computer with software for data storage. Data collection and receiver antennae were within 100 m of each other. Date, time, cow identification, and RuT (every 15 min) were transmitted by radiotelemetry and stored in the computer for analyses. Cows weighed 623 ± 44 kg, and had a BCS of 4.9 ± 0.4 (Wagner et al., 1988) before parturition. From 10 d before expected parturition to 7 d after parturition (February to March), cows and calves were maintained in a pen (60 m x 80 m). Cows were fed 1.8 kg/d of a 38% CP supplement with ad libitum water and prairie hay. Time of parturition was determined within 6 h and RuT was recorded from 7 d before to 3 d after parturition.

Estrous cycles of 21 of the initial 30 cows (BW = 545 ± 35 kg, BCS of 4.8 ± 0.4) were synchronized at 77 ± 7 d after calving (May to June) as described above. Chalk (ALL-WEATHER PAINTSTIK LA-CO Industries, Inc., Elk Grove, IL) was applied to the tail-head of each cow at treatment with $PGF_{2\alpha}$. Cows were maintained in a pen (60 m x 80 m) and were observed for 30 min at 0700 and 1900 h to detect estrus. Cows were considered in estrus if they stood to be mounted by another cow and the chalk that was present 12 h before was rubbed off the tail-head. Cows were inseminated 12 h after detection of estrus. Ruminal temperatures were collected from 48 h before to 48 h after cows were first observed in estrus. Pregnancy was confirmed by ultrasonography at 29 ± 1 d after AI. Ambient temperature was obtained from the Oklahoma Mesonet site (Marena; www.mesonet.org) located 6 km from cattle.

Statistical Analyses

Ruminal temperature was analyzed using MIXED (SAS Institute, Inc., Cary, NC) to evaluate repeated measurements for a cow. Ruminal temperatures < 37.72°C (10 to 12% of data) were considered a consequence of water consumption (Boehmer et al., 2009) and were excluded from analyses. However, analyses conducted with all data or with the exclusion of temperatures < 37.72°C resulted in similar results (data not shown). Ruminal temperatures were normally distributed and excluding values < 37.72°C reduced skewness and variance. Average daily ambient temperature was included in all models as a covariate. Effects that were not significant

($P > 0.40$) were eliminated from the final model. Six covariance structures (variance component, compound symmetry, Huynh-Feldt, first-order autoregressive, Toeplitz and unstructured) were examined to identify and use the best structure according to the goodness of fit statistics. Variance components for all analyses were estimated using the restricted maximum-likelihood method. The covariance structure with the best goodness of fit statistics was the first-order autoregressive for all analyses. The Kenward-Roger procedure was used to determine the denominator degrees of freedom.

The statistical model for daily variation in RuT included hour with average daily ambient temperature as a covariate. Average daily ambient temperature effect on daily variation in RuT was retained in the final model for parturition ($P = 0.39$) and deleted ($P = 0.82$) from the final model for estrus.

Mean daily RuT was calculated at parturition. The statistical model included day relative to parturition with average ambient temperature as a covariate. Daily ambient temperature ($P = 0.32$) was retained in the model.

Evaluation of RuT at estrus included several comparisons. Initially, the model included hour relative to first observed estrus with average daily ambient temperature as a covariate; average daily ambient temperature effect was not significant ($P = 0.83$), and was deleted from the model. Evaluations of RuT at different periods were made. Mean RuT for 3 periods per cow were calculated for comparisons. Periods were: from 8 h before to 8 h after estrus was first observed, from 4 h before to 4 h after estrus was first observed, and for 8 h from the time estrus was first observed (Figure 1). Periods used to evaluate RuT at estrus were selected considering characteristics of estrus, method of detection and daily variation in RuT. With twice daily visual detection of estrus, cows could be first observed in estrus at the actual onset, or at almost 12 h after the onset. Ruminal temperature has daily variation, therefore RuT were compared for time periods before, during, and after estrus that included the same daily hours the day before and the day after estrus. The statistical model for RuT at estrus included period. The period with the maximum increase in RuT at estrus was compared with the average RuT on the same daily hours of the previous 2 d.

Ruminal temperature at estrus was analyzed by adjusting RuT during visual detection of estrus to the hour of maximum RuT (8 to 19 observations per h). The statistical model included hour relative to maximum RuT, with daily hour ($P = 0.15$) and average daily ambient temperature ($P = 0.09$) as covariates.

Polynomial regression lines for RuT throughout time were calculated with Microsoft Office Excel 2003 (Microsoft Corporation, Redmond, WA) chart tools and were plotted on graphs.

RESULTS

One cow had RuT greater than 39.5°C for 6 d during the trial, was diagnosed with an infection, and was excluded from analyses. All cows had normal parturitions and healthy single calves. Technical difficulties with the equipment used to record RuT resulted in approximately 12 h of missing data per cow during the 7 d before to 3 d after parturition, and 2 d before and 2 d after estrus. Consequently, only cows with recorded RuT on at least 4 different hours on a day (6 to 85 observations per cow) were included in analyses for parturition, resulting in data for 20 to 29 cows per day. Only cows with records on at least 4 h on a day were included in estrus analyses, resulting in 12 to 21 cows per time period.

There was daily variation in RuT during parturition and estrus. Minimal and maximal daily RuT from 7 d before to 3 d after parturition occurred at 1130 h (38.50 ± 0.06°C) and at 2045 h (39.01 ± 0.07°C), respectively, when individual RuT < 37.72°C were deleted (Figure 2). Minimal and maximal temperatures 48 h before and 48 h after estrus occurred at 1115 h (38.22 ± 0.06°C) and at 2115 h (38.78 ± 0.07°C), respectively, when individual RuT < 37.72°C were deleted (Figure 3). At parturition (February to March), and at estrus (May to June), RuT decreased after 0700 h to the nadir at midday, and temperatures increased from 1230 h to peaks at 2100 h.

Figure 4 depicts RuT for an individual cow at 3 d after parturition. At 0915 h, RuT decreased 5°C, indicative of a water consumption event. Ruminal temperature was < 37.5°C at 0.5 h and > 38.0°C by 3 h after water consumption. A second water consumption event may have occurred at 1215 h when RuT decreased to 35.0ºC. A third water consumption event may have occurred at 1700 h, when RuT decreased to 37.0ºC. The decrease in RuT at 1900 h was for 15 min and may or may not have been associated with water consumption.

Parturition

Mean RuT, from 7 d before to 3 d after parturition, was 38.75 ± 0.01°C. Ruminal temperature was affected by day relative to parturition ($P < 0.001$; Figure 5). Daily RuT did not differ ($P = 0.36$) from -7 to -2 d (38.94 ± 0.05°C) before parturition (d 0). Daily RuT decreased ($P < 0.001$) from -2 to -1 d before parturition (38.88 ± 0.05 to 38.55 ± 0.05°C, respectively). Daily RuT did not differ ($P = 0.23$) from the day before parturition to 3 d after parturition (38.49 ± 0.05°C).

During parturition, daily average ambient temperatures ranged from 2 to 22°C, and daily minimum and maximum ambient temperatures ranged from -8 to 18 and 6 to 27°C, respectively. Daily average ambient temperature did not influence RuT at parturition ($P = 0.32$).

Estrus

Cows exhibited estrus within 5 d after treatment with $PGF_{2\alpha}$. Eighteen cows were in estrus after the first treatment, and 3 cows were treated twice with $PGF_{2\alpha}$ to induce estrus. Percentages of cows observed in estrus on d 2, 3, 4, and 5 after the first $PGF_{2\alpha}$ treatment were: 29, 29, 14, and 14%, respectively. Nine cows were first observed in estrus at 0700 h, and 12 cows were first observed in estrus at 1900 h.

Mean daily RuT (n = 21) during 48 h before and 48 h after first observed estrus was 38.54 ± 0.01°C. Ruminal temperature was greater ($P < 0.001$) from 8 h before to 8 h after first observed estrus compared with RuT the same daily hours the day before or day after estrus (Table 1). Similarly, RuT was greater ($P < 0.001$) from 4 h before to 4 h after first observed estrus compared with RuT the same daily hours the day before or the day after estrus, and RuT was greater ($P < 0.001$) from 0 h to 8 h after first observed estrus compared with RuT the same daily hours the day before or the day after estrus. Mean RuT was 0.44°C greater ($P < 0.001$) during 8 h before to 8 h after first observed estrus compared with the same hours the previous day; RuT was 0.52°C greater ($P < 0.001$) during 4 h before to 4 h after first observed estrus, compared with the same hours the previous day. Ruminal temperature was 0.61°C greater ($P < 0.001$) during 0 to 8 h after first observed estrus compared with the same hours the previous day (Figure 6). Ruminal temperature was greater ($P < 0.001$) during the first 8 h after cows were first observed in estrus (38.98 ± 0.10) compared with RuT on the same daily hours the 2 previous days (38.45 ± 0.10).

Ruminal temperature at estrus was greater ($P < 0.05$) from 2 h before to 2 h after maximum RuT compared with -3 to -10 h and 6 to 10 h relative to maximum RuT (Figure 7). The maximum RuT associated with estrus (h 0) was 39.88 ± 0.11°C, and occurred 1.8 ± 6.3 h before estrus was first observed.

Daily average ambient temperatures ranged from 17 to 25°C during collection of estrous data, and daily minimum and maximum ambient temperature ranged from 11 to 21 and 22 to 31°C, respectively. Daily average ambient temperature did not influence RuT during estrus ($P = 0.83$). Eighty-six percent of the cows inseminated at the synchronized estrus were confirmed pregnant by ultrasonography at 30 d after AI.

DISCUSSION

Daily variation in RuT that occurred in beef cows in late gestation and at estrus in this study was also observed in steers (Dye, 2005). Similar to the current experiment, minimal RuT (38.9°C) occurred from 0900 to 1100 h and maximum temperature (39.3°C) was at 2100 to 0200 h in steers, and RuT was positively associated with rectal temperature (Dye, 2005). Daily variation in RuT may be associated with water consumption. The decrease in RuT at midday was greater if RuT associated with possible water consumption were included. Ruminal temperature was decreased in steers (Dye, 2005), sheep (Brod et al., 1982), and beef cows (Boehmer et al., 2009) after water consumption, and the magnitude of the decrease was dependent on the volume and temperature of the consumed water. Ruminal temperatures in dairy cows decreased as much as 8.5°C after consumption of cold water, and volume and temperature of water affected the magnitude of the decrease and the duration of time for the RuT to return to the pre-drinking values (Bewley et al., 2008). When cows consumed water that was similar in temperature to body temperature, a decrease in 0.4°C and a rapid (15-min) return to pre-drinking RuT occurred (Bewley et al., 2008). Temperature of water that was consumed in the current experiment was always 15 to 20°C less than body temperature and decreases in RuT > 2°C occurred frequently, especially at midday. Time of water consumption was not determined in this experiment so the effect of water consumption on RuT cannot be determined.

Results of this study concur with previous reports that body temperature of cows decreases prior to parturition (Lammoglia et al., 1997; Aoki et al., 2005) and increases at estrus (Redden et al., 1993; Kyle et al., 1998; Fisher et al., 2008). Similar to the decrease in RuT the day before parturition, a decrease in body temperature occurred about 2 d before parturition in dairy cows (Wrenn et al., 1958; Ewbank, 1963; Aoki et al., 2005) and beef cows (Lammoglia et al., 1997). Vaginal temperature decreased 1 or 2 d before parturition in dairy cows (Wrenn et al., 1958).

Average ambient temperatures at parturition ranged from 2 to 20°C in the present study, and did not influence RuT. Warmer ambient temperature (16 to 26°C) influenced temperature in the flank of beef cows before parturition (Lammoglia et al., 1997). However, ambient temperatures between 6 and 23°C did not influence vaginal temperatures of cows before parturition (Aoki et al., 2005). Ambient temperature could have a greater impact on temperature of the *Obliquus internus abdominis* muscle in the flank of cows (Lammoglia et al., 1997) compared with temperature in the vagina or the rumen, which are deeper in the body.

Metabolic adaptation, and endocrine and behavioral changes during the periparturient period, may cause the decrease in RuT before parturition. Greater body temperatures during the last week of pregnancy, a decrease in temperature 1 to 2 d before parturition (Wrenn et al., 1958; Lammoglia et al., 1997; Aoki et al., 2005), and the correlation between progesterone in plasma and body temperature (Birgel et al., 1994), indicate a thermogenic effect of progesterone (Wrenn et al., 1958). Vaginal temperature increased in ovariectomized cows treated with progestagens compared with untreated cows (Wrenn et al., 1958). Greater vaginal temperatures during the luteal phase of the estrous cycle and reduced temperatures before and after estrus in cows (Bobowiec et al., 1990; Kyle et al., 1998) support the hypothesis of the thermogenic effect of progesterone.

Mean duration of estrus is approximately 6 h in suckled beef cows (Ciccioli et al., 2003; Lents et al., 2008), and 16 h in nonlactating beef cows (White et al., 2002). Ruminal temperature was greater during 8- or 16-h periods at estrus compared with RuT the same daily hours the day before or the average for the previous 2 d. An increase of 0.61°C was observed during 8 h after estrus was first detected with twice daily observations compared with the same daily hours on the previous day, and RuT was decreased during the same daily hours the day after estrus. Vaginal temperature increased at estrus in lactating dairy cows (Redden et al., 1993) and in lactating beef cows (Kyle et al., 1998), and vaginal temperature increased at estrus compared with the average of the previous 3 d in dairy and beef cows (Clapper et al., 1990; Mosher et al., 1990; Kyle et al., 1998).

Ruminal temperature, adjusted to the maximum at estrus, increased for 4 h at estrus in this study. Vaginal temperature increased during estrus for 11 h in dairy heifers (Mosher et al., 1990), and the duration of the increase in vaginal temperature at estrus was 4 to 8 h in dairy cows

(Clapper et al., 1990; Redden et al., 1993; Fisher et al., 2008) and beef cows (Kyle et al., 1998). Duration of the increase in body temperature during estrus may depend on equipment used, frequency of determination, environmental conditions, and physiological state of females. If body temperature is only recorded once a day it may not be possible to identify temperature changes associated with estrus.

Endocrine changes before, during, and after estrus may impact body temperature of cows and concentrations of progesterone in plasma during the estrous cycle have been associated with vaginal temperature (Wrenn et al., 1958). Vaginal temperature is greater during the luteal phase compared with the follicular phase of the estrous cycle, except for the increase in vaginal temperature at estrus (Bobowiec et al., 1990; Kyle et al., 1998). Increased estradiol during estrus may have an impact on body temperature. Treatment of ovariectomized dairy cows with estradiol-17β increased uterine blood flow (Roman-Ponce et al., 1978). Uterine blood flow increased during estrus in sheep (Roman-Ponce et al., 1983), cows (Bollwein et al., 2000), and mares (Bollwein et al., 2002). The increase in uterine blood flow during 48 h before to 24 h after first observed estrus was negatively associated with concentrations of progesterone in plasma and positively associated with the ratios of estradiol and estrone to progesterone in sheep (Roman-Ponce et al., 1983). Altered blood flow at estrus may be related to increase RuT at estrus.

In conclusion, ruminal temperature of beef cows changes before parturition and during estrus. Ruminal temperature is significantly decreased the day before parturition and is increased at estrus, and RuT may have potential to predict parturition and estrus. Use of ruminal boluses and telemetry may enhance determination of body temperature and its association with physiological functions. Measurement of ruminal temperature with a bolus is minimally invasive, allows frequent records of real-time data to be obtained, requires minimal labor, and permits cows to be maintained in a natural environment. Additional studies to evaluate the association of RuT with estrus and parturition may result in management systems to increase reproductive performance of beef cows.

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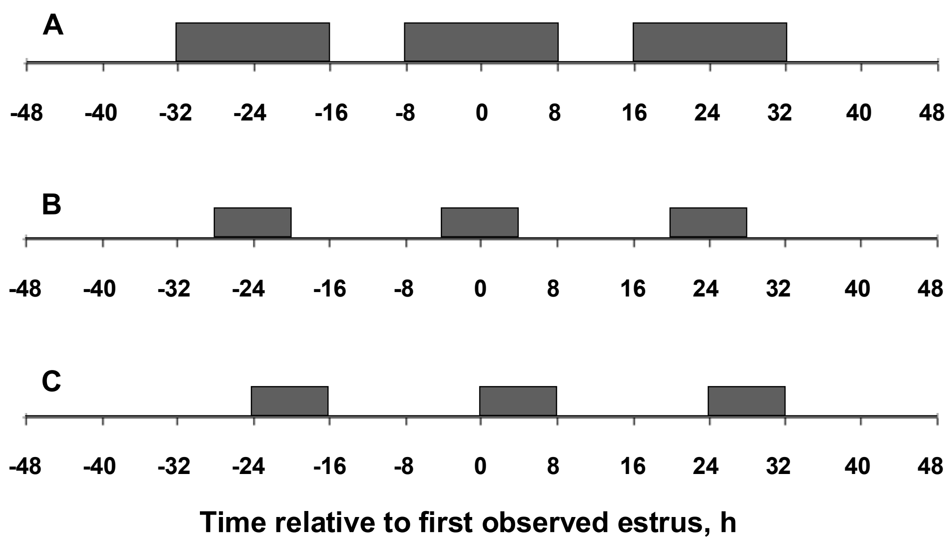
Table 1. Mean ruminal temperature (RuT) of beef cows at different periods relative to first time observed in estrus compared with the same daily hours the day before or the day after estrus

	Period relative to estrus[1]				
Item	Day before	Estrus	Day after	SEM	*P*-value
Time in the period, h	-32 to -16	-8 to 8	16 to 32		
Cows, n	15	21	20		
RuT, °C	38.23 [a]	38.67 [b]	38.04 [a]	0.10	< 0.001
Time in the period, h	-28 to -20	-4 to 4	20 to 28		
Cows, n	12	20	19		
RuT, °C	38.5 [a]	39.02 [b]	38.23 [a]	0.09	< 0.001
Time in the period, h	-24 to -16	0 to 8	24 to 32		
Cows, n	12	17	16		
RuT, °C	38.37 [a]	38.98 [b]	38.3 [a]	0.1	< 0.001

[1] Periods are hours relative to first observed estrus (h 0) including the same daily hours in 3 different days.

[a,b] Within a row, means without a common superscript differ ($P < 0.001$).

Figure 1. Time periods during which ruminal temperatures were compared relative to first observed estrus (hour 0). A) Period from 8 h before to 8 h after estrus was first observed was compared with the same daily hours the day before (-32 to -16 h) and the day after (16 to 32 h). B) Period from 4 h before to 4 h after estrus was first observed was compared with the same daily hours the day before (-28 to -20 h) and the day after (20 to 28 h). C) Period from the time estrus was first observed to 8 h after estrus was first observed was compared with the same daily hours the day before (-24 to -16 h) and the day after (24 to 32 h).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B
C
-48 -40 -32 -24 -16 -8 0 8 16 24 32 40 48
Time relative to first observed estrus, h

Figure 2. Daily variation in mean ruminal temperature (RuT) from 7 d before to 3 d after parturition for spring calving beef cows (n = 29) including all RuT or RuT ≥ 37.72°C. Polynomial regression lines are depicted by dotted lines. Hour 12 equals 1200 h.

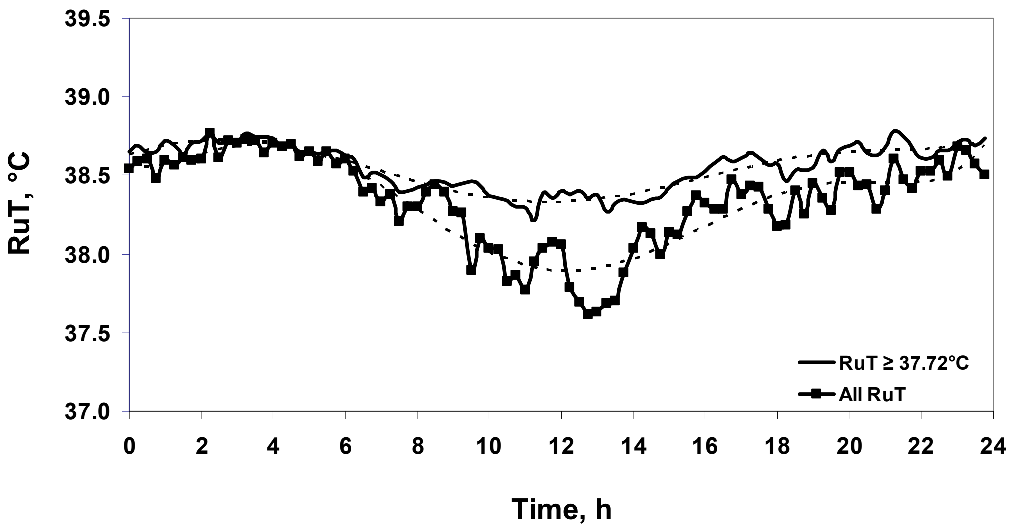
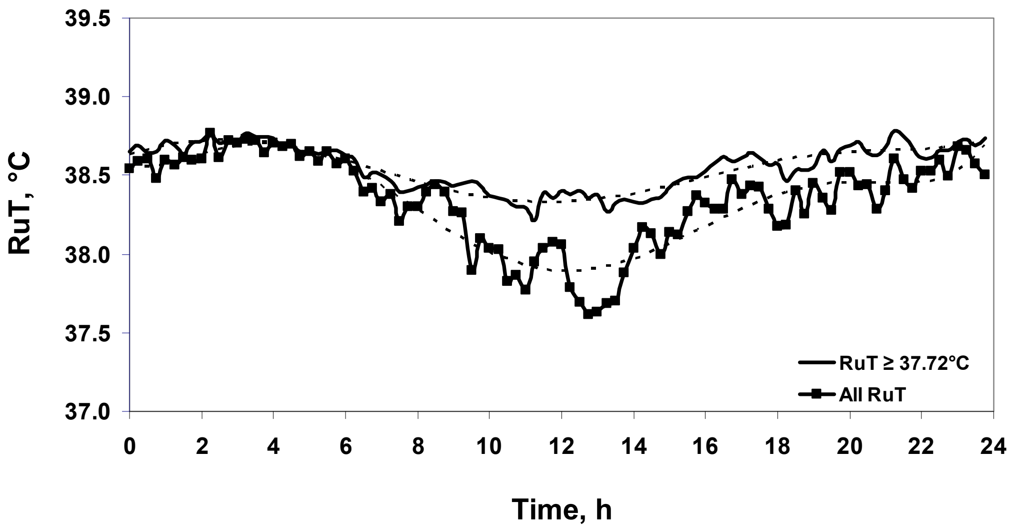

39.5
39.0
38.5
38.0
37.5
37.0
RuT, °C
0
2
4
6
8
10
12
14
16
18
20
22
24
Time, h
RuT ≥ 37.72°C
All RuT

Figure 3. Daily variation in mean ruminal temperature (RuT) from 48 h before to 48 h after estrus for spring-calving beef cows (n = 21) including all RuT or RuT ≥ 37.72°C. Polynomial regression lines are depicted by dotted lines. Hour 12 equals 1200 h.



39.5
39.0
38.5
38.0
37.5
37.0
RuT, °C
0
2
4
6
8
10
12
14
16
18
20
22
24
Time, h
RuT ≥ 37.72°C
All RuT

Figure 4. Ruminal temperature (RuT) of a typical beef cow on d 3 after parturition. Hour 12 equals 1200 h.

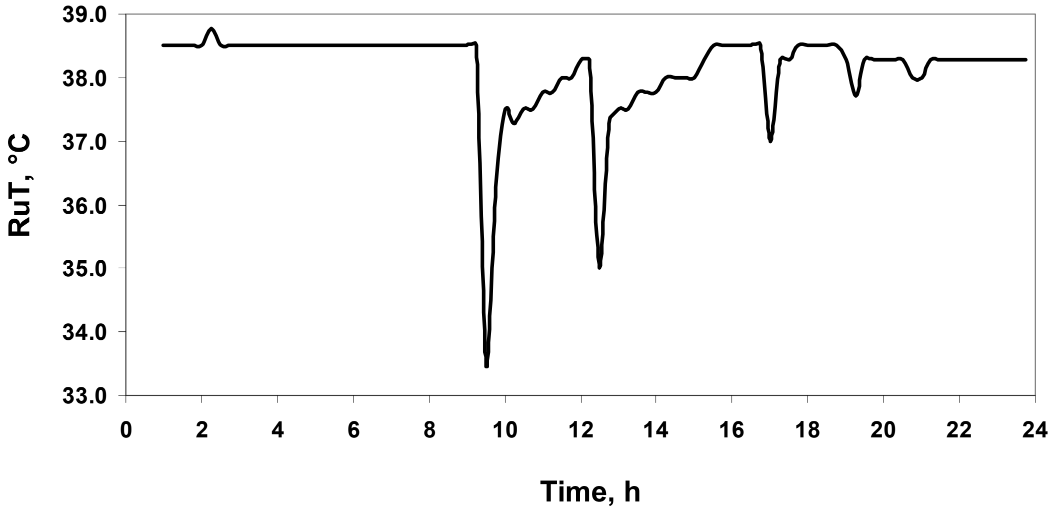

RuT, °C
39.0
38.0
37.0
36.0
35.0
34.0
33.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Time, h

Figure 5. Mean ruminal temperature (RuT) by day relative to parturition (d 0) and polynomial regression lines (dotted line) for spring-calving beef cows (n = 29). Ruminal temperatures < 37.72°C were excluded. [a,b] Means without a common superscript differ ($P < 0.001$). Standard errors over days averaged 0.08.

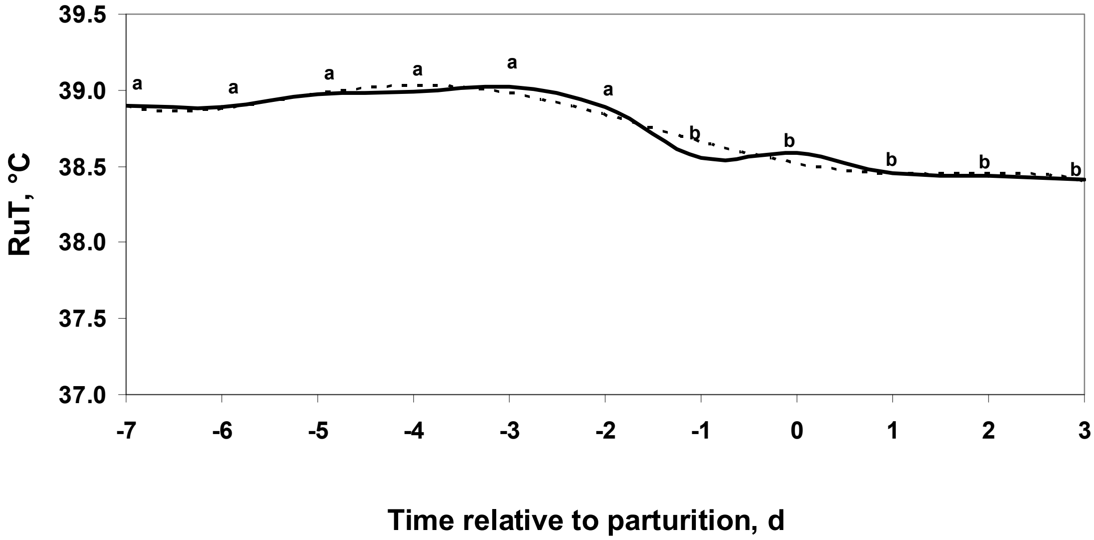

39.5
39.0
38.5
38.0
37.5
37.0
RuT, °C
a
a
a
a
a
a
b
b
b
b
b
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
Time relative to parturition, d

Figure 6. Mean ruminal temperature (RuT) relative to visual detection of estrus (h 0) and polynomial regression lines (dotted lines) for spring-calving beef cows. Ruminal temperatures < 37.72°C were excluded. Bars represent mean RuT for a period of 8 h after visual detection of estrus (38.98 ± 0.09°C, n = 17) and for the same daily hours the day before (38.37 ± 0.11°C, n = 12) and day after (38.30 ± 0.10°C, n = 16). [a,b] Means without a common superscript differ (*P* < 0.001) for periods. Standard errors over periods averaged 0.10.

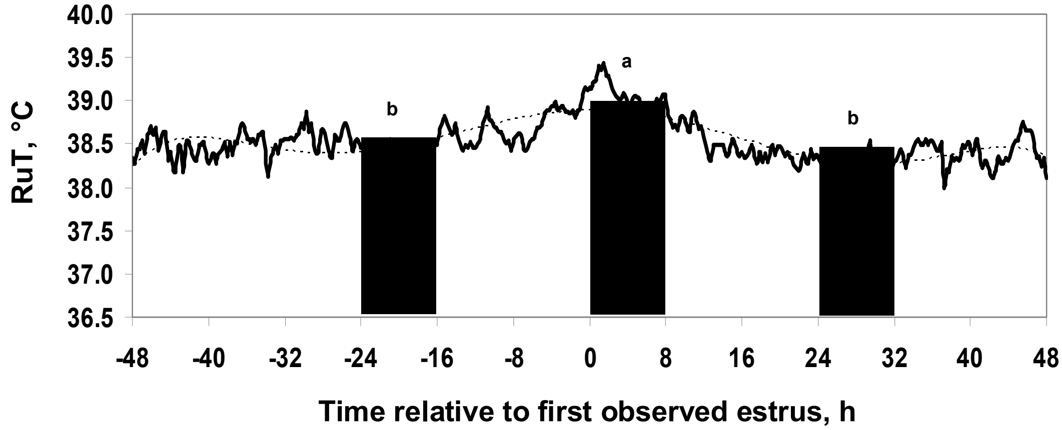
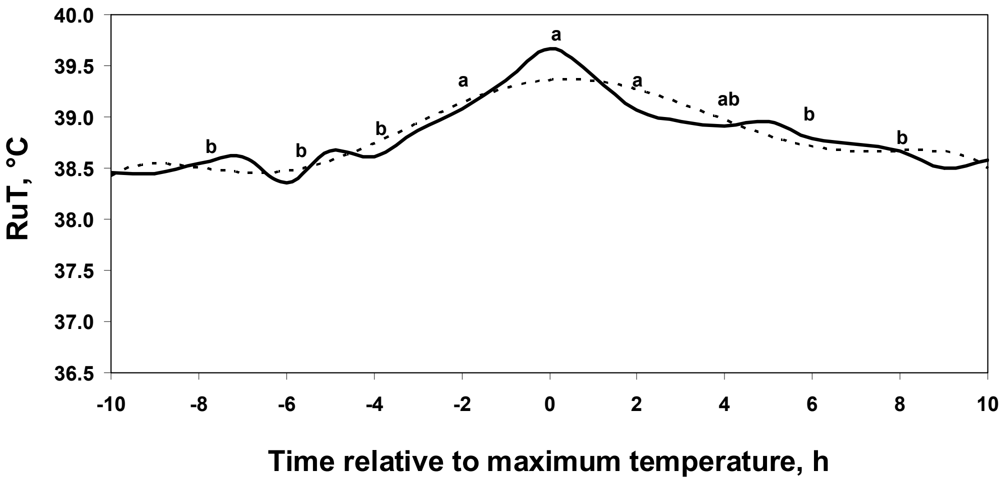

40.0
39.5
39.0
38.5
38.0
37.5
37.0
36.5
RuT, °C
a
b
b
-48
-40
-32
-24
-16
-8
0
8
16
24
32
40
48
Time relative to first observed estrus, h

Figure 7. Ruminal temperature (RuT) adjusted to the maximum at time 0 and polynomial regression lines (dotted lines) for spring-calving beef cows (n = 8 to 19 per h). Ruminal temperatures < 37.72°C were excluded. [a,b] Means without a common superscript differ (P < 0.05) . Standard errors over hours averaged 0.13.


40.0
39.5
39.0
38.5
38.0
37.5
37.0
36.5
RuT, °C
a
a
a
ab
b
b
b
b
b
-10
-8
-6
-4
-2
0
2
4
6
8
10
Time relative to maximum temperature, h