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Article

The Association of Lunar Phases on Calving in Montbéliarde Dairy Cows in the Franche-Comté Region, France

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Simple Summary

The belief that more animals are born during full moon nights is widespread, but it has rarely been investigated in dairy cattle. In this study, nearly 384,000 calvings of Montbéliard cows in eastern France were analyzed to determine whether the lunar cycle has relationship with birth patterns. The results showed that the highest number of calvings occurred during the new moon, while the lowest numbers were recorded during the full moon, except for male calves, where no clear effect was observed. An increase in births was found between the new moon and the waxing crescent, followed by a decrease toward the first quarter. These findings indicate that the lunar cycle has a measurable effect on calving distribution, although not in the way traditionally assumed in this region. Recognizing these patterns can help veterinarians and farmers prepare for periods of increased calving activity and ensure that newborn calves receive proper care, especially immediate access to colostrum, which is essential for their survival and health.

Abstract

The Moon is at the centre of many popular beliefs including that the number of births increases during Full Moon days, followed by many breeders to anticipate calving periods. However, it has been rarely explored in dairy cattle farming. This retrospective study was conducted to evaluate the association of lunar cycles on calving distribution, with particular focus on a potential increase during full-moon nights. Data from 383,926 calvings of Montbéliard breed that occurred between March 2022, and January 2025, mostly in Franche-Comté (98.2%), France were analyzed. Statistical analysis was performed using the Generalized Linear Mixed Model (GLMM). Results revealed significant association of the lunar cycle on calving distribution, it was observed a higher calving probability than the average ($p < 0.001$, +15%) during the New Moon, and a lower calving probability than the average during the First Quarter and Full Moon phases ($p < 0.001$ for both and -1.5% and -11%, respectively) in all groups, primiparous, multiparous, male and female. The observed patterns may have practical implications for veterinarians and breeders, particularly in ensuring adequate colostrum intake, thereby supporting improved management of parturition periods.

Keywords: calvings; dairy cattle; Montbéliard; lunar cycle; lunar relationship

1. Introduction

Since ancient times, the relationship of the Moon to the number of births or the onset of labor has been a source of much questioning, both in human and veterinary medicine.

In rural areas, many cattle breeders use the phases of the Moon to determine the final period of their animals' gestation, believing that the Full Moon increases the number of births [1,2]. Unlike

human medicine, few studies have been conducted in cattle breeding to verify this phenomenon. Among the existing studies, some have shown an relationship of the Moon on calving frequency, especially in populations of dairy cows [1] and dual-purpose crossbred cows [3–5], while others tend to refute it, as is the case with beef cow populations [6].

In cows, physiological calving results from coordinated series of events culminating in birth, with the timing primarily determined by the fetus. Parturition commences when the near-term fetus signals its readiness: as fetal maturation completes, the fetal hypothalamic–pituitary–adrenal axis triggers a surge of fetal cortisol, which in turn induces a cascade of maternal endocrine changes [7,8]. This fetal cortisol surge causes a shift from progesterone dominance to an estrogen and prostaglandin dominated hormonal environment [9] effectively withdrawing the progesterone block on the uterus. The increase in estrogens and PGF2 α , along with a late-gestational rise in relaxin, leads to accelerated cervical ripening and activation of myometrial contractility [10–12]. In the final weeks of gestation, the cow's cervix gradually softens under rising estrogen (and relaxin) influence, with increasing hydration and collagen disorganization in cervical tissues as term approaches [7].

Clinically, the first stage is cervical dilation, which allows fetal alignment. The increasing pressure of the calf and fetal membranes against the cervix stimulates stretch receptors, provoking oxytocin release from the dam's posterior pituitary and initiating the Ferguson reflex [12]. Oxytocin, together with elevated estrogen and prostaglandin levels, intensifies uterine contractions in a positive feedback loop. As contractions become organized and forceful, the cow enters the second stage, the expulsive phase. During this stage, strong coordinated myometrial contractions along with the cow's voluntary abdominal straining, propel the calf through the birth canal [7]. This is followed by the expulsive phase, resulting from the interaction of mechanical forces with hormonal control exerted by estrogens/PGF2 α and relaxin [11,12].

The final stage of labor is characterized by the expulsion of the fetal membranes, where the fetal cotyledons separate from the maternal caruncle crypts [12–14]. In summary, the timing of birth in cows is a finely tuned interplay between fetal signals and maternal physiological preparedness, ensuring that delivery occurs when the calf is mature and the dam's birth canal is optimally primed. Studies have shown that melatonin can have a positive effect on reproductive cycles [15,16] and that it plays a role in gestation duration and, therefore, in the calving date [17].

The precursors signs of labor are diverse, including physical changes but also behavioral ones, such as a cow becoming more anxious and tending to isolate itself [13]. Montbéliarde breed animals are known for their calm temperament, being docile animals, and thus do not need to isolate themselves to calve [18].

This study is based on the analysis of secondary data from bovine calvings in the Franche-Comté region, France. This region is considered rural, as 95% of its are a consists of rural properties [19]. In regional livestock, milk production represents a significant business volume and is mainly intended for cheese production. Given the socio-economic importance of dairy activity in the region, special attention must be given to herd health management, including possible assistance to primiparous calvings due to the higher frequency of dystocia [20–22] and care for newborns, such as colostrum feeding. Proper management in the first hours of the animal's life ensures a positive reflection on its health, impacting its productive capacity throughout life [23–25].

To study the possibility of the Moon's relationship on calvings, some knowledge about the Earth's only natural satellite, the Moon, is necessary [26]. It orbits the Earth in an elliptical translational movement [27], performing several revolutions, the most studied being the synodic revolution, which lasts 29.53 days [28]. This corresponds to the time the Moon takes to orbit the Earth, compensating for the Earth's movement around the Sun [29]. This means it is the time between two lunar cycles, from New Moon to the next New Moon [30].

The lunar cycle consists of several phases corresponding to the apparent illumination of the Moon in the Moon-Earth-Sun configuration [27]. In some literature, the cycle is composed of four phases, and in others, eight phases. These phases are divided as follows: when there are four phases, there is the New Moon, which corresponds to the phase when the Moon is in the same plan as the

Sun relative to the Earth, and therefore its illuminated face is facing the Sun and not illuminated from the Earth's view. The Full Moon corresponds to the phase when the Moon is on the opposite side of the Earth relative to the Sun, which illuminates it 100% from the Earth's view. The intermediate phases are called Quarters [31].

The four additional phases, when the cycle is considered as eight phases, are: the Waxing Crescent, when a quarter of the Moon is illuminated; the Waxing Gibbous, corresponding to three-quarters of the Moon illuminated; the Waning Gibbous, also with three-quarters illuminated but on the opposite side; and the Waning Crescent, corresponding to a quarter of the Moon illuminated, opposite to the Waxing Crescent. The Moon is considered waxing from New Moon to Full Moon, and waning from Full Moon to New Moon [31].

Another studied revolution is the tropical month, which lasts 27.32 days. This revolution refers to the Moon's position in the sky and is divided into two phases: Ascending Moon, when it appears higher in the sky relative to the horizon, and Descending Moon, when it descends toward the horizon [32,33].

This study aimed to determine whether lunar phases is associated to calving frequency in Montbéliarde dairy cows mostly from the Franche-Comté (98,8 %) region of France. The analysis was based on a large dataset spanning three years of calving records. I was also considered differences between lunar phases on calvings of primiparous and multiparous cows, as well as on the birth of males and females. After analysis and observed trends, such research may have practical implications for veterinarians and breeders, allowing optimization of management during calving periods.

2. Materials and Methods

2.1. Sample Characteristics

This retrospective study was conducted using a secondary database provided by the French Institute of Livestock (EDE) of Franche-Comté, under the supervision of the Ministry of Agriculture and Food Sovereignty. The data collected for the study are from calvings registered over three years, from March 1, 2022, to March 3, 2025, based on 801,977 records involving 55 different cow breeds and 5,434 Montbéliarde cattle farms.

From the initial dataset, including animal number, sex, dam number, calving order, breed type of the animal, dam, and sire, only Montbéliarde breed animals were selected, totaling 393,451 records. The selection was based on breed type, with calves and parents all identified as Montbéliarde, with breed code 46. The selection aimed to ensure genetic purity and a more homogeneous and well-defined population, avoiding breed interference in statistical analyses.

Franche-Comté comprises four departments: Doubs, Jura, Haute-Saône, and Territoire de Belfort. Among them, the Doubs departments is the most represented in the study ($n = 207,161$), followed by Jura ($n = 122,875$), Haute-Saône ($n = 55,014$), Territoire de Belfort ($n = 3,561$), and others ($n = 4,840$). The data analyzed represented 98.2% of Franche-Comté departments. Among them, Doubs is the most represented in the study, with 343,263 birth records, of which 207,161 are Montbéliarde cows. Of the 393,451 Montbéliarde calving dates analyzed, 126,678 corresponds to primiparous cows, 266,772 to multiparous cows, and one cow with unknown calving order, which was excluded from the analysis. Of these calving dates, 238,066 correspond to female births and 155,385 to male births.

The initial data were provided in a Microsoft Excel® file [34] directly by EDE, Franche-Comté. During calving, breeders digitally record information about the animal, such as calving date, sex, breed type, among others, which are collected and stored by EDE, a structure that is part of the Chamber of Agriculture, responsible for assisting breeders in managing and monitoring their herds. EDE collects zootechnical and health data, especially for animal identification and traceability, mainly in accordance with Article 6 of the Order of August 6, 2013 [35] regarding the identification of bovine animals.

Due to the large number of dairy farms, detailed information on herd reproductive management was not available. Therefore, possible variations in reproductive strategies among farms could not be considered, and this limitation should be considered when interpreting the results.

2.2. Characteristics of the Lunar Cycle

There are different ways to describe the lunar cycle. Each date in the Gregorian calendar was assigned a corresponding day or phase of the synodic lunar cycle, using age of the moon obtained directly from the National Aeronautics and Space Administration (NASA) website at 10:00 UTC, which corresponds to 12:00 (UTC+2) in France [36].

To ensure the same number of synodic lunar days, in each complete cycle ($n=36$), the study was conducted, from March 3, 2022, to January 29, 2025, covering from this moment 383,927 calvings. The data were initially distributed by day of the lunar cycle and then the Synodic Lunar days were defined using equal intervals of 1.02 days ($29.53 \div 29 = 1.02$), ranging from 1 to 29 (day 29 includes days above 28.56) for a homogeneous distribution by lunar cycle. Lunar days were rounded down, ranging from 0 to 29 [4].

Then, the data was distributed into four and eight phases of the lunar cycle, homogeneously separating the phases along the lunar calendar, knowing that the lunar cycle lasts, on average, 29.53 days (see Figure 1), and considering the phase of the Moon, Waxing or Waning. The four phases were categorized: New Moon (0-3.69 and >25.83); First Quarter (3.69-11.07); Full Moon (11.07-18.45); Last Quarter (18.45-25.83). The eight phases were categorized: New moon to Waxing Crescent (0 to 3.69) ($n = 49,958$); Waxing crescent to First Quarter (3.69-7.38) ($n = 46,653$); First Quarter to Waxing Gibbous (7.38-11.07) ($n = 48,126$); Waxing Gibbous to Full Moon (11.07-14.76) ($n = 47,500$); Full Moon to Waning Gibbous (14.76-18.45) ($n = 46,918$); Waning Gibbous to Last Quarter (18.45-22.14) ($n = 49,061$); Last Quarter to Waning Crescent (22.14-25.83) ($n = 47,173$), and Waning Crescent to New Moon (>25.83) ($n = 48,537$).

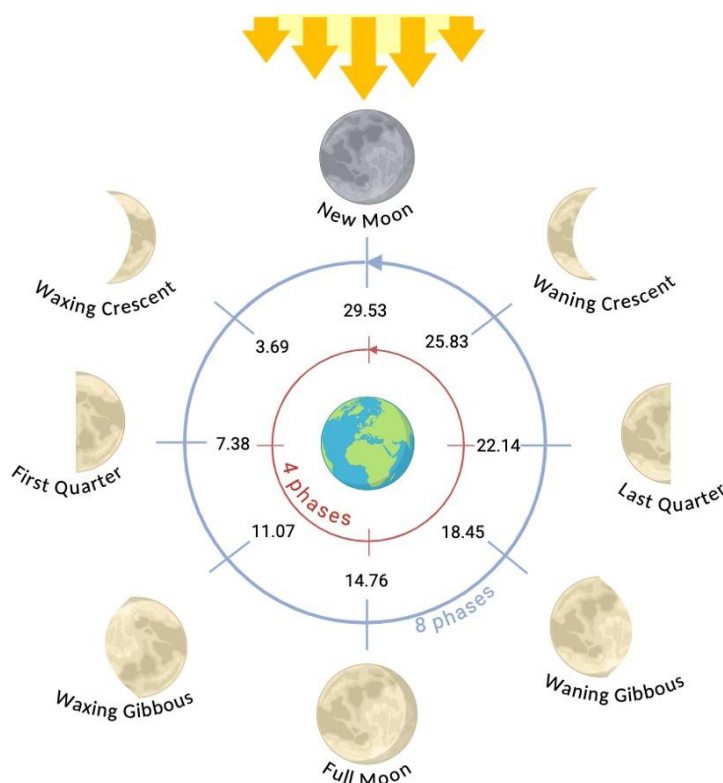


Figure 1. Division of the different phases of the lunar cycle in days (original source by the author, created with Biorender System).

Subsequently, it was decided to check for the impact of the ascending and descending phases of the Moon, which represents the lunar declination cycle (also known as the tropical month), they are not part of the synodic lunar cycle [33]. For this, a cross table allowed assigning each Gregorian calendar date the information about whether the Moon was ascending or descending, according to a lunar calendar [37].

2.3. Statistical Analysis

Data summaries were performed using Microsoft Power BI Desktop [38], based on information extracted from the database Microsoft Excel® [34] and formulas applied for calculations associated with lunar cycles.

Statistical tests were subsequently performed in R [39], using the Generalized Linear Mixed Method (GLMM) [40], with Lunar variables (Synodic day, Four moon phases, Eight moon phases, Waxing/Waning phases and Ascending/Descending phases) as fixed effects, farm region as random effect, and sex and mother birth rate (Primiparous/Multiparous) as control variables. Choosing the farm region as random effect resulted in the analysis of 3,163 variable combinations. The choice of statistical contrasts was defined according to the nature of the variables. Deviation contrasts were applied to lunar variables, comparing each category against the overall mean rather than a reference category, thereby eliminating reference selection bias and enabling assessment of deviations from expected average behavior. For the control variables (considered biological) deviation contrasts with biologically relevant reference categories were used: males for sex and primiparous for mother birth rate. A significant level of $p \leq 0.05$ was considered.

3. . Results

3.1. Monthly Distribution of Calving in Montbéliarde Cows

A descriptive analysis showed that the distribution of calving dates was not uniform throughout the months of the year. This distribution is likely due to the seasons. For illustration, data from March 1, 2022, to February 28, 2025, were analyzed. It was found that the number of calvings was highest in September, with 52,963 births, and lowest in June, with 19,489 births, as shown in Figure 2.

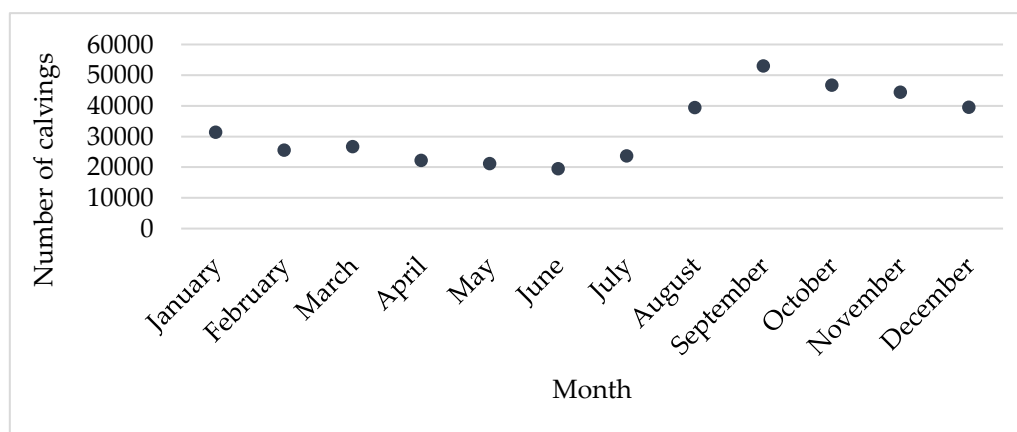


Figure 2. Distribution of calvings by month, 2022–2025.

The figure shows a distribution of calvings throughout the year, with a higher concentration beginning in late summer, remaining elevated during autumn, and declining in winter. In addition to the natural fluctuation of fertility rates in cows, reproductive management practices are also

implemented within herds to concentrate calvings during periods that favor calf rearing and enhance milk production at specific times of the year.

3.2. Analysis by Synodic Lunar Days

The result indicates that calvings are not uniformly distributed among synodic lunar days ($p < 0.001$, except for day 29), with a distribution as shown in Figure 3.

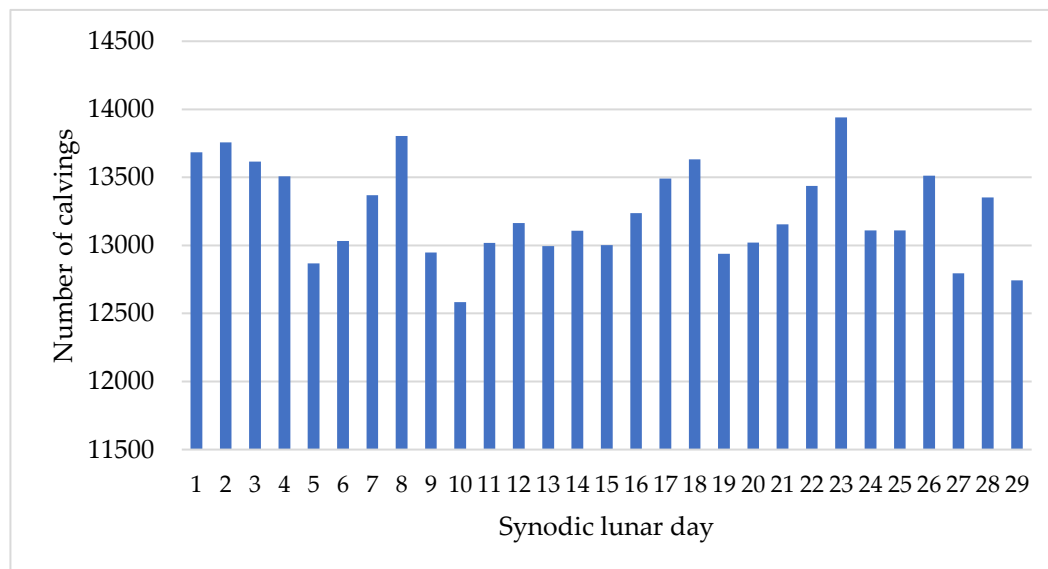


Figure 3. Distribution of calvings across the synodic lunar cycle.

By analyzing the results of the Model oscillating patterns were observed throughout the Synodic lunar cycle. Multiple peak periods with significantly increased calving probability ($p < 0.001$) were observed, with day 23 having the highest probability (+24%), followed by days 1-3 and 17-18 (+20-22.6%) and 5-7, 9-10, 12-14, 16, 20-21, 24-25, 27-28 with probabilities ranging from 12 to 19.4%. Days 4, 8, 11, 15, 19, 22 and 26 presented a significant ($p < 0.001$) lower calving probability (39-42%). Calving probability follows a wave-like pattern through the Synodic lunar cycle as shown in Figure 4.

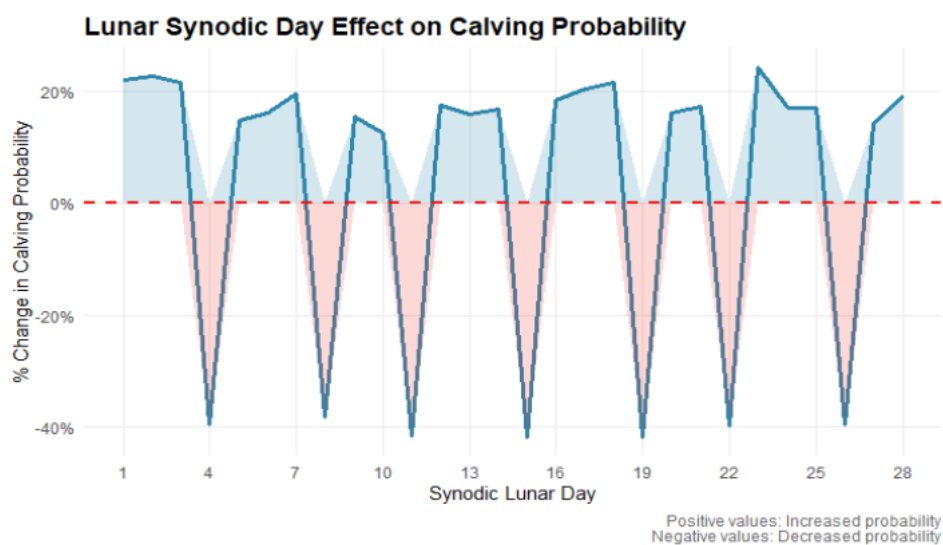


Figure 4. Daily percentage change in calving probability throughout lunar cycle.

Differences between primiparous and multiparous cows are presented in both Table 1 and Figure 5. Table 1 also includes the comparison between male and female calves, and both sets of data follow the same overall pattern.

Table 1. Association of synodic lunar days in primiparous and multiparous cows.

	P-value	Positive probability (day)	IRR ¹	Percentual effect	Negative probability (day)	IRR ¹	Percentual effect
Primiparous	< 0.001	1 - 3	1.21 - 1.25	21% - 25%	4	0.60	40%
		5 - 7	1.14 - 1.18	14% - 18%	8	0.62	38%
		9 - 10	1.11 - 1.17	11% - 17%	11	0.57	43%
		12 - 14	1.15 - 1.16	15% - 16%	15	0.58	42%
		16 - 18	1.21 - 1.23	21% - 23%	19	0.58	42%
		20 - 21	1.17 - 1.18	17% - 18%	22	0.60	40%
		23 - 25	1.16 - 1.25	16% - 25%	26	0.60	40%
		27 - 28	1.12 - 1.22	11% - 22%	-	-	-
Multiparous	< 0.001	1 - 3	1.21 - 1.22	21% - 22%	4	0.61	39%
		5 - 7	1.15 - 1.20	15% - 20%	8	0.62	38%
		9 - 10	1.11 - 1.17	11% - 17%	11	0.57	43%
		12 - 14	1.15 - 1.16	15% - 16%	15	0.58	42%
		16 - 18	1.21 - 1.26	21% - 23%	19	0.58	42%
		20 - 21	1.17 - 1.18	17% - 18%	22	0.60	40%
		23 - 25	1.16 - 1.25	16% - 25%	26	0.60	40%
		27 - 28	1.12 - 1.22	11% - 22%	-	-	-
Males	< 0.001	1 - 3	1.20 - 1.22	20% - 22%	4	0.605	39%
		5 - 7	1.13 - 1.20	13% - 20%	8	0.601	38%
		9 - 10	1.15 - 1.13	13% - 15%	11	0.591	41%
		12 - 14	1.18 - 1.19	18%	15	0.579	42%
		16 - 18	1.21 - 1.20	19% - 20%	19	0.588	41%
		20 - 21	1.16 - 1.18	16% - 18%	22	0.594	41%
		23 - 25	1.16 - 1.25	16% - 25%	26	0.601	40%
		27 - 28	1.16 - 1.21	16% - 21%	-	-	-
Females	< 0.001	1 - 3	1.22 - 1.23	22% - 23%	4	0.605	40%
		5 - 7	1.15 - 1.19	15% - 19%	8	0.620	38%
		9 - 10	1.12 - 1.16	12% - 16%	11	0.582	42%
		12 - 14	1.15 - 1.17	15% - 17%	15	0.583	42%
		16 - 18	1.17 - 1.22	17% - 22%	19	0.579	42%
		20 - 21	1.16 - 1.17	16% - 17%	22	0.607	39%
		23 - 25	1.18 - 1.24	18% - 24%	26	0.608	39%
		27 - 28	1.13 - 1.18	13% - 18%	-	-	-

¹ Incidence Rate Ratio.

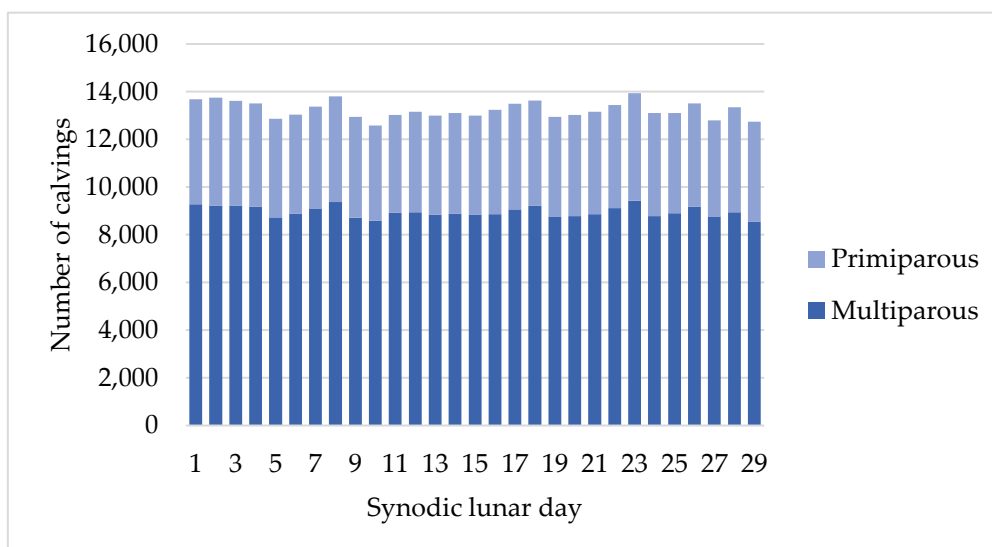


Figure 5. Distribution of births for primiparous and multiparous cows according to the synodic lunar days.

Synodic day 23, between last quarter and waning crescent, was the day with the highest probability of increase (above 22%) for all groups and day 29 was not statistically significant. Days 15 (close to full moon) and 19 (close to waning gibbous) were the ones with highest probability of decrease ($\leq -41\%$). Significance of control variables (calf sex and calf parity) and random variable (region) were consistent across all models confirming biological and herd-level variability.

3.3. Analysis by Lunar Phases

3.3.1. Synodic Waxing and Waning Phases

Calvings did not show a significant difference between synodic lunar phases, and therefore, the Waxing and Waning phases do not influence births. However, in primiparous and multiparous cows, it was observed that primiparous cows were also not influenced by the Waxing and Waning phases, but the distribution of calvings in multiparous cows is not homogeneous throughout the lunar phases with a slight increase probability of 0.43% ($p < 0.05$) in the waxing phase. For female and male births, there is also no influence by the Waxing and Waning.

3.3.2. Distribution in Four Phases of the Synodic Revolution

The GLMM model analysis demonstrated a higher calving probability than the average ($p < 0.001$, +15%) during the New Moon, and a lower calving probability than the average during the First Quarter and Full Moon phases ($p < 0.001$ for both and -1.5% and -11%, respectively) as observed in Figure 6.

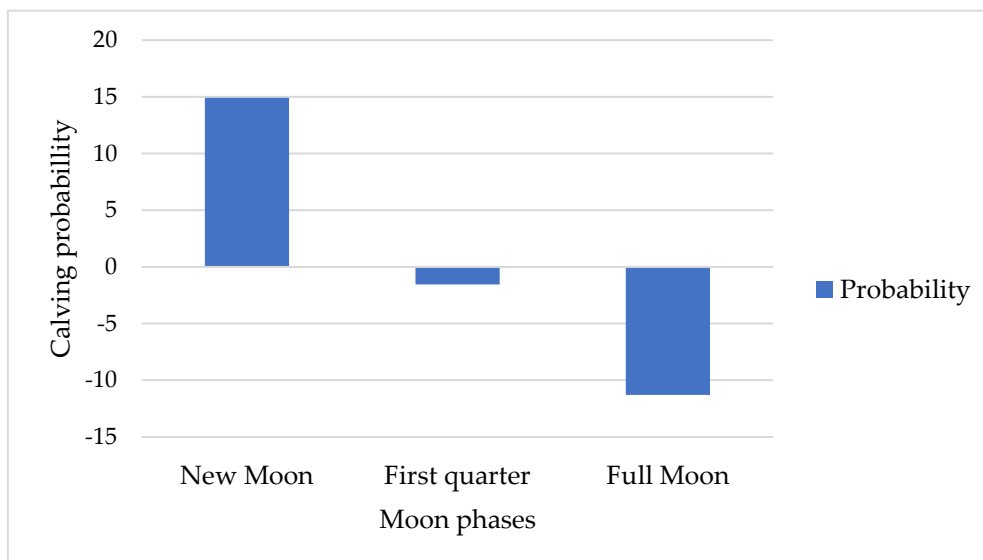


Figure 6. Four lunar phases with significant percentage change in calving probability.

The same association trend was observed in both primiparous and multiparous cows, as shown in Table 2.

Table 2. Relationship of Synodic Phases on Primiparous and Multiparous Cows.

	Positive probability (phase)	P-value	IRR ¹	Percentual effect	Negative probability (phase)	P-value	IRR ¹	Percentual effect
Primiparous	New Moon	< 0.001	1.16	16%	First Quarter	< 0.001	0.97	3%
					Full Moon	< 0.001	0.89	11%
Multiparous	New Moon	< 0.001	1.14	14%	First Quarter	< 0.001	0.99	0.9%
					Full Moon	< 0.01	0.88	11%

¹ Incidence Rate Ratio.

The same statistical principle was applied to the births of both females and males, as shown in Table 3.

Table 3. Relationship of synodic phases on the births of females and males.

	P-value	Positive probability (phase)	IRR ¹	Percentual effect	Negative probability (phase)	IRR ¹	Percentual effect
Male	< 0.001	New Moon	1.148	15%	First Quarter	0.99	2%
					Full Moon	0.89	11%
Female	< 0.001	New Moon	1.151	15%	First Quarter	0.98	2%
					Full Moon	0.88	12%

¹ Incidence Rate Ratio.

All models demonstrated a significant association of births with the Four Phases of the Synodic Revolution, with a probability of calving increase during the New Moon phase and a decreasing probability during the First Quarter and Full Moon phases, mostly during the Full Moon phase (< -11%).

3.3.3. Distribution in Eight Phases of the Synodic Revolution

The result indicates that calvings are not homogeneously distributed over the synodic cycle ($p < 0.0001$), as shown in Figure 7. Also, that the Moon exerts an association on calving dates when lunar phases are divided into eight.

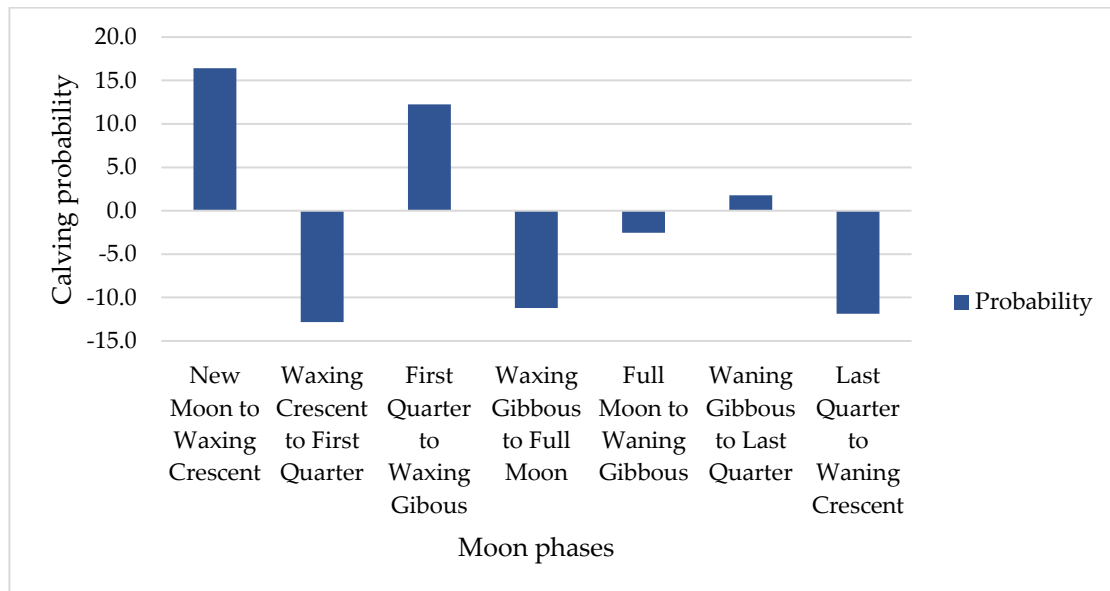


Figure 7. Eight lunar phases with significant percentage change in calving probability.

The GLMM model analysis demonstrated a higher calving probability than the average ($p < 0.001$) during the New Moon to Waxing Crescent (+16%), First Quarter to Waxing Gibbous (+12%), and Waning Gibbous to Last Quarter (+2%). A lower calving probability than the average ($p < 0.001$) was verified during the Waxing Crescent to First Quarter (-13%), Last Quarter to Waning Crescent (-12%), Waxing Gibbous to Full Moon (-11%) and Full Moon to Waning Gibbous (-3%).

The same association trends were observed in the births of both females and males and in multiparous cows, the exception in primiparous cows was for the period between Full Moon to Waning Gibbous with no statistical significance, as shown in Figure 8.

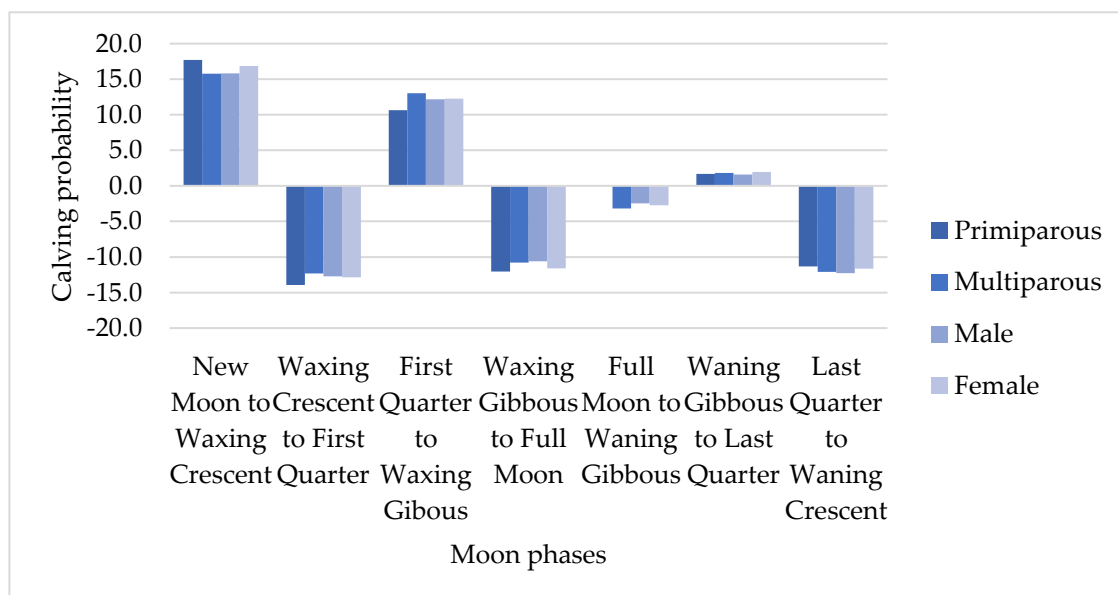


Figure 8. Eight lunar phases with significant percentage change in calving probability in primiparous and multiparous cows and on the births of males and females.

3.3.4. Analysis by the Tropical Month

For this revolution, the result indicates that calvings are not homogeneously distributed according to the periodic revolution, and that within this revolution the Moon exerts an association on calving dates ($p < 0.001$), with a lower-than-expected number of calvings during the Ascending Moon (-1%).

The tests on primiparous and multiparous cows, as well as on female and male births, showed the same result as observed for the total group of cows ($p < 0.001$).

4. Discussion

The results obtained in this study, to some extent, corroborate findings observed in literature, especially in studies conducted with dairy cows [1] and dual-purpose cows [3–5], where it was statistically shown that the Moon has an association on the distribution of calving over time.

A study on the bovine population of Switzerland, with more than two million calvings over three years, showed that the number of births per day was statistically higher between days 13 and 15 of the lunar cycle, and lower between days 9 and 12 [4].

In a study conducted from 5,869 calvings observed in crossbreed cows in Venezuela, statistical analysis showed a higher concentration of calvings around the New Moon and Full Moon [3]. Another study also carried out in Venezuela, with 121,276 births from crossbreed cows across 36 farms, also statistically showed a peak of concentrations around these two phases [5].

A study carried out solely with Holstein dairy cows showed that, in 428 calvings on a farm in Hokkaido over three years, there was a statistical increase in calvings from the New Moon to the Full Moon, followed by a decrease up to the Waning Crescent [1].

However, even if the Full Moon phase seems to be the phase with the highest concentration of calvings in the previously cited studies, this is not the case in the present study, which analyzed 383,926 calvings in the Franche-Comté region, France. In fact, the number of calvings in Montbéliarde dairy cows increased in the phase around the New Moon, with 98,495 calvings when dividing into four phases and 49,958 calvings in the New Moon to Waxing Crescent phase when dividing into eight phases.

Regarding the discrepancy in birth rates between males (39.5%) and females (60.5%), it is important to note that there is no available information in this study concerning the use of reproductive techniques such as sexed semen, which could explain such a difference. This represents a limitation in the analysis.

In beef cattle, however, it was not possible to corroborate the results obtained in this study. Indeed, a study conducted in Japan with 41,116 calvings showed no link between the lunar phases and the number of calvings [6].

To date, most studies on the relationship of the Moon on births have been conducted in humans. It can be observed that the results obtained conclude the absence of relationship of the lunar cycle on births according to some authors [41–46]. However, there are other studies that show a relationship with the Moon, but without consensus on the phase involved. In an Austrian study, an increase in births was noted between the Waxing Crescent and the First Quarter [47]. Another Iraqi study found an increase in births during the Full Moon and the Waning Gibbous phase [48]. In a French study with about 30 million births, a significant, albeit weak, Full Moon effect was evidenced [49].

The night-time calving rate varies from 24% to 54% [50], this may be related to the increase in calvings in the New Moon, when the impact of lunar luminosity during the night is lower. According to this study, births occur more frequently in a phase in which, at night, there is no illumination of the atmosphere by reflection of sunlight on the Moon. However, it is important to emphasize that the data analyzed corresponds to dates of birth, with no time recorded.

The behavioral phenomenon of pregnant animals induced by decreased luminosity seems a plausible cause. During bovine calving, the cow's behavior changes, and she isolates herself [13] and the condition of low lighting may be an advantage during calving to protect themselves. Indeed,

during the birth of animals in nature, they try to hide to avoid predators. In ruminants, they isolate themselves from the rest of the herd to be less visible and hide in topographical areas that are difficult to access [51]. Due to the docile temperament of the Montbéliarde cow [18], it doesn't seem to be a regular behavior to hide when giving birth.

Another consideration may be related to the secretion of melatonin, which varies as a function of light and the lunar cycle [1,3,52]. Articles on the Moon's relationship on cattle suggest that night-time secretion of melatonin has relationship with lunar phases, with a peak around the New Moon [1,4]. This hormone, present in the ovaries and myometrium of cows, may play a role in triggering calving [5]. In humans, an increase in melatonin levels was observed at the end of gestation, followed by a marked decrease at the time of birth [1]. In addition, melatonin production is higher at the beginning of the estrous cycle, a period centered around the New Moon [1,3,5,52].

In short, the association of gravitational force during the day and the absence of lunar luminosity at night could perhaps explain the significant increase in the number of calvings related to the New Moon. To better understand the relationship found in the periodic revolutions, additional studies could be carried out during these periods.

Knowing this variation in the number of bovine calvings throughout the different phases of the lunar cycle can allow veterinarians and breeders to optimize both herd management and the calving period and colostrum administration, in order to reduce failures in passive transfer of immunity as well as the associated economic losses [23]. In fact, for the calf to adequately absorb maternal immunoglobulins present in colostrum, its administration must be early, ideally between 0 and 2 hours of life, and mandatorily before 24 hours, in sufficient quantity (3 to 4 liters in the first administration) and with adequate time, with a minimum duration of 15 minutes [23–25].

The absence of the study of additional parameters, such as weather conditions, time of calving, dates of conception, use of artificial insemination, farm altitude, and stress factors, in order to establish a more precise reproductive scheme, are limitations of the study. These variables could be analyzed in future studies.

5. Conclusions

This study carried out with Montbéliarde cows in the Franche-Comté region showed a significant association, with little difference between primiparous and multiparous cows and between female and male births, between the distribution of calvings and the phases of the Moon, with a significantly higher calving probability on the New Moon a lower calving probability during the First Quarter and Full Moon phases.

Significance of control variables (calf sex and calf parity) and random variable (region) were consistent across all models confirming biological and herd-level variability.

This information can be useful for the breeders to provide the correct colostrum intake for the calves. It is also important to reinforce that for more assertiveness results it is desirable to do a prospective study including more variables that need to be evaluated, for example the use of reproductive biotechnologies.

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Abbreviations

The following abbreviations are used in this manuscript:

EDE	Institute of Livestock
H0	Null hypothesis
H1	Alternative hypothesis
IRR	Incidence Rate Ratio
GLMM	Generalized Linear Mixed Method
Km	Kilometers
NASA	National Aeronautics and Space Administration
UTC	Coordinated Universal Time
%	% - Percentage

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