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CASE STUDY: Pattern of Parturition as Affected by Time of Feeding and Prediction of the Time of Day that Parturition Will Occur in Spring-Calving Beef Cows[1]

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ABSTRACT

To determine if time of feeding affects time of day that parturition occurs and whether beef cattle display a predictable parturition pattern as individuals, calving data from 2 herds of spring-calving beef cows located at the University of Idaho (U of I) and Kansas State University Agricultural Research Center'Hays (KSU-ARCH) were analyzed. Each year, cows at U of I were fed between 0600 and 0800 h, and cows at KSU-ARCH were fed between 1600 and 1800 h. When feed was provided in the morning, parturition occurred randomly throughout the day. However, when cows were evening fed, more cattle gave birth during daylight hours ($P < 0.01$). The KSU-ARCH data indicated that cows giving birth during daylight hours tended to display less variation in parturition time than cows giving birth during dark hours. Average time of parturition was determined for each cow, and the difference from the individual's average for each parturition time was calculated. Mean difference from an individual's average time of calving was less than 4.25 h for the U of I data ($P = 0.01$) and less than 3.00 h for the KSU-ARCH data ($P < 0.01$). These data suggest that, for the animals examined, evening feeding will result in more daylight births, and the time of day that parturition will occur may be predicted within ± 4.25 h based on the average time of day that an individual had previously given birth. However, alteration of feeding time or other factors may affect the predictability of parturition time.

Key words: beef cattle, parturition, feeding, time of day

INTRODUCTION

Parturition is a critical stage in the reproductive cycle of the beef heifer and cow. Significant losses can occur due to calf mortality resulting from dystocia. Dystocia can also lead to postpartum complications including retained placenta, uterine infections, delayed return to estrual behavior, and poor fertility (Kiracofe, 1980; Short et al., 1990; Dohmen et al., 2000). Although the incidence of dystocia has been reduced by utilizing sires known to produce calves with lower birth weights, dystocia continues to plague beef producers. Herdsman presence at parturition could reduce calf loss and reduce distress on the cow and calf. Therefore, numerous researchers have attempted to more accurately predict when parturition will occur. Estimation of conception date with ultrasound (Wright et al., 1988), use of climatological data (Stevenson, 1989; Dickie et al., 1994), alteration of day length (Evans and Hacker, 1989), and modification of feeding time (Lowman et al., 1981; Hudgens et al., 1986; Stevenson, 1989) have all been utilized to predict or alter when parturition will occur with variable results.

Many of the methods previously examined attempted to modify group

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parturition patterns. If the time of day that parturition occurs could be predicted on an individual basis, loss due to dystocia could potentially be reduced and management of pregnant females improved. In this study, we were interested in investigating whether a cow has a tendency to repeatedly give birth at the same or similar time of day. Therefore, the objectives of this study were to determine how the time of day that feed is provided to near-term beef cattle affects their patterns of parturition and if a pattern exists for the time of day that parturition occurs on an individual cow basis. To achieve these objectives, a retrospective analysis of calving records from 2 separate spring-calving beef cow herds with diverse feeding patterns were examined for parturition patterns.

MATERIALS AND METHODS

Experiment 1

Spring-calving Hereford and Charolais beef cows at the University of Idaho were observed for parturition, and the time that parturition occurred was recorded to the nearest half-hour for 15 consecutive years. Each year the calving season began the third or fourth week of January and concluded the first week of April. Cows were observed approximately every 2 h during the calving season. Births that could not be estimated within an hour of occurrence were removed from these data. Cows ranged from 2 to 12 years of age and the number of observations for each animal ranged from 2 to 14, resulting in 1,210 observations for 256 different individuals. During all years, cows were fed alfalfa (*Medicago sativa*) and pea (*Pisum sativum*) or oat (*Avena sativa*) silage at near ad libitum levels daily between 0600 and 0800 h beginning approximately 2 mo before the expected start of the calving season.

Experiment 2

Spring-calving crossbred (Hereford × Angus and Brahman × Hereford × Angus) beef cows at the Kansas State University Agricultural Research Center-Hays were observed for parturition, and the time of day that parturition occurred was recorded to the nearest half-hour for 5 consecutive years. Each year the calving season began the third or fourth week of January and concluded the third or fourth week of April. Cows were observed at least every 2 h during the calving season. Births that could not be estimated within an hour of occurrence were removed from these data. Cows ranged from 3 to 7 yr of age and the number of observations for each animal ranged from 2 to 5, resulting in 537 observations for 201 different individuals. During all years, cows were fed forage sorghum (*Sorghum bicolor*) hay at near ad libitum levels daily between 1600 and 1800 h beginning 2 wk before the expected start of the calving season.

Data Analysis

For each experiment, the mean time of day that parturition occurred for each cow was calculated, and the difference between the mean and each yearly calving time for each cow was determined. Thus, variable numbers of differences from the mean were calculated for each cow, depending upon her number of parities. Additionally, they were correlated for each cow. Therefore, rather than treating them as independent outcomes and inflating the sample size, the mean of the differences from the average calving time for each cow was calculated.

To determine if daughters followed a calving pattern similar to that of their dam, the mean of the differences between the average time of calving for a dam and each actual calving time for her respective daughter was calculated for each experiment. In Exp. 1, the number of daughter parities ranged from 2 to 10, resulting in 343 observations for 79 individual dam-daughter pairs. In Exp. 2, the number of daughter parities ranged from 2 to 5, resulting in 181 observations for 35 individual dam-daughter pairs. Again, rather than treating each difference as an independent outcome, inflating the sample size, the mean differences between the average time of the dam's parturition and each actual calving time for her respective daughter was utilized for statistical analyses.

To further define calving patterns, each day was divided into 6 periods (**PER**) of 4 h duration: PER-1 = 0600 to 1000 h; PER-2 = 1000 to 1400 h; PER-3 = 1400 to 1800 h; PER-4 = 1800 to 2200 h; PER-5 = 2200 to 0200 h; and PER-6 = 0200 to 0600 h. This grouping allowed these data to be further examined for patterns in parturition time relative to feeding time and to determine if variability in individual time of calving was similar for all periods of a day.

Statistical Analysis

Statistical testing is usually not set up to prove the null hypothesis, but rather to possibly disprove the null hypothesis (Fisher, 1935). For this study, logically it is difficult to prove that a cow tends to give birth at similar time of day as a previous birth. However, a statistical technique which is popular in bio-equivalency studies was applied, namely to show that a new treatment is as effective as a standard treatment (Blackwelder, 1982). Here, instead of testing H_0: $\mu = 0$ vs. H_1: $\mu \neq 0$, we are testing H_0: $|\mu| \geq \delta$ vs. H_0: $|\mu| < \delta$, where μ is the mean difference of calving time from the average calving time, and δ is a fixed value. If H_0 is rejected for a chosen δ based on 0.05 test size, then we are 95% confident that a cow tends to calve within the time range of 2δ.

This kind of test can be performed with a basic knowledge of *t*-tests. The sample mean and the standard error of mean differences were computed described as above and denoted as α and SE, respectively. Using these values $|\alpha - \delta|$/SE was then calculated. This test statistic follows a standard *t* distribution with n – 1 degrees of freedom, where n is the number of cows with at least 2 births. A sequence of δ values were chosen, the correspond-

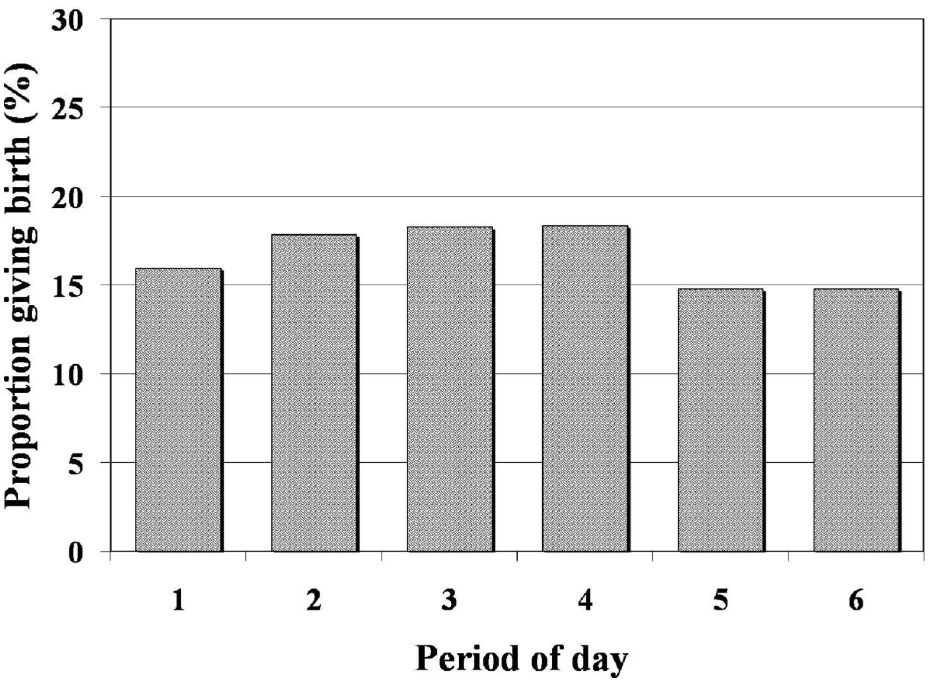

Figure 1. Distribution of all observed parturitions at University of Idaho by period of day (15 years of data, n = 1,210; Exp. 1). Period 1: 0600 to 1000 h; Period 2: 1000 to 1400 h; Period 3: 1400 to 1800 h; Period 4: 1800 to 2200 h; Period 5: 2200 to 0200 h; and Period 6: 0200 to 0600 h. Spring-calving cows were fed daily between 0600 and 0800 h (Period 1).

ing *t*-statistics and *P*-values were established, and it was then determined which δ was suitable for making a conclusion with 95% confidence.

RESULTS AND DISCUSSION

In Exp. 1, the distribution of all observed parturitions by period of day was nearly equal across the 6 periods (Figure 1). In addition, nearly equal proportions of cows gave birth during daylight hours (0600 to 1800 h) and nighttime hours (1800 to 0600 h; 52.1 vs. 47.9%, respectively). The mean of the differences between individual mean time of calving and actual time of calving by period (time of day) were also similar ($P > 0.05$) between the 6 periods (Table 1).

The mean difference from the average time of calving for all births was 4.07 ± 0.08 h and was calculated to be significantly ($P = 0.01$) less than 4.25 h, indicating that for this herd the time of day on average that parturition will occur can be estimated within ± 4.25 h of the previous time of day (or average time of day) that calving occurred. When mean differences from average time of calving were grouped into those occurring during daylight hours (PER-1, -2, and -3; 0600 to 1800 h) and those occurring during nighttime hours (PER-4, -5, and -6; 1800 to 0600 h), only minor differences were observed. The mean difference from the average time of calving for cows giving birth during daylight hours was 3.85 ± 0.11 h, which was calculated to be significantly ($P = 0.01$) less than 4.1 h, indicating that on average the time that parturition will occur (if the cow has previously given birth during daylight hours) can be estimated within ± 4.1 h of the previous time of day that parturition occurred. Cows giving birth during nighttime hours were found to be only slightly more variable in their mean difference from average time of calving. The mean difference from average time of calving for cows giving birth during nighttime hours was 4.31 ± 0.12 h and was calculated to be significantly ($P = 0.02$) less than 4.55 h. This indicated that for cows giving birth during nighttime hours (1800 to 0600 h), the time that parturition will occur can only be estimated within ± 4.55 h of the previous time of day that parturition occurred.

The mean of the differences between the average time of day that parturition occurred for a dam and each actual time of calving for her daughter in Exp. 1 was 5.73 ± 0.21 h and was calculated to be significantly ($P = 0.01$) less than 6.2 h, indicating that the time of day that a daughter will give birth can be estimated within ± 6.2 h of the average time of

Table 1. The mean of the differences between the individual mean time of calving and actual time of calving by period (time of day) when spring-calving cows at the University of Idaho were fed between 0600 and 0800 h and grouped into 6 periods based on their average time of parturition (Exp. 1)

n	Period	Time of day (h)	Mean difference[1]	SE
43	1	0600 to 1000	3.82	0.21
53	2	1000 to 1400	4.08	0.18
56	3	1400 to 1800	3.49	0.21
43	4	1800 to 2200	3.53	0.22
22	5	2200 to 0200	3.81	0.25
39	6	0200 to 0600	4.07	0.19

[1]Means are not significantly different ($P > 0.05$).

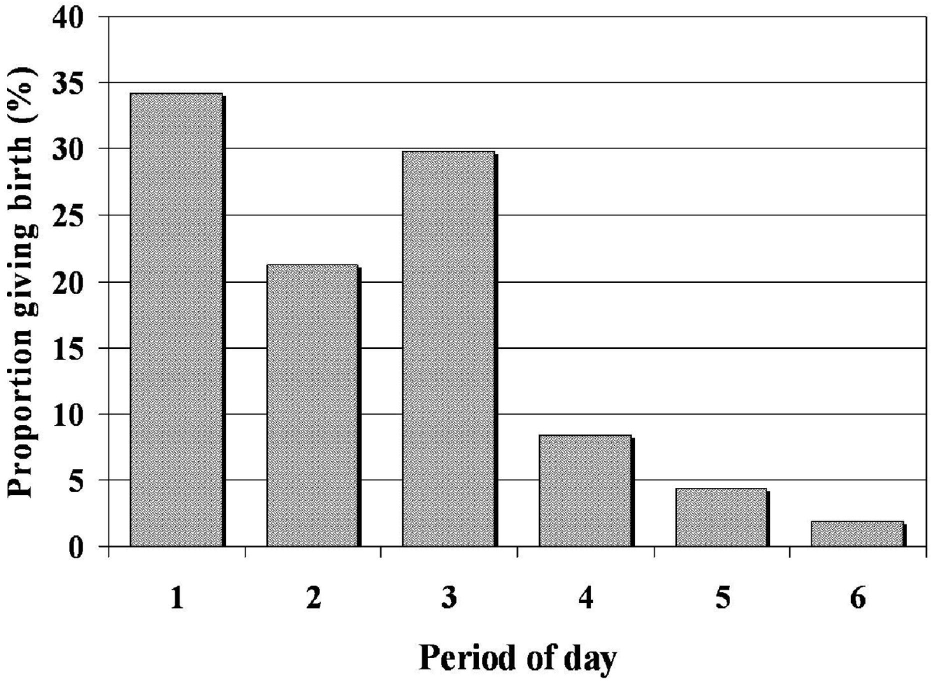

Figure 2. Distribution of all observed parturitions at Kansas State University Agricultural Research Center-Hays by period of day (5 years of data, n = 537; Exp. 2). Period 1: 0600 to 1000 h; Period 2: 1000 to 1400 h; Period 3: 1400 to 1800 h; Period 4: 1800 to 2200 h; Period 5: 2200 to 0200 h; and Period 6: 0200 to 0600 h. Spring-calving cows were fed daily between 1600 and 1800 h (Period 3).

day that her dam gave birth. These data suggest that a daughter will tend to give birth at a similar time (± 6.2 h) of day that her dam gave birth.

In Exp. 2, over the 5 yr of data examined, the percentage of all cows giving birth within each period was 34.6, 20.3, 30.5, 8.0, 4.7, and 1.9% for PER-1, -2, -3, -4, -5, and -6, respectively (Figure 2). A greater proportion of cows gave birth during daylight hours (0600 to 1800 h) as compared with the proportion giving birth during nighttime hours (1800 to 0600 h; 85.4% vs. 14.6%, respectively). This was a greater proportion of cows giving birth during daylight hours than Stevenson (1989) observed when dairy cows were fed between 1500 and 1600 h (56% gave birth between 0601 to 1800 h and 44% gave birth between 1801 to 0600 h). However, the proportion of cattle calving during daylight hours in Exp. 2 (85.4%) was similar to the proportion Lowman et al. (1981) predicted would give birth during daylight hours when fed in the late evening. In that study, utilizing limited numbers, Lowman et al. (1981) reported that feeding pregnant cows at 2000 h resulted in 79% of cows calving between 0600 and 2200 h, and that feeding at a more traditional time (0830 h) resulted in only 57% of cows calving during the same period — the latter value being similar to the proportion of parturitions (52.1%) observed during daylight hours in Exp. 1 when cows were fed between 0600 and 0800 h. However, that previous study did not provide any statistical evidence that the pattern of parturition relative to the time of feeding was different between cattle fed in the morning or evening. Nonetheless, in support of Lowman et al. (1981), Bosc et al. (1986) was able to demonstrate that providing food to pregnant rats only during periods of normal inactivity (0900 or 1400 h) caused a major shift in the time of delivery as compared with control rats fed ad libitum. In contrast, Hudgens et al. (1986) reported that there was no difference in the time of day when lambing occurred after pregnant ewes were fed at either 1000 or 2200 h, or fed 2 different forms of roughage (alfalfa hay or alfalfa haylage).

The mean of the differences between individual mean time of calving and actual time of calving by period (time of day) differed ($P < 0.05$) between the 6 periods (Table 2). In addition, the mean difference from the average time of calving for all births in Exp. 2 was 2.65 ± 0.12 h and was calculated to be significantly ($P < 0.002$) less than 3 h, indicating that in this herd of crossbred spring-calving cows, the time of day on average that parturition will occur can be estimated within ± 3 h of the previous time of day that calving occurred. However, when mean differences from average time of calving were grouped into those occurring during daylight hours (PER-1, -2, and -3; 0600 to 1800 h) and those occurring during nighttime hours (PER-4, -5, and -6; 1800 to 0600 h), significant differences were observed. The mean difference from the average time of calving for cows giving birth during daylight hours was 2.39 ± 0.12 h and was calculated to be significantly ($P < 0.002$) less than 2.75 h, indicating that on average the time that parturition will occur (if the cow had previously given birth during daylight hours) can be estimated within ± 2.75 h of previous time of day that parturition occurred. In contrast, cows giving birth during nighttime hours were found to be more variable in their mean difference from average time of calving. The mean difference from average time of calving for cows giving birth during nighttime hours was 4.11 ± 0.27 h and was calculated to be significantly ($P = 0.01$) less than 4.75 h. This indicated that for cows giving birth during nighttime hours (1800 to 0600 h), the time that parturition will occur can only be estimated within ± 4.75 h of the previous time of day that parturition occurred. This larger mean difference from average time of calving and asso-

Table 2. The mean of the differences between the individual mean time of calving and actual time of calving by period (time of day) when spring-calving cows at Kansas State University Agricultural Research Center-Hays were fed between 1600 and 1800 h and grouped into 6 periods based on their average time of parturition (Exp. 2)

n	Period	Time of day (h)	Mean difference	SE
52	1	0600 to 1000	1.85[a]	0.21
74	2	1000 to 1400	3.06[a]	0.17
45	3	1400 to 1800	1.94[a]	0.20
8	4	1800 to 2200	2.90[a]	0.70
4	5	2200 to 0200	5.08[b]	0.36
18	6	0200 to 0600	4.43[b]	0.25

[a,b]Means with different superscript letters are different ($P < 0.05$).

ciated large prediction interval for cows giving birth during nighttime hours could be due, at least in part, to a smaller sample size. Only 14.6% (78/537) of the cows displayed an average time of calving between 1800 and 0600 h. Bosc et al. (1986) suggested that pregnant rats seemed to be organized so that birth would occur either before the main daily physical activity or after it, depending on the environmental conditions. Possibly, the cows observed in Exp. 2 tended to be less variable during the early morning and afternoon because these were periods of relative inactivity, and the period in the middle of the day was coupled with increased activity associated with consumption of water or supplement. Unfortunately, animal activity patterns were not recorded in association with parturition patterns. In addition, the warmest temperatures of the day coincided with PER-2, which possibly affected their parturition pattern. This is supported in part by the observations of Stevenson (1989) who suggested that the interrelationship among environmental cues and feeding time might influence the fetus and modulate increased fetal secretion of glucocorticoids, which is thought to initiate parturition in the bovine. It is interesting to note that the smallest number of cows in Exp. 2, based on their average time of parturition, gave birth during PER-4 and PER-5, which were associated with the first 8 h immediately following feeding. In contrast, in Exp. 1 the largest number of cows gave birth during PER-2 and PER-3, the periods in this experiment associated with the first 8 h immediately following feeding. In addition, the smallest number of cows gave birth during PER-5, as was observed for Exp. 1. Although the pattern of parturition may be modified by the time of day that feed is provided to beef cattle, physical activity, daily rhythmic hormonal secretion, ambient temperature or darkness may have overriding effects on the pattern of parturition.

The mean of the differences between the average time of day that parturition occurred for a dam and each actual time of calving for her daughter in Exp. 2 was 4.70 ± 0.47 h and was calculated to be significantly ($P = 0.01$) less than 5.8 h, indicating that the time of day that a daughter will give birth can be estimated within ± 5.8 h of the average time of day that her dam gave birth. These data suggest that a daughter will tend to give birth at a similar time (±5.8 h) of day that her dam gave birth.

Although data from this study indicates that the time parturition will occur in beef cattle fed between 1600 and 1800 h can be estimated on average within ± 2.75 h for cows that have previously given birth between 0600 and 1800 h and within ± 4.75 h for cows that have previously given birth between 1800 and 0600 h, the problem of predicting which day the cow will give birth still exists. Wright et al. (1988) utilized ultrasound to predict calving date within 0.9 ± 0.5 d when cows of unknown conception date were scanned between 40 and 120 d after conception. Other researchers have attempted to link climatological events with the onset of parturition. Weather fronts the day before, the day after, or on the day of labor had no effect on the onset of parturition in swine or cattle (Dickie et al., 1994). However, these researchers did find that length of gestation was reduced by almost 5 d in a group of cows that went into labor on or after the sixth day of a constant weather situation. Dickie et al. (1994) also observed in swine that on the day before parturition the weather was correlated with the duration of gestation, and the weather on the day of parturition caused significant variations in the duration of gestation. In contrast, Stevenson (1989) found that the length of gestation of dairy cows was unaffected by all climatological variables measured (barometric pressure, precipitation, wind velocity, temperature, percent sunshine, and relative humidity). However, day length does appear to affect the length of gestation. For each hour decrease in day length from September to December, length of gestation increased by 1.3 d (Stevenson, 1989). In addition, it was observed that parturition was preceded in most cases by concurrent, but not always unique weather events of decreased barometric pressure, increased rainfall, and increased humidity. Stevenson (1989) also reported that the time of day which calving occurred was unrelated to any climatological variable measured during the week preceding parturition.

Evans and Hacker (1989) attempted to manipulate the time of calving of dairy cows by altering day length. Utilizing small numbers, these researchers found that providing 6 h of light from 0500 to 1100 h and a 2 h pulse of light from 1800 to 2000 h was effective in reducing the randomness of the time of day of calving (1315 ± 1.5 h) compared with control animals (1424 ± 8.6 h) exposed to 12 to 13 h of continuous light. It was also observed that the intake profile of the cows in the pulse 1800 to 2000 h group displayed an additional period of feed consumption during the pulse light period. This observation may help to explain the difference in the proportions of cows giving birth during daylight hours in Exp. 1 and 2. Perhaps providing feed to cattle only between 1600 and 1800 h in Exp. 2 modified these animals' activity pattern and reduced randomness in the time of day parturition occurred, similar to that observed in the earlier study.

Lammoglia et al. (1997) reported that an immediate precalving (48 to 8 h) decline in maternal body temperature was independent of either the sex of the calf or environmental temperature, but the magnitude of this decrease may be dependant on environmental temperature. Providing feed to cattle in the late afternoon and the before daily temperatures significantly decline should result in an increase in the metabolic heat load (Mader et al., 2002; Davis et al., 2003), possibly offsetting the daily nighttime decrease in environmental temperature and the precalving maternal body temperature decline, shifting more parturitions to daytime hours. These earlier researchers speculated that the precalving decline in body temperature and changes in blood hormone concentrations are factors to consider in predicting the onset of calving and that further research may allow development of an automated temperature measurement to accurately predict the onset of parturition and determine when obstetrical assistance should begin.

In conclusion, this study was designed to examine how the time of day feed is provided to beef cattle near-term affects their pattern of parturition and to determine if a pattern exists for the time of day that parturition occurs on an individual basis. Although these data were collected from herds that were distinctly different due to breed, geographic location, and diet, these data suggest that feeding near-term beef cattle in the late afternoon will result in a high incidence of births during daylight hours compared with when feed is provided in the morning (85.1 vs. 52.1%, respectively). In addition, these data suggest that evening feeding decreased the randomness of parturition (mean difference from average time of parturition) for individual cows compared with morning feeding (2.65 ± 0.12 vs. 4.07 ± 0.08 h, respectively). Perhaps more importantly, these data revealed that the time of day that a cow will give birth appears to be a pre-set pattern and possibly predictable. Based on the previous time of day that parturition occurred, the time of day that cows fed in the evening would give birth could be predicted within ± 3.00 h, and the time of day that cows fed in the morning would give birth could be predicted within ± 4.25 h. In addition, these data revealed the unforeseen observation that heifers appear to pattern their time of parturition to that of their dams. That is, based on previous observations, the time of day a daughter will give birth can be estimated within approximately 6 h of the average time of day that her dam gave birth.

IMPLICATIONS

Providing feed in the late afternoon to spring-calving beef cows may result in a greater number of calves born during daylight hours, which could assist producers in reducing mortality associated with dystocia due to lack of herdsman assistance during night-time hours. These data also imply that, regardless of when feed is provided, the time of day a cow will give birth may be predictable within ± 4.25 h based on the average time of day that parturition previously occurred. However, if feed is provided only during evening hours, the variability in parturition time is reduced and the time of day a cow will give birth may be predictable within ± 3.00 h. In addition, heifers appear to model their pattern of parturition to that of their dam. This knowledge, coupled with the expected due date, could be utilized to further limit calf losses due to dystocia.

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LITERATURE CITED

Blackwelder, W. C. 1982. "Proving the null hypothesis" in clinical trials. Control. Clin. Trials. 3:345.

Bosc, M. J., A. Nicoll, and D. Ducelliez. 1986. Time of birth and daily activity mediated by feeding rhythums in the pregnant rat. Reprod. Nutr. Dev. 26:777.

Davis, M. S., T. L. Mader, S. M. Holt, and A. M. Parkhurst. 2003. Strategies to reduce feedlot cattle heat stress: effects on tympanic temperature. J. Anim. Sci. 81:649.

Dickie, M. B., P. Sabo, and A. Schaller. 1994. Influence of meterological events on obstetrical data in cattle and swine. J. Reprod. Fertil. 102:41.

Dohmen, M. J., K. Joop, A. Sturk, P. E. Bols, and J. A. Lohuis. 2000. Relationship between intra-uterine bacterial contamination, endotoxin levels and the development of endometritis in postpartum cows with dystocia or retained placenta. Theriogenology 54:1019.

Evans, N. M., and R. R. Hacker. 1989. The chronobiological manipulation of time of calving and behavior of dairy cattle. Can. J. Anim. Sci. 69:857.

Fisher, R. A. 1935. The Design of Experiments. Oliver and Boyd, London.

Hudgens, R. E., J. L. Albright, and J. A. Pennington. 1986. Influence of feeding time and diet on time of parturition in multiparous ewes. J. Anim. Sci. 63:1036.

Kiracofe, G. H. 1980. Uterine involution: its role in regulating postpartum intervals. J. Anim. Sci. 51(Suppl. 2):16.

Lammoglia, M. A., R. A. Bellows, R. E. Short, S. E. Bellows, E. G. Bighorn, J. S. Stevenson, and R. D. Randel. 1997. Body temperature and endocrine interactions before and after calving in beef cows. J. Anim. Sci. 75:2526.

Lowman, B. G., M. S. Hankey, N. A. Scott, D. W. Deas, and E. A. Hunter. 1981. Influence of time of feeding on time of parturition in beef cows. Vet. Rec. 109:557.

Mader, T. L., S. M. Holt, G. L. Hahn, M. S. Davis, and D. E. Spiers. 2002. Feeding strategies for managing heat load in feedlot cattle. J. Anim. Sci. 80:2373.

Short, R. E., R. A. Bellows, R. B. Staigmiller, J. G. Berardinelli, and E. E. Custer. 1990. Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. J. Anim. Sci. 68:799.

Stevenson, J. S. 1989. Relationship among climatological variables and hourly distribution of calvings in Holsteins fed during the late afternoon. J. Dairy Sci. 72:2712.

Wright, I. A., I. White, A. J. F. Russel, T. K. Whyte, and A. J. McBean. 1988. Prediction of calving date in beef cows by real-time ultrasonic scanning. Vet. Rec. 23:228.