International Journal of Veterinary Sciences and Animal Husbandry 2026; SP-11(1): 129-134

ISSN: 2456-2912
NAAS Rating (2026): 4.61
VET 2026; SP-11(1): 129-134

www.veterinarypaper.com
Received: 29-12-2025
Accepted: 04-01-2026

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Behavioural Indicators for Early Prediction of Parturition in Dairy Cattle: A Review

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DOI: https://www.doi.org/10.22271/veterinary.2026.v11.i1Sb.2966

Abstract
Calving is a painful and stressful event for dairy cows, involving significant hormonal, physiological, physical, and behavioural changes. Calving difficulties negatively affect animal welfare, health, performance, and farm economics, making early prediction of calving time essential for timely intervention, dystocia management, and colostrum administration. Conventional methods such as continuous visual observation, hormonal assays, and manual temperature monitoring are time-consuming, costly, and impractical for most intensive dairy systems. Consequently, behavioural changes are widely used to predict the onset of calving and have driven the development of automated detection technologies. Key pre-calving behavioural indicators include reduced feed intake and rumination, altered lying behaviour and activity, tail raising, stepping, head turning toward the abdomen, increased lateral recumbency, and sniffing or licking the ground. These behaviours can be monitored using sensors such as tail, ear tag, noseband, and leg-mounted devices. Feeding, rumination, and activity typically decrease 24 to 4 hours before parturition, while tail raising increases approximately 6 hours before calving. Differences are also observed between primiparous and multiparous cows. Monitoring these behavioural changes enables accurate calving prediction and timely assistance, thereby improving animal welfare and calving outcomes.

Keywords: Behavioural change, Calving, Cattle, Prediction

Introduction
Parturition is a critical phase in the reproductive cycle of dairy cows, with dystocia and periparturient disorders negatively affecting animal welfare, calf survival, and farm profitability. The increasing prevalence of stillbirth and perinatal mortality in modern dairy systems underscores the need for improved calving management [23]. Accurate prediction of calving time is essential to ensure timely intervention, reduce complications, and safeguard the health and welfare of both cow and calf. Early detection of imminent calving enables prompt assistance in cases of dystocia, thereby minimizing calf and cow mortality and supporting sustainable milk production. Numerous techniques have been proposed to predict calving, including hormonal, physiological and imaging-based methods; however, none have achieved widespread on-farm adoption and visual behavioural observation remains the primary approach [38]. Consequently, automated calving detection systems based on behavioural changes are gaining attention as valuable management tools [36]. Pre-calving behavioural indicators—such as increased restlessness, reduced feed intake and rumination, posture changes, tail elevation, and increased lying bouts—can be effectively monitored using precision livestock farming technologies. Advances in sensor-based and real-time monitoring systems offer promising opportunities to improve calving detection while reducing labour demands and enhancing farm efficiency.

Parturition Process
Parturition refers to the act of giving birth to a fully developed foetus at the end of a normal gestation period. In dairy cattle, gestation length typically ranges between 277 and 287 days, influenced by factors such as breed, parity, twinning and calf sex. For example, average gestation lengths of 278 days in Holstein heifers and 279 days in Holstein cows have been

reported [35]. Parturition is conventionally described as occurring in three distinct stages, which progress sequentially and culminate in the birth of the calf followed by the expulsion of the placenta [34,48]. Parturition in dairy cows occurs in three stages. The first stage (dilation phase) involves relaxation and dilation of the pelvic ligaments, cervix and vulva, accompanied by increasing myometrial contractions and fetal positioning within the birth canal [34]. This stage may begin up to 24 hours before calving and is commonly associated with pelvic ligament relaxation, udder enlargement, and viscous or blood-tinged vaginal discharge, although these signs may also appear earlier or persist into later stages [41]. Myometrial contractions become more regular and intense approximately 12 hours before the second stage, and the first stage ends with complete cervical dilation and the appearance of the amniotic sac at the vulva. The second stage (expulsion phase) is characterised by rhythmic abdominal contractions, further dilation of the birth canal and delivery of the calf. Increased oxytocin release intensifies uterine contractions, and cows typically remain recumbent until delivery. In normal eutocic parturition, this stage lasts 60-110 minutes and is generally longer in primiparous than multiparous cows [48,41,9]. This stage concludes with complete calf delivery. The third stage involves expulsion of the fetal membranes, typically within 12-24 hours postpartum. During this period, myometrial contractions persist but gradually decrease in amplitude while becoming more frequent and irregular [34,48].

Why is it important to predict calving time early?

Dystocia refers to difficult calving that results in prolonged parturition and requires human assistance for calf delivery. Cows that take longer than 70 minutes to calve after the amniotic sac appears at the vulva are at increased risk of dystocia; however, timely intervention can reduce both its incidence and associated stress [46, 9, 27]. Dystocia is strongly linked to stillbirth and calf mortality within the first 30 days of life and occurs more frequently in primiparous Holstein cows (3-22.6%) than in multiparous cows (1.5-13.7%) [29]. Surviving calves face a higher risk of failure of passive transfer, increased disease incidence, and compromised welfare [2, 25]. In dams, dystocia is associated with increased postpartum disease, reduced milk production, impaired reproductive performance and higher culling rates [21]. Therefore, close monitoring during the second stage of parturition and accurate prediction of calving time are essential for improving animal welfare and farm efficiency. As herd sizes increase and labour availability declines, individual cow monitoring is becoming more challenging.

Methods for prediction of calving

Calving is accompanied by a range of hormonal, behavioural, physical, and physiological changes [53]. These physiological and behavioural alterations are commonly used to predict the timing of calving and may assist in determining the optimal moment to move prepartum cows to maternity pens. Indicators of impending calving include an increase in heart rate that peaks at expulsion [22], changes in plasma progesterone [28] and estradiol-17β concentrations within 24 hours before calving [50], as well as elevated inorganic phosphorus levels in udder secretions up to 72 hours prior to parturition. Despite their potential accuracy, these physiological indicators have primarily been investigated under experimental conditions and are not routinely applied in commercial dairy farm management.

3.1. Prediction of calving time based on hormonal changes

3.1.1 Progesterone

A decline in blood progesterone concentrations to below 1.2 ng/mL is a highly accurate and sensitive predictor of calving within 12-24 hours; however, this method is time-consuming, costly, and has limited practicality for on-farm use [52].

Estrogen

In Holstein dairy cows, maternal circulating concentrations of oestrone sulphate (E1S) and oestradiol-17β (E2) rise to peak levels approximately one day before calving (around 28 and 1 ng/mL, respectively) and then decline markedly within 24 hours postpartum to about 10 and 0.4 ng/mL [50]. However, the usefulness of these hormonal indicators is limited by low sensitivity, as only 13.5-35.0% of cows exhibit such elevated E2 concentrations during the 24 hours preceding parturition, resulting in many calving events being undetected.

Physiological changes

Maternal body temperature declines prior to calving and has been proposed as an indicator of impending parturition, with a decrease of approximately 0.5-1°C occurring within 24 hours before calving [18]. However, rectal and vaginal temperatures exhibit diurnal variation of up to 0.5°C, requiring consistent timing or continuous monitoring for reliable prediction [1]. Body temperature is also influenced by lactation stage and environmental conditions. In addition, heart rate increases 12-24 hours before calving, offering another potential physiological indicator of imminent parturition.

Physical Changes

Relaxation of the pelvic ligaments and udder enlargement are among the most reliable signs for predicting calving within 12 hours [52].

Why behavioural changes as prediction of calving?

Cows exhibit distinct behavioural changes during the final two to four days preceding parturition, with activity peaking in the last six hours before calf delivery. During this period, step count and the frequency of lying bouts increase, while overall standing time and the duration of individual lying bouts decrease. In addition, behaviours such as tail raising, licking of the ground and body, vocalisation and defecation become more frequent, whereas feeding, drinking, and rumination activities decline. These behavioural changes can be monitored using video cameras and and data transmission via the internet, enabling close supervision of parturient cows without requiring continuous human presence in the barn [8,10]. Consequently, automated monitoring systems that translate behavioural changes associated with calving into clear alarm signals have gained increasing interest within the dairy industry [32].

Pre calving behavioural indicators

Several behavioural indicators intensify as calving approaches, including increased lying time during the final two hours, heightened activity such as increased steps and restlessness on the day of calving and behaviours like head turning and stamping in the last two hours. The frequency of transitions between lying and standing increases on the day of calving, peaking in the final two hours, and cows also tend to isolate themselves during this period. Additional signs include tail raising in the final 2-4 hours, lateral lying with the head rested during the final four hours, and abdominal contractions occurring 4-8 hours before calving, with maximal intensity in

the last two hours. In contrast, feeding and drinking times, dry matter intake, rumination duration, and neck activity decrease as parturition approaches, with reductions observed from 18 hours to a few hours before calving. Together, these behavioural changes can be used to predict the timing of calving [44-45]. Recent advances in animal-mounted sensor technologies that monitor these behaviours offer promising opportunities for the development of automated systems for parturition prediction.

Sensors used for prediction of calving

Approximately 10-20% of cows, particularly primiparous animals, show few or no signs of the first stage of parturition and enter the second stage without detection, making frequent monitoring necessary but often impractical under commercial conditions [29,38]. As continuous visual observation is rarely feasible, especially on large dairy farms, monitoring technologies provide valuable alternatives and reduce reliance on skilled labour [5]. The development of accurate calving prediction systems could significantly reduce labour demands and prevent dystocia-related stillbirths. Various sensor-based technologies have been developed to detect calving, although many remain primarily in the research phase. Common non-invasive devices include abdominal belts to detect uterine contractions, accelerometers integrated into leg bands, ear tags, collars and tail-mounted inclinometers to monitor activity, lying behaviour and tail raising. More invasive approaches, such as ruminal boluses, intravaginal temperature sensors and vulvar dilatation detectors, have also been evaluated. Pedometers, accelerometers and collar-mounted microphones—originally developed for estrus detection—are widely used and reliably detect behavioural changes associated with calving, including alterations in rumination, activity, lying behaviour and tail movement. Deviations from behavioural baselines typically indicate calving within 6-12 hours. Systems such as the Moocall tail-mounted sensor exemplify this approach. Continuous body temperature monitoring also shows promise, as vaginal and ruminal sensors can detect a prepartum temperature decline of approximately 0.3-0.5 °C within 48-72 hours of calving, although ruminal sensors are not reusable once administered.

Changes in different behavioural activity near parturition time

Feeding behaviour

Changes in dry matter intake (DMI) and feeding behaviour are well documented around calving in dairy cows. DMI and feeding time typically decline in the hours preceding parturition, likely due to pain and discomfort associated with labour. Cows reduce DMI by approximately 30% on the day of calving, with decreases occurring 24-6 hours beforehand, and feeding time shows a similar but more variable pattern [19,40,47]. DMI also declines during the final week prepartum, and primiparous cows consume less feed than multiparous cows during the peri-calving period [3,33]. Automated monitoring of feeding behaviour is feasible in confinement systems but remains challenging in grazing systems, where no commercial electronic tools currently provide detailed prepartum monitoring. Consequently, although declines in DMI and feeding time are reliable indicators of impending calving, their measurement on commercial farms remains labour-intensive, observation-based, and prone to error [26]. Various studies on changes in feeding time and DMI is given below in Table. 1.

Table 1: Changes in feeding behaviour and dry matter intake in dairy cows before calving

Sensor	N	Findings	Reference
Automatic feed bins	101 22	↓ 32% at 24 hrs Prepartum compared to 2 days Prepartum	Huzzey *et al.* (2007) Proudfoot *et al.* (2009)
Neck collar	11	↓ 24% at 8 hrs Prepartum compared to 2-4 days Prepartum	Schirmann *et al.* (2013)
Automatic feed bins	17	↓ 56% at 6 hrs Prepartum compared to 3 days Prepartum	Buchel and Sundrum, 2014

*↓ - Decrease

Rumination Behaviour

Rumination time (RT) in dairy cows declines markedly during the final week before calving, with a pronounced reduction on the day of parturition [51, 37, 47, 7]. RT is a sensitive indicator of cow health and is widely used in automated monitoring systems, as it is suppressed by discomfort, stress and disease. Rumination is influenced by dietary factors, animal characteristics, health status and environmental conditions, making changes in RT a reliable indicator of physiological stress associated with calving [22]. Various studies on changes in rumination time before calving is given in following Table 2.

Table 2: Changes in rumination time in dairy cows during the prepartum period.

Sensor position	N	Findings	Reference
Neck collar	23	↓ 24 hrs prepartum	Calamari *et al.* (2014)
Neck collar	53	↓ 8 hrs prepartum	Borchers *et al.* (2017)
Nose band	17	↓ 6 hrs prepartum	Buchel and Sundrum. (2014)
Neck collar	11	↓ 4 hrs to 2 hrs prepartum	Schirmann *et al.* (2013)
Neck collar	27	↓ 24 hrs prepartum	Clark *et al.* (2015)
Neck collar	110	↓ 5 hrs prepartum	Miller *et al.* (2019)
Neck collar	54	↓ 4 to 2 hrs prepartum	Horvath *et al.* (2021)

7.3. Lying behaviour and activity

Reduced lying time, increased posture changes and increased activity are common behavioural changes in cows before calving [43]. During the 24 hours prepartum, cows exhibit shorter and more frequent lying bouts, with primiparous cows showing greater activity and more frequent posture changes than multiparous cows, particularly in the final hours before calving [33]. These differences likely reflect longer labour duration and increased uterine contractions in primiparous cows [48]. Lying behaviour also varies with calving difficulty, as cows experiencing dystocia show increased lying frequency closer to calving compared with eutocic cows [39]. Overall, lying bouts frequency and duration increase from 48 hours prepartum and peak on the day of calving, reflecting

restlessness and discomfort associated with labour [30,20]. Housing system further influences these behaviours, with pasture-based cows lying more frequently than those in freestall housing, likely due to greater comfort and increased walking associated with grazing [4]. Monitoring lying behaviour and activity is practical using widely available sensors; however, further research is needed to evaluate their effectiveness for predicting calving, particularly in grazing dairy systems. Various studies on changes in lying time before calving is given in following Table 3.

Table 3: Changes in lying time of dairy cows before calving under different housing systems.

Types of housing system	Sensor	Findings	Reference
Indoor	Video camera Leg band	↓ 24 hrs before calving	Miedema *et al*. (2011) Ouellet *et al*. (2016) Black and Krawczel. (2016) Borchers *et al*. (2017)
Pasture	Leg band	↓ 24 hrs before calving	Black and Krawezel. 2016 Rice *et al*. (2017) Sepulveda -varas *et al*. (2018) Hendriks *et al*. (2019)

Various studies on changes in lying bouts before calving is given in following Table 4.

Table 4: Changes in lying bouts of dairy cows prior to calving

Sensor	N	Findings	Reference
Neck collar	6	↑ 2 hrs before calving	Gonzalez-Sanchez *et al*. (2021)
Leg band	32	↑ 6 hrs before calving	Jensen. (2012)
Video camera Leg band	32 20	↑ 6 hrs before calving	Miedema *et al*. (2011) Ouellet *et al*. (2016)
Leg band	132	↑ 12 hrs before calving	Titler *et al*. (2015)
Leg band	53	↑ 18 hrs before calving	Borchers *et al*. (2017)
Leg band	14	↑ 24 hrs before calving	Black and Krawczel. (2016)
Leg band	310	↑ 24 hrs before calving (Pasture)	Hendriks *et al*. (2019)

* ↑- Increase

Tail raising

Tail raising has long been recognised as a behavioural indicator of impending calving, with this behaviour increasing approximately six hours before parturition [30]. It represents a consistent behavioural change observed in the hours leading up to calving [24]. Both the frequency and duration of tail raising rise markedly during the final 2-6 hours prepartum, reaching a peak in the six hours immediately before parturition. To monitor this behaviour, inclinometer- and accelerometer-based devices designed to detect tail movements are currently available. Various studies on changes in tail raising before calving is given in following Table 5.

Table 5: Changes in tail-raising behaviour in dairy cows before calving

Sensor/method	N	Findings	Reference
Tail sensor	110	↑ 2 hrs prepartum	Miller *et al*. (2019)
Video camera	32	↑4 hrs prepartum (Heifer) ↑2 hrs prepartum (Cow)	Miedema *et al*. (2011)
Tail sensor	12	↑24 to 3 hrs prepartum	Giaretta *et al*. (2020)
Accelerometer	54	↑ 4 hrs prepartum	Horvath *et al*. (2021)

7.5. Other activity

As calving nears, notable increases in step frequency, walking time, and neck movement have been observed, especially within the 24 hours preceding parturition. These patterns are associated with increased restlessness and discomfort, making them useful indicators for anticipating calving. Automated devices such as pedometers and neck-mounted activity sensors can reliably monitor these behaviours and support prompt management responses. Studies on number of Steps, Walking Time and Neck Activity is given in table 6.

Table 6: Changes in activity patterns (steps, walking time and neck activity) in dairy cows prior to calving

Behavioural measurement	Sensor	Findings	Reference
Number of steps	Leg band	↑8 hrs before calving	Borchers *et al*. (2017)
		↑12 hrs before calving	Titler *et al*. (2015)
		↑24 hrs before calving	Black and Krawczel. (2016)
Walking time	Video camera	↑ 24 hrs before calving	Miedema *et al*. (2011)
Neck activity	Neck collar	↑ 2 hrs before calving	Borchers *et al*. (2017)

8. Conclusion

Thus, Behavioural indicators provide valuable insights for the early prediction of parturition in dairy cattle. By closely monitoring these parameters, it becomes feasible to anticipate calving with increased accuracy, which is crucial for timely intervention and ensuring the health and well-being of both the cow and the calf. In Feeding behaviour, The significant decrease in dry matter intake (DMI) 24 to 6 hours before calving indicates a physiological shift in preparation for labor. A drop in feed consumption serves as an early warning signal for imminent parturition. In Rumination behaviour, the reduction in rumination time, particularly with the lowest levels observed 6-8 hours before calving, reflects a combination of discomfort and metabolic redirection as parturition nears. In Lying Behaviour, the decline in lying time to its lowest point 6-8 hours before calving signifies

heightened restlessness. This could result from increasing uterine contractions and physical discomfort. The highest frequency of lying bouts observed around 2 hours before calving highlights increased agitation and an attempt by the cow to find a comfortable position for delivery. In Tail-Raising Behaviour, the increased frequency and duration of tail raising, reaching its peak about 6 hours before calving, strongly correlates with uterine contractions and the positioning of the calf for delivery. Other activities like increase in steps and general activity, peaking approximately 2 hours before calving, is another clear sign of restlessness and preparation for labor. It reflects the cow's natural behavior to adapt its posture and surroundings for calving.In conclusion, The combination of reduced feed intake, altered rumination and lying patterns, increased activity, and tail-raising behavior creates a clear profile of pre-calving indicators. These behaviors, particularly when automated detection tools are employed, offer an effective means of predicting and managing the calving process in dairy cattle.

Conflict of Interest
Not available

Financial Support
Not available

Reference

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How to Cite This Article
Thakor HP. Behavioural Indicators for Early Prediction of Parturition in Dairy Cattle: A Review. International Journal of Veterinary Sciences and Animal Husbandry. 2026;SP-11(1): 129-134.